Internet of Things

Vinit Kumar Gunjan
Mohd Dilshad Ansari
Mohammed Usman
ThiDieuLinh Nguyen *Editors*

Modern Approaches in IoT and Machine Learning for Cyber Security

Latest Trends in AI

Springer

Internet of Things

Technology, Communications and Computing

Series Editors
Giancarlo Fortino, Rende (CS), Italy

Antonio Liotta, Edinburgh Napier University, School of Computing
Edinburgh, UK

The series Internet of Things - Technologies, Communications and Computing publishes new developments and advances in the various areas of the different facets of the Internet of Things. The intent is to cover technology (smart devices, wireless sensors, systems), communications (networks and protocols) and computing (theory, middleware and applications) of the Internet of Things, as embedded in the fields of engineering, computer science, life sciences, as well as the methodologies behind them. The series contains monographs, lecture notes and edited volumes in the Internet of Things research and development area, spanning the areas of wireless sensor networks, autonomic networking, network protocol, agent-based computing, artificial intelligence, self organizing systems, multi-sensor data fusion, smart objects, and hybrid intelligent systems.
Indexing: *Internet of Things* is covered by Scopus and Ei-Compendex **

Vinit Kumar Gunjan • Mohd Dilshad Ansari
Mohammed Usman • ThiDieuLinh Nguyen
Editors

Modern Approaches in IoT and Machine Learning for Cyber Security

Latest Trends in AI

Springer

Editors
Vinit Kumar Gunjan
Computer Science and Engineering
CMR Institute of Technology
Hyderabad, India

Mohd Dilshad Ansari
Computer Science and Engineering
SRM University Delhi-NCR
Sonepat, Haryana, India

Mohammed Usman
Electrical Engineering
King Khalid University
Abha, Saudi Arabia

ThiDieuLinh Nguyen
Hanoi University of Industry
Hanoi, Vietnam

ISSN 2199-1073 ISSN 2199-1081 (electronic)
Internet of Things
ISBN 978-3-031-09954-0 ISBN 978-3-031-09955-7 (eBook)
https://doi.org/10.1007/978-3-031-09955-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Paper in this product is recyclable.

Contents

About the Editors

Vinit Kumar Gunjan is Dean of Academic Affairs at CMR Institute of Technology Hyderabad (associated with Jawaharlal Nehru Technological University, Hyderabad) and Associate Professor in the Department of Computer Science and Engineering. As an active researcher, he has produced and edited multiple Springer series volumes, as well as published research papers in important IEEE, Elsevier, and Springer journals and conferences. In 2016, the Science Engineering Research Board, Department of Science and Technology, Government of India bestowed upon him the prestigious Early Career Research Award. He is a Senior IEEE member, an active volunteer of the IEEE Hyderabad section, and has served in various roles with IEEE, including: 2023 Chair IEEE Computer Society Chapter; 2023 Additional Treasurer, 2023-2022 SAMIEEE Coordinator; 2021 Additional Secretary;2021 Vice Chairman – IEEE Computational Intelligence Society; and volunteered as Treasurer, Secretary, and Chairman of the IEEE Young Professionals Affinity Group and the IEEE Computer Society. Many IEEE and Springer technical and non-technical workshops, seminars, and conferences have been organised by him. He has had the honour of collaborating with top IEEE leaders and was awarded the excellent IEEE Young Professional award by the IEEE Hyderabad Section in 2017.

Mohd Dilshad Ansari is currently working as Associate Professor in the Department of Computer Science and Engineering at SRM University Delhi-NCR, Sonepat, Haryana, India. He received B.Tech. in Information Technology from Uttar Pradesh Technical University, Lucknow, UP, in 2009. He received his M.Tech. and Ph.D. in Computer Science and Engineering from Jaypee University of Information Technology, Waknaghat, Solan, HP, India, in 2011 and 2018, respectively. He has more than 10 years of academic/research experience and has published more than 80 papers in international journals (SCIE/Scopus) and conferences (IEEE/Springer). He is the Member of various technical/professional societies such as IEEE, UACEE and IACSIT. He has been appointed as Editorial/Reviewer Board and Technical Programme Committee member in various reputed journals/conferences. He is also Guest Editor of Special Issues from reputed journals and has organized special sessions in IEEE/Springer conferences. His research interest includes Digital and Fuzzy Image Processing, Machine Learning, IoT and Cloud Computing.

Mohammed Usman received B.E. in Electronics and Communications from Madras University, India, in 2002. He received his M.Sc. and Ph.D. from the University of Strathclyde, UK, in 2003 and 2008, respectively. He is the recipient of the University scholarship from Strathclyde for his Ph.D. He has more than a decade of experience in academics and academic administration. He is a Senior Member of IEEE and IEEE Communications Society. He has been TPC Chair and Organizing Chair for IEEE conferences and actively involved in IEEE activities. He is currently working as Assistant Professor in the Department of Electrical Engineering at King Khalid University, Saudi Arabia. He received the & academic excellence' award from the College of Engineering at King Khalid University and also received the award for best project in 2016. His research is focused on technologies for next-generation wireless networks, signal processing for biomedical application, probabilistic modeling and channel coding.

ThiDieuLinh Nguyen, PhD is working in the Division of Electronics and Telecommunication Engineering in Electronics and Information, Faculty of Electronics Engineering Technology, Hanoi University of Industry, Vietnam (HaUI). Currently she is heading the department since 2015. She has more than 17 years of academic experience in electronics, IoT, Smart Garden and telecommunication. She has authored or co-authored more than 15 research articles that are published in journals, books and conference proceedings. She teaches graduate and postgraduate level courses at HaUI, Vietnam. She received Ph.D. in Information and Communication Engineering from Harbin Institute of Technology, Harbin, China, in 2013; Master of Electronic Engineering from Le Quy Don Technical University, Hanoi, Vietnam in 2006 and Bachelor of Electronic Engineering from HCMC University of Technology and Education, Vietnam, in 2004. She is an editor for *Artificial Intelligence Trends for Data Analytics Using Machine Learning and Deep Learning Approaches* and *Distributed Artificial Intelligence: A Modern Approach* publisher by Taylor & Francis Group, LLC, USA. She is also Board Member of *International Journal of Hyperconnectivity and the Internet of Things* (IJHIoT) IGI-Global, USA, *Information Technology Journal*, *Mobile Networks and Application Journal* and some other reputed journals and international conferences.

IoT Design Methodology: Architectures and Protocols

Abhishek Pathak, Jitendra V. Tembhurne, C. Kalaiarasan, and Tapan Jain

1 Introduction

The increasing demands of intelligent and user-oriented Internet of Things (IoT) applications are increasing the facilities of more improved and enhanced methods for automatising and revolutionising the world scenario. Internet of Things is providing a paradigm shift to physical devices connected with network for communication. Different heterogeneous devices with different standards are used in various applications. Because of this, several challenges are arising to improve the quality of services (QoS) such as security, privacy, energy efficiency, scalability, interoperability, standardisation of protocols, etc. In the coming years, huge amount of devices will get involved in building an automatic and intelligent world [2]. In addition, enhancement in IoT will enhance the challenging issues and services to the applications horizontally and vertically such as transportation, e-health, home and industry automation, agriculture, etc. [3]. IOT is a combination of large number of

A. Pathak
Department of Computer Engineering, St. Vincent Pallotti College of Engineering & Technology, Nagpur, Nagpur, India

J. V. Tembhurne
Department of Computer Science & Engineering, Indian Institute of Information Technology, Nagpur, Nagpur, India
e-mail: jitendra.tembhurne@cse.iiitn.ac.in

C. Kalaiarasan
School of Engineering, Presidency University, Bengaluru, India
e-mail: kalaiarasan@presidencyuniversity.in

T. Jain (✉)
Department of Electronics & Communication Engineering, Indian Institute of Information Technology, Nagpur, Nagpur, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_1

heterogeneous devices, and these devices send the data for communication. The data is generated from various types of devices in various forms; hence, data interoperability is a challenge in data extraction. To overcome this, adding semantics to it is the most promising method as discussed in [4]. A method of semantic analysis and extraction process is described [1, 10]. In a level-wise categorisation of IOT network, the secure authentication is provided for different non-intelligent and intelligent devices or nodes. Several research projects are developed and are in process to provide solutions to key challenges at various organisations and industries working in IOT. Many researchers are contributing to provide solutions to key challenges in terms of scalability and interoperability. In this chapter, we discussed the design methodologies and explained the description of each methodology in brief. Architecture with its key goals is explained. In Sect. 3, the building blocks and explanation about each level are provided. Section 4 explains about the elements considered for building the architecture. In Sect. 5, various protocols based on publish/subscribe and request/response category are highlighted with detailed explanation of message format.

2 IoT Design Methodologies

IoT has touched almost all the application areas in the world. The major enhanced sectors where big amount of contribution is going are healthcare, transport, agriculture, smart homes and industrial applications.

These IoT design and methods are required to implement the applications, and implementation varies as per the applications. In a broader scope, the key methodologies that should describe the specifications shown in Fig. 1 and as per the description presented in [22] are the following.

- Descriptions based on objectives and purpose
- Descriptions based on actions required
- Descriptions based on modelling
- Descriptions based on information
- Descriptions based on functions
- Descriptions based on networking and services

Description based on objectives This is the primary step to know the execution behaviour of the system, that is, factors to be considered while gathering the data, information retrieval, and system are collected.

Description based on actions This step specifies the manner of flow of actions, which are derived from the nature of the system. The behavioural aspects of the system, which is specific to the application, are identified.

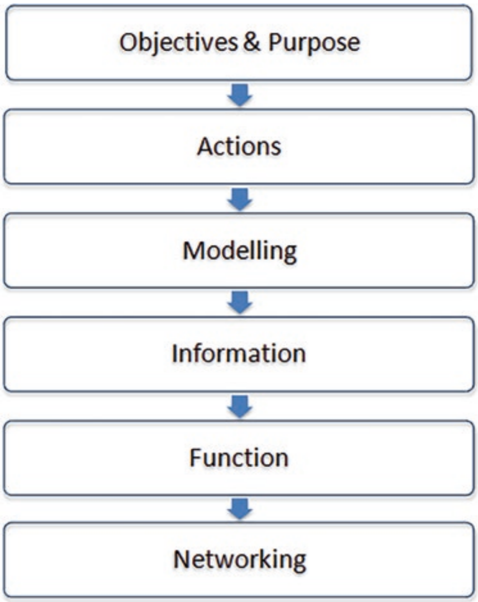


Fig. 1 Methodologies adopted in IoT

Description based on modelling In this step, the attributes related to the system devices and the relational effect of devices on each other are identified. The concepts involved between the devices are considered, and this helps in predicting the behavioural aspects involved in the system.

Description based on information We identified the structure of information, the different entities involved in the system, and the different structures on different levels, which require different parameters to be considered. This assists in receiving the details of information in the system.

Description based on function This level defines the specifications required for the functional overview of IoT structure. The functions depend on device, services, management and security.

Description based on networking This step specifies the networking and interconnection parameters on device and component level. Based on an application, the different devices and components utilised will communicate with their specific tools and platforms.

3 Architecture

IoT is an emerging area that offers support and services to all areas of engineering and science. All the components of the systems in machine to machine (M2M), industries as well as in other organisation develop their functional architectures based on the basic requirements used. To facilitate the management and support to these systems, an architecture needs to be developed in order to understand the interconnection of devices and components. The system should be capable of interconnecting the range of node and devices. In the future, IoT will become by default the basic requisite to the growth and development of business, agriculture and industry, which will facilitate the services to all the things used in day to day life. To fulfil the upcoming requirements of the infrastructure to support flexible system design, scalability and interoperability, we need robust and flexible infrastructure.

3.1 The Key Goals of Architecture

In this section, we discuss the key goals for designing the architecture of IoT.

3.1.1 Ready to Use

To achieve the objective and goals of IoT, we need to identify the usage, applications and technologies involved in it. The future application and usage will demand for updates, and changes at all levels of IoT are increasing rapidly with more number of devices. This gives rise to such an infrastructure, which is readily available for use, and software and hardware should be capable to update according to the changes in the application demands.

3.1.2 Modelling and Functionality

Many devices participate in communication and data gathering, and it is important to know which device is sending the data from which type of application. It may be possible that in a network, the same type of devices are connected, so distinguishing the device modelling is necessary in order to provide specific functionality and services to that application; therefore, devices are assigned with specific device identification.

3.1.3 Privacy and Security

As interoperability is a major issue in the field of IoT and as more heterogeneous devices communicate with each other, which give rise to the threats to the privacy of data, infrastructure should provide the functionality of identification, authentication, confidentiality, integrity and non-repudiation.

3.1.4 Localisation

Infrastructure should also support the mobility, reliability and availability features in network. The node may be mobile in nature, so communication between mobile-to-mobile types of devices or mobile to non-mobile types of device may happen. With this, the configuration continuously changes according to the location, thus availability of devices/nodes is the major factor in communication. Infrastructure should be capable of providing the functionalities according to the changes in location.

3.2 Building Blocks of IoT Architecture

Various architectures are proposed according to the technologies. As per the services and management, the IoT architecture must consist the three basic layers: Physical layer, Networking layer and Management layer, as shown in Fig. 2.

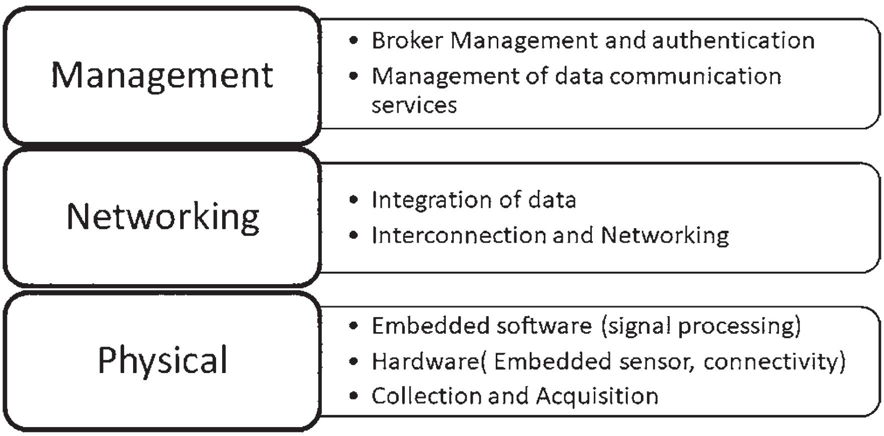


Fig. 2 IoT architecture

3.2.1 Physical Layer

As per the international standards for networking, the physical layer specifies the standards and procedures at basic level of any interconnection wherein physical means '*devices*'. In IoT, sensors and smart devices or hardware are involved in this category where a signal is sensed from physical devices, that is, signal form, and then transformed into the digital signals. Moreover, the developers embed their platforms into the devices according to the applications.

Example In applications related to healthcare, the sensing devices such as pulse sensors and heartbeat sensor sensed the pulse and heartbeats, respectively, and then the signals are converted into digital values and values are accumulated according to the application.

3.2.2 Networking

Networking is the most important part of infrastructure as a medium for process in IoT. It involves the connection topologies and methods for wired and wireless types of routing in IoT network. At this layer, basic structure is required to interconnect end-to-end communication and it differs with the types. These interconnections may be of same, different or hybrid types. The hybrid interconnection is more vulnerable to the updates and in the future attracts attention of network. In some applications, the technologies are embedded as per the application, which becomes rigid to the change. The key points to consider in networking are its technology, scalability and complexity. Technological revolution may give rise to the changes in the standards related to the topologies, methods and horizontal growth in wired and wireless topologies.

3.2.3 Management

Management of data is the most vital process in IoT ecosystem. In IoT, the various types of data are generated from a variety of devices and managing such data is the important task. Processing this enormous amount of data, which continuously gets pulled or pushed, needs management of the data. The key challenges to the data management are monitoring of data, deployment services, processing and connectivity. There are many technological concepts involved in data management such as:

(i) Event processing
(ii) Data collection and analytics
(iii) Semantics related to networking

Event processing Event processing in nodes and especially in virtual sensors is becoming one of the emerging research areas in the complex nature of event processing. It is based on the knowledge gained by the situations and actions to predict the behaviour in the future. It can be computational-based and detection-based.

Data collection and analysis Data collection and gathering is one of the revolutionising areas of IoT wherein data is collected and analysed to acquire specific information. It supports information exchange between various systems connected in a network.

Semantics related to networking In today's world, almost every data is collected on clouds and accessed. This data is growing to identify the features in application. So, a mechanism is needed to determine the type of data based on the complexity level of applications growing because of the increasing demand of data-related applications. To do so, data is annotated and interpreted to support the scalability and interoperability in the network.

4 Elements of Internet of Things

As Internet of Things is a paradigm of heterogeneous element, so based on the functionality, the elements of IoT differ. This section specifies the important elements to be considered for functionality based on services.

(i) Sensing and Identification
(ii) Computation and Services
(iii) Communication

Sensing and Identification The most important process in IoT is to gather the data coming from various physical objects connected in the network. These devices or nodes send the data through various links. The devices are assigned with specific device IDs, and the purpose of IDs are for identification in a network. Sensing and identification is also represented in Fig. 3.

Example Electronic product codec (EPC) and Ubiquitous are methods available for this purpose. Sensing and identification is the basic step in the world of IoT, which is important for further steps of communication and computation.

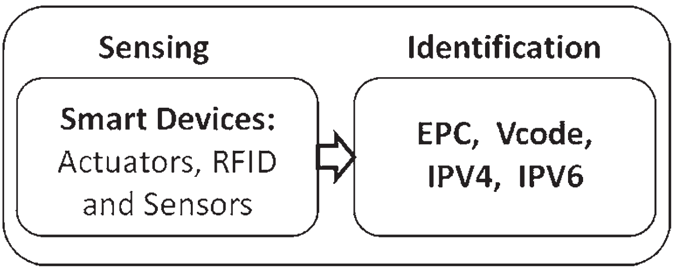


Fig. 3 Sensing and identification

Computation and Services In IoT, analysis is extracting useful information from the data for further processing. In analysis, the batches of data are sensed and gathered through embedded sensors. These data are heterogeneous and vary in type. The analysis helps in understanding the pattern and its structure reducing maintenance, avoiding failures and improving operations. In computation, the protocols verify the structures of these data and make them available for processing. The processing is done on hardware and software level of IoT. On software level, the recent technologies such as Fog and Cloud computing are used. In IoT, devices embedded with actuators and other devices are connected. These devices generate big data chunks in large amount, resulting in the requirement of complex computations to extract knowledge. In [8], illustration on various IoT platforms is given for utilising hardware such as the series of Arduino platforms and Rasberry-Pi, more modern and specific application platforms such as Intel Galileo, BeagleBone, Gadgeteer, WiSense, Cubieboard, T-Mote sky. In addition, researchers contributing to this field highlighted the applications related to smart devices such as smart phones and computing devices. These intelligently operating devices operate on different operating systems and software such as TinyOS, RiotOS, LiteOS, Contiki Android and C, C++ and JAVA. The recent learnings in the field of cloud and Edge computing is providing advanced computing ability to the field of IOT. A cloud platform provides facilities to store data on cloud where real-time data can be managed and can be processed for intelligent analysis.

Communication Communication in IoT is done between devices such as machine to machine (M2M), Device to Server (D2S) or Server to Server (S2S). These techniques are heterogeneous in behaviour and operation platform, as the objective of IOT is to connect everything, which is not smart and cannot perform operations. In such environment, communication protocols and standards make it possible to interpret and to understand the foreign object data. They facilitate and simplify the complexity involved in interacting with the other end device. Table 1 shows the information of variety of communication standards.

Table 1 Communication standards at different levels

Level	Communication standard
Infrastructural level	Wireless Fidelity (WiFi) Bluetooth IEEE 802.15.4 Z-Wave Long Term Evolution(LTE)-Advanced Near Field Communication (NFC) Radio Frequency Identification(RFID)
Management level	Advanced Message Queuing Protocol (AMQP) Constrained Application Protocol (COAP) Message Queuing Telemetry Transport (MQTT) Data Distribution Service (DDS) Extensible Messaging and Presence Protocol (XMPP)

Infrastructural Level The physical links are established by keeping range and power into consideration, as power consumption and depletion of devices is the key element that decides the operating life of devices in a network. Examples of such protocols, which are used in communication, are IEEE 802.15.4, Z-Wave and LTE-Advanced. Some technologies pioneered the requirement for M2M communication such as RFID, NFC and UWB. RFID facilitates the communication through radio links, and these radio links identify the object within the range of 10 cm to 200 m and communicate at 13.56 MHZ of frequency band. In addition, NFC protocols also communicate at the same high frequency of 13.56 MHZ and support range up to 10 cm. The most promising technology is the WiFi, which arises as a basic support for IoT infrastructure for communication and services within 100 m range [6].

Management Level As detailed in Sect. 3.2.3, data management involves monitoring data for exceptions and errors. To send pulled data from publisher to subscriber, it needs routing logic. The various management protocols are adopted to manage the communication method between the publishers and subscribers; this management is done at application layer. The various management protocols are available for IOT ecosystem such as AMQP, DDS, COAP and MQTT.

5 Standardisation and Protocols

Standardisation is the common set of rules defined to test the protocols on certain platforms; it is a common forum of industry, researcher centres, public authorities and consumers. The objective of defining the standard is to achieve common goals in terms of QoS in the performance of the devices and platforms. As IoT is a collection of heterogeneous devices, the devices need a common platform for understanding the communication [5, 7, 9].

Standardisation is essential to set the following:

- Interoperability across applications and services
- Maintain operation across system, syntax, semantics and domain knowledge
- Maintain regulations in economy between regulators and developers
- Provide security and privacy of contents

Nowadays, the key challenge to standardisation is maintaining the performance interoperability, availability and reliability. Many groups are in progress and are working in this direction. The major leading organisations are the European Telecommunications Standards Institute (ETSI), Institute of Electrical and Electronics Engineers (IEEE), Wide Web Consortium (W3C), Internet Engineering Task Force (IETF) and EPCglobal [23].

Protocols are the basic building blocks of the communication process in IoT. Various protocols are to facilitate the services offered in IoT. On each layer of interconnection, the specific protocols function for the task as explained in Table 2.

Table 2 Protocols and standards

Layers	Protocols and standards
Application layer	ONEM2M/ETSI, HTTP, COAP, SEP 2.0
Transport layer	TCP, UDP, ZigBee
Network layer	RPL, IPV6, 6LowPan
Data link layer	IEEE 802.15.4, Bluetooth, WiFi, NFC, 3GPP
Physical layer	

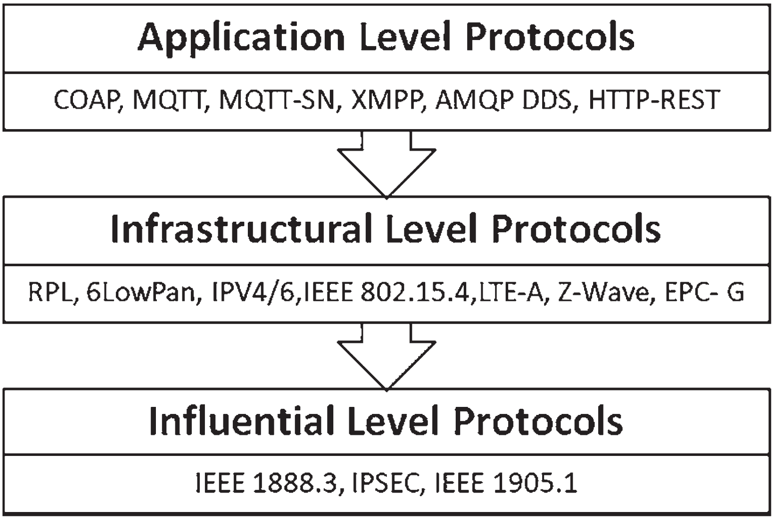


Fig. 4 IoT protocols

The protocols in IoT can be categorised based on the functionality assigned and level of management. Protocols in IoT can be categorised according to application level, infrastructural level and influential level. As shown in Fig. 4, the protocols at influential level are the protocols used with wide scope of usability at system level.

5.1 IEEE 1905.1

Protocol defines the standard for both wired and wireless media, especially the WiFi media used in the market. It supports connectivity to the heterogeneous types of devices with mobility benefits and is used as an intermediate between network and data link layer. IEEE 1905.1 message frame consists of 8 octets and variable length list. The frame slots are as follows and the frame format is shown in Fig. 5:

- Message version – 1 octet
- Reserved – 1 octet
- Message type – 2 octet

Message Version	Reserved	Message Type	Message ID	Fragment ID	Last Fragment Indicator	Relay Indicator	Reserved	List of Type Length Value

Fig. 5 IEEE 1905.1 frame format

- Message-Id – 2 octet
- Fragment-Id – 1 octet
- Last fragment indicator – 1 octet
- Relay indicator – 1 octet
- Reserved – 6 bits
- List of type length value (TLV)

5.2 IEEE 1888.3

Another protocol discussed in this category is IEEE 1888.3, a standard defined by ISO/IEC/IEEE. It is a protocol for security service enhancement and a standard proposed for Ubiquitous green community control network. It also helps to avoid unintended data disclosure. The processing of infrastructural layer and application layer related to protocols is listed as below:

- At infrastructural level, the protocols are applied for synchronisation of standard. The popular protocols in this category are RPL, 6LowPan, IPV4/IPV6, IEEE 802.15.4, LTE-A, Z-Wave and EPCglobal.
- Application layer protocols are responsible for data presentation and formatting. In constrained environments where heterogeneous nature of devices are connected, the IEEE 1888.3 protocol supports the communication of such heterogeneous environment. Many protocols are developed by keeping the objective of constrained environment, that is, COAP, AMQP and MQTT – these are standard communication protocols. The basic functionality of these protocols is to provide services based on message transmission and support the environment of request/response or publish/subscribe type. Maximum protocols in this category use routing schemes such as round robin and message queuing mechanism.

5.3 Constrained Application Protocol (COAP)

This is a protocol designed especially for constrained application devices to meet the requirement of the Internet and M2M communication and to support multicasting. It is a request/response type protocol, and message length is four byte with fixed header, version type, token length, request/response code and message ID. In COAP, GET, PUT, POST and DELETE are the operations to achieve Create, Retrieve, Update and Delete (CRUD) operations. It works on four types of messages, that is, confirmable, non-confirmable, reset and acknowledge [11–13].

Figure 6 explains the implementation view of COAP. The request from client is accessed by COAP server and is forwarded over the HTTP-REST to process the query on Internet storage. In addition, Representational State Transfer Protocol (REST) is cacheable connection. The CRUD operations are indicated, and type of value each operation hold is presented below [11–14]:

- Request
  - 0: Confirmable: Acknowledgement message
  - 1: Non-confirmable: Does not expect a confirmation message
- Response
  - 2: Acknowledgement: Acknowledge a confirmable message
  - 3: Reset: Received a message and not processed

COAP is a specialised application protocol designed by RFC7252. It is designed in such a way that it easily gets integrated with HTTP and UDP for seamless integration and useful in environment where M2M is implemented. The frame format of COAP is presented in Fig. 7; COAP is low overhead protocol thus providing easy integration and less outflows. The message format consists of version, message type, token length, request/response code and message id [17].

Queuing Mechanism The queuing mechanism protocols are more popular in use and attracted the researchers to investigate and resolve the issues related to interoperability and reliability. We enlist the protocol here, and the detailed working is highlighted in Sects. 5.4 and 5.5, respectively:

- Message Queuing Telemetry Transport (MQTT)
- Advanced Message Queuing Protocol (AMQP)

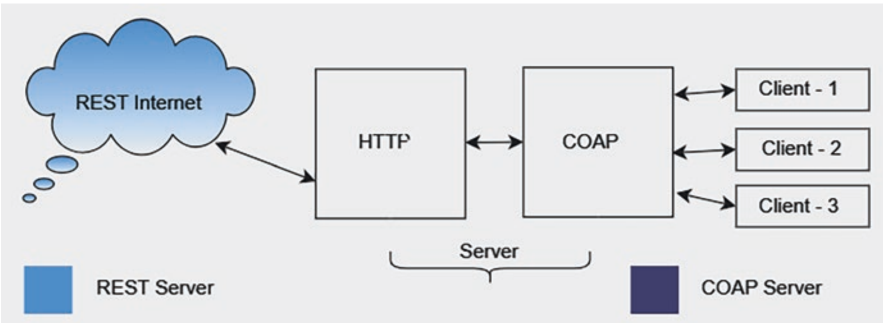


Fig. 6 Constrained application protocol

Version	Type	Token Length	Request / Response Code	Message ID

Fig. 7 COAP frame format

5.4 Message Queuing Telemetry Transport Protocol

MQTT is a binary-based lightweight protocol, bandwidth efficient and uses low battery consumption. It is an open source protocol designed on publish/subscribe scheme and introduced [24] and then modified to be standardised by OASIS in 2013 [15]. It is built on TCP protocol. The packet length of MQTT protocol is computed using control header, length, protocol level, connect flags and payload; the same is represented by Eq. (1).

$$\begin{aligned}&\text{MQTT packet length}\\&= \text{control header} + \text{length} + \text{protocol level} + \text{connect flags} + \text{payload}\end{aligned} \tag{1}$$

The protocol level defines the QoS level of delivery assurance. Herein, control header is fixed and is of 1 byte and packet length is of maximum 4 bytes. There are two versions of MQTT protocol: MQTT designed for TCP/IP protocol and MQTT-SN designed to work over UDP and ZigBee protocols. The architecture of MQTT [26] is presented in Fig. 8.

MQTT operations is categorised in two sub-operations, that is, from Publisher to broker and then from broker to consumer/client. As shown in Fig. 9, MQTT server as broker receives the messages from publishers and makes them available to get subscribed by appropriate client. The publisher publishes the message and gets the response/acknowledgement to publish. The broker consists of queue, and the

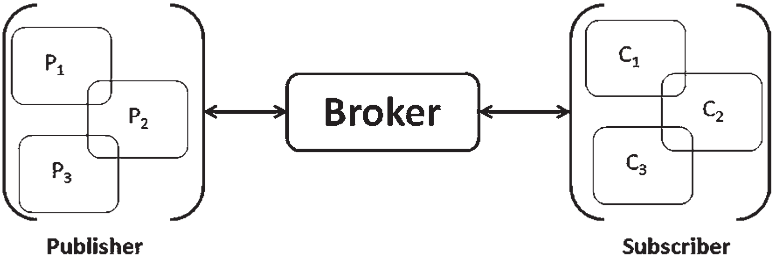


Fig. 8 MQTT protocol

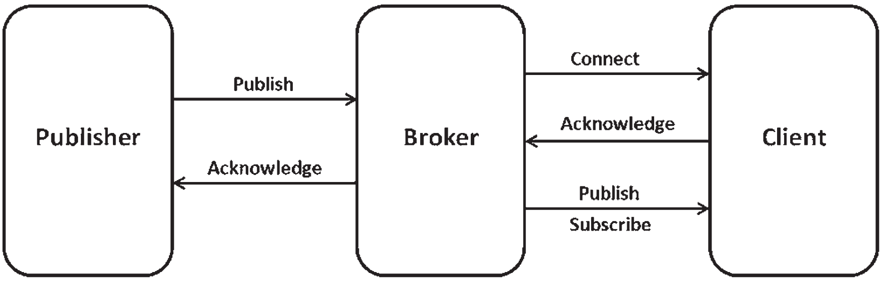


Fig. 9 MQTT operation

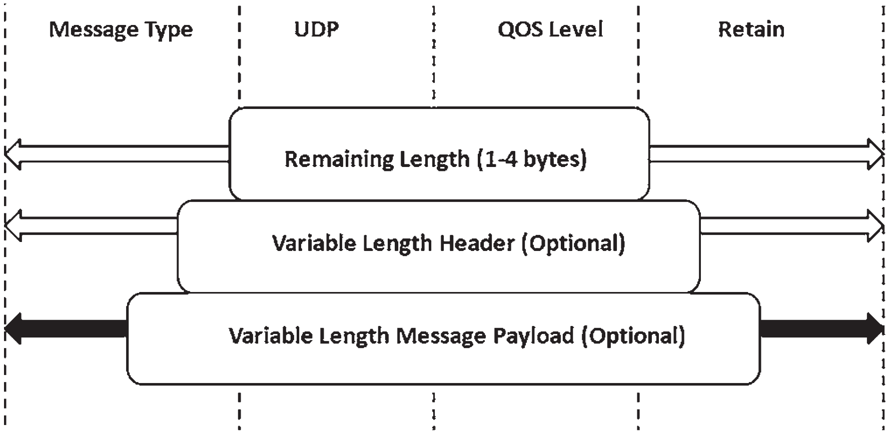


Fig. 10 MQTT message format

maximum queue length in MQTT is of 260 MB. The specific client accesses the specific message required. The client requests to connect with the broker, and the broker provides the acknowledgment to connect [19].

Figure 10 demonstrates the MQTT message format, which is a binary-based protocol. It consists of Message type of four bytes, UDP field of one byte, QoS level of two bytes and lastly one byte of retain field. The message format of MQTT consists of control header, packet length, variable length header and payload. The control elements are in the form of binary bytes not the text strings. It operates on request and response mechanism, that is, to each request, the acknowledgment is accepted [16].

5.5 Advanced Message Queuing Protocol (AMQP)

AMQP is an advanced message queuing protocol. Queuing mechanism targets the issues related to interoperability and reliability in IoT. In this concept, multiple queues can be implemented. AMQP is layered architecture that defines [18] the following:

Layer 1: Defines system and encoding process.
Layer 2: Defines transport layer and efficient, binary peer to peer protocol functioning.
Layer 3: Defines grouping for atomic transactions.
Layer 4: Defines security aspects.

The popular AMQP versions are RabbitMQ, OpenMQ, StormMQ, ApacheQpid and RedHat Enterprise MRG.

As shown in Fig. 11, the implementation of AMQP protocol consists of broker. The broker is an implementation of exchange and queues. The exchange is a software program that decides the assignment of messages to particular queue; the messages can be assigned based on Topic, Direct, Fan-out and Header and the exchange implement routing algorithm. Exchange is used to bind the queues [20, 25, 27].

Direct Exchange Direct exchange is used to deliver the messages to queues based on routing keys. It is well suited to unicast mode. Direct exchange is default exchange of AMQP protocol, and the same has been shown in Fig. 12.

Fan-Out Exchange This exchange supports broadcasting type of communication. If 'N' queues are connected with the exchange, then messages will be published to all the queues. The function of Fan-out exchange is presented in Fig. 13:

- Online multiplayer gaming
- Best suited to distributed environment concepts in which the server sends configuration messages and updates to all the clients

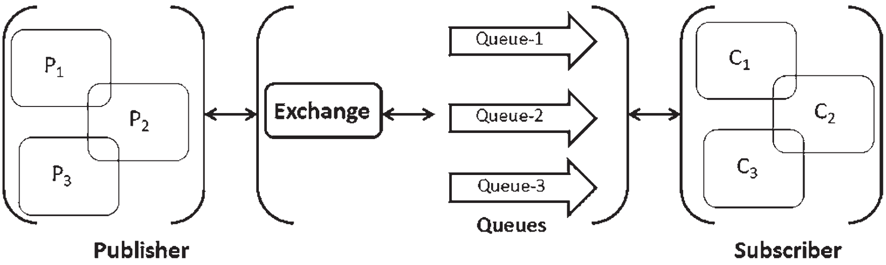


Fig. 11 AMQP protocol

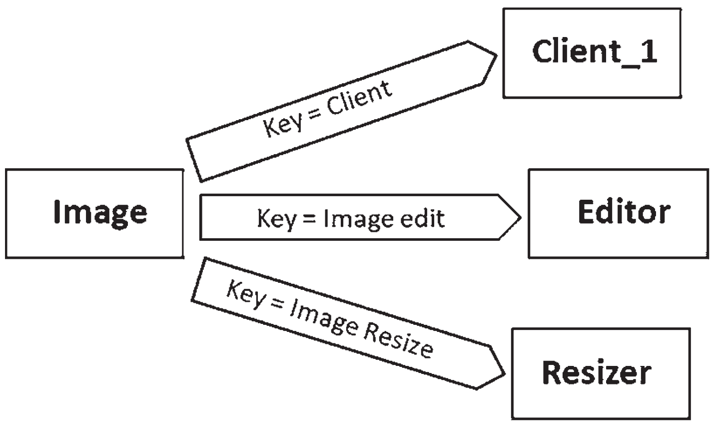


Fig. 12 Direct exchange

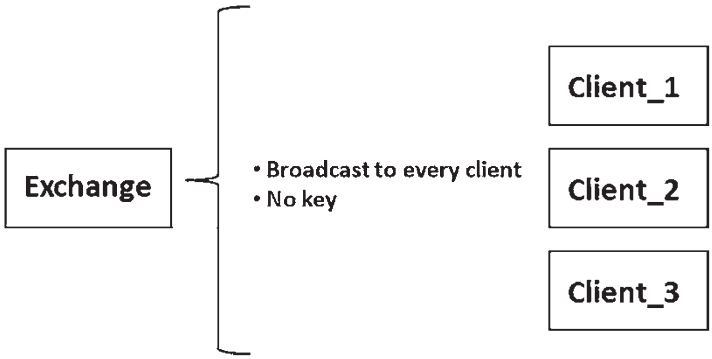


Fig. 13 Fan-out exchange

Topic Exchange This exchange type supports multicast. The routine is done to more queues simultaneously. The message gets delivered to queues based on matching key and pattern, for example, in Geographical cases, sending specific data to specific location user.

Header Exchange In this type of exchange, the messages are published as per the type of headers assigned as key. The key can be multiple in number. Based on matching key with only one type or all types, messages are published.

This exchange model accepts messages from the publisher and route them to queues according to the predefined criteria as shown in Fig. 11. It uses a routine and instances to examine the message and route it to proper queue by using key, which is actually a virtual address. In communication, the parameters used for message are as follows:

- Queue current status
- Time to live (TTL) for message expires
- Queue length
- Message type
- Message identifier
- Message order

Queue Status The queues used in messaging hold the data according to the capacity of queue. The messages/data are pulled from messages as per the parameter, that is, links defined for the consumer.

Time to Live (TTL) It is a live for which the message will remain in the queue. The time to live decides the life of message in the queue.

Queue Length The queue will decide the capacity of message to hold in communication by the queue.

Moreover, the features' targets in communication are as follows:

- Targeted quality of service
- Persistence
- Delivery of messages to multiple consumers
- Possibility of ensuring multiple consumptions

RabbitMQ It is basically a publish/subscribe model, a broker architecture. It uses queue exchange mechanism for publishing the message and subscribing the message from consumer. It is an advanced message queuing technology. The exchange implements routing logic to forward the message to the respective queue. The routing logic can be anything the user needs, but more preferably, round robin type of routing is common for forwarding the messages. As explained by RabbitMQ Pivotal, the message can be routed by using four different types of exchange mechanism, that is, Fan-out, Direct, Topic and Header. The exchange mechanism using the Fan-out message is forwarded to all queues, that is, messages get consumed by all the consumers. The Direct exchange mechanism binds the queues with consumer by using routing/binding keys. The Topic exchange mechanism provides the same mechanism as the Direct, but only adding some wild characters to the messages. The Header type keys and values as header in the message as a parameter to publish and consume.

The basic mechanism on which RabbitMQ works is Queuing mechanism. The queue gets bind with exchange, exchange routes the messages produced by the producer, and consumed by the consumer from queue. These producers and consumers may be of different and varying configurations and applications, which gives rise to the issues related with accuracy and interoperability, that is, mismatch between the number of message packets generated per second by the producer (publisher) and message packets consumed by the consumer because of different configuration platforms.

For example, in a company with various departments, where all departments are connected centrally, considering only three departments, Human Resource, Marketing and Administration maintain active directories. The same is presented in Fig. 14 and details are shown as follows:

Actors: Human Resource Department – producer
Marketing Department – consumer1
Administrative Department – consumer2
RabbitMQ system – Broker (exchange & queue)

RabbitMQ is a more sophisticated implementation of message queuing techniques. It is more scalable as it provides the mechanism to increase the use of queues. The number of queues may vary as per the number of exchanges used. It also provides the mechanism named as dead letter exchange (DLX) where the rejection of messages is avoided. Still, some issues related with availability of queues may arise, which results in the decrease in performance related to queues. Another more specific implementation of message queuing known as Kafka is attracting the

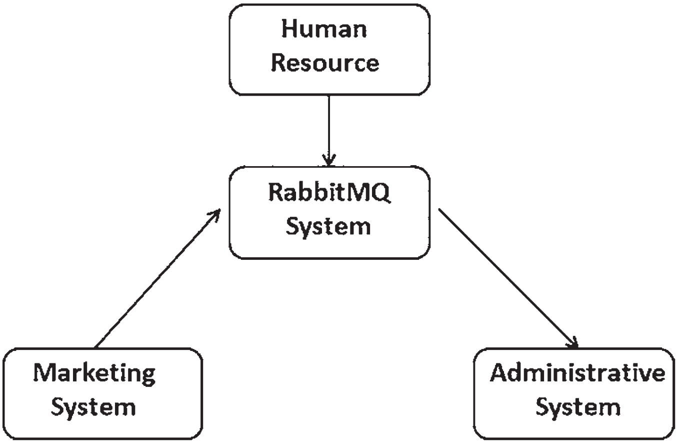


Fig. 14 Implementation example of RabbitMQ

Table 3 Protocol connectivity and security aspects

Protocols/connectivity	QoS	Transport	Security	Usage
AMQP	Yes	TCP	Yes	D2S/S2S
MQTT	3 levels	TCP	Yes	D2S
HTTP	No	TCP	Yes	Web
DDS	20 levels	TCP/UDP	Yes	D2D
Web-socket	No	TCP	Yes	Web

attention of researchers. In Kafka, the zookeeper concept is implemented to avoid the issues related with performance. Various research papers that describe the working of Kafka with zookeeper implementation as well as examples are explained.

Nowadays, researchers are focusing on issues related to communication in IoT. As heterogeneous devices are connected in IoT systems, we are facing continuous issues related to scalability and interoperability, so security and privacy become the most challenging tasks. MQTT protocol is light-weighted, consumes less power, requires less bandwidth and is utilised in heterogeneous devices connected in different environment. Hence, MQTT protocol is less secured because of the limited service of authentication process and there are no encryption capabilities as presented in [21]. Mechanism applied to overcome security issues can be implemented, which focuses on authentication and authorisation of devices at broker level. These mechanisms are best suited for constrained devices but for resource-constrained devices still need further development. AMQP protocol offers more secure architecture as it provides more reliable connection-oriented procedure. In addition, AMQP protocol facilitates diversity in application and becomes vulnerable to know threats to network. Table 3 presents protocols highlighted according to the security aspects.

Another important challenge is related to interoperability, and it is becoming a key challenge in communication between D2S and S2S. To address this, researchers are providing the solution related to analysis of data based on syntax and semantics. Semantic extraction of data helps in classifying and categorising the data, thus helping future issues related to scalability and interoperability. In IoT, the challenge related to interoperability can be addressed in basic connectivity between devices. Semantics provides potential strength to data extraction: the tags or labels are utilised to extract and classify the data through which domain knowledge and context information can be matched for accurate data extraction.

6 Summary and Future Direction

As predicted by various standard bodies and organisations, with the growth in number of devices and nodes in network, the challenges and threats related to communication and synchronisation will increase. In the coming years, the quality of services and performance of the system will depend on the networks' support for scalability with efficient interoperability. The coming era will be independent of the platform, and the modelling of the system will not depend on the specifications and requirements of functional modelling in the system. Various IoT platforms will get updated with the arising needs and requirements. It is clear that a single protocol and standard will not be sufficient to cope with publisher and subscriber synchronisation. The challenges will arise with quality of services (QoS) in the performance of protocols. In such a varying environment, the standards and protocols in IoT will play a vital role in seamless integration of devices with platforms to achieve objectives of IoT.

References

1. A. Mazayev, J.A. Martins, N. Correia, *Interoperability in IoT Through the Semantic Profiling of Objects Center for Electronic, Optoelectronic and Telecommunications* (University of Algarve, Faro, 2018)
2. D. Evans, *The Internet of Things: How the Next Evolution of the Internet Is Changing Everything* (Cisco Internet Business Solutions Group, San Jose, 2011)
3. A.N. Knaian, J. Paradiso, A.C. Smith, *A Wireless Sensor Network for Smart Roadbeds and Intelligent Transportation Systems* (Massachusetts Institute of Technology, 2000). https://dspace.mit.edu/handle/1721.1/9072. Accessed on 17 Jan 2018
4. F. Shi, Q. Li, T. Zhu, H. Ning, et al., A survey of data semantization in Internet of Things. Sensors **18**, 313 (2018)
5. M. Wazid, A.K. Das, V. Odelu, N. Kumar, M. Conti, M. Jo, et al., Design of secure user authenticated key management protocol for generic IoT networks. IEEE Internet Things J. **5**(1), 269–282 (2018)
6. J. Lin, W. Yuy, N. Zhangz, Z. Yang, H. Zhangx, W. Zhao, et al., A survey on Internet of Things: architecture, enabling technologies, security and privacy, and applications. IEEE Internet Things J. **4**(5), 1125–1142 (2017)

7. Y. Yang, L. Wu, G. Yin, L. Li, H. Zhao, et al., A survey on security and privacy issues in Internet-of-Things. IEEE Internet Things J. **4**(5), 1250–1258 (2017)
8. A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, M. Ayyash, et al., Internet of Things: a survey on enabling technologies, protocols, and applications. IEEE Commun. Surv. Tutor. **17**(4), 2347–2376 (2015)
9. P. Sethi, S.R. Sarangi, Internet of Things: architectures, protocols, and applications. J. Electr. Comput. Eng. **2017**, 25 pages (2017)
10. S. Wagle, Semantic Data Extraction over MQTT for IoTcentric Wireless Sensor Networks, in *2016 International Conference on Internet of Things and Applications (IoTA)*, (Maharashtra Institute of Technology, Pune, India, 22 January–24 January 2016)
11. A. Ludovici, P. Moreno, A. Calveras, TinyCoAP: A novel constrained application protocol (CoAP) implementation for embedding RESTful web services in wireless sensor networks based on TinyOS. J. Sens. Actuator Netw. **2**, 288–315 (2013)
12. Z. Shelby, K. Hartke, C. Bormann, B. Frank, et al., *Constrained Application Protocol (CoAP)* (Internet Engineering Task Force (IETF), Fremont, 2013)
13. C. Bormann, A.P. Castellani, Z. Shelby, CoAP: an application protocol for billions of tiny Internet nodes. IEEE Internet Comput. **16**(2), 62–67 (2012)
14. Amaran, M. H., Noh, N. A. M., Rohmad, M. S., & Hashim, H. et al., A comparison of lightweight communication protocols in robotic applications. Procedia Comput. Sci. **76**, 400–405 (2015)
15. Oasis, MQTT Version 3.1.1 Plus Errata 01 (2014). http://docs.oasisopen.org/mqtt/mqtt/v3.1.1/mqtt-v3.1.1.pdf. R. Cohn, Comparison of AMQP and MQTT. White Paper (2012). https://lists.oasisopen.org/archives/amqp/201202/msg00086/StormMQ_WhitePaper_Comparison_of_AMQP_and_MQTT.Pdf
16. A.S. Clark, H. Troung, MQTT for sensor networks (MQTT-SN) protocol specification (2013). http://mqtt.org//new/wpcontent/uploads/2009/06/MQTT-SN/_spec_v1.2.pdf
17. P. Madhumitha, B. Johnsema, D. Manivannan, Domination of constrained application protocol: a requirement approach for optimization of Internet of Things in wireless sensor networks. Indian J. Sci. Technol. **7**(3), 296–300 (2014)
18. J.E. Luzuriaga, M. Perez, P. Boronat, J.C. Cano, C. Calafate, P. Manzoni, et al., A comparative evaluation of AMQP and MQTT protocols over unstable and mobile networks, in *IEEE 12th Consumer Communications and Networking Conference*, (Las Vegas, NV, USA, 2015)
19. K. Grgić, I. Špeh, I. Heđi, A web-based IoT solution for monitoring data using MQTT protocol, in *International Conference on Smart Systems and Technologies (SST)*, (Osijek, Croatia, 2016)
20. J.E. Luzuriaga, M. Perez, P. Boronat, J.C. Cano, C. Calafate, P. Manzoni, et al., Testing AMQP protocol on unstable and mobile networks, in *Internet and Distributed Computing Systems. IDCS 2014. Lecture Notes in Computer Science*, vol. 8729, (Springer, Cham, 2014)
21. S. Andy, B. Rahardjo, B. Hanindhito, Attack scenarios and security analysis of MQTT communication protocol in IoT system, in *Proceeding of the EECSI 2017*, (Yogyakarta, Indonesia, 2017, 19–21 Sept)
22. A. Bahga, V. Madisetti, *Internet of Things, a Hands on Approach* (ISBN: 978-0996025515, 2015)
23. A. Pal, H.K. Rath, S. Shailendra, A. Bhattacharyya, et al., *IoT Standardization: The Road Ahead* (IntechOpen, 2018)
24. Dr Andy Stanford-Clark of IBM, and Arlen Nipper of Arcom (now Eurotech) (1999). https://www.ibm.com/support/pages/mqtt
25. G. Marsh, A.P. Sampat, S. Potluri, D.K. Panda, et al., *Scaling Advanced Message Queuing Protocol (AMQP) Architecture with Broker Federation and InfiniBand* (Ohio State University, 2008)
26. http://www.steves-internet-guide.com/mqtt-protocol-messages-overview. Accessed on 1st Oct 2020
27. A. Vijayakrishna, G. Gopichand, M.D. Ansari, G. Suryanarayana, IOT based smart agriculture using LIFI, in *2022 5th International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT)*, (IEEE, November 2022), pp. 1–7

Communication in IoT Devices

Dipak Wajgi, Jitendra V. Tembhurne, Rakhi Wajgi, and Tapan Jain

1 Introduction

Internet of Things (IoT) is becoming very popular nowadays since it provides solutions for many automated data collection system securely. The IoT refers to a new kind of environment in which a network is connected virtually to all the gadgets and appliances we use [1]. IoT's primary goal is to guide in a new "smart" world that is completely integrated with interactions between objects, their environment, and people more closely intertwined. However, if the system is more complex, a number of potential challenges may increase particularly in the areas of security, privacy, interoperability and standards, legality, regulatory, and rights issues.

IoT network uses smart IoT-enabled devices, which are lightweight and have less energy, limited storage, and less processing power. These devices are fitted with integrated sensors, actuators, processors, and transceivers for the intelligence and interconnections. IoT is not a single technology; rather, it is an agglomeration of different technologies operating in tandem. Sensors and actuators are the devices that help the physical world to communicate. The information obtained by the sensors has to be stored and processed intelligently. A cell phone or even a microwave

D. Wajgi · J. V. Tembhurne
Department of Computer Science & Engineering, Indian Institute of Information Technology, Nagpur, Nagpur, India
e-mail: jitendra.tembhurne@cse.iiitn.ac.in

R. Wajgi
Department of Computer Technology, Yeshwantrao Chavan College of Engineering, Nagpur, India

T. Jain (✉)
Department of Electronics & Communication Engineering, Indian Institute of Information Technology, Nagpur, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_2

oven can be counted as a sensor. Moreover, an actuator is a system that is used to effect a change in the environment. IoT devices communicate wirelessly as they are installed at different geographic areas. Hence, reliable communication among these devices without any disruption is one of the challenges. Although effective communication models are beneficial to the end user, they promote technological innovation and open doors for business development. IoT allows people and devices to be connected with anything and anyone at any time, anywhere preferably using some network and service. For this, IoT infrastructure requires state-of-the-art communication technology, which must provide a low-power, energy-efficient, and reliable communication. The central infrastructure of an IoT system consists of sensors, actuators, computing servers, and communication network. A middleware is required to connect and manage all these components. This architecture may be application dependent since the application area of IoT is widespread such as healthcare, home automation, environment monitoring, and energy conservation.

From an organizational viewpoint, it is important to think about how IoT devices connect and interact in terms of their technological communication models. The device-to-device communication model describes how two or more devices directly connect and interact with each other. This communication takes place at the IP network or the Internet. The protocols such as Bluetooth, Z-Wave, or ZigBee are applied for device-to-device communication. The IoT system connects directly to an Internet cloud service like an application service provider in a device-to-cloud communication model to share data and manage message traffic. Existing communication technologies such as wired Ethernet and WiFi are utilized to establish connection and communication. IoT system connects via an application layer gateway (ALG), which serves as a channel to access a cloud service in the system-to-gateway model. In this model, the application software runs on a local gateway system that serves as an intermediary between the system and the cloud offering protection and other features, that is, translation of data or protocols. Moreover, back-end-data sharing model refers to a communication architecture that allows users with data from other sources to export and analyze smart object data from a cloud service. This model is an extension of single device-to-cloud communication model. A back-end sharing architecture makes it possible to combine and analyze the data gathered from single IoT device to achieve interoperability of smart devices that are hosted in the cloud.

Every IoT-based application is using one of these models. The suitability of the model depends on the complexity of the communication in application. Performance and throughput of the IoT network are based on how well the connected devices can communicate with each other for the data exchange. Hence, the selection of the appropriate communication technology for the information interchange is also one of the challenges. This chapter discusses some widely used communication technology and protocol for the communication in IoT devices.

This chapter is organized as follows. Section 2 presents the architecture of Internet of Things. Its advantages, disadvantages, and characteristics of communication technology are discussed in Sect. 3. Section 4 deals with communication in IoT. Applications of IoT are described in Sect. 5, and Sect. 6 concludes this chapter.

2 Architecture of Internet of Things

The general architecture of IoT is described in this section. In addition, different architecture has been proposed for IoT in the literature. But here, we explore only three and five layer architecture of IoT.

2.1 Three Layer Architecture

Most of the researchers considered the three layer architecture of IoT as the standard architecture for the design and deployment of IoT-based applications in a variety of domains. Figure 1 shows the three layer architecture of IoT that comprises perception layer, network layer, and application layer. Perception layer is the lowest layer and is also called as physical layer that consists of sensors for gathering environmental information. The intended information is sensed by the sensing object and sent to the server. The middle layer, that is, network layer, is used for connecting all the devices in the network for the transmission and receiving of data among the sensing devices. Application layer is the top-most layer in the architecture and is used to provide the services for the various applications built using IoT.

2.2 Five Layer Architecture

The key concept of IoT is specified by the three layer architecture, but it is not sufficient for IoT design and deployment; hence, we also need to focus on the finer aspects of IoT. The five layer architecture consists of perception layer, transport layer, processing layer, application layer, and business layer for the design of IoT system. The perception layer and application layer functions are the same in both five layer and three layer architecture [2]. The transport layer transfers sensor data

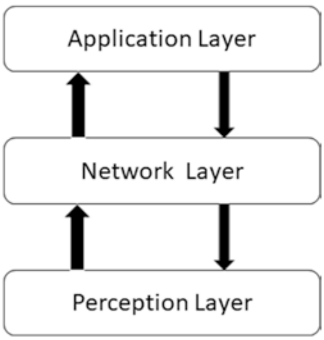


Fig. 1 Three layer architecture of IoT

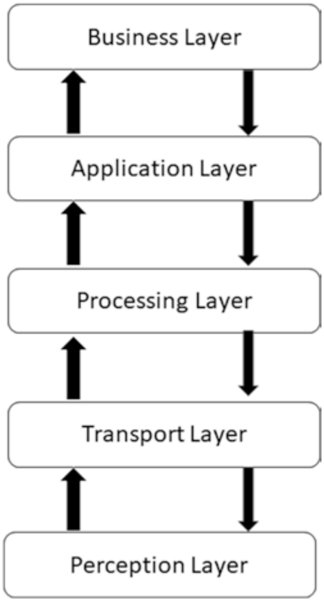


Fig. 2 Five layer architecture of IoT

from the perception layer to the processing layer and vice versa. Communication protocols such as Bluetooth, NFC, and RFID are utilized for this purpose. The processing layer is used to store, analyze, and process the data from the transport layer. It also manages the services from lower layers. Finally, the business layer, including frameworks, business and business models, and user privacy, controls the entire IoT framework [3]. Some other architectures can be applied, which are mostly application dependent (Fig. 2).

3 Advantages, Drawbacks, and Characteristics of Communication Technology

In this section, we present the different advantages, drawbacks, and characteristic features of communication technology in IoT ecosystem.

3.1 Advantages and Drawbacks

Communication protocols to be used in IoT infrastructure are application dependent. Their advantages and disadvantages are as follows:

Advantages:

1. Intelligent way of gathering the data or information with very less human intervention
2. Tracking of objects to trace its movement
3. Remote monitoring and control
4. Efficient data exchange
5. Time is saved by making the system autonomous and intelligent
6. Provide cost-effective solutions in many application

Drawbacks:

1. There are compatibility issues since no standard is available for tagging and monitoring with sensors.
2. Complexity of the system and interoperability are some issues in the system for not performing efficiently.
3. Security from different network attack has always been a concern.
4. Sometimes the speed of data transfer for the particular application does not match.

3.2 Characteristic Features

Every communication protocol has some characteristics, which determines the application domain of that protocol.

1. Connectivity: sensor or the IoT devices need to be connected with each other for the proper communication among them. Good connectivity among the IoT devices helps in exchanging the data and information in the network.
2. Communication: communication among the devices is the key to any IoT-enabled application. The communication protocols have been characterized according to the short range and high range of communication.
3. Data: IoT infrastructure is created especially for data collection and its analysis.
4. Scalable: the communication protocol should perform well when the size of the network increases. With the increasing number of nodes in the network, the throughput of the network should also increase.
5. Security: secure communication among the devices is intended. The network attacks can be repelled and network should not come at stand still.
6. Reliability: the reliable communication among the devices makes the system robust.

4 Communication in IoT

In this section, we present details about communication in different architecture and application in IoT. To exchange the information among various IoT devices, we require efficient and secure communication mechanism. Security capabilities of different communication protocols in IoT [4] were investigated to secure the network from the attackers and intruders. Security requirements are basically application-specific; to understand the need, various physical layer, Medium access control (MAC) layer, Network layer, and Application layer protocols are discussed. These protocols are compared based on data confidentiality, data integrity, data origin authentication, and data freshness, which comprehend various security demands. Hence, it is suggested to build secure IoT system, which can be trusted for different applications. Nevertheless, Fog computing platform along with layered IoT architecture [5] is proposed from computation point of view in different IoT applications. Embedded Systems Platforms for IoT Prototypes, Communications Technologies in IoT, backbone protocols for IoT architecture, Security in IoT, applications of IoT, and computing framework for IoT are elaborated. Fog and cloud computation models are also investigated for their performance in different applications. The need of IoT sensor network in the field of healthcare and transportation is explored to identify the required communication technologies for IoT applications [6].

Third-generation partnership project and low power wide-area solution in cellular technology for many IoT use cases are experimented. Moreover, new radio enhancement for 5G with new requirements and enhancements are also introduced in IoT communications. Possibilities of applying recent technologies, which are capable of enhancing the performance of IoT-based system, are investigated heavily. IoT applications based on context aware congestion control have given the new research directions. Managing and controlling the IoT network is still a big challenge, and it is suggested to develop a lightweight CoAP or UDP-based IoT network to support 5G network and its applications. Hence, the study of communication component in IoT highlighting the major approaches [7] plays a vital role in IoT communication. These approaches includes using a model of Internet devices based on the application requirement, specific case study, evaluation and comparison, and communication component for the application like smart home technologies. Different communication standards, communication protocols, QoS for IoT-based smart home technologies, and some IoT protocols are presented. It is suggested to handle the communication component properly to reduce the power consumption of IoT network. Furthermore, IoT architectures are reviewed for understanding the use of tools, technology, and methodology for different requirements in IoT applications [8]. The key utility factors such as communication protocols, scalability, security, and network integration are adopted to develop IoT system for various real-life problems. In addition, the challenges in IoT architecture are investigated to provide direction for the future research. Moreover, IoT architectures in many fields such as education, multimedia, and tourism are suggested to be explored in order to use it efficiently. An overview of IoT in 5G wireless system [9], wherein technology drivers such as new 5G radio, MIMO antenna with beam forming technology, mmWave communication technology, heterogeneous network, and role of augmented reality in IoT, is presented in detail. In addition, low power wide-area networks, security and its control measures in 5G IoT environment, research gap, and challenges in IoT are highlighted for future research in IoT applications in different areas. Promising technologies suggested for 5G technology are to be investigated for new research in the heterogeneous network in 5G environment related to mobility management in IoT.

Subsequently, a survey of application layer communication protocol to suite the IoT requirement [10] is provided along with their potential use in Fog and cloud architecture. The protocols such as HTTP, MQTT, CoAP, AMQP, DDS, and XMPP are elaborated for their operation with important component of the communication protocol, that is, characteristic features. The communication protocols are compared based on their performance in different environment, which includes latency, energy consumption, and network throughput. This helps to decide which communication protocol to be used in which environment. In [11], cross technology communication (CTC) in IoT devices with the hardware perspective is highlighted. CTC techniques are categorized as hardware-based and hardware-free. This categorization is based on the requirement of the dedicated hardware for communication or heterogeneous wireless devices in the network for communication. Different CTC techniques are compared based on the parameters such as throughput, communication range, energy efficiency, and cost. In [12], a review of Internet centric networking (ICN) in IoT is presented. ICN for communication is explored for IoT in various domains. Domain-specific ICN-IoT combination is investigated to explore the possibility of better performance in different environments wherein requirement changes based on environment. QoS, security, communication, and mobility parameter are the key parameters to examine related to IoT perspective. Furthermore, various IoT architectures and protocols are demonstrated [13] and classified based on a variety of features. In succession, challenges in IoT such as security, mobility, scalability, and energy efficiency are presented to meet the current and future research trends in IoT communication. Application-specific architecture and requirement of IoT, and wireless sensor network in IoT open an avenue to research in IoT communication.

Communication in network is considered to be a very important factor since the performance of the network depends on efficient communication among the network devices. The communication protocols help in gathering the data and information in the network. This information is used for further processing once it is sent to the server. Different types of statistical analysis are performed on the collected information, and conclusions are drawn for the particular scenario, which helps in deciding the further course of action.

4.1 IEEE 802.15.4

Operation of IEEE 802.15.4 along with the challenges in its successful deployment in IoT is discussed in [14]. Physical layer and MAC layer are very important in communication system and significant in network operation. IEEE 802.15.4 is specially designed for low data rate and low energy consumption devices in private area networks. It is utilized in the application that runs for longer duration and uses low-cost nodes [16]. The 802.15.4 specification is defined for limited set of power-management methods [16]. IEEE 802.15.4 MAC is used in a network that operates in beacon enabled and non-beacon enabled mode [16, 46]. IEEE 802.15.4 devices in IoT have many challenges such as identification of duty cycle, synchronization among the devices in multihop deployment, and identification of the right parameters for performance check. Hence, these challenges need to be overcome for the successful deployment of IEEE 802.15.4 devices in IoT. An improved modulation scheme based on IEEE 802.15.4 standard is proposed in [15] for impulse radio ultra wideband communication. This scheme increases the data rate and reduces the interference in multiple users. The unused time during communication is utilized to double the burst position, which allows the user to transmit during dedicated hopping positions and doubling the physical layer data rate. Here, the M array signaling is adopted during transmission. On Off Keying (OOK) and pulse shift keying (PSK) are used as additional modulation techniques by passing the burst position modulation (BPK). Moreover, the system model adds extra fields to the PHY header to inform the receiver about the modulation method that can be achieved by the presence of PHY layer and MAC layer. The data is collected from all the surrounding devices by using hub. Hence, the battery life and data rate are increased. It also provides the flexibility for scaling the network for additional user.

4.2 6LoWPAN

A low power wireless personal area network (LoWPAN) with additional layer and efficient IPv6 communication over IEEE 802.15.4, that is, 6LoWPAN is proposed in [16]. Wireless personal area network (WPAN) is specially designed to operate with low power. Moreover, the use of IEEE 802.15.4 in LoWPAN limits its capability and poses many challenges for its implementation. To remove this demerit, an additional layer is provided in 6LoWPAN protocol. The 6LoWPAN additional layer consists of three components – (1) header compression, (2) fragmentation, and (3) layer-two forwarding, which makes it suitable for many applications. The additional layer of 6LoWPAN uses stateless compression, which makes it adaptable for network and transport layers' header field. Hence, 6LoWPAN can be applied in many network applications in a physical environment with meaningful location. Furthermore, an implementation of 6LoWPAN with IPv6 adaptation layer for the Near Field Communication (NFC) devices is presented in [17]. NFC devices does not have unique id for auto-configuration of address, which needs to configure IPv6 address. In addition, IP header compression is also performed with address auto-configuration. Context Identifier Extension (CID) flag, Source Address Compression (SAC), Source Address Mode (SAM), Destination Address Compression (DAC), and Destination Address Mode (DAM) can be utilized for authentication while communicating with other devices. The addition of adaptation layer increases the performance of the network by reducing the initialization delay compared to the conventional NFC communication.

4.3 BLE

To establish an energy-efficient and cost-effective communication between sensors and Engine Control Unit (ECU), we can use Bluetooth Low Energy (BLE), and vehicular ad hoc network can also be formed using BLE [18]. BLE can be utilized for inter-vehicular and intra-vehicular wireless communication, and many applications such as biomedical, personal electronics, renewable green energy generation and distribution, security, and surveillance can be efficiently supported with one hop communication. BLE is suitable in applications where low duty cycle and less power consumption is the primary goal with low cost. Generic Attribute Profiles (GATT) is defined by BLE in client/server sensor architecture, while Generic Access Profile (GAP) is defined by BLE to decide the role of devices. BLE-based sensors are explored in a variety of sensor-based applications where low energy consumption is required [19]. BLE is connection-oriented in the sense that the two devices wanting to exchange the information should be connected with each other. To ensure the energy saving in Bluetooth network, the two devices must be connected only if there is a need of data transfer between these devices. Long connection time in traditional Bluetooth network is one of the biggest drawbacks, which is reduced in new BLE technology. Specific channel is used by BLE devices to send and receive the data. Moreover, in sensor network, lightweight BLE stack is applied, and good data throughput is achieved in BLE-based WSN. The interoperability of BLE and IEEE802.15.4 communication protocols that works well in some applications is investigated in [20]. BLE forms a star network at the link layer with a master orchestrating bidirectional communication with one or more slaves. As compared to IEEE 802.15.4, BLE is full protocol stack without having restrictions at the physical and MAC layers.

4.4 CoAP

The Constrained Application Protocol (CoAP) is a specialized web transfer protocol for use in the IoT with restricted nodes and restricted networks [21]. This is a specially designed protocol for IoT and lightweight M2M communication. This protocol is an enhancement over HTTP for low-power devices and work with UDP. CoAP deals with confirmable and no confirmable messages to handle the unreliability of UDP. CoAP is an application layer protocol and does not contain security features for the data transfer [22]. Datagram Transport Layer Security (DTLS) is used as a secure protocol and UDP as a transfer protocol in CoAP. It is designed for applications that are limited by the environmental condition like wireless sensor network. Moreover, CoAP suffers from parsing attack, caching attack, amplification attack, spoofing attack, and cross protocol attack. A new CoAP-based technique for communication through multiple smart objects with a community of resources is proposed in [23]. CoAP-enabled access is dramatically rising in numbers for intelligent devices. It is a lightweight protocol designed to meet the limitations of resources in IoT or sensor network. CoAP technology is applied to control individual resources in order to avoid increasing the footprint of restricted devices.

4.5 AMQP

Advanced Message Queuing Protocol (AMQP) is applied to design IoT-based smart system for cloud environment [24] wherein the smart devices are controlled remotely by the mobile user. AMQP is best suited for the application where Internet is unstable. The store and forward feature of this protocol saves the data temporarily if the Internet becomes unstable. AMQP is characterized by high interoperability and security, which makes it flexible for use in multiuser system. It is mainly adopted for smart home systems. It guarantees the smooth communication between sender and receiver if there is a disruption in the Internet. AMQP is a standard for an asynchronous messaging. The conventional messaging protocols have many limitations [25]. The main characteristics of AMQP are symmetric, secure, compact, multiplexed, reliable, and binary. Moreover, AMQP is usually layered over TCP and delivers reliable ordered sequence of frames.

4.6 IPsec

Since an Internet protocol is insecure, Internet Protocol Security (IPsec) protocol is designed to offer security in the network [26]. This security feature makes the IPsec better suited for the network applications. Security of the protocol is based on the cryptographic algorithm and strength of key used in the algorithm. IPsec maintains confidentiality in the communication, and its most used implementations are the IPsec deployments that run on the network layer. IPsec as a Virtual Private Network (VPN) application is applied by businesses, suppliers of services, and government networks. IPsec is considered as a set of services and protocols to deliver security in IP-based networks [27]. Because IPsec operates on the IP layer, it can provide these safeguards without the need of additional security methods for any higher layer TCP/IP application or protocol, which is its major strength. IPsec offers the integrity of a message to ensure that it is not altered during communication and establishes a secure communication path for the two devices for exchange of information. IPsec protocol suite comprises core protocols and support component as a major part. Authentication services are delivered by authentication header while integrity of data is ensured by encapsulating security payload, and services are provided by support component. Subsequently, a new IPsec protocol using IPsec tunnel and HTTP tunnel [28] is designed to provide security to IP data packets and to the upper

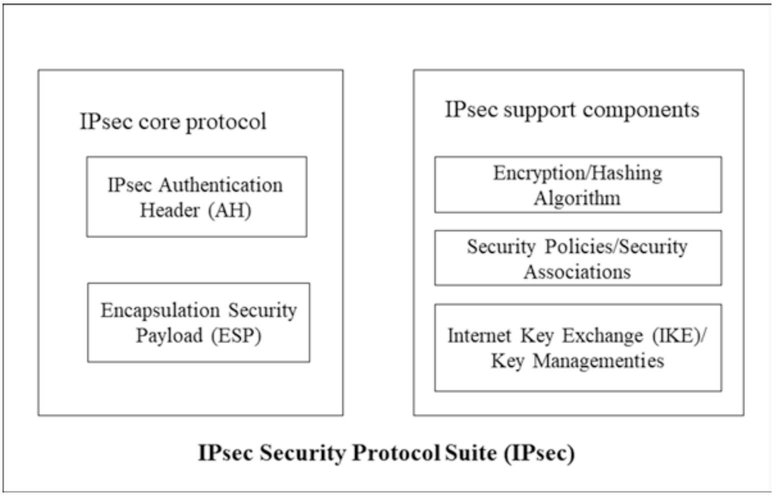


Fig. 3 IPsec protocols and components

layer by using authentication header and encapsulating security payload. This protocol solves the network adaptability problem efficiently (Fig. 3).

4.7 LoRAWAN

Long Range Wide Area Network (LoRaWAN) communication protocol is used in IoT-based WSN to increase the performance of the network [29]. Long range (LoRa) modulation is used in the physical layer of LoRaWAN communication protocol and specially designed for IoT applications. It uses unlicensed industrial, scientific, and medical (ISM) frequency, which is considered to be the biggest advantage of LoRaWAN [29, 30]. Duty cycle of the LoRaWAN devices is deliberated as the drawback since it depends on the geographical area where these devices are used. Many localization techniques adopted LoRa technology for communication. Three types of nodes are specified by LoRaWAN devices, that is, classes A, B, and C. Messages are sent to the gateway by class A devices, which are extended by class B devices by adding scheduled message reception slots, and class C devices prolong class A [29–31]. To achieve better results for communication range and data transfer rate, LoRa technology utilizes multiple spread factors. The LoRa unique architecture consists of end nodes and gateway modules that retransmit messages to the network server from the terminal nodes. The LoRaWAN protocol utilizes a communication mechanism of the Additive Links, On-line Hawaii Area (ALOHA) type, where the packet length is variable. Nodes can transmit at any time on any available channel using any available data rate, according to the LoRa protocol specifications. The frequency shift offers the key benefit of communication in LoRa, which is

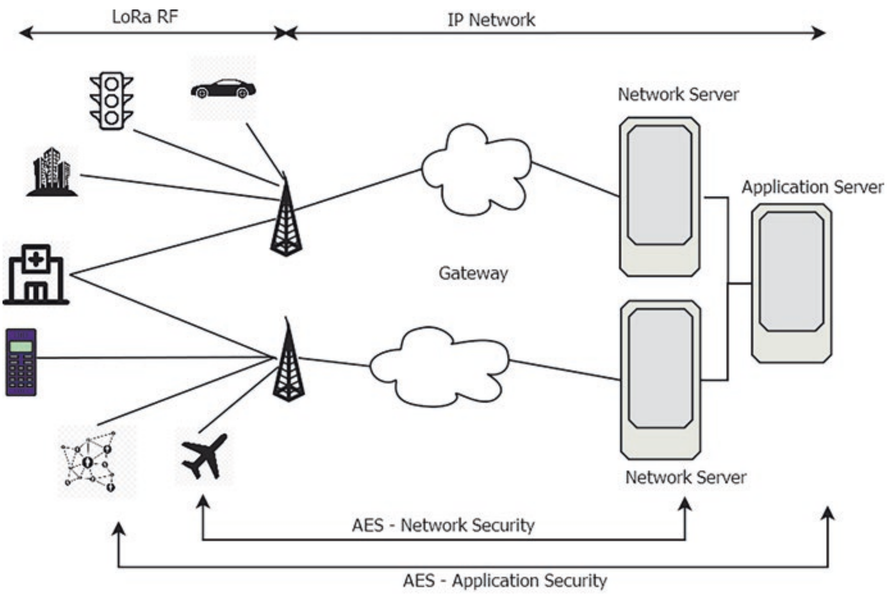


Fig. 4 LoRaWAN architecture

interference resistance. The LoRaWAN specification specifies a method for adapting the transfer rate of the Adaptive Data Rate (ADR) without providing any information on the parameters monitored or those involved in the process of rate selection. The low transfer rate LoRaWAN configuration is mostly used, since it guarantees the widest communication range by using a high spread factor. LoRaWAN is an open low power wireless area network (LPWAN) standard developed by the LoRa Alliance with key features such as low energy consumption, long-range communication, built-in security, and GPS-free positioning (Fig. 4).

The LoRaWAN network topology is known as star-of-stars from an architectural point of view. LoRaWAN is a MAC layer protocol aimed at solving network congestion management problems. LoRa modulation expands the conventional concepts of Spread Spectrum to reduce the amount of energy needed to transfer bits through the channel. In handling interference, the LoRa modulation has better efficiency than Frequency Hopping techniques. ALOHA-type random access is used by LoRaWAN to keep network complexity as easy as possible and optimize energy savings. To secure network protocol and user data, LoRaWAN has built-in protection available in itself. Advanced Encryption Standard (AES 128) encryption protects data via node-to-application and node-to-network-server, and LoRaWAN networks are ideally suited to outdoor IoT solutions such as smart cities, airports, and agriculture.

4.8 LTE

The Long Term Evolution Standard (LTE) is a high-speed data standard for mobile phones and data terminals for wireless communication. Although most of the existing IoT cellular networks operate over 2G and 3G, one of the major platforms for the emergence of new M2M communication systems is an LTE technology [32]. To replace signal exchanges at the cellular center for M2M communications, LTE mobile networks are proposed. LTE was designed to provide packet-switched services only and to provide IP access between the mobile devices and the Internet. Multiple bandwidth (BW) configurations are supported by the LTE standard, from 1.5 to 20 MHz with 10 MHz being the most frequently deployed. The LTE Random Access protocol is focused on the transmission of brief preambles containing one randomly selected signature from a pool of 64 signatures available. LTE has increased carrier capacity, high-speed data rate, reliable connectivity, and is cost-effective. In the LTE network, each device's identity is transmitted from user entity (UE) to mobility management entity over the air interface [33]. The overheads of communication and computation created by the current LTE protocols are very high and do not support network IoT functionality. Recent LTE technologies are expected to offer IoT artifacts with stable and efficient services.

4.9 MQTT

Message Queuing Telemetry Transport (MQTT) protocol is widely used in IoT applications for M2M communication in wireless communication environment with low bandwidth [34]. This protocol is intended to be used in devices with limited memory capabilities and limited processing capacity. MQTT protocol links middleware and applications to networks and systems. There are various types of MQTT such as mosquito, hivemq, and paho MQTT. The most favorable communication protocol for M2M and IoT is MQTT. MQTT is ideal for resource-constrained or unstable devices that are used in networks with limited bandwidth and appears above the Transport Control Protocol (TCP), that is, HTTP in application layer. Devices communicate with each other in many-to-many manner in MQTT protocol. A standard format of message is to be followed by all the devices using MQTT since it is message-oriented protocol and QoS profile decides the performance of MQTT protocol. MQTT protocol operates on the top of TCP for communication within an IoT environment [35]. MQTT is a messaging protocol that uses the publish-subscribe communication model where updates are not required by the customers themselves, which in turn leads to a decrease in resources utilization, making this model optimal for low-bandwidth environments. The protocol operates on a server-client basis where updates to MQTT clients are pushed by the server, called as broker and client/server does not bother to check the identity of each other. MQTT was developed for asynchronous communication where subscriptions or publications take place in parallel. It is also a lightweight protocol, which is used in IoT infrastructure for data transmission [36]. Moreover, MQTT is ideally suited for IoT nodes with restricted capabilities and resources.

4.10 NFC Protocol

Near Field Communication (NFC) is commonly applied in digital payments for authentication purpose in IoT-enabled services and applications [37] and is also employed in mobile IoT authentication for privacy security and lightweight specifications. NFC technology works on 13.56 MHz frequency band with the data transmission rate of 106–424 kbps. It uses a special technology for signal attenuation, and the effective radio range is below 20 cm. NFC is designed to provide IoT mobile devices with a low-cost, high-bandwidth, and low-energy communication system. NFC is widely accepted in different contexts such as electronic payment, identity verification, logistics monitoring, mobile IoT data collection, healthcare applications, social network services, educational services, and location-based services [37, 38]. Nowadays, a large range of devices suitable for IoT are implementing NFC technology [38]. In a variety of applications that belong to consumer electronic devices, NFC is applied for short-range communication [39]. Although it is very easy to use NFC, this technology is a threat to users due to many network attacks. Processing time is a crucial factor in NFC architecture since the NFC devices are used in real-time applications.

4.11 RFID

Radio Frequency Identification (RFID) technology is utilized to track the objects in IoT-based applications [40], and radio waves are used to identify an object. Three frequency regions are available for RFID radio waves: Low Frequency (LF), High Frequency (HF), and Ultra High Frequency (UHF). RFID automatically reads or writes information stored on RFID tags using radio waves and electromagnetic fields. In relation to its strength, there are three types of RFID tags: *passive*, *semi-passive*, and *active*. This classification of the RFID tag is based on the presence of power source and the operation performed. The detection of RFID tag occurs when the radio signal is transmitted by the reader next to the tag, near the RFID reader. RFID and IoT have a significant impact on the latest technological transition such as smart cities, smart highways, and smart medicine [41]. Three key components of RFID is a transponder, an interrogator or reader, and a communication channel [41, 42]. RFID standard consists of both frequency ranges and data formats; RFID suffers from the problem of collision between tags. Most IoT applications are based on RFID communication or technology or sensors. Key features of RFID are: it allows complex data to store and provides wireless communication without line of sight for identifying objects. RFID is a better and more realistic technology to be applied with the objects of different surfaces, allowing read/write capabilities without visual interaction [41, 42]. More secure RFID with efficient authentication is the requirement of the time.

4.12 WiFi

When higher data rates are needed in energy-constrained devices, it is suitable to adopt WiFi technology [43]. The hardware of these devices is designed to be extremely compact and energy-efficient. In order to minimize current consumption, these devices have the capacity to turn off various parts of the board. The system can thus achieve various low-power states depending on the components and parts of the board that are turned off. Depending on whether it is in the transmitting state, receiving state, wakeup/active, or one of the inactive states such as sleep, deep sleep, and hibernation, a system may have varying current consumption levels. The MAC layer mechanisms require the configuration of the end device client to allow it to wake up just in time to maintain connectivity. If the system client stays longer than the supported time in one of the available sleep states, then the system is disconnected from the network. With the use of WiFi, remote location can be connected with low cost. There are four main forms of WiFi technology at present, namely, WiFi-802.11a, Wi-Fi-802.11b, Wi-Fi-802.11g, and Wi-Fi-802.11n. 802.11a is one of a range of wireless technologies available that determines the format and structure of the radio signals transmitted by the routers and antennas of the WiFi network.

4.13 XMPP

The Extensible Messaging and Presence Protocol (XMPP) is an IP technology and Extensible Markup Language (XML)-based real-time information transmission specification that supports publishing/subscribing messaging systems [44, 45]. XMPP has been widely implemented and applied throughout the Internet. The Internet application of the XMPP protocol focuses mostly on data interaction, while the IoT application of the XMPP protocol is more concerned with the processing of data. The publish/subscribe architecture that is more fitting for the IoT is implicitly supported by XMPP. The good transparency and scalability of XMPP can be used to implement interoperability between large ranges of instant messaging systems. XMPP is a better suited protocol for the communication in IoT devices. XMPP is used as a base for many other products and solutions, including gaming, geolocation, and cloud computing [45]. XMPP provides real-time exchange of structured yet extensible data between network entities. XMPP is an ideal backbone protocol for various endpoint protocols to provide universal connectivity. To allow message-oriented communication services that are applicable in the Internet context, the

XMPP Protocol is better. Decentralized client/server model is used in XMPP architecture. A general structure for communicating through a network is provided by XMPP. This communication protocol is limited to text data transfer only.

4.14 ZigBee

The ZigBee is a secure, low-power, low-cost, and efficient technology for information network design [46]. It is a high-level communication protocol whose specification is based on IEEE 802.15.4 standard. For connecting sensors, instrumentation, and control systems, ZigBee is the most common wireless mesh networking standard in the industry. The data transfer rate for ZigBee is maximum up to 250 kbps, and in ZigBee network, a node can manage up to 254 sub nodes. The data integrity checks and authentication functions are provided by ZigBee and use AES128 for the security purpose. Support for star, mesh, and cluster tree is offered by ZigBee protocol [46, 47]. The structure of the ZigBee system consists of three separate device groups such as ZigBee coordinator, router, and end device. One coordinator node is a must in ZigBee network, which acts as a root and bridge for handling the data generated during transmission and receiving process. ZigBee routers play very important role in transmitting the data to and from other devices through them. Moreover, ZigBee network data transmission models are divided into three categories, that is, (1) transmission from the coordinator to the module of the sensor, (2) transmission from the module of the sensor to the coordinator, and (3) transmission between the coordinators. Beacon-based sensor network uses ZigBee network topology. The network and application layers, application framework, application profile, and security mechanisms are also quantified by ZigBee [47]. ZigBee delivers users with a simple and low-cost global network for specific applications that supports a large number of nodes with an exceedingly low battery drain. The ZigBee routers (ZRs) are utilized in tree and mesh topologies to increase the communication range at the network level. In sensor network most of the time, the sensor nodes are ZigBee devices with limited functionality and communicate with their parent device. The performance of ZigBee-based wireless sensor network is better as compared to other networks.

4.15 Z-Wave

Z-Wave is a useful technology for RF integration of sensors and actuators, which can be applied in smart home and office automation services [48, 49]. Z-Wave is a complete IoT substratum implementation comprising well-defined protocols for communication, networking, and application layer protocols. Z-Wave capable sensors, actuators, controllers, routers, and Internet gateways can be combined to provide home and office automation facilities. Messages are exchanged asynchronously as MAC Protocol Data Unit (MPDU) frames over the RF medium using the Z-Wave physical layer. Through the Security Command Class, Z-Wave offers privacy, source integrity, and data integrity services. It is known for providing a simple and secure way to monitor automated devices at home wirelessly. The Z-Wave network is an Internet-controlled remote network that uses a Z-Wave gateway or central control appliance. Z-wave devices communicate with each other using radio frequency (RF) technology. In addition, Z-Wave's MAC layer includes a collision avoidance (CA) technique that enables a frame to be transmitted when the channel is open and when no other nodes are transmitting. The Z-Wave protocol transfer layer manages the communication between two sequential devices, including transition, checksum screening, and acknowledgment, which indicates whether or not the communication has been successful so that the exchange of data between devices must be assured without errors. In the Z-Wave protocol, the routing layer manages to forward frames from one device to another via the Z-Wave network. The Z-Wave application layer is responsible for the delivery, decoding, and execution of commands and parameters of the frame payload on the Z-Wave network.

Table 1 highlights the different communication protocols utilized in IoT to allow the communication between various devices. The various facts and applications of these protocols help in identifying the suitability and applicability of each protocol in various system designs.

5 IoT Applications

IoT is used in a variety of applications where automated collection of information based on certain parameters in a system is required. Some of the applications are described in Fig. 5.

Smart Healthcare Medical devices can be integrated with IoT devices to assist the patient and doctor to monitor the health parameter. This will benefit in diagnosing the patient from remote place and to deliver better healthcare facilities. The elderly people and the patients who are not in a position to go to the hospital and get treatment will be benefitted if some devices, which monitor their health parameters, are mounted on them. The doctor can monitor the health parameter from the remote location and suggest proper medication for them. The communication protocols like XMPP are applied in developing healthcare application using IoT infrastructure.

Smart Homes IoT is applied to control the home appliances and electronic devices at home remotely. A mobile or laptop or some communicating gadget can be utilized for controlling these devices. Smart meters nowadays are used to measure the energy consumption at home. CCTV surveillance can be made smart by applying the IoT concepts. IEEE 802.15.4, LTE, Z-Wave, LoRawan, and AMQP are some communication protocols employed in smart home application [49].

Table 1 Communication protocols in IoT

Protocol	Facts and finding
IEEE 802.15.4 [14–16, 46]	Data rates: 250 kbps, 40 kbps, and 20 kbps 16-bit short and 64-bit IEEE addressing Supports critical latency devices CSMA-CA channel access Automatic network establishment by the coordinator Fully handshake protocol for transfer reliability Low power consumption 16 channels in the 2.4GHz ISM band 10 channels in the 915 MHz band One channel in the 868 MHz band
6LoWPAN [16, 17]	Used in small and low power devices having low processing capability Efficient in lossy network Uses packet compression Uses IPV6 packet transmission
BLE [18–20]	Low power consumption Cost-efficient and compatible Robust and reliable High throughput Higher connection range
CoAP [21–23]	M2M communication with constrained requirement Specialized web transfer protocol Asynchronous message exchange Low overhead Deals with confirmable and non-confirmable messages Vulnerable to different network attack
AMQP [24, 25]	Message-oriented Used in application where Internet is unstable Uses store and forward feature Offers asynchronous messaging Symmetric and secure Compact and reliable
IPsec [26–28]	Protection against reply attack Data origin authentication Security in data forwarding Confidentiality in communication Dynamic key formation Message integrity
LoRaWAN [29–31]	Low-power and low-cost communication Mobile and secure Supports large network Free from network congestion problem Supports redundant operations and geolocation Suitable for low-cost low-power applications
LTE [32, 33]	Increases carrier capacity High-speed data rate Reliable connectivity Cost-effective Supports packet-switched service Spectrum flexibility Use of multiple antenna

(continued)

Table 1 (continued)

Protocol	Facts and finding
MQTT [34–36]	Lightweight and bandwidth efficient Quality of service data delivery Used in devices with limited memory Asynchronous communication Ideal for resource-constrained devices Links middleware and applications Persistent session
NFC [37–39]	Low cost and low energy Short energy communication Uses 13.56 MHz frequency band Data transmission rate of 106–424 kbps Uses special technology for signal attenuation Used in identity authentication
RFID [40–42]	Communication frequency ranges from 860 to 920 MHz Good transmission distance Good transmission speed Used to track objects Allows complex data to store Communication without line of sight Collision of tags occurs
WiFi [43]	Higher data rate Energy-efficient Good load balancing during transmission Different modes of operation Scalable Network management Used in indoor as well as outdoor applications
XMPP [44, 45]	Instant messaging Lightweight middleware Content syndication Used in message-oriented services Universal connectivity Limited for text data
ZigBee [46, 47]	Low cost and low power Secure and energy-efficient Data transfer rate is 250 kbps Scalable Data integrity and authentication Uses star, mesh and cluster tree topology AES128 is used for security purpose
Z-Wave [48, 49]	Low energy and low cost Low power consumption Less interference Uses mesh topology Used in RF integration of sensors Interoperability Scalable and secure

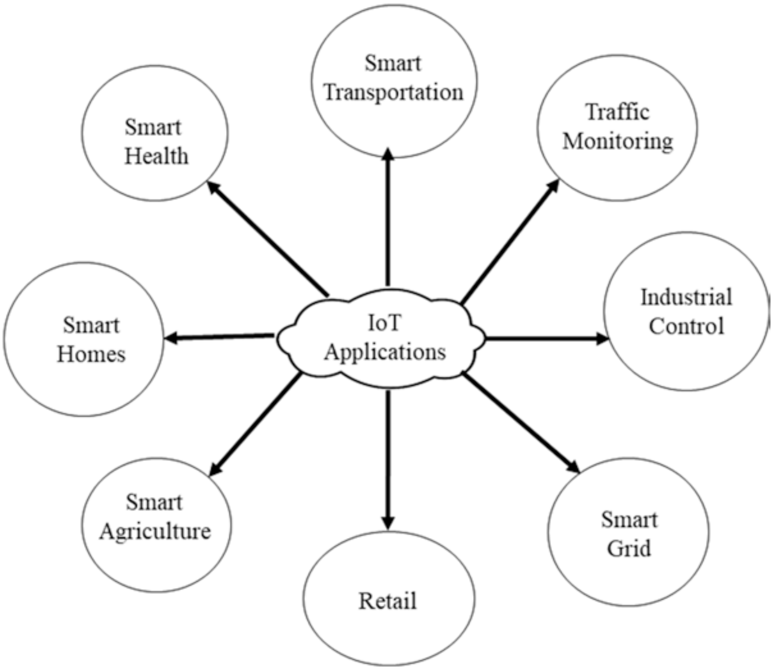


Fig. 5 Application of IoT

Traffic Monitoring In the control of vehicular traffic in big cities, IoT is very useful in contributing to the idea of smart cities. RFID and MQTT communication protocols are used in this application. When we use our cell phones as a sensor, through applications such as Waze or Google Maps, it captures and exchanges data from our cars. IoT system alerts us and at the same time contributes to traffic monitoring. It demonstrates the conditions of the different routes to provide the traffic condition on that route so as to find the best suitable route [50].

Agriculture Clever farms are a reality nowadays. In order to grow good crops, soil quality is important, and the IoT offers farmers the ability to access accurate knowledge and useful information on their soil condition. A large amount of data can be collected on the condition and phases of the soil through the implementation of IoT sensors. Information such as soil moisture, acidity level, presence of certain nutrients, temperature, and many other chemical characteristics help farmers monitor irrigation, increase the efficiency of water usage, determine the best times to start sowing, and even recognize the presence of plant and soil diseases. Communication protocols like CoAP and LoRaWAN are used in smart agriculture [51, 52].

Smart Grid and Energy Saving The incremental use of smart energy meters or sensor-equipped meters and the installation of sensors at various strategic points, from the manufacturing plants to the various distribution points, allow better monitoring and control of the electrical network. 6LoWPAN is the best suited communication protocol for this purpose. Information of huge value can be obtained for the identification, decision-making, and repair of faults by creating a bidirectional contact between the service supplier business and the end user. It also enables the end user to be presented with useful information about their usage habits and the best ways to minimize or change their energy expenditure.

Smart Transportation IoT is adopted to find the location of products in large warehouses or ports, to check quality conditions during the shipping of goods, and to monitor routes for sensitive products such as gold and medical drugs. RFID communication protocol is utilized to identify the tags and track the status in such application. Different sensors can assist in the analysis of traffic conditions and warning of traffic jams, collisions, and accessible parking spaces. Such data allows passengers to drive smartly and intelligently.

Retail IoT can be applied to track goods and to control storage conditions of goods and commodities. It can be used to provide shopping customers with feedback based on their habits, and can also be applied in the automated restocking phase by assisting in monitoring and rotating items in shops and warehouses. The communication technology like RFID for tagging and WiFi data communication is employed in such applications.

Industrial Control IoT is also integrated in industries to monitor air quality, temperature, and ozone presence, and to warn in the event of any emergency. CoAP communication protocol is best suited in such application. The baggage handling system used at airports is an example, where the sensors detect when the baggage moves on the conveyor belt and stops if no one moves. Based on the barcodes, luggage is marked and processed for the further delivery.

6 Conclusion

Communication among the devices in IoT network is very important for the better functioning of the network. Many communication protocols and techniques are available for the information exchange among the IoT devices, and most of them are application dependent. All communication techniques can be applied for all IoT-enabled applications with performance variation. This chapter demonstrates the communication techniques available for IoT infrastructure with their significance of existence. There are many parameters on which the performance of these communication techniques is dependent. Some can be applied in low power and low energy requirement while somewhere higher data rate and security of the network are more important. Mostly, communication techniques are based on the communication standard, that is, IEEE 802.15.4, since it used for low power, low data rate with short range of communication in the network. Some communication protocols are used in the applications where faster data rate is required, and they are message oriented. BLE, WiFi, and ZigBee are the specialized protocols, which are used in wireless sensor networks. AMQP, MQTT, XMPP, and CoAP protocols are used in IoT-enabled application and data transfer. Protocols like RFID are used for object tracking. Some protocols like LoRaWAN, LTE, and Z-Wave are used to solve congestion problems in network and RF integration.

Security is one of the main concerns for many communication protocols. The future work can be aimed at facilitating robust security in the protocols. Interoperability can be increased by allowing platform-independent communication among the IoT devices, and to do so, a new architecture can be designed. Many communication protocols are range and data rate constrained; hence, work needs to be done in this direction. Communication technologies have their advantages and drawbacks. Hence, while selecting the communication technology, its characteristic features must be taken into consideration.

References

1. P. Sethi, S.R. Sarangi, Internet of Things: architectures, protocols, and applications. J. Electr. Comput. Eng. **2017**, 1 (2017)
2. A.H. Ngu, M. Gutierrez, V. Metsis, S. Nepal, Q.Z. Sheng, IoT middleware: A survey on issues and enabling technologies. IEEE Internet Things J. **4**(1), 1–20 (2016)
3. M. Mukherjee, I. Adhikary, S. Mondal, A.K. Mondal, M. Pundir, V. Chowdary, A vision of IoT: applications, challenges, and opportunities with Dehradun perspective, in *Proceeding of International Conference on Intelligent Communication, Control and Devices*, (Springer, Singapore, 2017), pp. 553–559
4. D. Dragomir, L. Gheorghe, S. Costea, A. Radovici, A survey on secure communication protocols for IoT systems, in *2016 International Workshop on Secure Internet of Things (SIoT)*, (IEEE, September 2016), pp. 47–62
5. S. Tayeb, S. Latifi, Y. Kim, A survey on IoT communication and computation frameworks: An industrial perspective, in *2017 IEEE 7th Annual Computing and Communication Workshop and Conference (CCWC)*, (IEEE, January 2017), pp. 1–6
6. G.A. Akpakwu, B.J. Silva, G.P. Hancke, A.M. Abu-Mahfouz, A survey on 5G networks for the Internet of Things: communication technologies and challenges. IEEE Access **6**, 3619–3647 (2017)
7. A.A. Zaidan, B.B. Zaidan, M.Y. Qahtan, O.S. Albahri, A.S. Albahri, M. Alaa, et al., A survey on communication components for IoT-based technologies in smart homes. Telecommun. Syst. **69**(1), 1–25 (2018)
8. P.P. Ray, A survey on Internet of Things architectures. J. King Saud Univ. Comput. Inf. Sciences **30**(3), 291–319 (2018)
9. L. Chettri, R. Bera, A comprehensive survey on Internet of Things (IoT) toward 5G wireless systems. IEEE Internet Things J. **7**(1), 16–32 (2019)
10. J. Dizdarević, F. Carpio, A. Jukan, X. Masip-Bruin, A survey of communication protocols for internet of things and related challenges of fog and cloud computing integration. ACM Comput. Surv. (CSUR) **51**(6), 1–29 (2019)

11. Y. Chen, M. Li, P. Chen, S. Xia, Survey of cross-technology communication for IoT heterogeneous devices. IET Commun. **13**(12), 1709–1720 (2019)
12. B. Nour, K. Sharif, F. Li, S. Biswas, H. Moungla, M. Guizani, Y. Wang, A survey of Internet of Things communication using ICN: a use case perspective. Comput. Commun. **142**, 95–123 (2019)
13. C.C. Sobin, A survey on architecture, protocols and challenges in IoT. Wirel. Pers. Commun. **112**, 1–47 (2020)
14. D. Dutta, IEEE 802.15. 4 as the mac protocol for internet of things (IoT) applications for achieving QoS and energy efficiency, in *Advances in Communication, Cloud, and Big Data*, (Springer, Singapore, 2019), pp. 127–132
15. T. Paso, V. Niemelä, J. Haapola, M. Hämäläinen, J. Iinatti, Performance evaluation of IEEE 802.15. 4-2011 IR-UWB system with enhanced modulation scheme, in *Proceedings of the 10th EAI International Conference on Body Area Networks*, (September 2015), pp. 116–122
16. J.W. Hui, D.E. Culler, Extending IP to low-power, wireless personal area networks. IEEE Internet Comput. **12**(4), 37–45 (2008)
17. J. Park, S. Lee, S.H. Bouk, D. Kim, Y. Hong, 6LoWPAN adaptation protocol for IPv6 packet transmission over NFC device, in *2015 Seventh International Conference on Ubiquitous and Future Networks*, (IEEE, July 2015), pp. 541–543
18. N. Mirza, A.N. Khan, Bluetooth low energy based communication framework for intra vehicle wireless sensor networks, in *2017 International Conference on Frontiers of Information Technology (FIT)*, (IEEE, December 2017), pp. 29–34
19. E. Mackensen, M. Lai, T.M. Wendt, Bluetooth Low Energy (BLE) based wireless sensors, in *SENSORS, 2012 IEEE*, (IEEE, October 2012), pp. 1–4
20. P. Narendra, S. Duquennoy, T. Voigt, BLE and IEEE 802.15. 4 in the IoT: evaluation and interoperability considerations, in *International Internet of Things Summit*, (Springer, Cham, October 2015), pp. 427–438
21. D. Sembroiz, S. Ricciardi, D. Careglio, A novel cloud-based IoT architecture for smart building automation, in *Security and Resilience in Intelligent Data-Centric Systems and Communication Networks*, (Academic Press, 2018), pp. 215–233
22. S. Arvind, V.A. Narayanan, An overview of security in CoAP: attack and analysis, in *2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS)*, (IEEE, March 2019), pp. 655–660
23. I. Ishaq, J. Hoebeke, F. Van den Abeele, I. Moerman, P. Demeester, Group communication in constrained environments using CoAP-based entities, in *2013 IEEE International Conference on Distributed Computing in Sensor Systems*, (IEEE, May 2013), pp. 345–350
24. T. Adiono, R. Muttaqin, R.M. Rahayu, R.V.W. Putra, Cloud system design using AMQP protocol for smart devices system applications (2020)
25. M. Lebiedz, Advanced Message Queuing Protocol (AMQP) as a communication protocol standard for IoT, ppt
26. M. Elezi, B. Raufi, Conception of Virtual Private Networks using IPsec suite of protocols, comparative analysis of distributed database queries using different IPsec modes of encryption. Procedia Soc. Behav. Sci. **195**, 1938–1948 (2015)
27. IP Security Protocol, https://cdn.ttgtmedia.com/searchEnterpriseLinux/downloads/Kozierok_Ch29.pdf. Accessed on 9th Oct 2020
28. M. Song, Z. Yun-he, One new research about IPSec communication based on HTTP tunnel, in *2009 IEEE International Symposium on Parallel and Distributed Processing with Applications*, (IEEE, August 2009), pp. 253–257
29. A. Lavric, A.I. Petrariu, LoRaWAN communication protocol: the new era of IoT, in *2018 International Conference on Development and Application Systems (DAS)*, (IEEE, May 2018), pp. 74–77
30. A. Lavric, V. Popa, Performance evaluation of LoRaWAN communication scalability in large-scale wireless sensor networks. Wirel. Commun. Mob. Comput. **2018**, 1 (2018)

31. M.A. Ertürk, M.A. Aydın, M.T. Büyükakkaşlar, H. Evirgen, A survey on LoRaWAN architecture, protocol and technologies. Futur. Internet **11**(10), 216 (2019)
32. R.P. Jover, I. Murynets, Connection-less communication of IoT devices over LTE mobile networks, in *2015 12th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON)*, (IEEE, June 2015), pp. 247–255
33. N. Saxena, S. Grijalva, N.S. Chaudhari, Authentication protocol for an IoT-enabled LTE network. ACM Trans. Internet Technol. (TOIT) **16**(4), 1–20 (2016)
34. M.B. Yassein, M.Q. Shatnawi, S. Aljwarneh, R. Al-Hatmi, Internet of Things: Survey and open issues of MQTT protocol, in *2017 International Conference on Engineering & MIS (ICEMIS)*, (IEEE, May 2017), pp. 1–6
35. D. Dinculeană, X. Cheng, Vulnerabilities and limitations of MQTT protocol used between IoT devices. Appl. Sci. **9**(5), 848 (2019)
36. M. Kashyap, V. Sharma, N. Gupta, Taking MQTT and NodeMcu to IOT: Communication in Internet of Things. Proc. Comput. Sci. **132**, 1611–1618 (2018)
37. K. Fan, C. Zhang, K. Yang, H. Li, Y. Yang, Lightweight NFC protocol for privacy protection in mobile IoT. Appl. Sci. **8**(12), 2506 (2018)
38. A. Asaduzzaman, S. Mazumder, S. Salinas, M.F. Mridha, A security-aware near field communication architecture, in *2017 International Conference on Networking, Systems and Security (NSysS)*, (IEEE, January 2017), pp. 33–38
39. D. He, N. Kumar, J.H. Lee, Secure pseudonym-based near field communication protocol for the consumer internet of things. IEEE Trans. Consum. Electron. **61**(1), 56–62 (2015)
40. Y.L. Dos Santos, E. Dias Canedo, On the design and implementation of an IoT based architecture for reading ultra high frequency tags. Information **10**(2), 41 (2019)
41. S. Hadjer, C.E.Y. Mustapha, R. Touhami, Role and application of RFID technology in Internet of Things: Communication, authentication, risk, and security concerns. ISeCure ISC Int. J. Inf. Secur. **11**(3), 9–17 (2019)
42. X. Jia, Q. Feng, T. Fan, Q. Lei, RFID technology and its applications in Internet of Things (IoT), in *2012 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet)*, (IEEE, April 2012), pp. 1282–1285
43. A. Varghese, D. Tandur, A. Ray, Suitability of WiFi based communication devices in low power industrial applications, in *2017 IEEE International Conference on Industrial Technology (ICIT)*, (IEEE, March 2017), pp. 1307–1312
44. H. Wang, D. Xiong, P. Wang, Y. Liu, A lightweight XMPP publish/subscribe scheme for resource-constrained IoT devices. IEEE Access **5**, 16393–16405 (2017)
45. A. Iivari, T. Väisänen, M. Ben Alaya, T. Riipinen, T. Monteil, Harnessing xmpp for machine-to-machine communications & pervasive applications. J. Commun. Softw. Syst. **10**(3), 163–178 (2014)
46. İ. Ünal, Integration of ZigBee based GPS receiver to CAN network for precision farming applications. Peer-to-Peer Netw. Appl. **13**, 1–12 (2020)
47. J.S. Lee, Y.M. Wang, Experimental evaluation of ZigBee-based wireless networks in indoor environments. J. Eng. **2013**, 286–367 (2013)
48. C.W. Badenhop, S.R. Graham, B.W. Ramsey, B.E. Mullins, L.O. Mailloux, The Z-wave routing protocol and its security implications. Comput. Secur. **68**, 112–129 (2017)
49. M.B. Yassein, W. Mardini, A. Khalil, Smart homes automation using Z-wave protocol, in *2016 International Conference on Engineering & MIS (ICEMIS)*, (IEEE, September 2016), pp. 1–6
50. J. Zhu, L. Huo, M.D. Ansari, M.A. Ikbal, Research on data security detection algorithm in IoT based on K-means. Scale. Comput. Pract. Exp. **22**(2), 149–159 (2021)
51. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
52. A. Vijayakrishna, G. Gopichand, M.D. Ansari, G. Suryanarayana, IOT based smart agriculture using LIFI, in *2022 5th International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT)*, (IEEE, November 2022), pp. 1–7

IoT Security and Privacy

Jitendra V. Tembhurne, Tausif Diwan, and Tapan Kumar Jain

1 Introduction

Enabling various kinds of devices to interconnect with each other over the internet to exchange information is widely explored by the industry and academia. It is possible due to the revolutionized advancement in the technology specifically Internet of Things (IoT). Nowadays, many devices are connected over the internet, and they play a vital role in the life of people. The functionalities supported by these devices are recording medical health, pollution monitoring, activity under surveillance, logistic management, environment management, etc.

1.1 IoT Evolution and Adoption

The invention of the IoT has been widely experimented with, tested, and accepted, and has become a business growth entity. Due to the need of machine-to-machine (M2M) connectivity, a variety of inventions were proposed by the technology innovators. In manufacturing goods, specifically inventory management for retailers, radio frequency identification (RFID) was utilized for a longer time with

J. V. Tembhurne · T. Diwan
Department of Computer Science & Engineering, Indian Institute of Information Technology, Nagpur, India
e-mail: jtembhurne@iiitn.ac.in; tdiwan@iiitn.ac.in

T. K. Jain (✉)
Department of Electronics & Communication Engineering, Indian Institute of Information Technology, Nagpur, India
e-mail: tapankumarjain@gmail.com

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_3

the objective of optimizing operational efficiency in distant communication. Kevin Ashton proposed the integration of network technology and RFID, namely IoT. The basic aim was to connect the devices remotely and monitor the various activities; hence, the adoption of IoT for various frameworks increases exponentially.

IoT was proposed by Kevin Ashton in 1999, which is capable for collecting data and generating viable information utilized in perceiving, identifying, and recognizing the world by computing system. In the same year, 'Six Webs' platform was presented by Bill Joy to offer communication between devices, i.e. device-to-device (D2D). The first refrigerator connected to the Internet was developed by LG Internet Digital in 2000. To track the life cycle of goods or products, an electronic product code (EPC) was proposed by David Brock (2001) via internet. The universal identification system was introduced in 2003 over global barcode to identify the various objects by unique number or code. Later, this system is called 'Internet of Things'. Hence, to promote the use of connected devices, different stakeholders from industry formed an alliance in 2008, namely Internet Protocol for Smart Objects (IPSO) for the implementation of IoT in real life such as business and industry. Progressively, IoT is adopted in various domains and now it is part of life such as IoT-homes, IoT-cars, IoT-logistics, IoT-healthcare, IoT-manufacturing, IoT-solar trackers, etc.

There are various factors in the adoption of IoT, which is increasing exponentially in various domains but significantly used in industry. The various factors are advancement in network functionality and connectivity, cloud integration, tools for data analytics and low cost computing devices, which are explained as follows:

Advancement in network functionality and connectivity – devices can communicate through various wireless technologies such as Bluetooth, Wi-Fi, ZigBee, Z-Wave, etc. Additionally, to support direct connectivity amongst the devices, peer-to-peer communication without access points using DLNA, UPnP and AllSeen can be used.

Cloud integration – with the advent of cloud computing infrastructure, the accessibility of IoT devices is easily managed. The services provided by cloud are 24/7 connectivity and accessibility, low cost, on-cloud storage, information processing and data analytics. Due to affordability of cloud infrastructure, cloud and IoT are integrated together to facilitate the implementation of complex industry or business problems with greater ease.

Tools for data analytics – data handling and data analysis are the most important aspects of any business. We witness the significant improvement in robust data handling and data analytics techniques, which can be easily integrated with IoT and cloud. In IoT, collection and analysis of data are very important in order to identify and recognize the behaviours of IoT system. Due to the connectivity of numerous devices and exchange of data in large volume, data may be represented in different formats. The application of data analytical tools in the conversion of data in decision making improves the profit of businesses. To do so, we have analytical tools to process large volume of data generated by IoT system, i.e. Big data.

Low-cost computing devices – to develop IoT application for businesses, many low-cost sensory devices for connectivity leverage can help the businesses to grow.

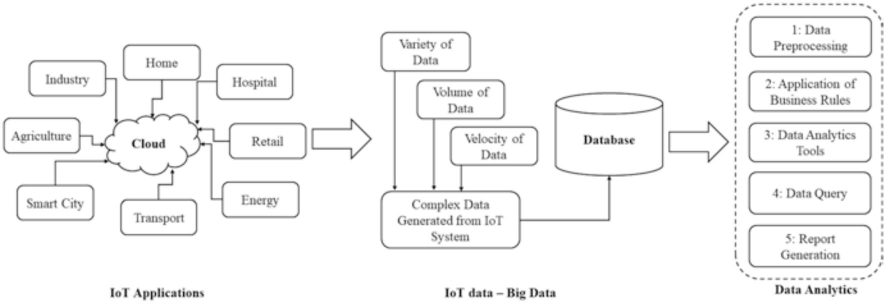


Fig. 1 IoT application in different domains, IoT Big data and data analytics on IoT Big data

Moreover, as a timely advancement in IoT, today's IoT infrastructure is available in affordable cost for providing computation, connectivity, communication and memory.

Figure 1 shows the IoT adopted in various areas and how Big data collection is processed by the data analytics tools to produce the viable information to improve the business.

Basically, we want M2M communication in IoT between connecting devices without any human intervention. To support this communication over wired or wireless medium, various protocols, standards and technologies are evolving. For communication, IoT devices can use point-to-point connection or GSM, 3G, 4G and 5G technologies, which has its own advantages and disadvantages. Table 1 highlights the technology, distance, standards, merits and demerits of widely used communication infrastructures. Hence, providing privacy and security in such a heterogeneous communication infrastructures utilized in IoT is a challenging task. So, we need to provide the best in class privacy and security for communication among IoT devices via communication infrastructure and also apply various security techniques. In this chapter, we investigate the various security and privacy issues in the communication of IoT devices.

This chapter is arranged as follows: Sect. 2 highlights the application domains of IoT specifically healthcare and smart homes. Section 3 presents the various security attacks that happen to IoT. The security and privacy challenges in IoT are demonstrated in Sect. 4. Existing solutions and applicability of deep learning in securing IoT system are presented in Sect. 5. Finally, conclusions and future directions are proposed in Sect. 6.

2 IoT Applications

In this section, we discuss the applications of IoT in various domains to identify the need of security and privacy. We know that IoT can be applied in various domains, but here, we concentrate on healthcare and smart homes only.

Table 1 Communication infrastructure utilized in IoT

Technology	Distance	Standards	Merits	Demerits
Satellite	10–15 miles	GSM, GPRS, CDMA, GPRS, 2G/GSM, 3G, 4G/LTE, EDGE/5G	Universal compatibility Stable connection	Higher cost Higher power consumption No direct communication
WiFi	≤66 feet	WLAN (IEEE 802.11)	Affordable Compatible to universal smartphones	Instability Inconsistency Higher power utilization
Radio Frequency	≤100 feet	ZigBee, Z-Wave (IEEE 802.15.4)	Independent of new features of smartphones Low energy Simplistic technology	Not for smartphones No central connector for RF devices
RFID	<2 m	Active Reader Passive Tag (ARPT) ISO/IEC 18000	No power requirement Established technology Widely utilized technology	Secured Cost per card Tags is an identifier Incompatible through smartphones
Bluetooth	50 m	Bluetooth, BLE, iBeacon	Used in smartphones Established technology Widely utilized technology	Low-bandwidth Hardware dependent Battery operated
Near Field Communication (NFC)	<20 cm	ISO/IEC 18092	Connection is low speed Offers encryption Bootstrapping wireless connections	Short range

2.1 IoT in Healthcare

Due to the widespread adoption of IoT and inventions of IoT medical devices, the on-time health monitoring and diagnosis system leverage the doctors or medical practitioners to take the preventive measures related to patients. In [18], IoT-based patient health monitoring system is presented for special biomedical application in wireless body area network (WBAN). The patient data under consideration are plethysmogram, pulse rate and oxygen ratio for health monitoring. The data collected are then transferred to centralized database through IoT technology. It is important to get correct data; hence, the system's performance is estimated in the context of correct and flexible data under various parameters such as effective range, network stability and network topology. Another approach is designed for health surveillance using natural language processing (NPL). NLP-based IoT healthcare system is developed [17] to help in urgent and important task handling for the patients. The word similarity is applied in medical terms, questions, diagnostic and prescription to suggest the best treatment.

Furthermore, cloud computing and IoT are combined in order to design and deliver fast and efficient facilities to elderly patients [22]. The lifecycle of patients is utilized to offer personalize health management. The cloud computing is employed to monitor, diagnose and predict various health aspects of individual patients through medical devices such as wearables as per the need of patient (i.e. elderly). The aim here is to provide real-time interactions between patient and health observer.

Subsequently, Blockchain is applied to develop the healthcare system (i.e. healthcare 4.0) under the assumption of industry 4.0, which includes IoT, fog computing, cloud computing and industrial IoT. The integration of Blockchain and healthcare 4.0 is employed in order to provide autonomous and robust healthcare system to the health workers and patients. The various optimizations are suggested for healthcare 4.0 to improve Blockchain's performance, i.e. payment process and trust management.

The security of health data is very important in IoT [15, 20] due to the distributed environment and openness of medical sensors. Moreover, transmission of medical data through medical sensors via internet is also a challenging task in IoT. Hence, achieving reliable transmission of data by routing protocol with characteristics of energy efficient and priority of transmission can be the target [16].

To maintain the security and integrity of data in medical domain, a hybrid model is proposed in [20] wherein diagnostic texts from medical images were secured. For hybridization, 2D discrete wavelet transform (DWT) 1 level or 2D DWT 2 level were applied as a steganography method, and RSA and AES as the encryption standards.

Initially, secret data are encrypted, then steganography is applied on RGB as well as grey scale images. Hence, the medical data security is achieved with higher accuracy and low errors. Moreover, the entire processing of the model is demonstrated in Fig. 2 wherein the hybridization is applied at both ends, i.e. at encryption and decryption.

Furthermore, the privacy of healthcare data exchange via internet in IoT is also a challenging task due to the mobility of IoT devices. In IoT healthcare system, health data play a vital role in instantaneous medicinal consultancy and diagnosis. In [21], IoT and Fog computing are combined to design healthcare system in order to offer speedy response with low latency and low delay. This kind of development may lead to privacy and security problems. So, privacy under considered system is managed by electronic medical records (EMRs), which is unique for every patient. In addition, to secure the health data, Elliptic Curve Cryptography (ECC) is applied. The complete functionality of the proposed model is presented in Fig. 3 wherein an integration of Fog computing with IoT on public cloud is adopted. Data are received from the sensory devices termed as terminal, then these data are sent to Fog layer for further processing.

The Fog layer consists of key centre, identity manager, query handler and fog accumulator. The data from fog nodes are aggregated by fog accumulator and

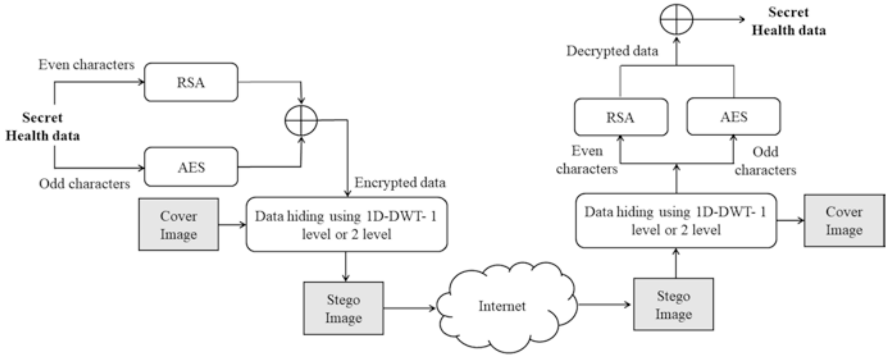


Fig. 2 Hybrid Data Security Model

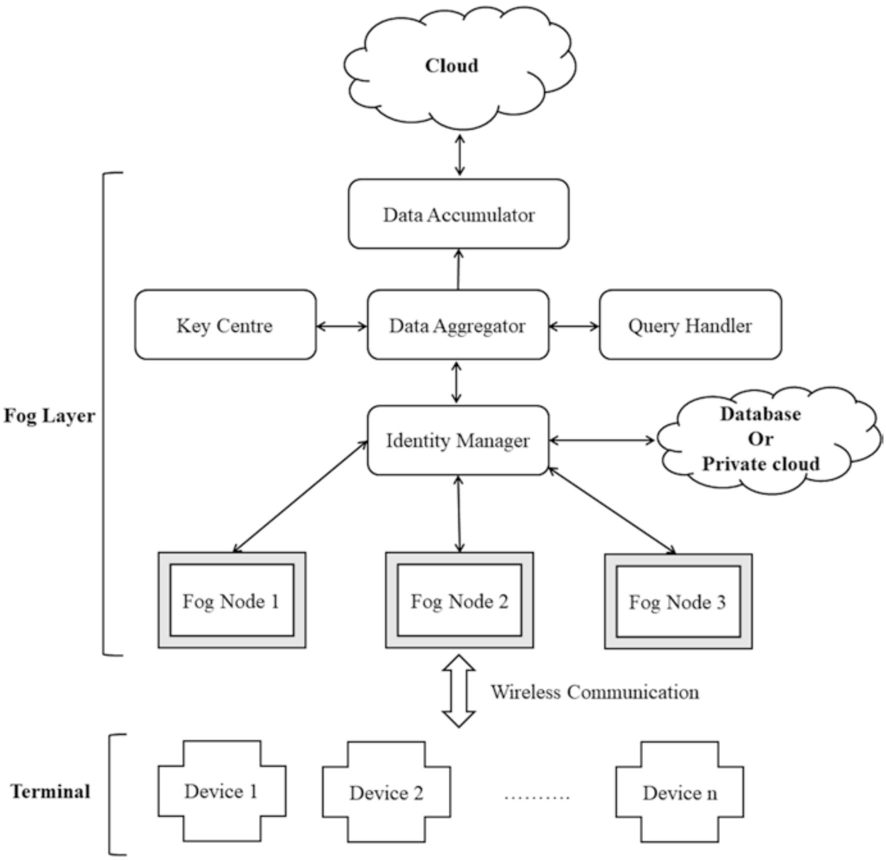


Fig. 3 Integration of IoT, Fog, and Cloud Computing for Security System

forwarded to public cloud. Caching mechanism is adopted at fog accumulator to improve the performance. To generate and verify the key, a key centre is responsible. The job of a query handler is to manage the various queries at the time of processing. The mapping of the identity of the patient with pseudo identity to secure the details is done by the identity manager. Data aggregator serves as a central authentication point utilized for minimizing the communication overhead. The confidentiality is ensured by ECC, and agreement technique is applied for reliable EMR transactions.

In Internet of Medical Things (IoM), data are gathered and analysed based on patient's physiological parameters. To do so, medical sensors are implanted in the body of the patient, hence the medical information of patient traverses via public internet. To preserve and secure these pieces of information is a challenging task in IoM. Thus, authentication method is proposed [23], which is based on user anonymity in healthcare for secure communication.

2.2 IoT in Smart Homes

In [24], thermal energy prediction in smart home using IoT is proposed wherein classifier ensemble method is. employed, which is based on the various parameters such as energy usage, characteristics of building, and weather conditions. In addition, Edge computing is applied to provide energy-efficient mechanism for building works. An online learning approach is utilized for the predictive model and performance is evaluated on new data under the same environment. In addition, managing various resources in IoT-based smart homes is a challenging task. Thus, an intelligent resource supervision is presented in [31] by using IoT, cloud computing and Fog computing to facilitate the best utilization of resources. In [33], to assist the elderly people, IoT-based smart home is designed. The safety and warning mechanisms are implemented to solve the problems that may arise, especially at the time of emergency. For this, continuous data gathering is performed from the sensory devices, and during emergency, relevant information is shared with the relatives or caretakers. The various scenarios are monitored such as water tap left open, gas leakage due to improper closure, sudden fall, etc. Thus, appropriate preventive and corrective action is initiated by the system.

A mathematical model is proposed for data traffic in IoT (a statistical model) for smart homes [26]. For the experimentation of the proposed model, data are collected over the years from the various devices connected in smart homes and sensing the different parameters such as pressure, intensity, temperature movements, etc. Hence, data packet exchange amongst the devices is monitored; by using Kolmogorov–Smirnov test, the intervals are calibrated for data packets and correlations between distributed and aforementioned parameters are established. The proposed system facilitates to monitor the traffic accurately in real-time IoT setup.

Due to the advancement in communication technology, home automation is explored to offer better living at homes under which home appliance are monitored and controlled. A hybrid and cost-effective IoT smart home is developed in [27] to support remote and local access of home appliances via laptop or smartphone. The home appliances are efficiently with all ease controlled via internet; moreover, home safety is managed by various automatic operations. Thus, cost-effective, reliable, energy-efficient and safe smart homes are offered for the residents.

Privacy and security is the major concern in any automation system, and hence, sophisticated mechanism needs to be adopted to maintain privacy and security [32]. In IoT-based home automation systems, security and privacy is a challenging task due to the rapid development in communication and IoT technologies. Moreover, data exchange between smartphone and home appliances needs to be secured because these data include secret and critical information. In [28], a secure route optimization technique is proposed to protect the data exchange in IoT homes. The security technique comprises protecting privacy, mutual authentication, key management and forward security. The security analysis of the proposed technique is verified by BAN-logic using AVISPA tool and is found efficient compared to the state-of-the-art techniques.

The challenges of IoT in offering security is due to limited resources, heterogeneous communication protocol and devices. Thus, we need such a security technique that utilizes less computing power, less storage and is compatible with various communication standards. In [30], a lightweight security technique is proposed for IoT-enabled smart homes. The technique comprises mutual authentication and key management. The anonymous user authentication offered at nodes and session establishment is accomplished using controller node under dynamic identity and symmetric key generation mechanism. The sender identity is managed by Keyed-hash function, and relevant security policy is enforced amongst the nodes for communication. Once again, BAN-logic is employed for security analysis on ASVIPA tool.

Subsequently, Blockchain is applied in the development of smart homes due to the polarity of IoT. In IoT-enabled smart home, almost all the devices are connected via internet such as door, cooling system, power supply, etc. Hence, these devices are vulnerable to variety of attacks under limited resources. Thus, lots of efforts are invested to implement efficient security scheme, which also attracted various researchers to contribute and propose robust security methods. In [25], home automation development using IoT and the role of Blockchain in IoT is discussed. The applicability of Blockchain at various levels is explored, i.e. home gateway, fog-to-core gateway and network across the home. Furthermore, Blockchain with cryptography is adopted to develop security system for IoT-based smart homes [29]. Blockchain is becoming a substitute for traditional security techniques and offering better security mechanisms.

The identified security issues in smart homes are trespass, information monitoring, leakage of personal information, DoS, DDoS and falsification.

3 Security Attacks on IoT

In IoT, common attacks that happen at different layers are presented in this section. The types of attacks are Malicious node [1], Internal attacks [2], Routing attacks [3], Deceptive attack [4], Power analysis attack [4, 6], Spoofing [7], Impersonation attack [8], Active attacks [9], Man in the Middle attack [10], Side channel attack [11], Intrusion detection System (IDS) [12] and Access control [13].

Malicious Node In IoT networks, nodes are connected in distributed fashion and susceptible to attacks specifically the insider attacks. Hence, to detect the malicious node in the IoT ecosystem in timely manner is important. The attacks performed by the mobile malicious node are hazardous, and timely detection reduces the damages because malicious node keeps on changing its location. Firstly, the malicious node problem is reported by Ho et al. [14] in 2012 in wireless sensor network (WSN), and the limitations to prevent this problem are identified. In addition, a scheme is proposed under static sensor networks for the detection of malicious node. The strategy is applied to monitor the silent node namely sequential hypothesis analysis, wherein low power consumption and accurate detection of malicious node are achieved. In [1], a malicious node detection approach is presented using k-means and perceptron namely perceptron detection. The trust values of IoT nodes are computed, and malicious node detection is achieved accordingly. Moreover, the reported detection accuracy in comparison with exiting technique is increased from 20% to 30%.

Internal attacks In IoT, the challenge is to determine the legitimate sensor node, which is trustworthy. A sensor node or a group of sensor nodes in an IoT network that tries to cause a disruption or exploit the computing resources is called internal attack. Mostly, an attacker is capable to launch various attacks and also destroy the attack evidences. In [2], an architecture is proposed to analyse the behaviour of sensor node in IoT; the trust assessment mechanism is adopted, which is code-based to detect and separate distrustful sensor node. Through the mobile interface, the important details of sensor node are extracted to prepare the trust report for reliable or unreliable sensor node detection. In addition, less energy is consumed for malicious node detection and reduction of message overheads is reported, i.e. 50%.

Routing attacks In IoT, routing is performed by Routing Protocol for Low Power and Lossy Networks (RPL), which is the de-facto and most popular. The main characteristics of RPL are adaptability, security and energy-efficient in resource-constrained IoT networks. Routing attacks are mostly associated with RPL in IoT networks wherein Internet is untrusted for connecting devices under resource-constrained environment and lossy connections links. Various attacks are possible on RPL such as neighbour attack, version attack, relay attack and rank attack. In [3], mitigation and IDS for RPL attacks were illustrated wherein classification of mitigation techniques for RPL attacks were presented.

Deceptive attack Communication through public channel can transfer untruthful information, which in turn is utilized for deception. In deceptive attack, we have interaction between target and deceiver, where deceiver convinces the target for the acceptance of false information, and forces the target to perform some activity by which deceiver gets benefited. So, to prevent the IoT system from such attacks, deception technique based on honeypot is presented in [4], which is found to be secured in modern IoT networks. A game theoretical model is adopted to protect the IoT network from the deceiver or attacker; under this scenario, various attacks are initiated by an attacker to convince the target but honeypots is applied by the target to deceive the attacker.

Power analysis attack This attack is related to side channel attacks, i.e. physical attacks, wherein consumption of power is utilized to attack the system. This attack depends on the device's physical characteristics such as voltage and currents. In this attack, the secret key is recovered from cryptographic algorithm applied on the system to offer security. Power analysis attacks are of two types, i.e. simple- and differential-power analysis attacks. The power traces are visualized from the graph in simple-power analysis. Moreover, differential-power analysis involves power consumption analysis (i.e. statistically) for the computation of cryptographic operations. In [5], various attacks on Edge computing in AES algorithm are proposed and the prevention of these attacks using different AES implementations are presented. Moreover, various prevention mechanisms were discussed to secure the system from physical attacks. In [6], the protection of IoT applications from power analysis attacks is demonstrated. A lattice-based Ring-LWE cryptography is presented to prevent from eavesdropping effects in IoT devices working on different bit-length microcontrollers. Different attack setups with preventive measures were analysed for 8-bit microcontroller in IoT applications.

Spoofing In spoofing, a node or device is successfully recognized as another node or device by fabricating the data, to take illegitimate benefits. Due to the spread of IoT, devices are located as per the Geo-spatial locations, hence location spoofing attacks are increasing. To prevent the location spoofing attacks, secure location of things architecture is developed in [7], where node audibility information, i.e. ability to communicate, is utilized to estimate the location. Hence, the location identification leads towards predicting the malicious node in the application based on Geo-spatial location.

Impersonation Attack In this attack, an intruder falsely uses the identity of legitimate node or user in the network or protocol for communication. The objective of a robust identity or authentication technique is that by the identity of node A, node C communicates to node B and causes to perform the operation by accepting the identity of node A, which needs to be determined correctly. Under this scenario, many fraudulent activities can be initiated by the node, which is the threat to the IoT network. Hence, security at physical layer is investigated for IoT in Fog computing environment to accurately detect the node causing an impersonation attack [8].

Moreover, identifying constraints in accurate channel for fog node and end user is a challenging task. Henceforth, reinforcement learning, i.e. Q-learning, is adopted to achieve optimal value corresponding to test threshold to detect impersonation attack. The test comprises various parameters such as rates of average error, false alarm and miss detection, and average time under dynamic environment.

Active Attacks An unauthorized node or user attempt to make the changes in the system is called as active attack. In active attack, intruder can create new data or modify the stored data or update the transmitted data. It is categorized in four types: denial-of-service, message modification, message replay and masquerade. To safeguard security in IoT against active attack, a relay-aided vectorized technique to secure the data transmission is proposed in [9]. Pilot sequences sent by intruder are utilized by sender to compute the channel state information under beamforming/precoder design. Later, signal vector is generated by applying data symbols on random complex matrix, which is then sent over a communication channel. During security analysis, it is observed that the recovery of signal vector is accomplished only by legitimate receiver.

Man in the Middle (MitM) attack In this attack, an intruder interrupts in the communication of two parties wherein it tries to update the information exchange between the two. Under this attack, intruder can spy, corrupt data and steal private data or credentials of login. In [10], MitM's potential threats were inspected for software-defined networking (SDN) under IoT-Fog infrastructure to secure the system. Various attacks related to MitM were simulated to demonstrate the undecorated threats. Bloom filters were applied to develop lightweight prevention prototype to trace any alteration in the packets. Moreover, it is observed that the prevention system built using Bloom filter consumes limited resources.

Side Channel Attack In this attack, an adversary senses the operation performed by a computing device, determines the cryptographic operations and utilizes the sensed information to play with the security system. Basically, power consumption is monitored by an intruder to snip the cryptographic information. To overcome the side channel attack, an efficient side channel analysis (SCA) scheme of Unbalanced Oil and Vinegar (UOV) is presented in [11], and to offer more security, 80 bits were utilized. This scheme is specifically targeted to secure the IoT-cloud infrastructure; the security analysis using SCA scheme is performed by combining Hamming distance power and inducing fault.

Intrusion Detection System Due to the integration of IoT with cloud computing, data management and data analytics over IoT network became the part of IoT application wherein huge amount of data need to be processed, hence Fog computing and improved data processing is adopted on the edge of network. So, the integration of various technologies into businesses requires reliable, secure and efficient connection. If attacks happen on this system, it causes loss of viable information and then robust security mechanism needs to be enforced. Intrusion detection is the technique adopted by various security systems. IDS analyzes events performed on the device or network for detecting attacks, reporting attacks, and diminishing the dangerous influence of the identified attacks. Due to different and irregular nature of attacks, IDS is vulnerable to detect false attacks, i.e. attack is detected when there is no attack on the system and no attack is detected when attack happens on the system. Basically, IDS categorizes in signature and anomaly detection methods. Attacks detection using signature approach compares an event with the stored patterns for the identification of attack. In anomaly detection approach, the behaviour of the device or network is determined to detect the attacks when abnormal behaviour is identified. In [12], artificial intelligence is applied to propose autonomous intrusion detection system that protects from cyber attacks related to Fog security. In addition, recurrent neural networks (RNNs) are employed to enforce the classification task in the intrusion detection system wherein multiple layers of RNNs were modelled.

Access Control Attack Nowadays, IoT is becoming a part of our lives, which is a variety of smart IoT devices connected via internet and vulnerable to different threats. Therefore, securing the IoT devices is challenging and it is the urgent need. Access control is a security mechanism to allow the access of data or resources to legitimate user under different level of permissions. Attacks on access control usually circumvent applied access control mechanism to snip user's credentials or data. Hence, attacker can easily enter into the system and modify the confidential information of system. In [13], an access control technique is developed for IoT to overcome the problem of unauthorized access by using ID-based encryption. To prevent unauthorized functionality to user or node, a fine-grained access is offered. Moreover, constant operation cost is involved for every access operation under the proposed technique, and security investigation reported that the access is prevented, if it is over-privileged.

4 Security and Privacy Challenges in IoT

In this section, we highlighted the security and privacy challenges that arise in IoT system in various situations.

4.1 Security Challenges in IoT

Security is to offer the confidentiality of the data exchange over the public communication channel. In IoT, security is the major challenge due to the following parameters, i.e. resource-constrained devices, heterogeneous communication technology, heterogeneity in devices, ad-hoc nature of devices, authentication and identity management. Due to the wide-range applicability of IoT, robust and efficient security mechanism is required to facilitate the secure communication, authentication and authorization.

Security in IoT consists of the following challenges, and these challenges need to be resolved intelligently based on the different application scenarios.

1. Resource-constrained device: In IoT, devices have low computing capability and limited power, which confines the speedy computation. Thus, we need the security that can be provided with respect to the limited resources. Moreover, resource constraints cause poor performance in maintaining secrecy and integrity in IoT. By using public key, we can achieve secrecy and integrity, but it is beyond the scope of resource-constrained devices.
2. Identity and authentication: Identity concerns the unique identification management of devices, and authentication is the process of validating the identity in communication. Due to the rapid change in technologies, technology adoption and interoperability for identity and authentication management are the global threats. Without proper authentication, IoT system will have insecurity and an adversary can easily attack the system.
3. Access control and authorisation: Access control is a mechanism that allows the access in IoT network. It is important to establish the notion that once the user is identified and validated, access to the resources requested will be allowed. Hence, access control and authorization is challenging in the IoT ecosystem.
4. Heterogeneity: In IoT, heterogeneity is the biggest challenge related to devices, protocol and security breaches. Thus, the security solution must be able to handle all the heterogeneity across IoT infrastructures.
5. Protection of data: The numerous types of data are generated by devices and are also shared. Thus, data protection and confidentiality is the highest priority in the life cycle of data.
6. Secure things: In IoT, devices are connected and communicated in various ways. Hence, devices need to be capable in protecting themselves. So, security policy needs to be maintained at various levels in IoT system.

4.2 Privacy Challenges in IoT

Privacy is the right to protect the identity of person or device. In IoT, privacy is the major security issue investigated by various researchers in the academia as well as in industry. Moreover, integration of IoT in a variety of applications such as healthcare monitoring, energy management, smart trafficking and smart manufacturing system is a challenging task to offer the best privacy policies. These applications heavily use the user's personal data, which need to be protected by external unknown entities, i.e. attacker or intruder.

To offer the best privacy in IoT, the following challenges need to be resolved by providing the frameworks under IoT ecosystem.

1. Profiling and Tracking: Every individual has some identity; similarly, IoT devices are identified by their associated identity. Hence, the leak of this identity may cause an attack, namely profiling and tracking. So, in IoT, we have to intelligently tackle such activity and adopt the prevention mechanisms.
2. Localization and Tracking: In localization, systems attempt to identify and report people or device location via space and time. We need such a protocol in IoT for interactions to disallow such activity, which is also the major challenge. Moreover, profiling of individual to infer correlation amongst other profiles and relevant data may cause frauds in applications in e-commerce. The challenge here is to balance profiling interest in businesses and analysis of data to maintain the privacy of user.
3. Secure Data Transmission: Another aspect of privacy is to conceal the data at the time of transmission over the public communication medium. So, the data exchange amongst the devices cannot be accessed by unauthorized entity.

5 Existing Solutions

Various security solutions are provided by the different researcher from the point of IoT utilization in different domains. Recently, in [37], an architecture is developed by using IoT, cloud and smartphone. The centre of this architecture is mobile app, and relevant security attacks such as authentication, reply attack and unforgeability are prevented. In [38], a comprehensive security mechanism is offered for IoT devices; protection method and reconfigurable hardware for device isolation are applied to identify the malicious node and protect IoT device from damage. The protection method is implemented on cloud as an authority to track the traffic among the devices. Periodically, the upgradations are performed on protection method to learn the changes in the IoT network. Moreover, Narrowband IoT is investigated, and many security issues are brought into notice to be researched by the academia and industry. The Narrowband IoT is best suited for defence security but having security breaches. These devices are very small and utilized to monitor the activities of enemy but vulnerable to bugs. Hence, to resolve these issues, a security method is proposed in [39]; various attacks are analysed to evaluate the performance of the system. Authors claimed that the security rate is promising and the system is preventing against various attacks.

5.1 Machine Learning and Deep Learning in IoT Security

The adoption of machine learning (ML) and deep learning (DL) is increasing day-by-day ranging from medical imaging to sentiment analysis. The applicability of ML and DL is also appreciated in security and privacy of various domains; moreover, extensive research is performed to propose the new security system with intelligence. Due to the popularity of IoT and cloud computing, the integration of computation services is investigated to design efficient security model. In [35], various security and privacy problems are discussed and traditional security schemes are found not suitable to apply in IoT devices. The use of ML, artificial intelligence along with Blockchain is presented to develop efficient security and privacy in IoT. Moreover, various research challenges pertaining to ML, artificial intelligence and Blockchain are highlighted towards the proposal of security system.

In [34], DL-based IoT system is proposed to safeguard smart city wherein Blockchain is applied for communication in distributed environment. Scalability, central control and communication latency issues are resolved at application layer by adopting DL-based cloud. Hence, cost effective computing infrastructure is made available to smart city for providing security and privacy. In [36], another security model is designed to detect the security threats in IoT using deep learning. A comparative study is presented to adopt DL, Big data and IoT security to derive the relationship amongst them. Furthermore, challenges in the adoption of DL, Big data and IoT security are enlisted for future research.

6 Conclusions

Protecting and securing the IoT systems is a challenging task. In this chapter, we presented the various applications of IoT specifically healthcare and smart home, and various possible attacks on IoT are discussed in detail. These attacks are the security breaches to the IoT systems implemented in various domains. In addition, different challenges associated with privacy and security are investigated in order to offer the best security services in IoT for healthcare and smart homes. The recent development of security methods is highlighted by which different security and privacy problems can be resolved. Lastly, the adoption of ML and DL is demonstrated to offer efficient and robust security services in various domains of IoT.

Furthermore, due to the rapid advancement in communication and IoT technologies, authentication, integrity, secrecy and confidentiality are the major concerns pertaining to providing the efficient security for IoT systems. So, the utilization of ML and DL will be a great help in developing trustworthy security systems to tackle all the security attacks intelligently.

References

1. L. Liu, Z. Ma, W. Meng, Detection of multiple-mix-attack malicious nodes using perceptron-based trust in IoT networks. Futur. Gener. Comput. Syst. **101**, 865–879 (2019)
2. N. Tariq, M. Asim, Z. Maamar, M.Z. Farooqi, N. Faci, T. Baker, A Mobile Code-driven Trust Mechanism for detecting internal attacks in sensor node-powered IoT. J. Parallel Distrib. Comput **134**, 198–206 (2019)

3. A. Raoof, A. Matrawy, C.H. Lung, Routing attacks and mitigation methods for RPL-based Internet of Things. IEEE Commun. Surv. Tutor **21**(2), 1582–1606 (2018)
4. Q.D. La, T.Q. Quek, J. Lee, S. Jin, H. Zhu, Deceptive attack and defense game in honeypot-enabled networks for the internet of things. IEEE Internet Things J. **3**(6), 1025–1035 (2016)
5. J. Moon, I.Y. Jung, J.H. Park, IoT application protection against power analysis attack. Comput. Electr. Eng **67**, 566–578 (2018)
6. Y. Niu, J. Zhang, A. Wang, C. Chen, An efficient collision power attack on AES encryption in edge computing. IEEE Access **7**, 18734–18748 (2019)
7. P. Zhang, S.G. Nagarajan, I. Nevat, Secure location of things (SLOT): Mitigating localization spoofing attacks in the Internet of Things. IEEE Internet Things J. **4**(6), 2199–2206 (2017)
8. S. Tu, M. Waqas, S.U. Rehman, M. Aamir, O.U. Rehman, Z. Jianbiao, C.C. Chang, Security in fog computing: A novel technique to tackle an impersonation attack. IEEE Access **6**, 74993–75001 (2018)
9. N. Zhang, R. Wu, S. Yuan, C. Yuan, D. Chen, RAV: Relay aided vectorized secure transmission in physical layer security for Internet of Things under active attacks. IEEE Internet Things J. **6**(5), 8496–8506 (2019)
10. C. Li, Z. Qin, E. Novak, Q. Li, Securing SDN infrastructure of IoT–fog networks from MitM attacks. IEEE Internet Things J. **4**(5), 1156–1164 (2017)
11. H. Yi, Z. Nie, Side-channel security analysis of UOV signature for cloud-based Internet of Things. Futur. Gener. Comput. Syst. **86**, 704–708 (2018)
12. M. Almiani, A. AbuGhazleh, A. Al-Rahayfeh, S. Atiewi, A. Razaque, Deep recurrent neural network for IoT intrusion detection system. Simul. Model. Pract. Theory **101**, 102031 (2020)
13. H. Yan, Y. Wang, C. Jia, J. Li, Y. Xiang, W. Pedrycz, IoT-FBAC: Function-based access control scheme using identity-based encryption in IoT. Futur. Gener. Comput. Syst. **95**, 344–353 (2019)
14. J.W. Ho, M. Wright, S.K. Das, Distributed detection of mobile malicious node attacks in wireless sensor networks. Ad Hoc Netw. **10**(3), 512–523 (2012)
15. H. Zakaria, N.A.A. Bakar, N.H. Hassan, S. Yaacob, IoT security risk management model for secured practice in healthcare environment. Proc. Comput. Sci **161**, 1241–1248 (2019)
16. A.A. Bahattab, A. Trad, H. Youssef, PEERP: An priority-based energy-efficient routing protocol for reliable data transmission in healthcare using the IoT. Proc. Comput. Sci **175**, 373–378 (2020)
17. D. Zhang, X. Xia, Y. Yang, P. Yang, C. Xie, M. Cui, Q. Liu, A novel word similarity measure method for IoT-enabled Healthcare applications. Futur. Gener. Comput. Syst. **114**, 209–218 (2021)
18. M.A. Akkaş, R. Sokullu, H.E. Çetin, Healthcare and patient monitoring using IoT. Internet of Things **11**, 100173 (2020)
19. A. Kumar, R. Krishnamurthi, A. Nayyar, K. Sharma, V. Grover, E. Hossain, A novel smart healthcare design, simulation, and implementation using Healthcare 4.0 processes. IEEE Access **8**, 118433–118471 (2020)
20. M. Elhoseny, G. Ramírez-González, O.M. Abu-Elnasr, S.A. Shawkat, N. Arunkumar, A. Farouk, Secure medical data transmission model for IoT-based healthcare systems. IEEE Access **6**, 20596–20608 (2018)
21. R. Saha, G. Kumar, M.K. Rai, R. Thomas, S.J. Lim, Privacy ensured ${e} $-healthcare for fog-enhanced IoT based applications. IEEE Access **7**, 44536–44543 (2019)
22. Y. Liu, L. Zhang, Y. Yang, L. Zhou, L. Ren, F. Wang, et al., A novel cloud-based framework for the elderly healthcare services using digital twin. IEEE Access **7**, 49088–49101 (2019)
23. B.D. Deebak, F. Al-Turjman, M. Aloqaily, O. Alfandi, An authentic-based privacy preservation protocol for smart e-healthcare systems in IoT. IEEE Access **7**, 135632–135649 (2019)
24. H. Xu, Y. He, X. Sun, J. He, Q. Xu, Prediction of thermal energy inside smart homes using IoT and classifier ensemble techniques. Comput. Commun. **151**, 581–589 (2020)
25. D. Minoli, Positioning of blockchain mechanisms in IOT-powered smart home systems: A gateway-based approach. Internet of Things **10**, 100147 (2020)

26. C. Majumdar, M. López-Benítez, S.N. Merchant, Real smart home data-assisted statistical traffic modeling for the Internet of Things. IEEE Internet Things J. **7**(6), 4761–4776 (2020)
27. W.A. Jabbar, T.K. Kian, R.M. Ramli, S.N. Zubir, N.S. Zamrizaman, M. Balfaqih, et al., Design and fabrication of smart home with internet of things enabled automation system. IEEE Access **7**, 144059–144074 (2019)
28. D. Shin, K. Yun, J. Kim, P.V. Astillo, J.N. Kim, I. You, A security protocol for route optimization in DMM-based smart home IoT networks. IEEE Access **7**, 142531–142550 (2019)
29. S. Arif, M.A. Khan, S.U. Rehman, M.A. Kabir, M. Imran, Investigating smart home security: Is Blockchain the answer? IEEE Access **8**, 117802–117816 (2020)
30. M. Alshahrani, I. Traore, Secure mutual authentication and automated access control for IoT smart home using cumulative keyed-hash chain. J. Inf. Secur. Appl. **45**, 156–175 (2019)
31. S.S. Gill, P. Garraghan, R. Buyya, ROUTER: Fog enabled cloud based intelligent resource management approach for smart home IoT devices. J. Syst. Softw. **154**, 125–138 (2019)
32. D. Mocrii, Y. Chen, P. Musilek, IoT-based smart homes: A review of system architecture, software, communications, privacy and security. Internet of Things **1**, 81–98 (2018)
33. R. Sokullu, M.A. Akkaş, E. Demir, IoT supported smart home for the elderly. Internet of Things **11**, 100239 (2020)
34. S.K. Singh, Y.S. Jeong, J.H. Park, A Deep Learning-based IoT-oriented infrastructure for secure smart city. Sustain. Cities Soc. **60**, 102252 (2020)
35. B.K. Mohanta, D. Jena, U. Satapathy, S. Patnaik, Survey on IoT security: Challenges and solution using Machine Learning, Artificial Intelligence and Blockchain technology. Internet of Things **11**, 100227 (2020)
36. M.A. Amanullah, R.A.A. Habeeb, F.H. Nasaruddin, A. Gani, E. Ahmed, A.S.M. Nainar, M. Imran, Deep learning and big data technologies for IoT security. Comput. Commun. **151**, 495–517 (2020)
37. H. Liu, J. Li, D. Gu, Understanding the security of app-in-the-middle IoT. Comput. Secur. **97**, 102000 (2020)
38. F. Hategekimana, T.J. Whitaker, M.J.H. Pantho, C. Bobda, IoT device security through dynamic hardware isolation with cloud-based update. J. Syst. Archit. **109**, 101827 (2020)
39. R.K. Jha, R.S.H. Kour, M. Kumar, Layer based security in narrow band Internet of Things (NB-IoT). Comput. Netw. **185**, 107592 (2020)

Learning Approaches for Security and Privacy in Internet of Things

T. Daniya, M. Geetha, Velliangiri Sarveshwaran, and Ch. Madhu Babu

1 Introduction

The Internet of Things (IoT) has enabled everything and anything to be connected to the internet. By transforming how people use technology, it has caused a multimedia revolution in the physical world that surrounds it. Supervisory surveillance, gadgets, commercial vehicles and medical equipment, alarms, fluorescent lamps, refrigerators, aircraft, pet supplies, smart TVs, and electronic set-tops boxes can now be connected to the internet through IoT [1]. Industrial applications are becoming more complex and broader as science and technology advance. Many vital processes that rely on technology have large-scale control systems in place to keep them running normally [2]. The Internet of Things (IoT) is a network of uniquely recognizable, embedded computing equipment that can send and receive data without contact between people-to-people or people-to-computer relations [3].

Many countries have identified cybersecurity as a key national policy concern. The financial consequences of cybersecurity and cyber warfare are rising as IoT-based devices are incorporated into intellectual production and marketing, cities, advanced transmission networks, intelligent networks, and more elements of

T. Daniya (✉)
Department of CSE (AI & ML), GMR Institute of Technology, Rajam, India
e-mail: daniya.t@gmrit.edu.in

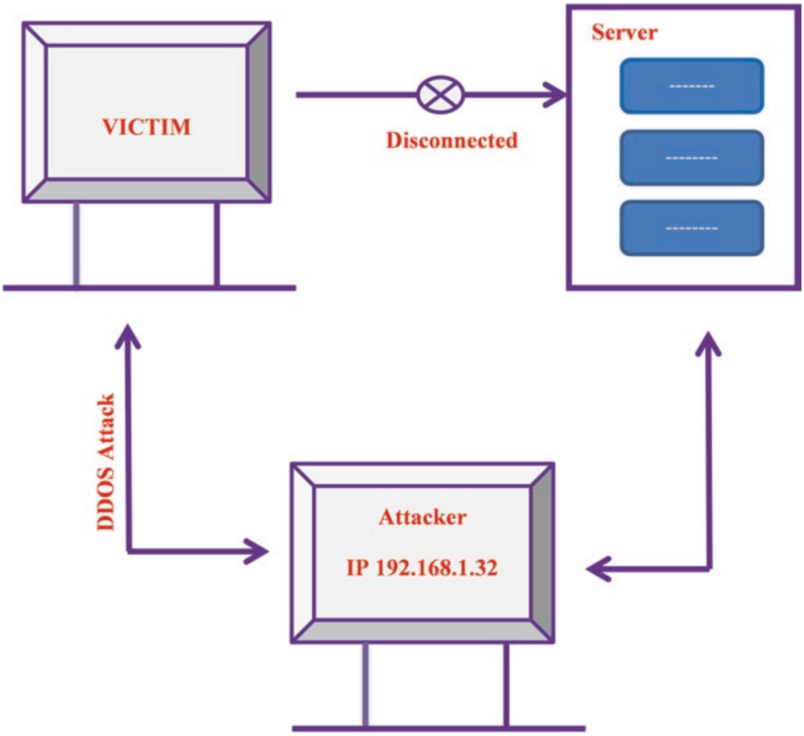
M. Geetha
Department of Information Technology, S.A Engineering College, Chennai, Tamilnadu, India

V. Sarveshwaran
Department of Computational Intelligence, SRM Institute of Science and Technology, Kattankulathur, Chengalpattu, Chennai, Tamilnadu, India

C. M. Babu
Department of CSE, B V Raju Institute of Technology, Narsapur, Telangana, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_4

contemporary life such as banking, finance, independent vehicles, and personal medicinal devices. More and more cyber-attacks are occurring, and they threaten IoT devices progressively (such as the Mirai botnet) [4].



Cybersecurity Attacks

Consumer data security breaches, along with major cybersecurity assaults networks around the world, have caused IoT users to lose faith in distributors who do not undertake the precautions necessary to secure its applications [5]. The problem of IoT networks is cybersecurity, which is a key worldwide problem that necessitates a comprehensive evaluation by either the academic or the manufacturing sectors [6]. Human involvement elevates it to a Cyber-Physical-Human System, also CPHS, which can be regulated by a human [7].

In CPHS, understanding, validating, and defending such structures are difficult due to the difficulty of modeling human behavior. Spam and phishing emails, exploitation of the web address of the network, replication assaults, and denial of service attacks, in which cyber criminal's elements, error-prone, and malicious people block honest messages from secure broadcast communication, are all threats to the CPHS [8].

Cyber-Physical System (CPS) can carry out self-confidence, self-adjustments, and decisions [9]. The way to implement CPS' environmental tier function is through machine-to-machine (M2M) communications. In M2M, both wired and wireless connections communicate between sensors and smart/mobile devices [10]. Moreover, cyber-attacks in networks of the wireless sensor include attacks on a denial-of-service (DoS), misdirection, selective redirection, sinkhole, Sybil, wormhole attacks, and HELLO floods attacks [11].

The probability of severe economic impact from attacks can only be established through subjective assessment without the relevant threat appraisal process [12]. Cyber risk would contribute to feedback sensors and data structures instantaneously, which link financial impacts of various IoT vertical systems through collision pattern to crucial foundation. It would help industry and lawmakers to view the issue and handle the economic burden of IoT-related cyber-attacks [13].

The conceptualization of cyber risk is examined in terms expressed by two categories of experts: cybersecurity specialists and developers of cybersecurity conceptual frameworks [14]. Both groups attach importance to the postulation of vulnerability and to their misuse by the assaulter [15]. Hence, the comprehensive survey has to be discussed for machine learning-based cybersecurity on IoT.

The primary contributions of the article are as follows:

- Firstly, it discusses about the review on various attacks on cybersecurity based on Internet of things including Denial of Service (DoS) and distributed Denial of Service (DDoS) attacks, Man-in-the-Middle (MitM) attack, Phishing and spear Phishing attacks, Drive-by attack, Password attack, SQL injection attack, Cross-site scripting (XSS) attack, Eavesdropping attack, Birthday attack, and Malware attack.
- Secondly, it discusses about the comprehensive survey of security and privacy authentication of cybersecurity-based machine learning approach on IoT.

The rest of the survey paper is structured as follows: Sect. 2 describes the review on cybersecurity based on IoT; Sect. 3 describes the comparison on cybersecurity based on IoT; Sect. 4 describes the future research direction; and finally Sect. 5 concludes the survey paper.

2 Cybersecurity-Based on Machine Learning Algorithms in Internet of Things

This section, discusses the cyber security-based machine learning on IoT including various attacks, security, and privacy in cybersecurity.

2.1 Various Attacks in Cybersecurity

Sarker et al. [16] analyzed that the prominence of Internet-of-Things (IoT) and the huge extension of the communications systems, as well as numerous applications, have recently paid enormous attention to cybersecurity problems today. Thus, it became increasingly important to detect different cyber assaults or abnormalities in the device to build a powerful intrusion detection system that was essential to safety today. An intelligent intrusion detection system based on data can be used for the construction of artificial intelligence, in particular machine learning techniques. To achieve this objective, this chapter presented a machine-learning security model based on Intrusion Detection Tree ('IntruDTree'), which first takes into consideration the safety function ranking based on its significance and then builds, based on the key extracted features, a tree-based generalized intrusion detection model. This system not only works to predict precision of unidentified test scenarios but also reduces the computing complexity by decreasing the size of the characteristics.

I.H Sarker et al. [17] presented Cyber Learning, a machine learning model with a set of the correlated functions and an extensive empirical assessment on the effectiveness of various model machine learning. In cyber learning models, a binary classification model to predict threats and a multi classification model for a wide range of cyber-attacks are needed. To create the security model, the 10 popular methodologies, namely Naive Bayes, Logistic regression, Stochastic gradient descent, K-nearest Neighbours, Support Vector Machine, Decision Tree, Random Forest, Adaptive Boosting, eXtreme Gradient Boosting, and Linear discrimination analysis, are employed. The artificial network-based security model was presented with a perspective to multiple hidden layers.

Syed et al. [18] analyzed that the usage of appropriate data packets, the implementation, and the operation of the persistent Internet of Things (IoT) depend deliberately. The Message Queuing Telemetry Transport (MQTT) protocol, based on the publication/subscription landscape, is popular. Cybersecurity threats are expected to increase with the growing usage by IoT producers of the MQTT protocol. In particular, IoT may be vulnerable to a Denial of Service (DoS) protocol-based Application Layer attack that was found to trigger service of interruptions in heritage systems. The application layer DoS attack detection strategy was then proposed for the MQTT protocol and the scheme tested for legit and protocol-compliant scenarios for the attack DoS. A machine-based learning detection framework developed for the MQTT protocol was proposed to secure the MQTT message from such assaults. The influence of these assaults on different MQTT brokers was also demonstrated, and the effectiveness of the introduced strategy for the detection of these malicious attacks was evaluated.

Damaševičius et al. [19] discussed that Information security is one of the biggest challenges organizations and institutions face. In recent years, cyber crime has increased frequency and magnitude with new ways in which information systems can be stolen, changed and destroyed, and disabled every day. Malware is one of the types of penetration of confidential data in information systems. An intruder penetrates malware into a computer network whereby the data management has sensitive data information, which is accessed completely or partially. This paper proposed a group-based malware detection classification methodology. A stacked group of dense (without a connection) and convolutional neural networks (CNN) performs a first-phase classification, while a meta-learner performs the final phase classification. A group of five dense neural networks with CNN and ExtraTrees as a meta-learner is the best performance possible.

Subburaj et al. [20] aimed to investigate and examine various means of protecting websites from SQL attacks through injection. Machine learning algorithms have been used to detect such attacks in this research project. Machine learning (ML) algorithms are algorithms that can learn from the given data and deduce interesting dataset outcomes. The technology was used to detect malicious code through SQL code as data and ML algorithms. This research project has established a machine learning model that can predict potential attacks.

Shafiq et al. [21] proposed a hybrid algorithm and a new model architecture to addressed this issue. The BoT-IoT recognition dataset is first applied, and its 44 effective functions for machine learning algorithms are selected from a variety of features. Then five efficient machine-learning algorithms are chosen to recognize malicious and anomalous traffic and also to pick the most commonly used metrics for ML algorithms. A bijective soft set approach and algorithm are explored to identify which ML algorithm is successful and should be used to determine IoT anomaly and traffic intrusion. This has used the proposed algorithm based on a bijective soft set approach that effectively detects attacks.

Katzir et al. [22] proposed an adverse detection method durability based on a supervised model of machine learning. Emphasis on multisensory fusion systems for systematic description of adversarial resilience is given. The Model Robustness Score (MRB), a measure for assessing the relative resilience of various designs, is also established, and two new algorithms for the selection of adversary classifiers are also proposed. The first algorithm only selects features that cannot be realistically altered by the opponent; the second algorithm controls the durability versus the precision compromise. Ultimately, the strategy to real-life malware classification with a comprehensive, up-to-date body of benign and malware executables was assessed. The ability to use adversely aware feature selection to create more robust classifiers has also been shown, and the empirical evidence supporting ensemble algorithms inherent resilience compared with single model algorithms is provided.

2.2 Security and Privacy in Cybersecurity

Li et al. [28] analyzed that safety approach and smart control system for solar thermal use are of great functional significance in the advancement of Energy Internet of Things (EIoT), which aims to optimize operational performance and enables intelligent dynamic change. Computational fluid dynamics modeling was utilized for the analysis of the solar energy output mechanism for buildings combined with solar water heating systems. A machine-based approach to predict energy conversion is proposed. This paper proposed a new EIoT platform for the cyber protection analysis based on machine learning and implements the temperature control platform. The EIoT method showed a high success with the Extreme Gradient Boosting

(XG Boost) training algorithm following an assessment of a machine-based learning cybersecurity analysis.

Kumar et al. [29] presented the Trustworthy Privacy-Preserving Secured Framework (TP2SF) for smart cities. This system consists of three modules: a confidentiality module, a double-level data protection module, and the intrusion detection module. The blockchain credibility scheme is built in the trustworthiness module. A blockchain-based enhanced Proof of Work (ePoW) technology and Principal Component Analysis (PCA) concurrently are implemented to convert data to a new reduced form in order to avoid interference and toxic attacks on the two-level privacy modules. An optimized gradient tree boost method (XGBoost) is used in the intrusion detection module. Finally, the combined Fog-Cloud infrastructure, CloudBlock and FogBlock, has introduced the proposed TP2SF platform in the intelligent city due to its legacy strengths and limitations.

Zhu et al. [30] analyzed that data protection and privacy are becoming more and more relevant topics in the healthcare industry at present. In introducing digital health reports based on legislation, restructuring of services, and requiring to share data between patients, providers and payers, it is emphasized that information security is improved. Big information about health care would likely change the outcomes of the patient, forecast epidemics, gain useful expertise, mitigate illness, minimize health costs, and improve quality of life research. In this article, the Safety and Privacy Big Data Analytics Framework for healthcare applications has been introduced. To maintain a trustworthy Big Data system, there is a need to recognize the shortcomings of current technologies in future study. In addition, electronic health records (EHRs) can be shared by different consumers with a view of the quality of healthcare services. This adds to the major privacy problems to be dealt with in order to enforce the EHR. It incorporates many technological frameworks and environmental safeguards and is proven sufficient to address joint risks to network security appropriately.

Liu et al. [31] analyzed that information can be dynamically interpreted for situational awareness in power systems with the production and broad implementation of measurement equipment. However, data spoofing attacks are also jeopardizing the cybersecurity of power networks. This paper suggested an algorithm based on the extraction techniques of measurement data source authentication (MDSA) including ensemble empirical mode decomposition (EEMD), fast Fourier transformation (FFT), and real-time data classification machine learning. The proposed algorithm is capable of achieving greater precision MDSA with a shorter data window from closely positioned synchrophasor sensors.

Lee et al. [32] discussed that when an internet site emerged, a representative authentication mechanism for the customer was a key issue. However, different attack methods appeared in this authentication process to steal keyboard password entries. The keyboard information therefore may not ensure security. A random data generation data security strategy was developed to detect and mitigate such an assault. This technique defends keyboard information with dumb keyboard information generation when the attacker receives keyboard information. The viability for the disclosure of keyboard information using the data security technique has been shown in this analysis. To illustrate the assault-presented strategy, all the ridiculous keyboard information developed via defensive tool and the user's actual keyboard information feedback were collected and the threats to cyber protection of keyboard information were evaluated based on the offensive method of machine learning. This confirmed that an opponent got 96.2% accurate keyboard data even though the attack technique, which prevents the keyboard data exposure from attacking, is being used.

Karimipour et al. [33] analyzed that intelligent grid technology improves electrical grid reliability, safety, and performance. Its strong relationships on digital communication technology moreover create new security flaws, which must be taken into account for secure and economical power distribution. In this article, a statistical association between measurements is proposed for an unsupervised detection of anomalies. The objective is to design an anomaly detector that can discriminate between a perturbation and an intelligent cyber-attack. It ideals with larger intelligent smart grids. The proposed approach uses symbolic dynamic filters (SDF) as a functional extraction to minimize computation complexity and to detect causal interactions between subsystems.

Yin et al. [34] discussed that a cybersecurity solution-based groundbreaking strategy to the intrusion detection mechanism in which a malicious operation in Supervision Control and Data Acquisition (SCADA) systems targets the Distributed Network Protocol (DNP3). Due to the extreme connections between industrial control systems and the outside Internet world using IoT technologies, information and communication systems are susceptible to severe and cyber-attacks. In certain circumstances, cyber-attacks lead to various threats affecting the infrastructure and continuity of businesses. Owing conventional process systems specificities like insecure real time protocols, the general-purpose ICT safety mechanisms in SCADA systems are not completely stable. In this article, a new way of assessing and selecting the vulnerability model in various layers using the parsed DNP3 protocol for machine learning, with additional data containing malware samples, was introduced. In addition, a cyber-attack algorithm was developed that included a method for classifying and visualizing. In an IoT-based communications environment, the suggested technique was capable of detecting attacks in real time.

Thakong et al. [35] focused that cybersecurity issues have arisen in many business applications in recent times. While researchers previously suggested addressing cybersecurity issues, their methodologies frequently replicated training program to identify datasets of these concerns in non-stationary streaming environments. The traditional approaches can worsen the adaptive solution to avoid these problems in dynamic environments. The paper proposed to use the hierarchical structure of the network to fix these issues in a dynamic environment to create a one-pass throw away learning environment. In addition, new principles of learning in the form of recursive functions have been implemented to accelerate the computation time and to preserve a minimum space complexity for streaming data. In order to minimize the time of preparation, knowledge gain-based feature selection was also employed.

3 Comparison for Cybersecurity Based on Machine Learning in Internet of Things

In this segment, comparison table for various attacks, security, and privacy authentication in Cybersecurity-based machine learning approaches can be depicted below:

3.1 *Various Attacks in Cybersecurity*

S. No	Author	Methodology	Advantage	Disadvantage
1.	Anthi et al. [23]	Adversarial machine learning using Jacobian-based Saliency Map attack	It is more robust	This method may not be sufficient also difficult
2.	Bilen et al. [24]	Support vector machine and Linear regression	Faster and more effective to detect crime and criminals	Technical details can be easier to steal
3.	Singh et al. [25]	Variational mode decomposition (VMD) and Decision Tree (DT) algorithm	Better efficiency and computational Processing time can be achieved	Cyber-attack resiliency cannot be enhanced
4.	Tariq et al. [26]	Genetic Algorithm (GA) with Reinforcement Learning (RL)	Accuracy is high and effectively detects the attack	Payload fluctuation will be high
5.	Ghiasi et al. [27]	Hilbert-Huang Transform Methodology with Blockchain-based Ledger Technology	Enhance information exchange privacy, more precision and robust	Cyber-attack details for unofficial users are not accessible

3.2 *Cybersecurity and Privacy Authentication in IoT*

S. No	Author	Methodology	Advantage	Disadvantage
1.	Kalinin et al. [36]	Neural network approach	High classification accuracy when working with big data	New features to datasets cannot be added.
2.	Serrano et al. [37]	Blockchain random neural network for cybersecurity applications in holistic digital and physical cybersecurity users and channel authentication methods	Cybersecurity resilience increased, decentralized the user access and connectivity	Block chain with another neural network cannot be validated

(continued)

S. No	Author	Methodology	Advantage	Disadvantage
3.	Zhang et al. [38]	Mobile edge computing enabled federated learning framework (FedMEC)	It achieves both efficiency and privacy	Optimum perturbation strength for private data cannot be explored
4.	Latif et al. [39]	Block chain-based architecture	Reduces computational complexity and enhances security	Great potential of block chain technology for smart industry cannot be achieved
5.	Abramson et al. [40]	A trust framework based on decentralized identifiers and verifiable credentials for ML	Performed privacy preserving workflow	Messaging function with separate structure for ML communication cannot be focused

4 Future Research Direction for Cybersecurity

- Future work can evaluate IntruDTree model efficacy through accumulating huge amounts of datasets with larger sizes of IoT protection and by measuring their effectiveness in the area of cybersecurity at application level.
- The IoT device can accumulate latest security details with larger sizes and construct a safe system handled by data through learning technology in future.
- As future work, the intention is to study an authentic MQTT dataset to evaluate its characteristics and how these can help to unmark legitimate and malicious MQTT traffic.
- In order to offer valuable knowledge to malware analysts, the use of explanatory artificial intelligence (XAI) strategy to decipher the results of deep learning models for malware detection would be implemented in future. It also plans to investigate the architectures of group learning and to do more tests on broader malware databases. This seeks to enhance the classification potential and precision of the ensemble learning algorithm by refining and validating the model design for many malware datasets in future work.
- For future work, a prototype that examines the conceptual safety requirements of the overall strategy will expand the proposed structure. In addition, the TP2SF architecture will be studied to integrate deep learning and edge computing in smart cities. This will take into account a blockchain network-allowed edge and deep learning in the intelligent city. This incorporation will help to improve the safety and privacy demands of developing intelligent cities.
- Moreover, interactive and distributed machine-based learning systems are not investigated. On distributed and heterogeneous devices, IoT needs ML-based solutions. Such strategies must work together and do not rely on centrally trained results. Federated learning will in this respect be seen as a basis for such methods.

- This will in the future strengthen the mathematical integration to describe various machine learning tasks and unsupervised machine learning cases in a correct way.
- The strategy to distributed multisensory SIEMs is to be tested in the future. These systems use a wide range of independent sensors that improve detection capacity. Today's major challenge among modern SIEMs is how to decrease false alerts so that safety professionals use these systems more efficiently. The forensic analysis showed signs of the attack, which were initially ignored due to the large number of false alarms in virtually every public-ally documented attack on a larger organization. Thus, the purpose of this paradigm is to test strategy and to verify that an intruder is unable to increase the number of proven false warns intentionally.
- In the future, a 6G device is designed to increase scalability and reliability, very low latency and low energy use. However, there may be restrictions on current blockchain consensus algorithms about scalability, durability, latency, and energy consumption. Implementing blockchains to achieve key design features, such as fault tolerance, safety, low latency, and decentralization at the same time creates significant challenges to scalability and confidence, one of 6G systems' main objectives. In order to profit from the deployment of blockchain in 6G systems, a new consensus algorithm, which offers increased reliability and scalability while offering tradeoffs between intrusion detection, protection and delay, should be suggested.

5 Conclusion

In some domains like IoT, cybersecurity has historically been one of the key issues of ICT and is even more important. This paper surveyed the state of the art of the existing researches in Cybersecurity-based machine learning approaches on Internet of things. It analyzed the various attacks in cybersecurity including malware attack, cross-site scripting attack, DoS attack, etc. Also, this article surveyed the security and privacy authentication in cybersecurity. Then the comparison table was analyzed with advantages and disadvantages. Finally, the future research directions were discussed in IoT-based on cybersecurity. As a result, cybersecurity will progress and become more critical as the intelligent world proliferates on machine learning approaches in IoT.

References

1. K. Kimani, V. Oduol, K. Langat, Cyber security challenges for IoT-based smart grid networks. Int. J. Crit. Infrastruct. Prot. **25**, 36–49 (2019)
2. M.M. Rana, R. Bo, IoT-based cyber-physical communication architecture: Challenges and research directions. IET Cyber-Physical Systems: Theory & Applications **5**(1), 25–30 (2020)

3. S. Tanwar, S. Tyagi, S. Kumar, The role of internet of things and smart grid for the development of a smart city, in *Intelligent Communication and Computational Technologies*, (Springer, Singapore, 2018), pp. 23–33
4. P. Radanliev, D. De Roure, S. Cannady, R.M. Montalvo, R. Nicolescu, M. Huth, Economic impact of IoT cyber risk-analysing past and present to predict the future developments in IoT risk analysis and IoT cyber insurance (2018)
5. A. Jain, T. Singh, Security challenges and solutions of IoT ecosystem, in *Information and Communication Technology for Sustainable Development*, (Springer, Singapore, 2020), pp. 259–270
6. S. Tweneboah-Koduah, K.E. Skouby, R. Tadayoni, Cyber security threats to IoT applications and service domains. Wirel. Pers. Commun. **95**(1), 169–185 (2017)
7. S.K. Sowe, E. Simmon, K. Zettsu, F. de Vaulx, I. Bojanova, Cyber-physical-human systems: Putting people in the loop. IT Prof **18**(1), 10–13 (2016)
8. S.A. Kumar, B. Bhargava, R. Macêdo, G. Mani, Securing iot-based cyber-physical human systems against collaborative attacks, in *2017 IEEE International Congress on Internet of Things (ICIOT)*, (IEEE, 2017, June), pp. 9–16
9. Y. Jiang, S. Yin, O. Kaynak, Data-driven monitoring and safety control of industrial cyber-physical systems: Basics and beyond. IEEE Access **6**, 47374–47384 (2018)
10. K.M. Renuka, S. Kumari, D. Zhao, L. Li, Design of a secure password-based authentication scheme for M2M networks in IoT enabled cyber-physical systems. IEEE Access **7**, 51014–51027 (2019)
11. B. Ali, A.I. Awad, Cyber and physical security vulnerability assessment for IoT-based smart homes. Sensors **18**(3), 817 (2018)
12. P. Radanliev, D.C. De Roure, R. Nicolescu, M. Huth, R.M. Montalvo, S. Cannady, P. Burnap, Future developments in cyber risk assessment for the internet of things. Comput. Ind. **102**, 14–22 (2018)
13. P. Radanliev, D. De Roure, S. Cannady, R. Mantilla Montalvo, R. Nicolescu, M. Huth, Analysing IoT cyber risk for estimating IoT cyber insurance, in *Living in the Internet of Things: Cybersecurity of the IoT-2018. IET Conference Proceedings*, (The Institution of Engineering and Technology, London, 2018)
14. S. Velliangiri, K.K. Kasaraneni, Machine Learning and Deep Learning in cyber security for IoT, in *ICDSMLA 2019*, (Springer, Singapore, 2020), pp. 975–981
15. K. Kandasamy, S. Srinivas, K. Achuthan, V.P. Rangan, IoT cyber risk: A holistic analysis of cyber risk assessment frameworks, risk vectors, and risk ranking process. EURASIP J. Inf. Secur. **2020**, 1–18 (2020)
16. I.H. Sarker, Y.B. Abushark, F. Alsolami, A.I. Khan, Intrudtree: A machine learning based cyber security intrusion detection model. Symmetry **12**(5), 754 (2020)
17. I.H. Sarker, CyberLearning: Effectiveness analysis of machine learning security modeling to detect cyber-anomalies and multi-attacks. Internet of Things **14**, 100393 (2021)
18. N.F. Syed, Z. Baig, A. Ibrahim, C. Valli, Denial of service attack detection through machine learning for the IoT. J. Inf. Telecommun **4**(4), 482–503 (2020)
19. R. Damaševičius, A. Venčkauskas, J. Toldinas, Š. Grigaliūnas, Ensemble-based classification using neural networks and machine learning models for windows PE malware detection. Electronics **10**(4), 485 (2021)
20. V.H. Subburaj, B.A. Pham, Cybersecurity: Using Machine Learning Algorithms to Detect SQL Injection Attacks (2020)
21. M. Shafiq, Z. Tian, Y. Sun, X. Du, M. Guizani, Selection of effective machine learning algorithm and Bot-IoT attacks traffic identification for internet of things in smart city. Futur. Gener. Comput. Syst. **107**, 433–442 (2020)
22. Z. Katzir, Y. Elovici, Quantifying the resilience of machine learning classifiers used for cyber security. Expert Syst. Appl. **92**, 419–429 (2018)
23. E. Anthi, L. Williams, M. Rhode, P. Burnap, A. Wedgbury, Adversarial attacks on machine learning cybersecurity defences in industrial control systems. J. Inf. Secur. Appl. **58**, 102717 (2021)

24. A. Bilen, A.B. Özer, Cyber-attack method and perpetrator prediction using machine learning algorithms. PeerJ Comput. Sci **7**, e475 (2021)
25. V.K. Singh, M. Govindarasu, A cyber-physical anomaly detection for wide-area protection using machine learning. IEEE Transactions on Smart Grid. **PP**, 1 (2021)
26. I. Tariq, M.A. Sindhu, R.A. Abbasi, A.S. Khattak, O. Maqbool, G.F. Siddiqui, Resolving cross-site scripting attacks through genetic algorithm and reinforcement learning. Expert Syst. Appl. **168**, 114386 (2021)
27. M. Ghiasi, M. Dehghani, T. Niknam, A. Kavousi-Fard, P. Siano, H.H. Alhelou, Cyber-attack detection and cyber-security enhancement in smart DC-microgrid based on blockchain technology and Hilbert Huang transform. IEEE Access **9**, 29429–29440 (2021)
28. Q. Li, L. Zhang, R. Zhou, Y. Xia, W. Gao, Y. Tai, Machine learning-based stealing attack of the temperature monitoring system for the energy Internet of Things. Secur. Commun. Netw **2021**, 1 (2021)
29. P. Kumar, G.P. Gupta, R. Tripathi, TP2SF: A trustworthy privacy-preserving secured framework for sustainable smart cities by leveraging blockchain and machine learning. J. Syst. Archit. **115**, 101954 (2021)
30. S. Zhu, V. Saravanan, B. Muthu, Achieving data security and privacy across healthcare applications using cyber security mechanisms. Electron. Libr. **38**, 979 (2020)
31. S. Liu, S. You, H. Yin, Z. Lin, Y. Liu, W. Yao, L. Sundaresh, Model-free data authentication for cyber security in power systems. IEEE Trans. Smart Grid **11**(5), 4565–4568 (2020)
32. S. Velliangiri, An enhanced multimedia video surveillance security using wavelet encryption framework. J. Mobile Multimed **15**(3), 239–254 (2020)
33. H. Karimipour, A. Dehghantanha, R.M. Parizi, K.K.R. Choo, H. Leung, A deep and scalable unsupervised machine learning system for cyber-attack detection in large-scale smart grids. IEEE Access **7**, 80778–80788 (2019)
34. S. Velliangira, J. Premalata, A novel forgery detection in image frames of the videos using enhanced convolutional neural network in face images. Comput. Model. Eng. Sci **125**(2), 625–645 (2020)
35. M. Thakong, S. Phimoltares, S. Jaiyen, C. Lursinsap, One-pass-throw-away learning for cybersecurity in streaming non-stationary environments by dynamic stratum network. PLoS One **13**(9), e0202937 (2018)
36. M. Kalinin, V. Krundyshev, P. Zegzhda, Cybersecurity risk assessment in Smart City infrastructures. Mach. Des. **9**(4), 78 (2021)
37. W. Serrano, The blockchain random neural network for cybersecure IoT and 5G infrastructure in smart cities. J. Netw. Comput. Appl. **175**, 102909 (2021)
38. J. Zhang, Y. Zhao, J. Wang, B. Chen, FedMEC: Improving efficiency of differentially private federated learning via mobile edge computing. Mobile Netw. Appl **25**(6), 2421–2433 (2020)
39. S. Latif, Z. Idrees, J. Ahmad, L. Zheng, Z. Zou, A blockchain-based architecture for secure and trustworthy operations in the industrial Internet of Things. J. Ind. Inf. Integr. **21**, 100190 (2021)
40. W. Abramson, A.J. Hall, P. Papadopoulos, N. Pitropakis, W.J. Buchanan, A distributed trust framework for privacy-preserving machine learning, in *International Conference on Trust and Privacy in Digital Business*, (Springer, Cham, 2020, Sept), pp. 205–220

Blockchain Security for the Internet of Things

N. Nasurudeen Ahamed, P. Karthikeyan, S. Velliangiri, and Vinit Kumar Gunjan

1 Introduction

Internet of Things (IoT) has numerous IoT devices such as cameras, sensors, mobiles, smart refrigerators, and smartwatches. IoT devices face many challenges when transferring data from one IoT device to another. IoT devices are attacked or misused by the hacker or attacker devices made to secure data transfer using Blockchain Technology. Blockchain innovation is the disappeared connect to determine protection and unwavering quality uncertainties on the IoT. Blockchain is the silver shot required by the IoT business. It very well may be utilized in following billions of associated gadgets, permitting the handling of exchanges and harmonization between gadgets. This takes into consideration critical investment funds for IoT industry makers. This decentralized approach would crash weak links, making a heartier biological system for the gadgets. The cryptographic method utilized by blockchains would make customer information more classified. The principal benefits of the Blockchain are extraordinary straightforwardness, upgraded security, further developed detectability, high proficiency, low costing, and no outsider intercession. The IoT empowered Blockchain, and very much planned motivations will

N. N. Ahamed
Department of Computer Science & Engineering, Presidency University, Bangalore, India
e-mail: nasurudeenahamed@presidencyuniversity.in

P. Karthikeyan (✉)
RV University, Bangalore, India
e-mail: karthikeyanp@rvu.edu.in

S. Velliangiri
SRM Institute of Science and Technology, Chennai, Tamilnadu, India

V. K. Gunjan
CMR Institute of Technology, Hyderabad, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_5

motivate to replace consumer information [1]. Many facets of today's markets are likely to be impacted by the large-scale adoption of the blockchain method.

Blockchain Technology provides security and privacy, for example, Bitcoin [2]. The Internet of Things (IoT) speaks to one of the essential troublesome improvements of this century [3]. It is a characteristic development of the Internet (of PCs) to the inserted and cyber-physical frameworks, "things" that, while not PCs themselves, by and by have PCs inside them. IoT exponential growth in research and industry, however contempt, all experiences protection and security vulnerabilities [4]. Systematic security and protection methods will generally be inapplicable for IoT, for the most part, because of its decentralized topology and the asset limitations of most of its gadgets. The Blockchain supports digital money [5].

IoT Blockchain Platform Architecture IoT blockchain platform has four layers: (1) application layers, (2) IoT blockchain service layer, (3) connectivity layer, and (4) physical layers. Figure 1 shows the IoT Blockchain Platform Architecture.

Application Layers The application layer contains an application program that can communicate with IoT devices and perform a particular task.

IoT Blockchain Service Layer This helps the layer contain all modules that put together standard administrations to give different provisions of blockchain innovations like Identity management, consensus, and peer-to-peer management. The dispersed record is an agreement of recreated, shared, and synchronized computerized information spread across the blockchain network, where network individuals claim the duplicate of the record. It gives extra safe room to record the gadget organization and detect information given by actual sensors. Any progressions to the record are reflected in all duplicates in the blockchain network in practically no time. The record can be either permissioned or premise.

Connectivity Layer The primary function provided by the connectivity layer is routing management. Self-association is required since actual gadgets themselves have no worldwide web conventions (IPs). This layer likewise incorporates different modules for giving underneath administrations: network the administrators, secure the administrators, message representative, and route the administrators.

Physical Layer This contains an immense quantity of IoT devices, user devices, data storage, local bridges, and servers that are linked together around a peer-to-peer blockchain network.

Blockchain technology became well-known with the emergence of cryptocurrency mining. However, it now has a lot to do with the Internet of Things. The quantity of data handled by IoT devices is massive. It is all sent in a chain, leaving it vulnerable to hackers. In this context, the opportunity to use the Blockchain architecture to verify, standardize, and safeguard the adoption of data handled by devices presents itself. For IoT security, the Blockchain can track the data gathered by sensors and prevent it from being replicated by erroneous data. To secure the

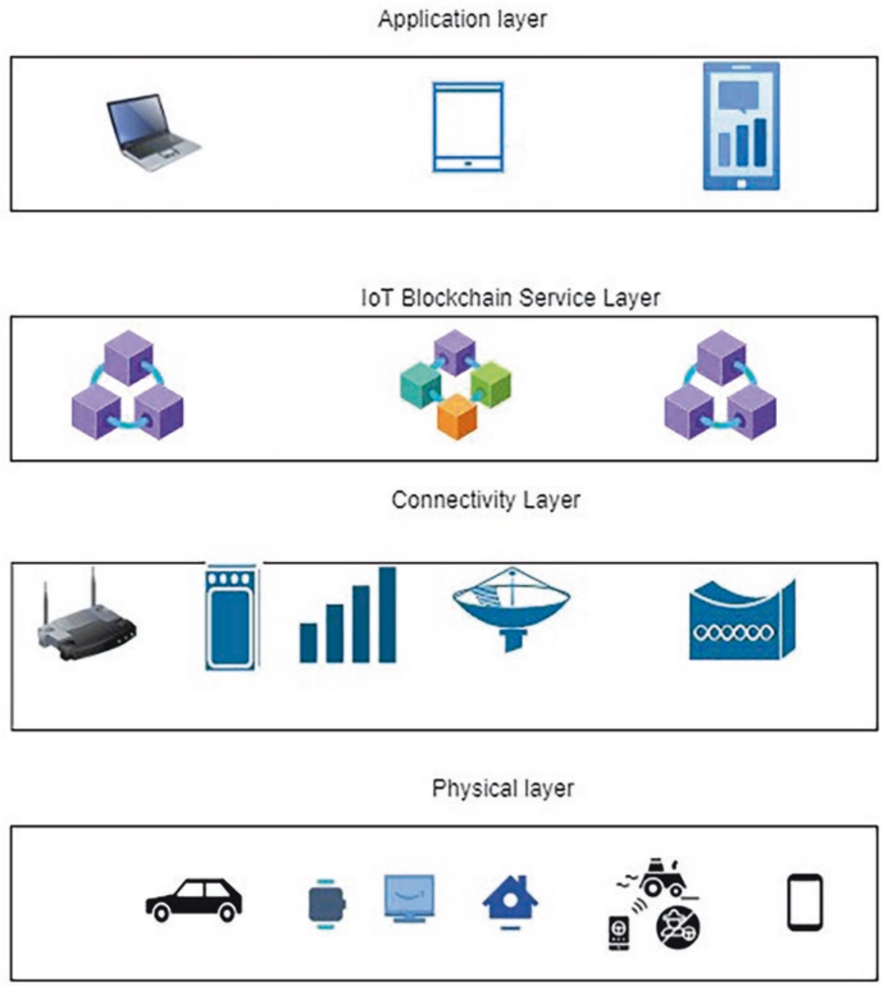


Fig. 1 IoT Blockchain platform architecture

end-to-end integrity of the gathered data and related interactions, IoT applications require trust mechanisms that cut across these layers. Transparency of data collecting procedures and related interactions, as well as the ability to audit these processes and interactions, are critical to meeting these criteria. The needs for openness and auditability encourage the use of blockchain to support IoT trust. Blockchain is immutable because network participants control it together using a consensus method such as Proof-of-Work (PoW) and Proof-of-Stake (PoS). Inter-node interactions and data collection are both part of the Internet of Things. Existing research treats the IoT trust challenge as two distinct issues, proposing reputation and trust techniques. For IoT data collection or inter-node communication, there is one. As a result, there is a clear requirement for an integrated architecture that provides end-to-end trust across data gathering and blockchain. In the Internet of Things, node interactions are important. In Blockchain-based IoT applications, layered trust architecture is used.

This book chapter is organized as follows: Sect. 2 applies blockchain security and privacy for the Internet of Things. In Sect. 3, we provide the conclusion of the blockchain applications in a secure manner.

2 Related Works

This section aims to discuss the blockchain applications in different areas and address the significant security challenges and overcome the breaches. Blockchain has a different application. In this paper, we have mentioned the following list of applications: (a) Supply Chain and Logistics, (b) Insurance, and (c) Society Application [6].

2.1 *Supply Chain and Logistics*

Goods exchange between supplier and consumer is a complex task because Blockchain is comfortable for Supply Chain and Logistics [7] and is transparent to the customer. It gives assurance to the companies who send the product to the customer. Before, they were given a clear audit trail to manage the risk and reduce the supply chain failures; now, in this digital advertising, using Blockchain implemented the IoT devices as follows:

Figure 2 shows the supply chain management using a blockchain-enabled IoT device. Blockchain Technology provides accurate and end-to-end tracking of supply chain management systems [7]. Supply chain management can be done using two different tag types: (1) NFC (Near Field Communication) and (2) RFID (Radio Frequency Identification) (Table 1).

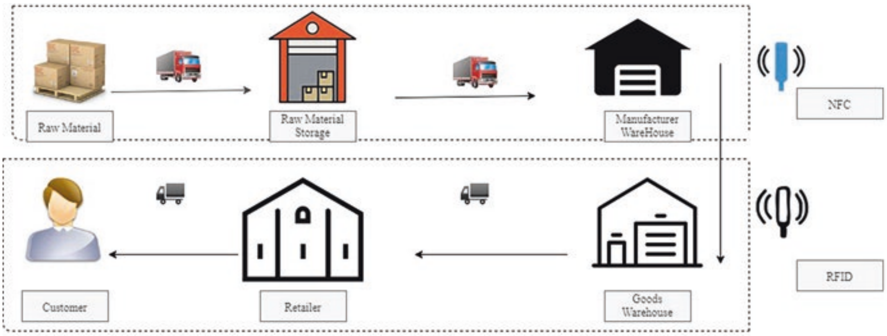


Fig. 2 Supply chain management using blockchain-enabled IoT device

Table 1 Comparison between RFID and NFC

Parameter	RFID	NFC
Network Type	Point – Point	Point – Point
Communication	Unidirectional	Bidirectional
Range	Up to 100 m	More than 0.2 m

The raw material is transferred to raw material storage using NFC, and it is used for short communication. When any goods are exchanged, it will create a blockchain node that contains information about the excellent exchange. That node is also added to the distributed ledgers. Raw material storage to manufacturer is also exchanged using NFC. Goods warehouse to retailer and retailer to customers are exchanged using an RFID tag. An RFID tag is used for long-distance communications. Blockchain technology characteristics such as decentralization and immutability improve supply chain management [8].

2.2 *Insurance*

Traditional Insurance Policies are the expected protection arrangements that are regularly handled on paper contracts, which means cases and installments are mistakes inclined and regularly require human supervision. Modern systems are considered as a kind of distributed ledger in the Blockchain. The distributed ledger is one of the significant advantages of blockchain technology. It improves the efficiency of fraud elimination and data analysis with the Internet of Things [9]. Exchanges are attached in a dispersed framework on the system, which makes framework recuperation by disposing of a solitary purpose of disappointment or incorporated element, during the distributed ledger in the insurance application to enable the IoT smartphone devices to access the Insurance policy in the distributed ledger [1, 10]. The best five protection giants mutually forced blockchain Insurance Industry Activity (B3I) to examine the application practicality of Blockchain in the protection industry [11] and create blockchain-based verifications of ideas for protection in the proofs of concept for Insurance [2, 12–14] (Fig. 3).

2.3 *Society Applications*

Society Application is a significant concern in blockchain technology. In feature generation, we have to solve the traditional borrowing relationship that reduces the credit problems. So we have to change the smart contract. Trust and security are the significant advantages of the intelligent contract [15].

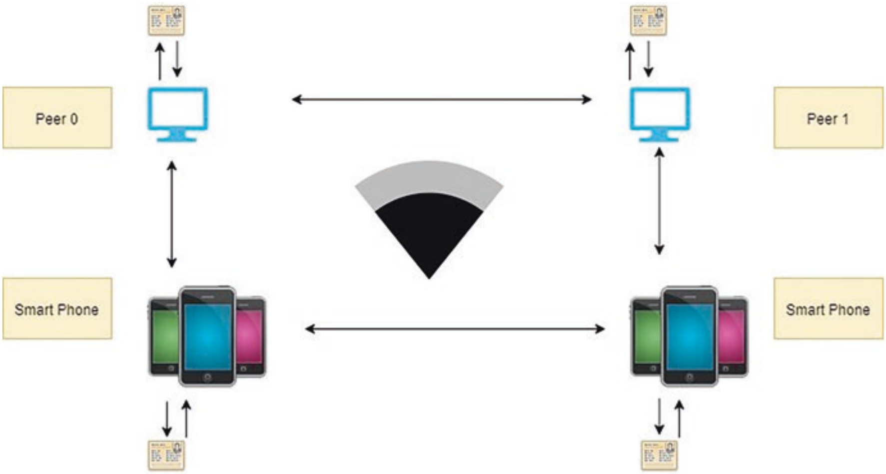


Fig. 3 Distributed ledger using IoT smartphone device

2.4 Blockchain Music

In traditional music recording in the film industry, the copyright amount is not claimed for the Musician's music because it has directly gone to the copyright seller. This problem never occurs when using blockchain secure manner; this should be implemented in this music era [9, 11]. For example, copyright sellers give the royalty to the Musician and the buyer of the music got and used it in concerts. Figure 4 depicts the music seller's copyright using a blockchain smart contract to the buyer and gives the royalty amount to the appropriate Musician [6]. The benefits of this smart contract are the easiest way together with the Blockchain and speed and accuracy, trust, savings, and security. The digital artwork and healthcare industry as well as diamond industry are the other applications used in the smart contract [11].

2.5 Energy Financing

Blockchain will simplify raising capital for the perfect vitality ventures using interfacing progressively potential financial specialists [16]. Now, India also launched a smart city [17]. To develop each state and mainly concentrate the green energy field, the cryptocurrencies are utilized [18] (Fig. 5).

This book chapter provides the blockchain application in various organizations, and the individual domain uses blockchain technology. Blockchain is also used in education, transportation and charity. We have described the comparison between blockchain technology and IoT applications.

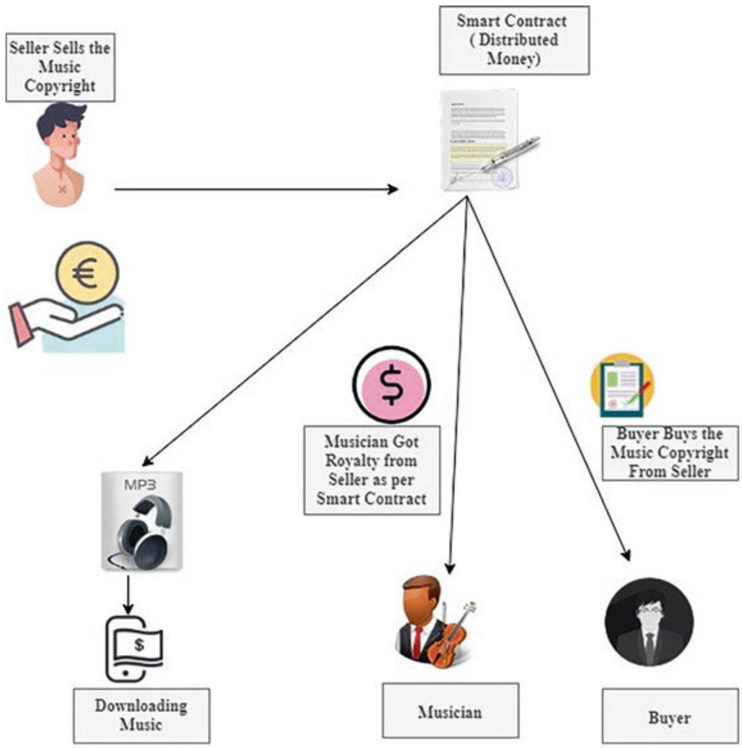


Fig. 4 Music copyright using smart contract

Fig. 5 Green energy using blockchain technology

2.6 Automotive Industry in IoT and Blockchain

Digitization is turning into a serious necessity. The auto business is utilizing IoT-empowered sensors to construct completely independent vehicles. Associating Industrial IoT arrangements in the car area to a decentralized organization permits various clients to share basic data quickly. The car area is an appealing blockchain IoT use case, as the joined innovation can disturb, for example, gasoline installment frameworks, autonomous vehicles, and automated traffic light with clever leaving. NetObjex has shown how Blockchain and IoT might be utilized to make a smart stopping framework. For acknowledging ongoing vehicle and distinguishing the accessibility of parking spots, the firm has joined forces with a leaving sensor startup called “PNI.” The association smoothes out the most common way of discovering a parking space and computerizes installments utilizing digital currency wallets. Stopping time costs are determined utilizing IoT sensors, and paying is done straightforwardly through the crypto-wallet [19].

In the case of carsharing, blockchain technology may be able to provide a secure digital identification. Personal preferences and settings may be safely kept in the automobile via blockchain, preventing exposure to third parties. This might potentially make peer-to-peer carsharing possible. Meanwhile, consumers may benefit from blockchain since a single registration in the blockchain ecosystem may be utilized for all carsharing offers from various service providers in the ecosystem.

Purchasing or selling a vehicle: For automobile owners, blockchain-based registries would make it easier to verify a vehicle’s history (for example, if it has been in an accident), allowing for greater openness when buying a car. Another advantage would be having a comprehensive picture of the vehicle’s components: users could research the origins of the carpeting and solve repair-related issues, not to mention that a smart contract allows the seller and buyer to enforce a products’ transaction without the use of an intermediary. Vehicle finance and leasing: We were able to improve and automate several procedures in the car leasing and finance sector, thanks to blockchain-based smart contracts. Deactivating the unlocking system, for example, can prohibit an automobile from being utilized if the lease fee has not yet been paid.

2.7 Smart Home Using Blockchain and IoT

Smart IoT-enabled gadgets are becoming increasingly important in our daily lives. The Internet of Things (IoT) blockchain enables home security systems to be controlled remotely from a smartphone. The typical centralized way of exchanging data created by IoT devices, on the other hand, lacks security requirements and data ownership. By addressing security concerns and eliminating centralized infrastructure, Blockchain has the potential to take smart homes to the next level. Each bright house in British Columbia is built for a unique purpose. Devices produce store transactions in order to store data. An SP or the house owner generates an access transaction. Make use of cloud storage: A homeowner or a service provider creates a transaction for monitoring to watch a gadget regularly. It is possible to add a new gadget to the smart home. A device is removed through a genesis transaction and a deletion of the transaction. All of the deals mentioned above have been completed. To keep communication safe, a shared key is utilized. Lightweight to identify any changes in transactions, hashing is used. Biometrics, voice recognition, and face recognition are examples of sensitive user data kept on the Blockchain for better

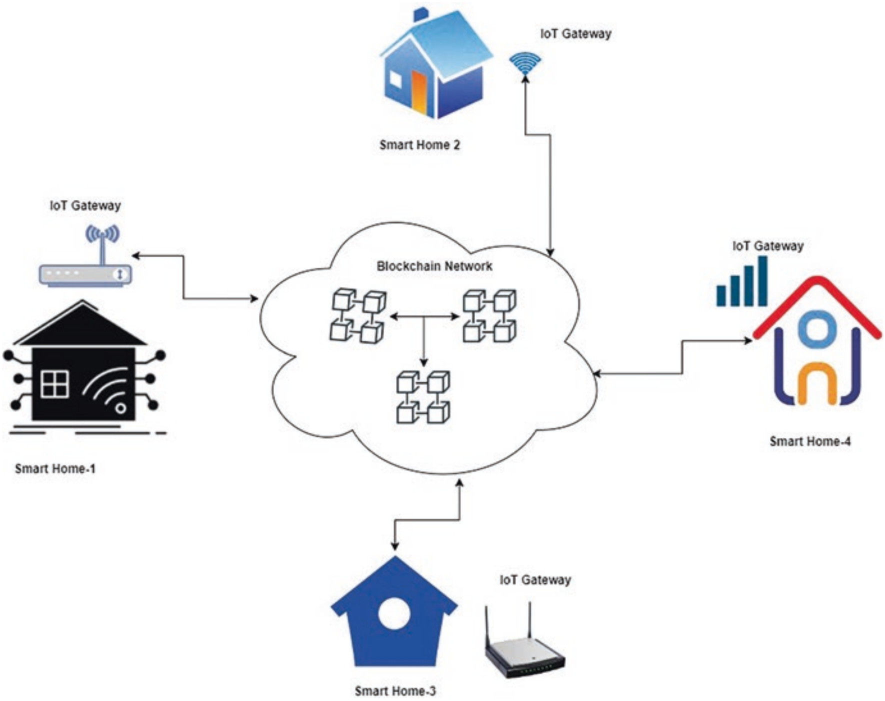


Fig. 6 Smart home management using IoT and Blockchain

security. Once data is recorded on the Blockchain, it cannot be changed, and only the proper people have access to it. Figure 6 depicts the overview of innovative home management using Blockchain and IoT.

2.8 Pharmacy Industry

The problem of counterfeit medications in the pharmaceutical industry is getting worse day by day. The pharmacy industry is in charge of medication development, manufacture, and distribution. As a result, tracing a drug's whole route is challenging. The transparent and traceable characteristics of blockchain technology can aid in tracking medicine shipments from their point of origin to their final destination in the supply chain.

Medi ledger is a blockchain IoT use case for tracking the lawful transfer of ownership of prescription medications. When it comes to monitoring delicate healthcare goods, transparency and traceability are critical. Manufacturers, distributors, dispensers, and end-customers may access data recorded on the distributed ledger, which is immutable and timestamped. Medi ledger is a blockchain-based technology that allows consumers to regulate their access and prevent counterfeit medications from entering the supply chain.

2.9 Agriculture Industry

Agriculture industries are increasing the use of farmland to generate the best feasible yields in order to profit and meet human food demands. Growing more food for the growing population while reducing environmental impacts and maintaining supply chain transparency is critical for optimum consumer satisfaction. The combination of Blockchain and IoT can completely transform the food production business, from farm to grocery store to house. Installing IoT sensors in farms and transmitting the data straight to the Blockchain can improve the food supply chain. Figure 7 depicts the overview of Blockchain and IoT use cases in the agriculture industry.

Data received from farms utilizing smart agricultural instruments is extremely valuable since it aids in the making of profitable decisions. Because there is no

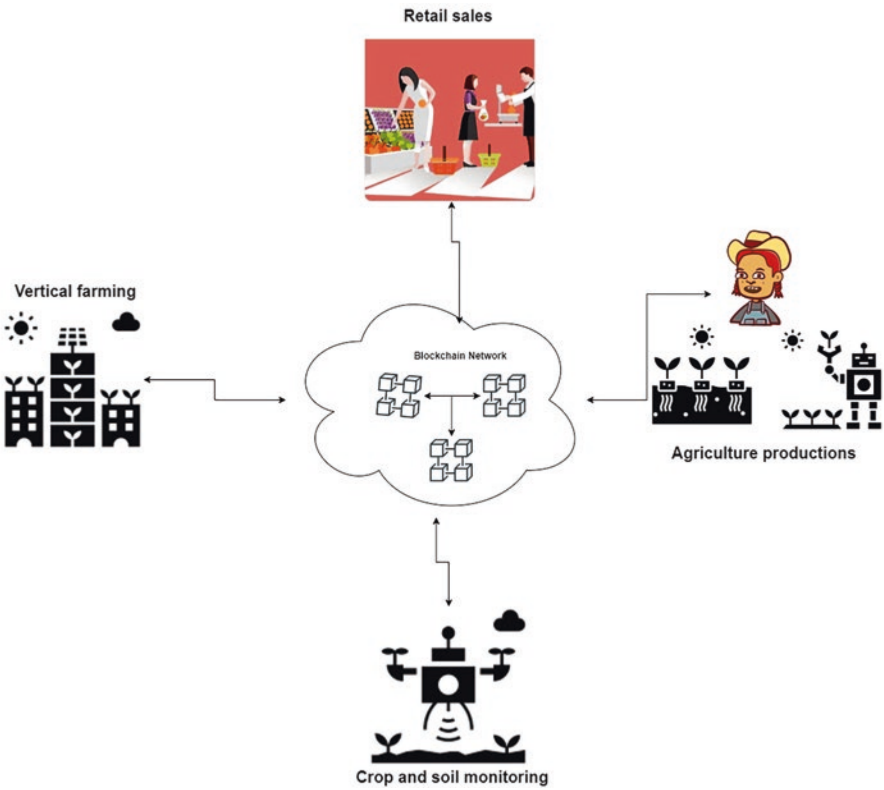


Fig. 7 An overview of Blockchain and IoT use case in the agriculture industry

industry standard for handling agricultural data, producers have a tough time doing so. Many farmers and producers are unaware of how to effectively use data for decision-making. As a result, it's critical to provide farmers and producers with the tools and strategies they need to successfully gather, organize, process, and apply data.

2.10 Water Management

Distribution of water resource to the end users is complicated because water management has traditionally relied on outdated technology and convoluted methods that may no longer be applicable today. Water the board project has been proposed to utilize Blockchain and IoT in order to evaluate stream contamination. Libelium and Airalab have worked together on a task called "Robot on the Volga." It gathers water contamination levels independently by utilizing a robot equipped with IoT sensors and blockchain innovations. The robot takes water readings from the Volga River's Kuybyshev Reservoir. He communicates the information on the Ethereum Blockchain continuously. The robot can utilize IoT to sort out where and when estimations were gotten, helping researchers in deciding the wellspring of contamination. It can screen and save information by means of NetObjex's IoT and blockchain administrations (Table 2).

2.11 IoT and Blockchain Security Challenges

Combining Blockchain with IoT leads to a lot of potential problems, which will enable hackers to steal the information present in the IoT edge devices. Blockchain-enabled identity access management provides security to the IoT edge devices. IoT devices developers and IoT services providers face many security challenges when they want to develop secure IoT devices for the end users using blockchain technology. The security challenges are discussed in these sections [20–23]. Figure 8 depicts the security challenges of Blockchain and IoT.

2.11.1 Overly Large Attack Surface

IoT devices has large attack surface if you consider smart home IoT application hackers can steal the information from any devices attached to smart home. The managing of IoT devices is through the Internet, and more prominent quantity of administrations might be assaulted. The attack surface is the term for this. One of the main stages during the time spent ensuring a framework is to lessen the assault surface. There might be open ports on a gadget with administrations running that aren't really essential for working. An attack on a particularly futile assistance

Table 2 IoT based Blockchain applications and challenges

S.No	Blockchain applications	Challenges	Advantages
1.	Supply chain and logistics	Lack of transparency Advertisements fraud	Using NFC and RFID Tag gives transparency to the Seller and Consumer. Can monitor the goods easily so no possible fraud.
2.	Insurance	Traditional insurance is the paper contract, and brokers' challenges occur.	Distributed ledgers are used to improve efficiency. IoT smartphones are also used to eliminate the fraud/brokers in the insurance sector.
3.	Society application	Traditional borrowing has some credit problems.	Implement the intelligent contract to improve the accuracy and trust between the lender and borrower.
4.	Blockchain music	Traditionally musician cannot get royalty to the particular seller in the music industry.	Implement the blockchain technology so the seller can sign the intelligent contract using music industry, the musician can get royalty, and the buyer can get the copyright from a seller without any risks.
5.	Energy financing	Internal (investors) and external workflows have not been fulfilled in the energy field.	It is easier to raise the capital/smart city with clean and green energy by utilizing the funds.
6	Automotive industry	The rise of autonomous vehicles and the evolution of connected vehicles	A blockchain-based system that allows automakers to identify automobiles with problematic parts and, as a result, issue-customized recalls or service advisories for such vehicles.
7	Smart home	Although gateways play an important role in smart homes, their centralized structure exposes them to various security risks, including integrity, confidentiality, and authorizations.	Biometrics, voice recognition, and face recognition are examples of sensitive user data kept on the Blockchain for better security. Once data is recorded on the Blockchain, it cannot be changed, and only the proper people have access to it.
8	Pharmacy industry	Blockchain can revolutionize the pharmaceutical business by introducing three key elements: privacy, transparency, and traceability.	Blockchain in the pharmaceutical supply chain can enable the precise location of medications to be identified. Batch reminders may be sent out or carried out in a timely and effective manner while ensuring patient safety.
9	Agriculture industry	Deal with climate change, soil erosion, and the loss of biodiversity.	It supports the creation and implementation of data-driven technologies for intelligent farming and index-based agriculture insurance by providing a safe way to store and manage data. Blockchain and IoT-enabled agriculture provides low cost and high revenue generations
10	Water management	Distribution of water resource to the end users is complicated because water management has traditionally relied on outdated technology and convoluted methods that may no longer be applicable today.	provide constant nature, speed, and clarity of data, allowing partners to be a part of the ongoing process rather than being beneficiaries of retrospective analysis and investigations.

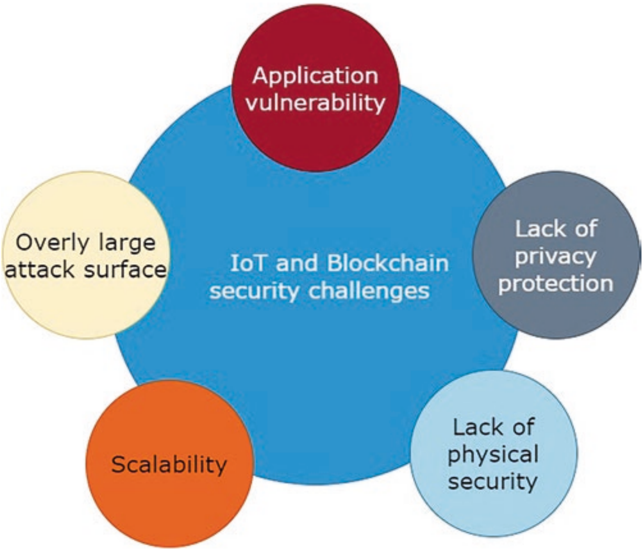


Fig. 8 Security challenges of Blockchain and IoT

might be handily stayed away from by not uncovering it. During advancement, administrations like Telnet, SSH, or an investigate interface might be helpful; however, they're seldom utilized underway.

2.11.2 Application Vulnerability

IoT devices use application to provide a service to end-users. Application contains security hole to attack the IoT devices. In uncommon conditions, the assailant might have the option to run their own code on the IoT devices, permitting them to reap delicate information or target outsiders. Security weaknesses, as other programming interface, are difficult to altogether dispose while planning programming. There are, in any case, ways of forestalling notable weaknesses or limit the probability of them happening. There are suggested rehearses for keeping away from application weaknesses, like after procedures are accepted consistently.

2.11.3 Lack of Privacy Protection

IoT devices are transferring information from one device to another. The information transmitted lacks integrity and privacy. IoT devices that are associated with a remote organization save the organization's secret phrase. Cameras can record video and sound of the space in which they are introduced. On the off chance that aggressors approached this data, it would be a significant break of protection of gadgets, and associated administrations should deal with touchy information fittingly, safely, and just with the end-authorization. client's This is valid for both the capacity and dispersal of touchy information.

2.11.4 Lack of Physical Security

IoT edge devices lack physical security. Hackers can open it and assault its equipment. Any defensive modification, for instance, can be bypassed by getting to the substance of memory parts directly. Moreover, the IoT edge devices might incorporate troubleshooting contacts that are available subsequent to opening the gadget, giving an assailant additional alternative. Actual attacks influence only one gadget and require actual contact. Since these attacks cannot be brought out in mass through the Internet, we don't believe them to be one of the most genuine security issues, yet they are as yet included.

2.11.5 Scalability

One of the most significant challenges still facing IoT devices is scalability. IoT devices deal with the huge volumes of data received by a big network of sensors, as well as the potential for slower transaction processing rates or latency. Defining a distinct data model ahead of time helps save time and avoids problems when it comes to putting the solution into production.

2.12 Blockchain and IoT Companies

Helium
Helium is a San Francisco, California-based IoT blockchain startup known as the principal decentralized machine network on the planet. The organization influences blockchain for interfacing low-power IoT machines like microprocessors and switches to the web. The blockchain-based remote web foundation of Helium is likewise one of the trademark features of the startup. With a blockchain-based framework utilizing radio innovation, Helium is one of the fruitful blockchain IoT organizations with capacities for fortifying web associations. Furthermore, the blockchain-based framework of Helium likewise helps in accomplishing critical decreases in power needed for working shrewd gadgets.

NetObjex
One more top expansion among blockchain IoT projects in the current occasions would be NetObjex. The Irvine, California-based startup has been effective in making a norm, decentralized foundation for IoT gadgets to empower correspondence between them. Moreover, the blockchain-based IoToken presented by the

organization conveys a safe advanced stage to empower connection and correspondence between savvy gadgets in a single environment.

NetObjex states that the IoToken is likewise reasonable for consistent correspondence with different gadgets in a wide scope of businesses. For instance, benefactors could utilize the IoToken through their crypto-wallets to make installments for their suppers. What's more, IoToken could likewise be valuable for drone conveyance by denoting the place of conveyance and guaranteeing installment check.

Xage Security

Xage Security is one more miracle among blockchain IoT new businesses to rise out of California. It is one of the exceptional blockchain-based security stages for IoT. Curiously, the focal point of Xage Security on various businesses like transportation, horticulture, utilities, and energy demonstrates a great deal about its usefulness.

The blockchain of Xage guarantees that IoT gadgets are sealed and can get to get lines of correspondence between shrewd gadgets. Besides, Xage additionally includes a lengthy set-up of decentralized IoT applications with different capacities. You can discover applications for security strategy the executives just as ones for giving moment warnings in regards to vindictive hacking exercises.

Grid+

The Austin, Texas-based Grid+ is likewise one of the top names in blockchain IoT projects with generously valuable functionalities. Grid+ uses Ethereum blockchain for empowering customers to get energy-productive IoT gadgets. The organization's representative buys and sells power for the sake of a Grid+ client.

Moreover, the Grid+ application offers refreshed data in regards to energy utilization with the organization's savvy meter associated remotely to energy-proficient shrewd gadgets. The Ethereum blockchain of Grid+ helps specialists in paying for power at a hole of like clockwork. In particular, the principles of cutting edge blockchain cryptography enable the security of installments and general network safety on the application.

Atonomi

Atonomi is one more illustration of blockchain IoT new companies zeroed in on engaging IoT gadget security. The essential objective of Atonomi centers around expanding IoT gadget security. It perceives that the absence of gadget security hampers the improvement of IoT innovation impressively.

Atonomi offers the extraordinary functionalities of personality approval, extensible engineering, interoperability, gadget notoriety, and an exchange-based climate. Curiously, Atonomi has been customized as an installed blockchain-based answer for engaging IoT.

Riddle&Code

Riddle&Code is likewise one more fascinating expansion among IoT blockchain new companies. It offers cryptographic labeling answers for blockchain in savvy store network and coordinations of the executives. Riddle&Code brings exceptional worth from the blend of disseminated record organizations and IoT gadgets.

Thus, it could convey a coordinated, protected equipment and programming answer for empowering entrusted and secure communications with machines in IoT biological systems. In actuality, Riddle&Code fundamentally offers a "confided in computerized character" to machines or any actual gadget. The striking part of Riddle&Code alludes to the right harmony between the requirement for actual documentation and the benefits of blockchain.

HYPR

HYPR is one more conspicuous passage among blockchain IoT organizations with a great deal of possibilities. The organization uses decentralized organizations or the force of blockchain for the security of associated ATMs, homes, locks, and vehicles. Digital assaults can be incredibly wrecking because of compromises in unified information bases, which house multitudinous passwords in a single spot. HYPR follows an extraordinary instrument of putting away logins on its blockchain. Thus, it can guarantee security and decentralization of significant and touchy data.

A portion of the significant biometric security conventions of HYPR incorporate the special voice, facial, palm, and eye acknowledgment instruments for IoT gadgets. Moreover, HYPR is likewise one of the best blockchain IoT projects lately with its genuine use cases. For instance, the stage has tried biometric checks on cell phones for empowering admittance to ATM individual banking. Moreover, HYPR has likewise fostered a DLT-advanced key for mortgage holders to empower a solitary passageway for nearly everything, including IoT-empower entryways just as brilliant diversion communities.

Chronicled

Chronicled is effectively one of the top augmentations among IoT blockchain new businesses with promising potential. The stage has successfully consolidated blockchain and IoT items for conveying a start to finish production network arrangement. The essential focal point of Chronicled is by and by on the drug and the food supply businesses.

The organization uses IoT-empowered steel trailers and sensors for getting to ongoing reports with respect to the transportation cycle. The execution of blockchain in IoT gadgets in the clinical or food inventory network helps increment straightforwardness all the while. Above all, it further develops familiarity with the chain of authority for resolving any issues emerging throughout delivery.

IOTA

IOTA is fundamentally a convention to guarantee quicker exchange settlement with the worth of information respectability. It is one of the fascinating blockchain IoT projects, which includes a Tangle record for lessening the requirement for costly mining. Particle offers a productive foundation for IoT gadgets that need to manage handling of enormous measures of microdata.

The provisions of Tangle record, the blockchain record supporting IOTA, enable the abilities of the IOTA convention. A portion of the unmistakable provisions of Tangle incorporate quantum-safe information, machine-to-machine correspondence, and charge less micropayments. Besides, IOTA has additionally fostered a sensor information commercial center with plans for entering the area of information driven examination and experiences.

ArcTouch
The last expansion among the best blockchain IoT new companies in the current occasions would point towards ArcTouch. The organization represents considerable authority in planning blockchain-based programming with help for better combination with IoT arrangements. ArchTouch has fostered a scope of associated, keen arrangements, including brilliant TVs, voice colleagues, and even wearables.

The organization likewise centers around the advancement of tweaked decentralized applications (DApps) that associate with the IoT gadgets. Moreover, decentralized applications created by ArcTouch include an upgraded level of IoT security. Simultaneously, it could empower quicker handling of arrangements through savvy contracts.

3 Conclusion

Blockchain is a significant era in the recent modern computer technology and is to be implemented in different areas. Blockchain technology has found diverse applications in various sectors, including but not limited to advertising, insurance, societal use cases, energy financing, automotive, and the agriculture industry. The prior survey on blockchain addresses either technical issues or specific applications in the Internet of Things (IoT). Our paper presented the security and privacy for the Blockchain and IoT-based applications. A future direction is to take many Blockchain applications to be implemented in IoT in order to improve the security and privacy in different areas.

References

1. S.A. Abeyratne, R.P. Monfared, Blockchain ready manufacturing supply chain using distributed ledger. Int. J. Res. Eng. Technol. **05**(09), 1–10 (2016)
2. H. Si, C. Sun, Y. Li, H. Qiao, L. Shi, IoT information sharing security mechanism based on blockchain technology. Futur. Gener. Comput. Syst. **101**, 1028–1040 (2019)
3. T. Duong, A. Chepurnoy, H.S. Zhou, Multi-mode cryptocurrency systems, in *BCC 2018 - Proc. 2nd ACM Work. Blockchains, Cryptocurrencies, Contract. Co-located with ASIA CCS 2018*, (2018), pp. 35–46
4. S.K. Lo et al., Analysis of Blockchain solutions for IoT: A systematic literature review. IEEE Access **7**, 58822–58835 (2019)
5. S. Moin, A. Karim, Z. Safdar, K. Safdar, E. Ahmed, M. Imran, Securing IoT is distributed blockchain: Analysis, requirements and open issues. Futur. Gener. Comput. Syst. **100**, 325–343 (2019)
6. W. Chen, Z. Xu, S. Shi, Y. Zhao, J. Zhao, A survey of blockchain applications in different domains. ACM international conference proceeding series, pp. 17–21, 2018

7. S. Mondal, K.P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar, P. Chahal, Blockchain inspired RFID-based information architecture for food supply chain. IEEE Internet Things J. **6**(3), 5803–5813 (2019)
8. H.R. Hasan, K. Salah, Blockchain-based proof of delivery of physical assets with single and multiple transporters. IEEE Access **6**(8), 46781–46793 (2018)
9. S. Biswas, K. Sharif, F. Li, B. Nour, Y. Wang, A scalable blockchain framework for secure transactions in IoT. IEEE Internet Things J. **6**(3), 4650–4659 (2019)
10. K. Fan, S. Wang, Y. Ren, H. Li, Y. Yang, Medlock: Efficient and secure medical data sharing via Blockchain. J. Med. Syst. **42**(8), 1–11 (2018)
11. J. Al-Jaroodi, N. Mohamed, Blockchain in industries: A survey. IEEE Access **7**, 36500–36515 (2019)
12. W. Liang, M. Tang, J. Long, X. Peng, J. Xu, K.C. Li, A secure FaBric blockchain-based data transmission technique for industrial internet-of-things. IEEE Trans. Ind. Informatics **15**(6), 3582–3592 (2019)
13. S. Tanwar, K. Parekh, R. Evans, Blockchain-based electronic healthcare record system for healthcare 4.0 applications. J. Inf. Secure. Appl. **50**, 102407 (2020)
14. A. Dubovitskaya, Z. Xu, S. Ryu, M. Schumacher, F. Wang, Secure and trustable electronic medical records sharing using blockchain, in *AMIA Annual Symposium Proceedings. AMIA Symposium*, vol. 2017, (2017), pp. 650–659
15. G. W. Peters, E. Panayi, Understanding modern banking ledgers through blockchain technologies: Future of transaction processing and smart contracts on the internet of money (pp. 239–278). Springer International Publishing (2016)
16. J. Frechette, Blockchain technology: Digitizing the global financial system, Honor. Progr. Theses Proj. (2017)
17. C. Shen, F. Pena-Mora, Blockchain for cities - a systematic literature review. IEEE Access **6**, 76787–76819 (2018)
18. J. Hwang et al., Energy Prosumer Business Model using Blockchain system to ensure transparency and safety. Energy Procedia **141**, 194–198 (2017)
19. L. Ting et al., A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022a)
20. S. Velliangiri, P. Karthikeyan, Blockchain technology: challenges and security issues in consensus algorithm. 2020 international conference on computer communication and informatics (ICCCI), IEEE, 2020
21. N.N. Ahamed et al., Sea food supply chain management using blockchain. 2020 6th international conference on advanced computing and communication systems (ICACCS), IEEE, 2020
22. A. Ksibi, H. Mhamdi, M. Ayadi, L. Almuqren, M.S. Alqahtani, M.D. Ansari, et al., Secure and fast emergency road healthcare service based on Blockchain Technology for Smart Cities. Sustainability **15**(7), 5748 (2023)
23. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022b)

IoT and Blockchain-Enabled Charging Station for Electric Vehicles

J. Shanmugapriyan, N. Karuppiah, Velliangiri Sarveshwaran, and S. Muthubalaji

1 Introduction

Electricity-based transport is said to be the future in the transportation sector. But still, there are a lot of roadblocks needed to be crossed. Factors like a suitable battery are presently under research. Suitable in the sense that it should be cost-effective, long-lasting, efficient, and various other factors. It is not only about the selection of batteries but also about the availability of charging stations. In the present-day world, most people hesitate to buy an electric vehicle due to the lack of availability of charging stations fearing their vehicle stopping midway without a way to charge. Moreover, charging station companies are required to do a lot of background work before setting up a charging station in a particular area. The key factor is the existing demand in a particular area (let's call each area a cell). We aim to overcome these drawbacks and encourage people to switch to electric modes of transportation.

J. Shanmugapriyan
Department of Electrical and Electronics Engineering, NSN College of Engineering and Technology, Karur, Tamilnadu, India

N. Karuppiah
Department of Electrical and Electronics Engineering, Vardhaman College of Engineering, Kacharam, Shamshabad, Hyderabad, Telangana, India

V. Sarveshwaran
Department of Computational Intelligence, SRM Institute of Science and Technology, Kattankulathur, Tamilnadu, India

S. Muthubalaji (✉)
Department of Electrical and Electronics Engineering, CMR College of Engineering &Technology, Hyderabad, Telangana, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_6

To achieve this, we use blockchain technology. Blockchain in simple words is a distributed ledger with each action being recorded and validated. There are two keys in a blockchain algorithm: a private key and a public key [1]. Each transaction or in other words an event is validated and processed only when the public key and the private key match. This paper coins an idea of using blockchain technology for allocating charging space for a vehicle on a particular charging station analyzing various factors like battery level of the vehicle, distance from the station, etc. The data of the charging stations within a particular cell is recorded and analyzed. Based on the analysis, the scope for setting up more charging stations in that cell or nearby cell can be evaluated.

The proposed system connects all the vehicles in a particular area to the charging station when the charge level in the battery falls under a particular percentage depending on vehicle type and battery capacity as in a blockchain structure. The major components include a microcontroller, communication module, display module, and ID module.

2 Related Works

DinanFakhri et al. have compared two communication systems. One system has blockchain technology and the other system does not have blockchain technology. The communication protocol used in IoT systems without blockchain is MQTT. Meanwhile, Ethereum is used in the blockchain platform. Both of these IoT systems are analyzed for their security level by simulating attacks, and their security aspects are observed. The test results show that the IoT system based on blockchain technology has a higher level of security than the IoT system without blockchain technology [2]. Chan Hyung Lee et al. developed a blockchain-enabled IoT based on one machine-to-machine (M2M) IoT standard and a hybrid blockchain application. The blockchain technique that has been implemented is known as log chain because of its consensus algorithm [3]. IoT devices are applicable for scalable configurations with a distributed approach. In this paper, a suitable mechanism is proposed to reduce the resource utilization process. REST API mechanism is used to decouple the IoT devices from the blockchain operations. A testbed has been developed to evaluate the performance and feasibility of the proposed architecture. The results of the work proved that it is capable of providing scalable solutions on demand with less resource utilization on IoT devices [4]. IoT is gaining popularity and finds its use in almost all the applications of today's life. As its popularity increases, the possibility of getting hacked by cybercriminals also increases. Therefore, a more secure and resilient network has to be created using IoT. For this purpose, blockchain technology is being used. In this, work blockchain-based IoT is proposed, which provides security, and its feasibility was also tested [5]. In this paper, allocation of charging stations for electric vehicles has been discussed. While allocating the charging station, the factors considered are the length of the car, its models, charging time, and the number of allotted cars for a particular charging station. A Simulated Annealing algorithm is used for the allocation of vehicles in a charging station. Different charging scenarios are considered, and the charging time is calculated for each scenario. The results proved that considerable charging time was reduced if the vehicles were properly allotted to the charging stations [6].

2.1 Background Work

Different people have different opinions. We as a group have been committed to the development and future of electric modes of transportation. We want to know what people around the society think about an EV and the various factors and ideas that are in their minds. We have conducted a survey consisting of about 700–800 persons from our Indian society. The survey was entirely online-based, and it consists of various questions right from knowing the person's age, profession, and experience with EVs.

The main aim of this survey is to know the mindset of the common man about an EV. We started with knowing about the age group of the respondent so that it would be convenient to put into perspective the different generations so involved. Most of the respondents in this survey were in their early 20's (76.9% to be exact) and were at the graduate level. Seeing at the present-day trend in our youth, they are more likely to switch on to an EV if they are completely satisfied. The respondents do agree that an EV is more eco-friendly than the vehicles that we use at present, and they are more likely to switch to electricity-based transport in the next five years. The first factor to be considered in switching over to an EV is the mileage per charge ratio. They expect to have their vehicles have a high mileage per charge ratio. The next prominent factor is the lack of charging stations, and this is what most of us fear before buying an electric vehicle.

The lack of availability of charging stations is given as the main reason that prevents them from buying an electric vehicle. The major reason for the lack of a proper charging station is that it needs good background work to set up a charging station, and also, the costs that are involved in doing so are high. Factors like demand, profit, and others are taken into consideration while doing so. We also wanted to know how far on average a person travels in a week? The results showed that the majority of the respondents on average travel less than 100 kms in a week. This is shown in Fig. 1. The next factor is the expectation of the people on how far they want their electric vehicle to travel per full charge? The results show that less than 1 percent is fine with a mileage of less than 100 kms if there are sufficient charging stations available, while the majority of the respondents voted for 100–200 kms per full charge of the vehicle with sufficient charging stations; this is shown in Fig. 2.

To know more as to why people are hesitant to charge a vehicle within medium intervals, we asked about the charging time within which they want their vehicle to be charged, and the result shows that the majority of the respondents wanted their vehicle to be charged within an hour or two as shown in Fig. 3.

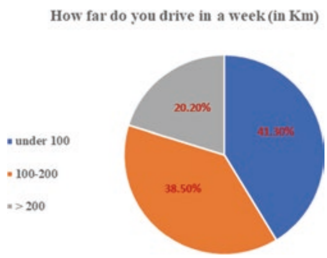


Fig. 1 Survey results on distance travelled in a week

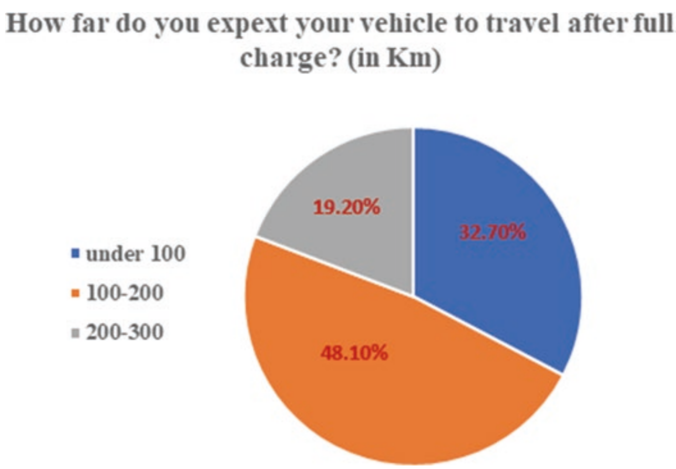


Fig. 2 Survey results on expected travel distance per full charge

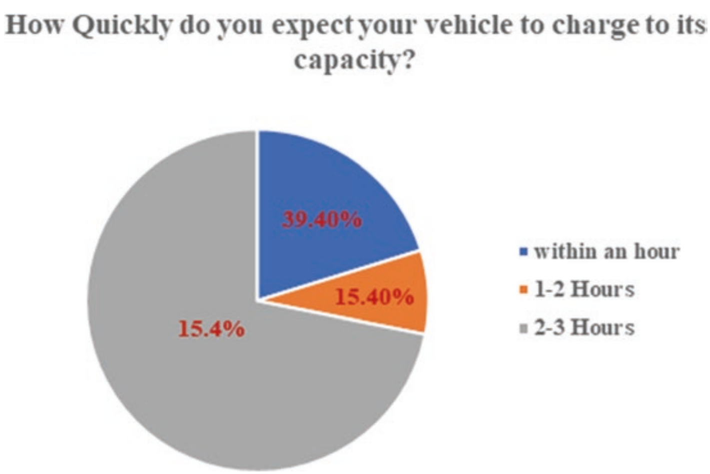


Fig. 3 Survey results on charging time

So, everyone expects to have a perfect mode of electric transportation. Keeping this thought, we are proposing a way to not only make charging of an EV feasible but also help in the analysis and development of a nearby charging station or increase the capacity of the existing one. To conclude on the survey, the majority of them wanted their EV to be an ideal one without any flaws or drawbacks, and the charging station should be within touching distance.

2.2 Existing System

Ever since the idea of an EV came around in the mid-nineteenth century, there has been drastic development around it. During those days, the selection of a motor, cost, and its implementation were the major factors that hindered its development. Also, there was no technology to store and reuse electric energy (i.e., the rechargeable battery didn't exist until the late 1950s). The growth of Electric vehicles started to pick up pace in the early 2000s with the more feasible version of the brushless DC (BLDC) motor. Moreover, the use of induction motors in modern-day EVs speaks for its development. The one major thing that's under development is an eco-friendly and cost-effective battery source and effective ways of charging it. In the present situation, the method for finding a charging station is more or less internet-based and is a form of open-loop control system where the user or the person inside the vehicle has to search it manually via an app through the internet [7, 8, 10].

From Fig. 4, it is seen that any car at any given place can search and find a charging station by using an app on a Smartphone. It is also well known that this kind of

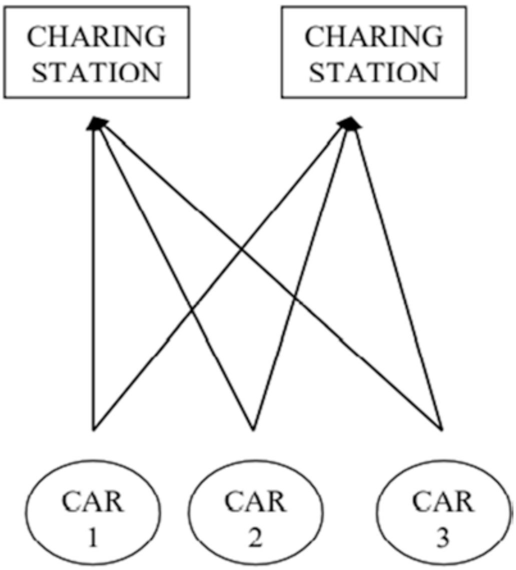


Fig. 4 Block diagram for existing system

system is not reliable because the place of the station cannot be booked as such and hence there is no guarantee that there will be space when that vehicle reaches that station because it might be occupied by another vehicle. And there is also no priority listing of the cars.

Consider both car 1 and car 2 are going for the only available slot at station 1. Consider all other slots at station 1 and station 2 are full. Car 1 has a charge of 20% of its full capacity left, while car 2 has a charge capacity of 40% of its full capacity left, and consider both the cars to be at the same capacity. Now, if car 2 that has a charge capacity of 40% left enters station 1 to charge with car 1 coming next, then car 1 has to wait and charge. Otherwise, car 1 will run out of charge while going to the next station.

There are two perspectives in this case. First, the perspective of car 2 is considered. In case car 2 didn't get to charge at station 1, it has to move over to the next station, which is 4–5 kms away (since station 2 is full). Even though there is a 40% charge left, there is no guarantee that car 2 can make it to the next charging station because it depends on the vehicle's lifetime and the amount of service done so that he would end up in the nearby station.

Now coming to the perspective of car 1, it is simply because the person driving the car cannot afford to be at another station that is far from the nearby one. They simply have to charge with the nearby station, but this adds up to their time since the slots are full. The car before them has to get charged first, and then they have to be charged. This adds to the frustration and causes more wastage of time.

3 Proposed Methodology

The drawbacks of the existing system are known now. The proposed system is a different model from the existing one. Let's divide it into two parts: (i) the car and (ii) the charging station. But first, divide the given region into cells. These are similar to a telecom tower under a cell as shown in Fig. 5.

These cells are formed with an area of a maximum radius of 2 kms. There will be at least one charging station inside these cells with minimum capacity depending on the demand of that particular cell. The station's capacity can be upgraded depending on the demand, or a new station can also be built in the same cell based on the data that is received and analyzed. There are receiving posts in every street that has the entry to a particular cell. These receiving posts act as a mediator between the vehicles entering into the cells and the stations within the cell. These receiving posts carry a trans receiver. This trans receiver module is used to communicate between the vehicle to the station and then from the station to the vehicle. The processing part takes place in the station. It all begins from the car Battery Management System (BMS), which initiates the process. The BMS system has a sensor that continuously monitors the battery level. And when the level of the battery is low, the next set of a process is started automatically. Also, there are a bunch of sensors that operate behind the process like a trans receiver, ID tag, a tag reader, etc.

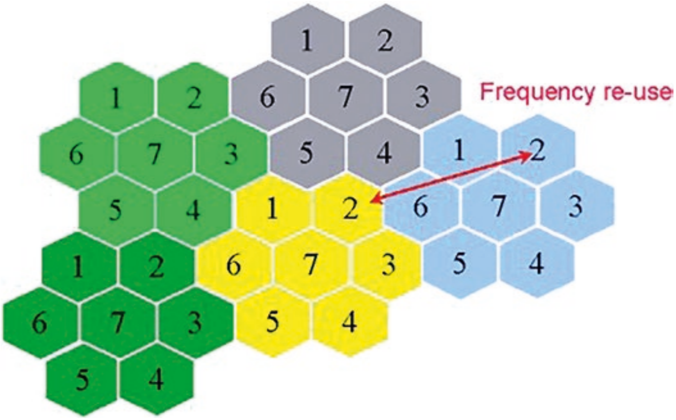


Fig. 5 Representation of cell clusters

The proposed system has three levels of low battery, namely less, low, and critical. These three levels of battery depend on the type of electric vehicle. If the battery level reaches the first level (less) of a particular vehicle, then a signal is transmitted to the receiving post of the cell where the car is traveling. If all the charging slots inside that cell is full, then it is redirected to the next cell. This is the first stage of the low battery level, and this level of the battery should be set such that it can carry the vehicle to another cell from the farther end of the previous cell. Likewise, it can skip two or more cells before it reaches the low level [9, 11, 12].

Now let us consider the second case where the battery level is low, and if it enters the cell, it is given a higher priority than the less level and lower than the critical level. Let's say there is no slot left for charging for the vehicle of this category then the driver has an option of skipping that cell to move on to the next cell. But it can skip only one cell. In the next cell, it is forced to charge even if it has to wait for charging.

If a car reaches the critical battery level, a signal from the car is sent to the stations inside that cell. First, consider a case where all slots are full. The car that is concerned has no other choice but to charge within this cell since its battery level has gone so low that it can operate within that cell radius and cannot go to the next cell. So, the car has to wait until the previous allotted cars have completed their charging.

The other case is common to all, i.e., when there is more than one station in a given cell. Figure 6 RP represents the receiving posts present at the start of each street in that particular cell. When there is more than one charging station in that cell, then the charging station near a given post is allocated for that car. Since all cars are designed to travel at least within a cell, so again another two categories of classification can be done here. First, the cars under the first and second categories have the option to skip the charging station because their destination could be in the very next cell, so a skip option is given to them, which should be done within a specific time, let that time be 10–20 seconds. If the person in that car doesn't give away the skip option, then they have the option of going to that corresponding

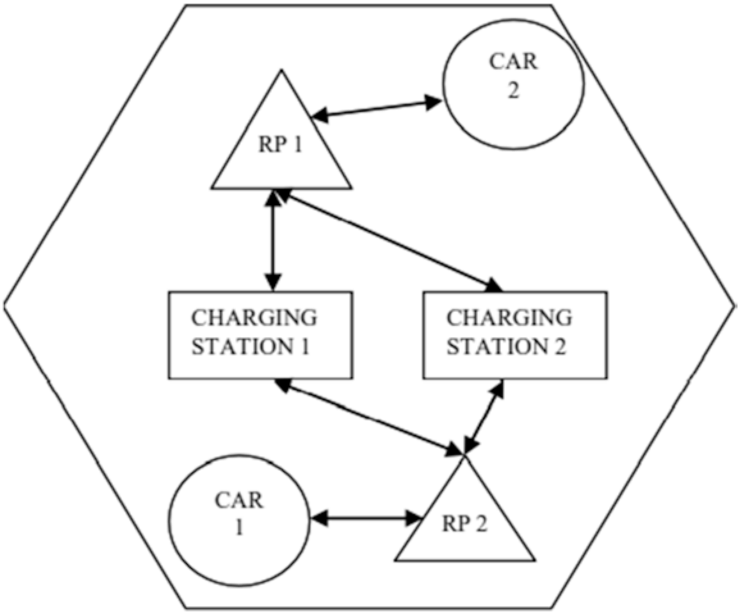


Fig. 6 Block diagram of the proposed system

station and giving a skip. Since the system is block chained, the cells are also block chained. If that car doesn't give a skip and doesn't arrive at the corresponding station and instead goes on to the next cell, then the slot allotted in the station on the next cell indicates it to the cells adjacent to it so that the previously allotted slot is canceled and is made available for some other vehicle.

The next case is about the third category of vehicle; there won't be any choice but to charge inside that cell even though the final destination is in the next cell. The person has to charge until the battery level reaches at least the next higher category, which is category two, and when this level is reached, the person has the option to stop the operation and carry on to the next cell to his destination. Now coming to the blockchain part, the entire system is block chained, as known there are two keys in a blockchain – a private key and a public key. The private key lies with the car, while the public key will be with the station. When a slot for a vehicle is allotted, then the public key of that station is sent to the vehicle, while the private key of the car is sent to the particular station; when these public key and private key match, then only that particular vehicle is allowed to charge at the particular charging station. Also, a ledger in all the stations in that particular area keeps a record of the number of vehicle charging requests and the time at which it occurs. Hence this stored data can be used for analysis and development of new charging stations or even upgrading the existing ones.

4 Conclusion

IoT and Blockchain-Based Electric Vehicle Charging Station (EVCS) Allocation System is the proposed system that overcomes the drawbacks of the existing system and provides perfect utilization of charging space and helps in the development of a new charging station or upgrading the existing one. A block chained system also ensures that the charging space allotted for a particular vehicle isn't taken away by another vehicle with the use of public and private keys.

References

1. J.P. Martins, J.C. Ferreira, V. Monteiro, J.A. Afonso, J.L. Afonso, IoT and Blockchain paradigms for EV charging system. Energies **12**(2987), 1–25 (2019)
2. D. Fakhri, K. Mutijarsa, Secure IoT Communication using Blockchain Technology. 2018 international symposium on electronics and smart devices (ISESD), Bandung, Indonesia, pp. 1–6, 2018. https://doi.org/10.1109/ISESD.2018.8605485
3. C. Lee, N. Sung, L. Nkenyereye, J. Song, Blockchain enabled Internet-of-Things service platform for industrial domain. 2018 IEEE international conference on industrial internet (ICII), Seattle, WA, USA, pp. 177–178, 2018. https://doi.org/10.1109/ICII.2018.00033
4. Q. Le-Dang, T. Le-Ngoc, Scalable Blockchain-based architecture for massive IoT reconfiguration. 2019 IEEE Canadian conference of electrical and computer engineering (CCECE), Edmonton, AB, Canada, pp. 1–4, 2019. https://doi.org/10.1109/CCECE.2019.8861858
5. M. Singh, A. Singh, S. Kim, Blockchain: A game changer for securing IoT data. 2018 IEEE 4th world forum on Internet of Things (WF-IoT), Singapore, pp. 51–55, 2018. https://doi.org/10.1109/WF-IoT.2018.8355182
6. J. Qarebagh, F. Sabahi, D. Nazarpour, Optimized scheduling for solving position allocation problem in electric vehicle charging stations. 2019 27th Iranian conference on electrical engineering (ICEE), Yazd, Iran, pp. 593–597, 2019. https://doi.org/10.1109/IranianCEE.2019.8786524
7. S. Velliangiri, G.K.L. Kumar, P. Karthikeyan, Unsupervised Blockchain for safeguarding confidential information in vehicle assets transfer. 2020 6th international conference on advanced computing and communication systems (ICACCS), pp. 44–49, 2020. https://doi.org/10.1109/ICACCS48705.2020.9074285
8. Z.A. Jaaz, M.D. Ansari, P.S. JosephNg, H.M. Gheni, Optimization technique based on cluster head selection algorithm for 5G-enabled IoMT smart healthcare framework for industry. Paladyn, J. Behav. Robot **13**(1), 99–109 (2022)
9. S. Velliangiri, P. Karthikeyan Karunya, Blockchain technology: Challenges and security issues in Consensus algorithm. 2020 international conference on computer communication and informatics (ICCCI), pp. 1–8. IEEE, 2020
10. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
11. J. Zhu, L. Huo, M.D. Ansari, M.A. Ikbal, Research on data security detection algorithm in IoT based on K-means. Scal. Comput. Pract. Exp **22**(2), 149–159 (2021)
12. V.S.R. Manoharn, S. Ramachandran, V.R. Rajasekar, Blockchain based privacy preserving framework for emerging 6G wireless communications. IEEE Trans. Industr. Inform. https://doi.org/10.1109/TII.2021.3107556

Human Activity Recognition: Approaches, Datasets, Applications, and Challenges

Alisha Banga, Ravinder Ahuja, and S. C. Sharma

Abbreviations

ANN	Artificial Neural Network
Bi-GRU	Bidirectional GRU
Bi-LSTM	Bidirectional LSTM
CA	Correlation Analysis
CAE	Convolutional Auto Encoder
CNN	Convolutional Neural Network
DT	Decision Tree
GRU	Gated Recurrent Unit
HAR	Human Activity Recognition
HMM	Hidden Markov Model
KNN	K-Nearest Neighbor
LR	Logistic Regression
LSTM	Long Short-Term Memory
NB	Naïve Bayes
NN	Neural Network
PCA	Principal Component Analysis
RF	Random Forest
SVM	Support Vector Machine
TCN	Temporal Convolutional Network

A. Banga (✉) · R. Ahuja · S. C. Sharma
Electronics and Computer Discipline, Indian Institute of Technology, Roorkee Saharanpur Campus, Roorkee, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_7

1 Introduction

Nowadays, Internet of Things (IoT) has inspired a lot of researchers. IoT is taken into account as a part of the future Internet and will compose trillions of connected "devices" or "things" [1]. IoT has many applications. Human Activity Recognition (HAR) is one of them. Human Activity Recognition, HAR, is the mechanism for "classifying sequences of accelerometer data recorded by the specialized harness or smart phones into known well-defined movements." Human Activity Recognition can recognize different human body movements or gestures, which helps determine human actions or activities. Due to the up-gradation of computer vision and some technologies (like artificial intelligence and IoT), and advancements in various sensor technologies (like cheap cost, low power consumption, and real-time streaming of data), the area of HAR has become one of the active research areas. Using HAR, many human actions like sitting, sleeping, bathing, accelerating, decelerating, walking, jumping, dancing, cooking, or some abnormal activities can be recognized. This is helpful in the case of monitoring elderly people's activities and health when no one is there with them. Other applications of HAR are security surveillance (crime rates are reduced), keeping track of military actions, monitoring driving activities to assure safe travel, and many more.

HAR is made possible by the use of cameras, sensors, and accelerometers [2]. Cameras are used to capture or record videos. Some of the sensing technologies used in HAR so far are infrared sensors, wearable devices, and RGB (Red, Green, and Blue) cameras [3]. Due to privacy issues, sensors are dominated over cameras. In the case of wearable devices, the sensors are worn by elderly people. These sensors will collect the data in the form of audio or images. Then this data is stored in a platform as a dataset. This dataset is further used to train different machine learning and deep learning algorithms [4]. The various approaches for human activity recognition classification are given in Fig. 1.

In this chapter, we have briefly described various approaches presented in the literature based on machine learning and deep learning, few datasets, applications, and challenges.

The chapter contains six sections: Sect. 1 describes HAR and its importance, Sect. 2 contains various approaches used in human activity recognition, Sect. 3 contains description about various datasets used, Sect. 4 contains various applications, Sect. 5 contains challenges, and Sect. 6 is conclusion.

2 Related Work

The general process of human activity recognition is given in Fig. 2. It consists of four stages, i.e., sensor selection and deployment, data collection from sensors, preprocessing the data, and in the last stage, applying machine learning algorithms. In this section, we will discuss various machine learning and deep learning approaches applied by various researchers in the past.

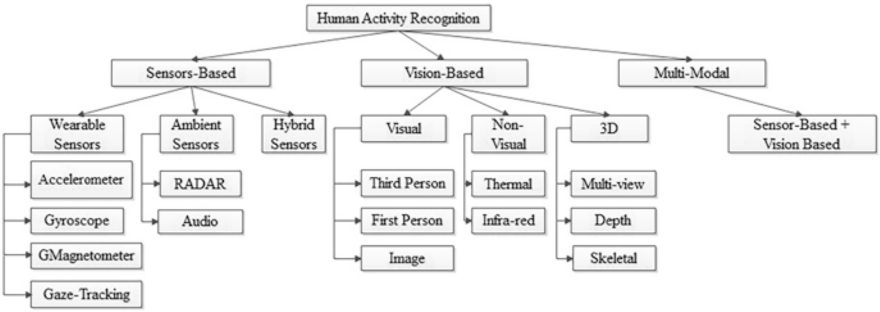


Fig. 1 Human activity recognition approaches classification

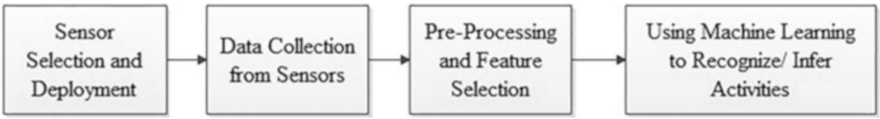


Fig. 2 General process of human activity recognition [10]

2.1 Machine Learning-Based

Long Cheng et al. [9] have applied SVM, NN, and HMM algorithms for human activity classification datasets taken from the UCI machine learning repository. Zameer Gulzar et al. [11] have applied six classification algorithms, namely RF, NB, KNN, Gradient descent, and logistic regression algorithms for human activity classification. They have taken the dataset from the UCI machine learning repository. They have found that neural network and logistic regression algorithms have performed better among all the algorithms. Min-Cheol Kwon et al. [19] have applied an artificial neural network on the dataset collected through a smartwatch. They have considered 11 activities. They have applied DT, SVM, RF, and ANN classification algorithms. They have found ANN as the best algorithm giving an accuracy value of 95%. Haritha Vellampalli [20] has applied two-dimensionality reduction techniques, namely, PCA and CA on the dataset. After the dimensionality reduction, he has applied five classification algorithms, namely, KNN, DT, NB, LR, and ANN. He has found that ANN with CA feature reduction method is the best among all the combinations applied with an accuracy value of 97%. Abdul Lateef Haroon PS et al. [21] have proposed a novel system that can recognize the joints. The temporal and spatial features extracted are passed to the KNN classification algorithm. They have observed an increase in accuracy with the increase in memory requirements. Ya Min et al. [22] have applied six classification algorithms, namely, J48, Decision Tree, JRIP, NB, AD1, and random forest, on the WISDM dataset. They have found that the random forest algorithm is the best, with an accuracy value of 94.68%. Nadeem Ahmed et al. [23] have developed a method for feature selection that is a combination of filter and wrapper method. The extracted features are passed to the support vector machine (multiclass) with a non-linear kernel. They have reported an accuracy value of 96.81% with their approach. Jitenkumar B Rana et al. [24] have performed four classification algorithms, namely, decision tree, random forest, AdaBoost, and SVM, on the publicly available dataset. They have found that random forest is giving the highest accuracy value of 99.80%.

2.2 *Deep Learning-Based*

Aaditya Agrawal et al. [16] have applied CNN, LSTM deep learning for human activity classification on the WISDM dataset. They found that LSTM is better among two algorithms with an accuracy value of 92%. Farzan Majeed Noori et al. [25] have fused data collected from multiple sensors with different representations at decision level, data level, and feature level. The fused data are then passed to the CNN algorithm for classification. They have used three publicly available datasets. Piyush Mishra et al. [26] have applied machine learning algorithms, namely, KNN and random forest and deep neural network, with feature reduction techniques. They have found that the deep neural network model performed better among all, with an accuracy value of 97.32% on a publicly available dataset. Alawneh et al. [27] have applied LSTM and GRU on three publicly available datasets. They have used time-series data augmentation to enlarge the dataset. They have found that GRU has performed better on all the datasets in terms of accuracy and training time. Browne et al. [28] have proposed the CAE-TCN model for human activity recognition. They have considered two sets of datasets (set A and set B). The Convolutional Auto Encoder (CAE) model is used to eliminate the noise and complexity, and a further temporal convolutional network is applied. Saedeh Abbaspour et al. [29] have applied hybrid deep learning models involving LSTM, CNN, Bi-LSTM, GRU, and Bi-GRU on the PAMAP2 dataset. Gaddam et al. [30] have applied deep learning models, namely, CNN on publicly available datasets. They have also explored hyperparameters. Rashid et al. [31] have applied vision-based object model with different object tracking human activity recognition. Gaddam et al. [32] have applied CNN on the publicly available dataset for human facial emotion detection.

3 Datasets

The datasets of human activity recognition are mainly classified as sensor-based and camera-based. Some of the datasets used in human activity recognition are as follows:

3.1 UCI-HAR Dataset

UCI-HAR Dataset [5] is publicly available and most widely used. For creating this database, a total of 30 people have been taken wearing a waist-mounted smartphone with embedded sensors that are capturing ADL (Activities of Daily Living). Only six activities have been recorded, which are: Walking, Walking_Upstairs, Walking_downstairs, Laying, Sitting, and Standing. The smartphone used was Samsung Galaxy S II. Sensors like accelerometers and gyroscopes were used. There are 10,299 numbers of instances in the dataset. For each record, 3-axial acceleration and 3-axial angular velocity have been provided. The total number of attributes with time and frequency domain variables is 561. These data were published on December 10, 2012.

3.2 Van Kasteren Dataset

Two datasets are publicly available on Ubicomp (Ubiquitous Computing) [6]. The first dataset is corresponding to house 1 (Apartment), having three rooms of a 26-year-old male. The duration of the dataset is 25 days, in which the kitchen dataset and bathroom dataset are extracted. Another dataset is for house 2, having six rooms of a 57-year-old male. The duration of the dataset is 19 days. These datasets are publicly available at http://sites.google.com/site/tim0306/. Sensors like reed switches are used to sense the state of doors and cupboards (whether open or closed), mercury contacts are used to sense the movement of objects like drawers, and Passive infrared sensors are used to detect motion.

3.3 Real-Life-HAR Dataset

Garcia-Gonzalez et al. [7] have presented human activity recognition dataset, which is placement independent, orientation independent, and subject independent. The dataset is collected using the gyroscope, accelerometer, GPS, and magnetometer of the smartphone. The dataset is publicly available at this link (https://lbd.udc.es/research/real-life-HAR-dataset/). The measurement is made for four activities, namely, active, walking, driving, and inactive. The data were collected through an android app over a period of one month. The people who participated in the data collection process were asked to set the activity in the android app before starting the activity. In this way, each activity is stored in a separate session. The data stored correspond to the gyroscope, accelerometer, and magnetometer are tri-axial values. Corresponding to GPS, device increments in terms of longitude, latitude, and altitude are stored.

3.4 Wireless Sensor Data Mining (WISDM)

The dataset collected by members of the wireless sensor data mining lab [8] is collected through accelerometer and gyroscope sensors of a smartphone and smartwatch. Fifty-one people have performed 18 different activities of daily living for 3 minutes. The activities include brushing, folding clothes, eating foods, drinking, jogging, writing, clapping, walking, etc. This dataset can be accessed from UCI machine learning repository. The data have six attributes, namely, subject-id (unique for each person), activity code (total of 18 activities, ranging from A to S), timestamp, x, y, and z (sensor value for each axis). There are a total of 15,630,426 records in this dataset.

3.5 Opportunity Dataset

Ricardo Chavarriaga et al. [18] have devised this dataset for benchmarking human activity recognition from ambient, wearable, and object sensors. The dataset contains readings of motion sensors while humans perform daily activities. There are four users, and six runs are performed for each user. Five runs are done for daily activities and one drill run. The daily activities include groom, prepare coffee, drink coffee, clean up, break, prepare sandwiches, and eat sandwiches. The drill run includes drink while standing, clean the table, open and close the fridge, dishwasher, drawers, and doors. There are a total of 2551 instances with 242 attributes. The data are collected over a period of 30 days. This dataset can be accessed from UCI machine learning repository.

4 Applications

HAR has been considered a very important parameter in many fields. Some of the areas are discussed as follows [12]:

4.1 Security and Surveillance System

One of the applications of HAR is in security and surveillance systems at public places like railways, markets, banks, airports, malls, and many more. HAR has proved very useful in decreasing the crime rate and the risk of dangerous activities from occurring at these kinds of public places. It becomes easy to detect suspicious human–human interaction at a very early stage. As an example, the surveillance systems at the airport are used for baggage unloading, aircraft arrival preparation, or refueling operation [13].

4.2 Healthcare Monitoring

HAR plays a very significant role in healthcare monitoring. The systems are installed at residential areas, hospitals, or rehabilitation centers. These healthcare systems can be used for detecting fall detection in the case of elderly people; other daily activities of humans can also be monitored by using this system; for example, children having motor disabilities can be traced when they are doing physical exercises [14]. The sensors are worn by the people on their waist, elbows, or on other parts of the body. Whenever the sensors detect some suspicious activity, immediately the third parties (whether medical agency or family members of the concerned people) are notified so that necessary actions can be taken.

4.3 Active and Assisted Living Applications for Smart Homes

A smart home is an environment in which sensors are placed to monitor the residents and assist in their daily needs. This helps to improve the quality of life and enhances the independence of the residents, especially the elder and the disabled people [4]. This is possible by the use of wearable sensors (that are worn on the body of residents) and some sensors placed in the environment that gives audio-video based solutions for supporting the people. By doing this, a high cost that would occur by long hospitalization of the elderly people can be cut.

4.4 TI (Tele-Immersion) Application

These kinds of applications are used where the users want to share a physical, virtual environment and can interact with other people in real-time. Their physical environment is common, but their geographical environment is different. Video conferencing is one of the examples of TI applications [17]. One of the drawbacks of these applications is that very big data have to be transferred over the transmission channel. So data compressors are needed in these cases.

5 Challenges

As there are many technologies used in HAR like sensor technologies, which are large datasets, processing of these datasets for machine learning and deep learning algorithms increases the complexity of HAR, which further gives rise to various challenges that are being faced in this field of the research area. Some of them are highlighted as follows [15]:

1. *Deployment of sensors:* The basic requirements for HAR are sensors. These sensors are worn by the people, and the data are collected using these sensors. So the placement of these sensors is one of the big challenges.
2. *Sensors' limitation:* The data are continuously received by the sensors. So in case of faulty sensors, the data collected would be incorrect. Immediate knowledge of the faulty sensors is also a challenge.
3. *Feature Extraction:* The other challenge in HAR is principal features extraction. There can be interactivity similarity that occurs in HAR; for example, walking and running are two different activities but have some similarities between the two. So extracting features from these kinds of activities is difficult.
4. *Multiple activities and people:* If there are more than one elder people in a house or if a person is performing multiple activities at the same time or if different people may have different activity styles, then mapping the activities at such instances is difficult.
5. *Interpretation insufficiency:* When using machine learning algorithms, their training and evaluation require a lot of interpreted data samples, which further increases the cost and time consumption due to sensory activity data.
6. *Data Segmentation:* Some activities are composite activities like washing hands, which can be composed of turn on the tap, soaping, rubbing hands, washing, and then drying. Basically, composite activities are the sequence of some activities. So, correct recognition of these activities depends on a very precise data segmentation process.
7. *Privacy*: As sensors are capturing every moment of people, there is a risk of personal information disclosure.
8. *Understandability of the recognition system:* Text or image data are easily readable data, but the data collected from sensors are not easily readable as the sensor data contain some noise information due to imperfections of sensors. So the recognition system should differentiate between the data that facilitate recognition and the one that crumble it.

6 Conclusion and Future Scope

This chapter explores various techniques, datasets, applications, and challenges in human activity recognition. This chapter has discussed a broad classification of human activity recognition systems. The further general process that has to be followed in HAR is discussed. Different approaches like machine learning-based and deep learning-based have been surveyed. HAR is an emerging area of research and development, so many sensors (wearable and non-wearable) have also been discussed. The whole process depends upon the data collection by the sensors and processing of that datasets. There are many datasets (text, images, audio-based, and video-based) that are publicly available, and some of the important datasets are surveyed here. Further, there is a wide range of applications of HAR, which have been explored in this chapter. Finally, challenges that are being faced in this research area has been discussed.

In the future, we can implement various machine learning and deep learning algorithms on various datasets that are publicly available. The other approaches, datasets, and approaches can be explained.

References

1. A. Li, L.D.X. Shancang, S. Zhao, The internet of things: A survey. Inf. Syst. Front. **17**(2), 243–259 (2015)
2. C. Jobanputra, J. Bavishi, N. Doshi, Human activity recognition: A survey. Proc. Comput. Sci **155**, 698–703 (2019)
3. O.C. Ann, L.B. Theng, Human activity recognition: A review, in *2014 IEEE International Conference on Control System, Computing and Engineering (ICCSCE 2014)*, (IEEE, 2014)
4. D. Yacchirema et al., Fall detection system for elderly people using IoT and big data. Proc. Comput. Sci **130**, 603–610 (2018)
5. D. Anguita, A. Ghio, L. Oneto, X. Parra, J.L. Reyes-Ortiz, A public domain dataset for human activity recognition using smartphones, in *21th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, ESANN 2013*, (Bruges, Belgium, 2013, 24–26 April)
6. B. Laluza, S. Kozina, M. Lustrek, The activity recognition repository: Towards competitive benchmarking in ambient intelligence, in *Proc. AAAI Activity Context Represent, Techn. Lang*, (2012, Jan), pp. 44–47
7. D. Garcia-Gonzalez, D. Rivero, E. Fernandez-Blanco, M.R. Luaces, A public domain dataset for real-life human activity recognition using smartphone sensors. Sensors **20**(8), 2200 (2020)
8. G.M. Weiss, K. Yoneda, T. Hayajneh. Smartphone and smartwatch-based biometrics using activities of daily living. IEEE Access **7**, 133190–133202 (2019)
9. L. Cheng, Y. Guan, K. Zhu, Y. Li. Recognition of human activities using machine learning methods with wearable sensors, in *2017 IEEE 7th Annual Computing and Communication Workshop and Conference (CCWC)*, (IEEE, 2017, Jan), pp. 1–7
10. Z. Hussain, M. Sheng, W.E. Zhang, Different approaches for human activity recognition: A survey. arXiv preprint arXiv:1906.05074 (2019)
11. Z. Gulzar, A. A. Leema, I. Malaserene Human Activity Analysis using Machine Learning Classification Techniques, Int. J. Innov. Technol. Explor. Eng **9**(2), 3252–3258 (2019)
12. S. Ranasinghe, F. Al Machot, H.C. Mayr. A review on applications of activity recognition systems with regard to performance and evaluation. Int. J. Distrib. Sensor Netw **12**(8), 1550147716665520 (2016)
13. F. Fusier, V. Valentin, F. Bremond, et al., Video understanding for complex activity recognition. Mach. Vis. Appl **18**(3–4), 167–188 (2007)
14. Y.J. Chang, S.F. Chen, J.D. Huang, A Kinect-based system for physical rehabilitation: A pilot study for young adults with motor disabilities. Res. Dev. Disabil. **32**(6), 2566–2570 (2011). https://doi.org/10.1016/j.ridd.2011.07.002. Epub 2011 Jul 23 PMID: 21784612
15. K. Chen, D. Zhang, L. Yao, B. Guo, Z. Yu, Y. Liu, Deep learning for sensor-based human activity recognition: overview, challenges and opportunities. arXiv preprint arXiv:2001.07416 (2020)
16. A. Agrawal, R. Ahuja, Deep Learning Algorithms for human activity recognition: A comparative analysis. Cybernetics, cognition and machine learning applications: Proceedings of ICCCMLA 2020, p. 391, 2021
17. J.M. Lien, G. Kurillo, R. Bajcsy, Multi-camera tele-immersion system with real-time model driven data compression. Vis. Comput. **26**(1), 3–15 (2010)
18. R. Chavarriaga, H. Sagha, A. Calatroni, S.T. Digumarti, G. Tröster, J.D.R. Millán, D. Roggen, The opportunity challenge: A benchmark database for on-body sensor-based activity recognition. Pattern Recogn. Lett. **34**(15), 2033–2042 (2013)

19. M.C. Kwon, S. Choi, Recognition of daily human activity using an artificial neural network and smartwatch. Wirel. Commun. Mob. Comput. **2018**, 1 (2018)
20. H. Vellampalli, Physical human activity recognition using machine learning algorithms (2017)
21. P.S. Abdul Lateef Haroon, Human activity recognition using machine learning approach. J. Robot. Contr **2**(5), 395–399 (2021)
22. Y. Min, Y.Y. Htay, K.K. Oo, Comparing the performance of Machine Learning Algorithms for human activities recognition using WISDM dataset. Int. J. Comput **38**(1), 61–72 (2020)
23. N. Ahmed, J.I. Rafiq, M.R. Islam, Enhanced human activity recognition based on smartphone sensor data using hybrid feature selection model. Sensors **20**(1), 317 (2020)
24. J.B. Rana, R. Shetty, T. Jha, Application of Machine Learning Techniques in Human Activity Recognition. arXiv preprint arXiv:1510.05577 (2015)
25. F.M. Noori, M. Riegler, M.Z. Uddin, J. Torresen, Human activity recognition from multiple sensors data using multi-fusion representations and CNNs. ACM Trans. Multimed. Comput. Commun. Appl. (TOMM) **16**(2), 1–19 (2020)
26. P. Mishra, S. Dey, S.S. Ghosh, D.B. Seal, S. Goswami, Human activity recognition using Deep Neural Network, in *2019 International Conference on Data Science and Engineering (ICDSE)*, (IEEE, 2019, September), pp. 77–83
27. L. Alawneh, T. Alsarhan, M. Al-Zinati, M. Al-Ayyoub, Y. Jararweh, H. Lu, Enhancing human activity recognition using deep learning and time series augmented data. J. Ambient. Intell. Humaniz. Comput. **12**, 1–16 (2021)
28. D. Browne, M. Giering, S. Prestwich, Deep learning human activity recognition, in *CEUR Workshop Proceedings*, vol. 2563, (Sun SITE Central Europe, 2019), pp. 76–87
29. S. Abbaspour, F. Fotouhi, A. Sedaghatbaf, H. Fotouhi, M. Vahabi, M. Linden, A comparative analysis of hybrid deep learning models for human activity recognition. Sensors **20**(19), 5707 (2020)
30. D.K.R. Gaddam, M.D. Ansari, S. Vuppala, V.K. Gunjan, M.M. Sati, Human facial emotion detection using deep learning, in *ICDSMLA 2020*, (Springer, Singapore, 2022a), pp. 1417–1427
31. E. Rashid, M.D. Ansari, V.K. Gunjan, M. Ahmed, Improvement in extended object tracking with the vision-based algorithm, in *Modern Approaches in Machine Learning and Cognitive Science: A Walkthrough*, (Springer, Cham, 2020), pp. 237–245
32. D.K.R. Gaddam, M.D. Ansari, S. Vuppala, V.K. Gunjan, M.M. Sati, Human facial emotion detection using deep learning, in *ICDSMLA 2020*, (Springer, Singapore, 2022b), pp. 1417–1427

Deep Learning for IoT

Tausif Diwan, Jitendra V. Tembhurne, Tapan Kumar Jain, and Pooja Jain

1 Introduction

With the advent of 5G technology and evolving Artificial Intelligence (AI), Internet of Things (IoT) has attained a huge popularity and has a wider scope. IoT describes the uses and applicability of the interconnected devices and systems for leveraging the data generated through various embedded sensors and devices. The connected devices are not limited to mobile phones or systems but cover a wide spectrum of things such as connected homes and connected buildings. Conclusively, the objects or things that we are talking about may be mobile or static. As per statistics, the mobile connections will grow in size very rapidly and it will be accounted approximately 10 billion by the end of 2020. However, the count of connected devices will reach to approximately 25 billion by the end of 2020. IoT can benefit to a wide range of consumers for delivering a dramatically improved version of solutions with enhanced security, usability, satisfiability, and many other aspects of the day-to-day life. Retail sector, agricultural, industries, manufacturing, health division, and many more sectors are benefitted with the development technology of IoT. In addition, Machine to Machine (M2M) solutions are also known as a subfield of IoT, in which devices are connected with the help of wireless communication over internet. This subfield is capable in delivering improved services to the wide range of industries

T. Diwan (✉) · J. V. Tembhurne · P. Jain
Department of Computer Science and Engineering, Indian Institute of Information Technology, Nagpur, India
e-mail: tdiwan@iiitn.ac.in; jtembhurne@iiitn.ac.in; pjain@iiitn.ac.in

T. K. Jain
Department of Electronics and Communications, Indian Institute of Information Technology, Nagpur, India
e-mail: tapan.jain@iiitn.ac.in

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_8

with minimum human intervention. The major role and outcomes of IoT-based devices and applications can be summarized as: (i) Core sectors that play a major role in driving economy of any country are benefitted with the help of IoT-based services; (ii) To capture the global aspects of the consumers with the help of IoT-based global models and services; (iii) Adjacent industries jointly develop the IoT-based services to capture and fulfil the end customer need efficiently; (iv) The research in the direction of improvement for value-added services of the IoT services; and (v) Handling and satisfying the varying need of IoT devices and applications.

Enormous amount of unstructured data is generated from various sources, collectively known as Big data. Big data can be considered as distributed database wherein big data files are stored, accessed, updated, and analysed by different big-data technologies for performing various tasks. IoT devices and their applications are important sources of data and also contribute to the big data database. Generally, deep learning models are preferred for processing and analysing the large-sized data only. At the same time, model performance is also higher when introduced to large amount of data, which is the basic need for various IoT devices and applications.

The rest of the chapter is organized as follows. The second section covers the introduction to Deep Learning and deep models utilized in various IoT devices and applications. Specifically, we preset Convolutional Neural Networks (CNN) and variants, RNN, LSTM, and some generative models that shall be utilized in the subsequent sections of the chapter. After these, we summarize the role and applicability of deep models for IoT in some of the selected domains with an emphasis to healthcare. Subsequently, the role and applicability of various deep models in IoT devices and applications for several other domains such as smart homes, smart cities, and smart transportation are covered in brief. The last section concludes the paper and presents the future scope in the context of architectural advances of mainstream deep models for the betterment of IoT devices and applications. The taxonomy of the entire chapter is summarized in Fig. 1.

2 Deep Learning and Models

Deep learning was introduced in the early 2000s after Support vector machines (SVM), Multilayer perceptron (MLP), Artificial Neural Networks (ANN), and other shallow neural networks got popularized. Many researchers term it as a subset of Machine learning (ML), which is considered as a subset of Artificial Intelligence (AI) in turn [1]. During the early stage of modernization, deep learning didn't draw much attention due to scalability of data and several other influential factors. After 2006, it has changed its gear and got popularized tremendously as compared to its contemporary ML algorithms because of three main reasons: (i) availability of abundance of data for processing, (ii) availability of high-end computational resources, and (iii) success stories of deep learning in various other domains. Multiple layers of neurons are utilized for minimization of loss or error components for realization of any particular supervised or unsupervised task in the presence of

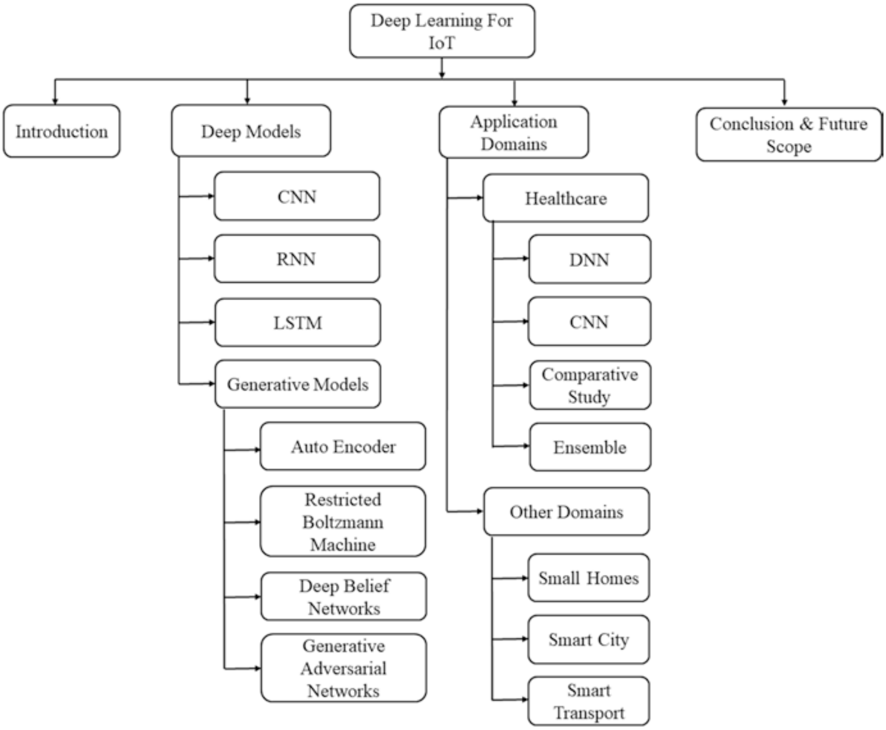


Fig. 1 Taxonomy of the chapter

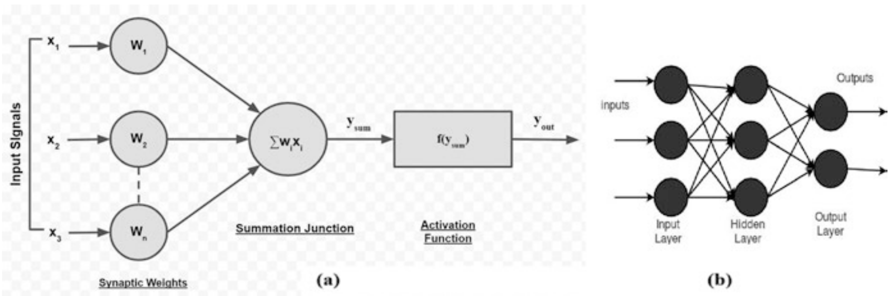


Fig. 2 (**a**) Sigmoidal neuron (**b**) Deep neural network

huge amount of data. Figure 2 represents the computational analogy of a single sigmoidal neuron and general schematic of fully connected deep neural network. Deep learning basically captures the representational features of learning using an incremental approach with the help of multiple layers wherein each layer is responsible for synthesization of extracted features from the previous layers. In addition, initial layers are responsible for capturing the low-level features. However, later layers are designed for grasping the high-level features. Traditional ML algorithms rely on handcrafted feature extraction followed by feature selection for performing any prediction or classification tasks. Usually, these algorithms spend a huge amount of time in choosing the best method for feature extraction. In order to overcome these drawbacks, researchers, industrialists, and academicians are actively working in deep learning. Commonly applied deep learning models include deep neural networks, Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and its architectural variants such as Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU), Generative Adversarial Network (GAN), and different types of auto encoders, and are chosen as per the application's nature and characteristics. CNN is an important deep learning model adopted for computer vision at its inception level. However, in other research areas such as Natural Language Processing (NLP), robotics is also getting benefitted by this model. This model suggests fewer parameters as compared to dense deep neural networks leveraging comparatively lesser time for model convergence and offers parameter sharing. Moreover, RNN and its architectural variants such as LSTM and GRU are basically employed for the features' extraction from temporal or sequential data such as time series forecasting. Broadly, neural networks are divided into two categories viz. generative and discriminative models. Boltzmann machine is stochastic in nature based on generative neural networks through which one can learn the probability distribution over set of input provided to this model. Auto encoders are special kind of neural networks utilized for learning the compact representation of the input, specifically employed for dimensionality reduction of the input. Deep Belief Network (DBN) is another important category of generative models wherein smaller unsupervised module such as auto encoders or Restricted Boltzmann Machine (RBM) are stacked multiple times such that output of a layer acts as an input for the next layer for a generative task. All these deep models are being applied heavily for capturing, processing, and analysing the sensory data for better feature extraction and further processing on various IoT devices and applications. Herein, we briefly elaborate and summarize these deep models, their architectural aspects, and applicability in the context of IoT.

2.1 CNN

Due to scaling inefficacy in deep neural networks, CNN is widely adopted to capture the spatial and contextual information with fewer parameters [2, 9]. While handling with high-dimensional inputs, it is almost impractical to connect a neuron of any particular layer to all the neurons in the previous layer. However, one neuron is connected to only a local region of previous layer in the CNN architecture. This introduces a considerable reduction in the model complexity and considered as the backbone of CNN analogy. Three major operations constitute the main pillars of CNN architectures viz. *convolution*, *pooling*, and a *non-linear activation* preferably ReLU. The general architecture of the CNN is presented in Fig. 3 wherein two convolutional layers are followed by fully connected or dense layers. However, convolution and pooling operation are represented with the help of Fig. 4. Convolutional

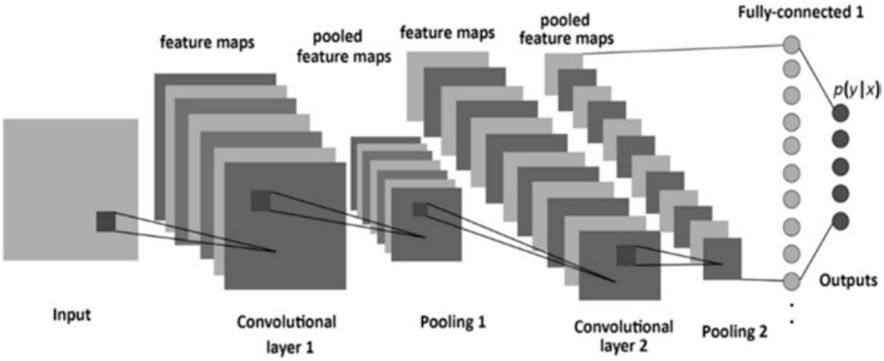


Fig. 3 Generic architecture of CNN

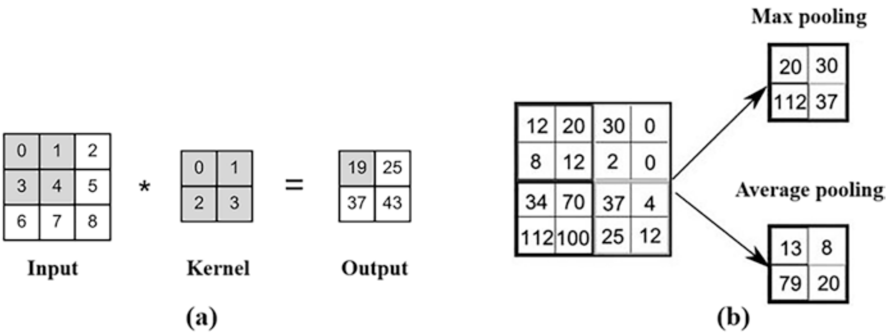


Fig. 4 Convolutional neural network operations. (**a**) Conv-layer. (**b**) Max-pooling layer

operation refers to applying a sliding filter over the entire input volume and generating a weighted sum as illustrated in the convolution operation wherein a 3 × 3 filter is applied on an input volume of size 5 × 5 and generating an output of size 3 × 3 [3]. Three hyperparameters viz. filter size, stride, and padding decide the size of the output volume in the convolution operation. Pooling refers to the down sampling of an input volume, specially utilized for capturing the dominating features [4]. Max- and Average pooling are the two major types of pooling employed in the CNN. Pooling layers are optional in the architecture and can be used depending upon the architecture and application requirements. No parameters are associated with the pooling layers; however, convolutional and dense layers are characterized by the number of parameters associated with them. Similarly, a non-linear activation function is utilized for the activation of the neurons belonging to convolutional and dense layers.

Object detection and its related tasks such as classification, localization, and segmentation form a very important category in various IoT applications. Object detection problem generally performs the features extraction followed by the classification and localization, implemented in two stages, and the corresponding architectures are known as two-stage object detectors. The first stage is responsible for generating Regions of Interest (RoI) using Region Proposal Network (RPN). However, the second stage is responsible for predicting the objects and bounding boxes for the proposed region. The latest example in this category includes Region based convolutional neural networks (RCNN), fast RCNN, and faster RCNN [5]. Faster R-CNN is a successor of R-CNN and Fast R-CNN, and was released in early 2016. It had two modules: (1) First is a CNN, i.e., Region proposal network, which is responsible for generating region proposals. It takes a single image as input and outputs the bounding boxes and object scores. (2) During training, RPN is trained on ImageNet then region proposals are used for object detection, and lastly Fast R-CNN is fine-tuned with unique layers. However, with the advent of You Only Look Once (YOLO) and its successors, attempts are being heavily appreciated for solving these tasks in one shot/stage wherein localization problem is formulated as a regression problem with the help of deep neural networks. The authors of YOLO [6] have reframed the problem of object detection as a regression problem instead of classification problem. A convolutional neural network predicts the bounding boxes as well as class probabilities for all the objects depicted in an image. As this algorithm identifies the objects and their positioning with the help of bounding boxes by looking at the image only once, hence they have named it as YOLO. The architecture of YOLO is inspired by GoogLeNet architecture. It was implemented and tested on VOC Pascal Dataset 2007 and 2012 for an object detection task, and Darknet framework is utilized for the training of the model. Herein, *inception* modules of GoogLeNet were replaced by (1 × 1) convolution followed by (3 × 3) convolutional filters, and only the first convolutional layer has a (7 × 7) filter. YOLO has 24 convolution layers followed by two fully connected layers as shown in Fig. 5.

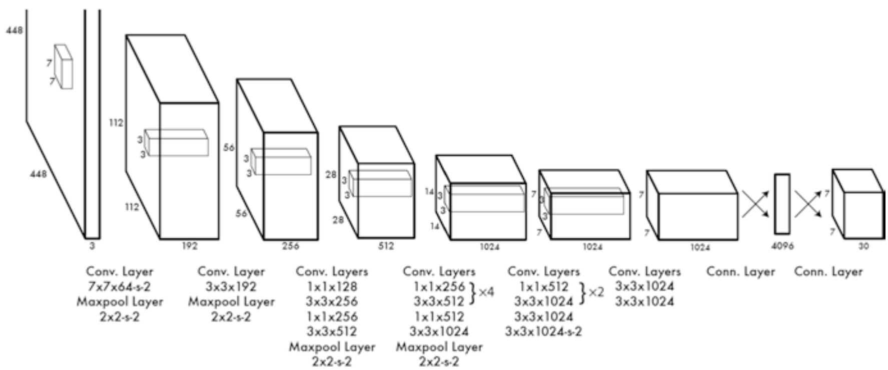


Fig. 5 YOLO architecture

2.2 Sequence Models

RNN and its successors such as LSTM, GRU, and transformers constitute another important category of deep learning model for extracting the features and performing classification on the time series or sequential data, and these models are tremendously performing well on a variety of domains ranging from stock prediction to wind estimation and forecasting [10]. As most of the IoT devices generate or operate on sequential data, these models and their role and applicability are explored by the research community for the betterment of IoT devices and its applications. Sequential data is characterized by the different time steps. The generic architecture of RNN is presented in Fig. 6 wherein output of an RNN cell is not only determined by the current time step input but also depends on the outputs on the previous cell. Specifically, a cell takes two parameters as inputs, namely, current timestep input and hidden output of the previous cell. This is the basic philosophy of any cell in all the aforementioned sequential models. One thing should be noted that the parameters, i.e., weight matrices are shared across different time-steps. Conclusively, temporal ordering across the input is taken care of using the sequential processing by this family.

RNN cells are comparatively simpler in comparison with LSTM and GRU cells due to its fewer tensor operations. The inability of capturing long-term dependency is one of the major bottlenecks of the RNN that is taken care of in the other members of the family at an expense of increased cell complexity. For the sake of weight updating and the model convergence, gradient is back propagated from the current timestep cell to the initial cell, known as back-propagation with time (BPTT). The gradients at the distant cells get vanishes as the gradients get multiplied in a chain rule manner in the course of BPTT. This problem is widely regarded as vanishing gradient problem. As an example, sometimes the distant information should be given more emphasis as compared to neighbouring cells for the current prediction and RNN is unable to handle this situation intelligently due to the absence of storage unit of cells.

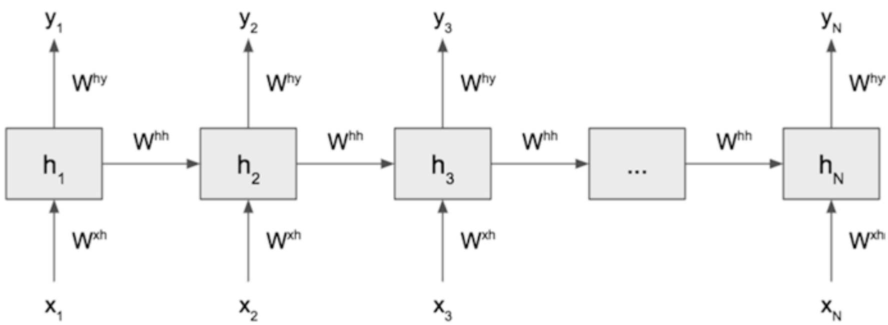


Fig. 6 Recurrent neural networks

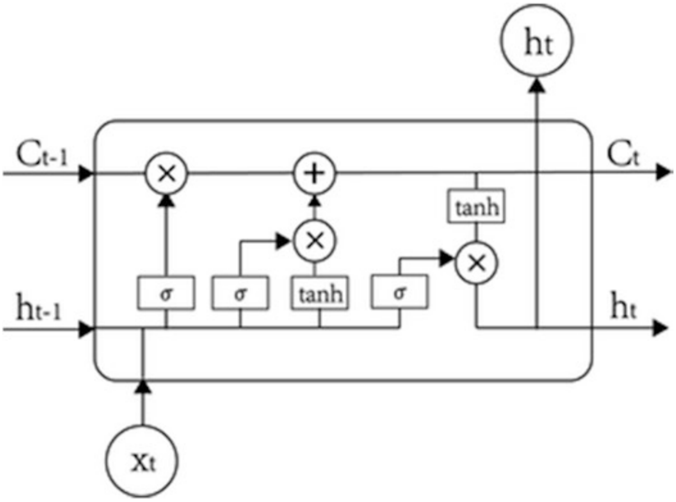


Fig. 7 Long short-term memory

To address the aforementioned problem and for the improved modelling of long-term dependency across the cells, LSTM and GRU were proposed [7, 8]. These models are capable of mitigating the effect of vanishing gradient problems by introducing several gates in the cells. These gates are responsible for storing and transferring the past important information to the next cell and removing the irrelevant information. Cell state information is maintained in each cell that includes the necessary information and removes the non-necessary information in the course of model training. Figure 7 illustrates the single cell corresponding to the LSTM architecture wherein three different gates viz. *forget*, *input*, and *output* gates are maintained for the fulfilment of long-term dependency. Sigmoid activation draws an important role in distinguishing necessary and non-necessary information as it squishes between 0 and 1.

Input at current timestep is concatenated with hidden output of the previous cell and passed to the various activation functions to perform different gating operations. *Forget* gate decides the importance of the previous information and pass it further for updating the current cell state. Cell state decides whether the information is added, retained, or subsidized. Cell state gets modified by taking into account the *input gate*, *forget gate*, and previous cell state. *Output* gate is responsible for the generation of the hidden state that shall be utilized in the next LSTM cell.

2.3 Generative Models

RBM are generative probabilistic models consisting of two layers of artificial neural networks. These models are capable of performing dimensionality reduction, standard supervised tasks such as classification and regression, feature learning, and collaborative filtering by learning the probability distribution in the input. These are extremely simple models having input and output layers, generally referred to as visible and hidden layers. Connections are established between the neurons belonging to different layers but not from the same layer. In other words, neurons belonging to these two different disjoint sets form a symmetric bipartite graph. In the learning phase of these models, parameters shall get updated in the direction of effective and meaningful reconstruction of the input by minimizing the reconstruction error [11]. Furthermore, Auto encoders are neural networks utilized for learning the compact representation of the input, specifically employed for dimensionality reduction of the input or data [12]. As IoT devices and applications signify the short of resources, reduced computational complexity with the help of such models leads to better resource utilization. Encoders and decoders are the two main pillars of auto encoders wherein dimensionality reduction is achieved using encoder network and decoder tries to reconstruct the same data by introducing latent space representational layer between these two modules. Auto encoders and RBM are very simple networks and unable to learn the complex features of efficient reduction. However, these modules are stacked multiple times to form aDBN, a complex structure capable of handling bottlenecks of the aforementioned simpler models. Nowadays, GAN has earned a huge popularity in the race of generative models. It has two main modules viz. generator and discriminator. New data instances having resemblance with the input data are generated by the generator module; however, validity of the newly created instance is verified using discriminator module [13].

3 Deep Learning for IoT in Healthcare

With the advent of Artificial intelligence techniques, especially deep learning algorithms, e-health has become quite prevalent. In the corona times, when people are forced to stay at home, digital health has become all the more useful and important. People believe in getting medical aid from the comfort of their home. Various deep learning methods are used to help the people to track their medical problems. Figure 8 illustrates the generic diagram of deep learning for IoT in healthcare.

Clinical workflow of the ECG is completely dominated and determined through the ECG interpretation [14]. With proper and accurate interpretation from the ECG, one can get the prioritized medical diagnosis. A **DNN** is developed for the classification among 12 rhythm classes using approximately 90 k ECGs, collected from 50 k patients using single-lead ambulatory ECG monitoring devices. It was an attempt to mitigate the misinterpreted ECGs. The constructed DNN achieves an area under ROC curve of 0.97 on validating the model on an independent annotated dataset. However, an F1-sore of 0.83 is recorded in comparison with 0.78 recorded by the expert cardiologists.

Poorly handled blood sugar may cause damage to the tissues at the retinal back area, known as Diabetic Retinopathy [15]. Referring to the medical experts for the detection of this disease is a time and resource consuming process. Diabetic

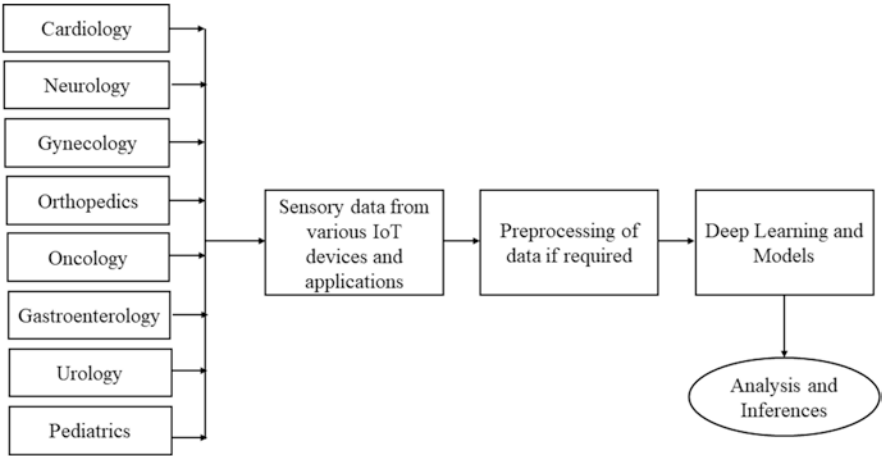


Fig. 8 Deep learning for IoT in healthcare

retinopathy detection with the help of retinal fundus images is realized using DCNN, and the model demonstrates high sensitivity and specificity compared to the state-of-the-art models. The DCNN was tested on EyePACS-1 dataset consisting of 9963 retinal fundus images from 4997 patients. Eventually, WHO reports unhealthy life style as a leading cause of mortality [16]. Lack of data related to unhealthy lifestyle is the main hurdle to approach this problem efficiently and intelligently. A CNN-based smart personal health advisor (SPHA) is proposed that periodically monitors the physiological and psychological activities of the end user for the better health monitoring and to further assist with proper guidelines. Accurate detection of pills by observing the pill image is a challenging task [17]. Blurring, shading, background colour, resizing, and different illumination are considered as the five main challenges in the exact detection of the pill from the visual content. A multi CNN-based MobileDeepPill model is proposed for this task wherein each CNN takes care of different challenges for the sake of the improvement of the recognition performance.

The cause of various chronic diseases such as diabetes, obesity, and cardiovascular abnormalities may be inferred from day-to-day ambulatory activities, which can be identified by energy expenditure in turn [18]. Exact estimation and prediction of Energy Expenditure is an important task for the identification of various ambulatory activities such as walking, standing, climbing, etc., and to further assist the person from preventing any chronic disease. Direct estimation of energy expenditure with the help of wearable sensors has a limited accuracy. Hence, **CNN** is employed for the accurate estimation of Energy Expenditure from the data collected by different wearable sensors, specifically triaxial accelerometer and heart rate sensors in this case. CNN extracts the useful features automatically from the data collected through such sensors and outperform other state-of-the-arts by producing 30% lower Root Mean Square Error (RMSE). The data for this experimentation is gathered from the aforementioned wearable sensors by around 30 volunteers performing routing ambulatory activities.

Intelligent deep models that enabled diagnosis based on medical imaging may further assist the medical experts in deciding the better diagnosis path for the patients [19]. One such example is the early stage skin cancer detection followed by proper diagnosis, which can affect the survival to a greater extent, and is also a challenging task for the expert medical practitioners. VGG-based CNN model leveraging the benefit of transferring the learnt parameters from the pretrained architecture is developed for the early stage melanoma detection. The model is tested on ISIC Archive dataset, a dermoscopic images dataset containing the malignant or benign skin lesions and demonstrates a considerable sensitivity of 78.66%. Intelligent medicine recognition device ST-Med-box is implemented for proper, on-time, and in-sequence medication to patients consuming multiple medicines [20]. An android-based intelligent mobile device is realized using CNN-based inception-v3 network that captures the medicine features with the help of bounding box prediction and Region of Interest.

Effective segmentation is a challenging task in the medical diagnosis [21]. It became more difficult in the case of three-dimensional images such as MRI. Anatomical segmentation from medical images is generally carried out using voxel classification. There is a trade-off between applying multiple lower dimensional filters and single higher dimensional filters for extracting features from multidimensional inputs with the help of CNNs. In this direction, DCNN is experimented for the segmentation task based on voxel classification wherein three two-dimensional CNNs are employed for the three different planes instead of applying single three-dimensional filter on the three-dimensional MRI images. CNN are capable of learning low level features from the initial convolutional layers and high-level features from the later convolutional layers. The features are fused, which are extracted from the three different CNNs for effective segmentation, and constructed model outperforms state-of-the-art and expert radiologists. The model was evaluated on 114 knee MRIs with approximately two million voxels in each MRI. The performance criteria used in this experimentation was dice similarity coefficient (DSC) between manual and automatic segmentation.

Subsequently, movement data is analysed with the help of CNN and LSTM, and combined results are utilized for a better prediction of freezing gaits in the patients suffering from Parkinson disease [22]. Three benchmarking datasets viz. Opportunity dataset (Opp), PAMAP2 dataset, and Daphnet Gait dataset (DG) have been experimented for this prediction task that employed the wearable sensors for the collection of various movement data. On each of these datasets, **DNN**, **CNN**, and **RNN**, and its architectural variants such as LSTM, bi-LSTM, and GRU, are experimented for the prediction of various movement gestures such as running, walking, swimming, etc. With the help of more than 4000 experiments, suitability and applicability of each model for different tasks in Human Activity Recognition (HAR) is tested in the context of ideal hyperparameters setup specially learning rate, regularizations, and architectural changes. Actually, hyperparameters setup is a dominant factor deciding the model's selection and performance for any particular task that is nicely investigated in this research, and conclusive guidelines were presented for the model-specific performance enhancement. In the context of sequence modelling such as HAR activities, sequential deep models outperform in comparison with other deep models. Here, RNNs suffer from vanishing gradients problem, unable to capture long-term dependencies but enjoying simple architectures, and perform well for various short activities. However, LSTMs outperform its predecessor in case of long activity recognition. CNN is preferred for such HAR activities that don't require any short- or long-term dependencies because of its ability of capturing local patters or features efficiently.

In ensemble architectures, a combination of **CNN** and **RNN** is most popular for spatiotemporal inputs wherein CNN is employed for the features' extraction and these temporal features are provided as an input to the sequence models [23]. In one such study, recurrent 3D convolutional neural network (R3D) is presented for the action recognition task from the spatiotemporal input datasets. Three dimensional convolutional filters are utilized for features' extraction; however, these extracted features are given as input to the different cells of LSTM. LSTM captures temporal, the long-term dependencies from the fused features generated from 3D-CNNs. Specifically, 3D-CNN convolves over the video frames to capture the short-term spatiotemporal features from different time steps, which is further aggregated to extract the long-term spatiotemporal features with the help of LSTM. This architecture is tested for monitoring various human activities of the patients or older person, and is considered as a prominent step in the direction of intelligent healthcare. Experimentations are performed on UCF101, a large-scale dataset consisting approximately 13 k video clips for around 100 action classes. There are two aspects of the results for this category of tasks: (1) How accurately it is predicting the actions, and (2) How fast the prediction occurs and it can be counted as frames per second (fps), generally depends on the underlying hardware. Moreover, with the advent of latest multicore architectures and many core GPUs, the computation time is getting reduced to a large extent. R3D achieves a benchmarking accuracy of 85.7% by processing 427 fps. In many studies, deep models are employed for the features extraction followed by a support vector machine (SVM) that acts as a classifier. The reason behind this is that SVM performs better as a classifier in comparison with the deep models. In this experimentation, an improved accuracy of 86.8% is achieved by applying an SVM on the extracted features by CNN and LSTM. However, on the downside, computational time is increased by applying another layer of linear classifier, and a slight reduction is observed in fps.

4 Deep Learning for IoT in Other Domains

In this section, we basically cover some of the important domains that are rigorously exploring deep learning and models for IoT such as Smart homes, Smart cities, and Smart transportation. With the evolution of IoT technologies and deep learning, huge automation has been introduced in smooth functioning of various tasks related to the aforementioned domains.

4.1 Smart Homes

With the advancements of **smart home** devices and an intelligent interconnect among them, it leverages the better standard of the in-house living. In-house localization is very useful for various IoT-enabled applications such as monitoring of kids and older person, anomaly detection, intruder detection, and many more. Finger printing-based in-house localization outperforms other approaches in case of large-labelled data, which is time consuming and a labour-intensive approach [24]. Semi supervised approach is applicable in the presence of small amount of labelled and large quantity of unlabelled data. A novel approach for in-house localization is presented based on semi supervised learning, deep learning, and extreme deep learning that outperforms other features' extraction approaches for in-house localization problem. Another approach for handling large unlabelled data is the use of auto encoder and its variants [25]. In most of the smart homes' IoT applications, an action is decided based on sequence of previous events; Reinforcement Learning (RL) generally performs better as compared to other deep models. In one such study, variational auto encoders (VAE) are utilized for the in-house localization with the help of Bluetooth Low Energy (BLE) signal strength. The proposed model outperforms deep reinforcement learning for deciding the best action policies based on the near optimal estimation for in-house localization. Deep Fi is another deep learning-based novel architecture wherein fingerprinting-based in-house localization problem is targeted very efficiently with the help of channel state information [26]. Shadowing effect is utilized for localization and activity recognition problem without explicit usage of any device [27]. With the help of the surrounding wireless links, the model employs the sparse auto encoder to learn the discriminative features without an essence of labelled data.

Furthermore, voice assistants are getting huge popularity in many smart homes and smart cities' IoT applications. Voice assistant in combination with assistive robots performs significantly well for various physical activities on voice commands [28]. A CNN-based model is proposed for improving human robot interaction by improving the recognition accuracy of various objects, and further movements and repositioning of these objects are suggested using robots. A coordination between hand and eye is a very much essential component for grasping any object [29]. Subsequently, DCNN is trained to enable efficient and successful grasping irrespective of the current pose of the robot.

4.2 Smart Cities

IoT applications related to **Smart cities** are trained and tested for a deployment in real environment such as self-driving cars. Runtime and accurate detection of the various objects using implanted high-quality cameras in self driving cars is a challenging task as resulting actions are completely determined based on these decisions. Detection of various sign boards, pedestrian movements, traffic lights, and other vehicles and their relative movements are the important things and needs to be captured in real time without any failure. The challenges in these applications to cover all real-life scenarios that are not always possible while training the model or application. A CNN-based real-time object detection mechanism is implemented for autonomous driving and the proposed architecture is computationally efficient, fast, and accurate [30]. An end-to-end CNN architecture is implemented for the real time object detection in the self-driving cars [31]. Herein, end-to-end architecture maps the real time images captured by single front faced camera to the car commands with appropriate processing of the images followed by further necessary actions executed with the car commands. As driving is a sequential activity and it can be learnt using different driving videos covering all possible real-life driving scenarios, an LSTM-based model is introduced using large-scale dataset containing car driving videos in the crowded areas [32].

4.3 Smart Transportation

Smart transportation is a key ingredient in the development of smart cities. Various IoT devices and applications related to smart cities and smart transportation are leveraging the benefits of various deep models in processing, analysing, and drawing the appropriate decisions. Traffic prediction and monitoring are the two key aspects of the smart transportation. Deep belief network is proposed for traffic prediction, unsupervised feature representation as an input to the DBN and multi-task regression is applied on the top, and an output layer for traffic flow prediction [33]. As RBM and auto-encoders are the simpler networks, capturing the complex unsupervised features is impossible. Auto encoders are stacked multiple times known as stacked auto encoders (SAE). SAE is proposed for the same task for learning the complex features from the traffic flows [34]. As LSTMs are designed for learning spatiotemporal features, traffic flow and correlation among the extracted features are learned using this sequence model [35]. CNN-based model utilizing the skip or residual connections is proposed for learning spatiotemporal features for the crowed traffic data [36]. As we can notice from the literature, almost all the deep models are experimented for the traffic flow prediction task. This results in a competitive environment suggesting further scope of improvements. CNN-based RPN, SSD, faster RCNN, and YOLO are quite popular for object detection task in a real time scenario, capable of generating exact bounding boxes covering all visible objects form the captured images [5, 6]. Incremental approach is adopted for an improvement in different version of YOLOs. For example, YOLO v1 is unable to capture the small sized objects that are further rectified using higher version of YOLOs.

5 Conclusions and Future Scope

We summarize the role and applicability of deep models for IoT in various domains with an emphasis to healthcare. The advancements of IoT technologies and deep learning fields introduce automation, intelligence, and smooth functioning of various entities related to these domains. A detailed overview is presented for various deep models applied on IoT devices and applications in the healthcare domain. However, we also brief deep learning for IoT in smart homes and smart transportation.

Recent advances in CNN such as tiled-, dilated-, and transpose-convolution should be utilized for efficient features extraction for various IoT devices and application [9]. As most of the IoT devices are having resource constraints and demand time-bounded output, different optimization techniques such as batch normalization, residual or skip connections, and different augmentation techniques should be explored for the improved performance of CNNs for IoT applications. For fast processing of the CNNs, techniques such as weight compression, usage of low precision, and Fast Fourier Transform (FFT) should be carefully examined. On the sequence models' side, architectural variants of RNNs and LSTMs should be employed for better feature learning and contextual information extraction from time series data in the course of better performance of various IoT devices and applications [10].

References

1. S.M. Ahmed, B. Kovela, V.K. Gunjan, IoT based automatic plant watering system through soil moisture sensing—A technique to support farmers' cultivation in rural India, in *Advances in Cybernetics, Cognition, and Machine Learning for Communication Technologies*, (Springer, Singapore, 2020), pp. 259–268
2. S. Albelwi, A. Mahmood, A framework for designing the architectures of deep convolutional neural networks. Entropy **19**(6), 242 (2017)
3. S. Kumar, M.D. Ansari, V.K. Gunjan, V.K. Solanki, On classification of BMD images using machine learning (ANN) algorithm, in *ICDSMLA 2019*, (Springer, Singapore, 2020), pp. 1590–1599
4. Z. Ibrahim, D. Isa, Z. Idrus, Z. Kasiran, R. Roslan, Evaluation of pooling layers in convolutional neural network for script recognition, in *International Conference on Soft Computing in Data Science*, (Springer, Singapore, 2019, August), pp. 121–129
5. S. Ren, K. He, R. Girshick, J. Sun, Faster r-cnn: Towards real-time object detection with region proposal networks, in *Advances in Neural Information Processing Systems*, (2015), pp. 91–99

6. J. Redmon, S. Divvala, R. Girshick, A. Farhadi, You only look once: Unified, real-time object detection, in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, (2016), pp. 779–788
7. S. Kumar, V.K. Gunjan, M.D. Ansari, R. Pathak, Credit card fraud detection using support vector machine, in *Proceedings of the 2nd International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications*, (2022), pp. 27–37
8. M. Husein, I.Y. Chung, Day-ahead solar irradiance forecasting for microgrids using a long short-term memory recurrent neural network: A deep learning approach. Energies **12**(10), 1856 (2019)
9. J. Gu, Z. Wang, J. Kuen, L. Ma, A. Shahroudy, B. Shuai, et al., Recent advances in convolutional neural networks. Pattern Recogn. **77**, 354–377 (2018)
10. V.K. Gunjan, P.S. Prasad, R. Pathak, A. Kumar, Machine learning methods for extraction and classification for biometric authentication, in *ICDSMLA 2019*, (Springer, Singapore, 2020), pp. 1984–1988
11. T. Jaakkola, D. Haussler, Exploiting generative models in discriminative classifiers, in *Advances in Neural Information Processing Systems*, (1999), pp. 487–493
12. E. Rashid, M.D. Ansari, V.K. Gunjan, M. Khan, Enhancement in teaching quality methodology by predicting attendance using machine learning technique, in *Modern Approaches in Machine Learning and Cognitive Science: A Walkthrough*, (2020), pp. 227–235
13. A.Y. Hannun, P. Rajpurkar, M. Haghpanahi, G.H. Tison, C. Bourn, M.P. Turakhia, A.Y. Ng, Cardiologist-level arrhythmia detection and classification in ambulatory electrocardiograms using a deep neural network. Nat. Med. **25**(1), 65 (2019)
14. V. Gulshan, L. Peng, M. Coram, M.C. Stumpe, D. Wu, A. Narayanaswamy, R. Kim, Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA **316**(22), 2402–2410 (2016)
15. M. Chen, Y. Zhang, M. Qiu, N. Guizani, Y. Hao, SPHA: Smart personal health advisor based on deep analytics. IEEE Commun. Mag. **56**(3), 164–169 (2018)
16. X. Zeng, K. Cao, M. Zhang, MobileDeepPill: A small-footprint mobile deep learning system for recognizing unconstrained pill images, in *Proceedings of the 15th Annual International Conference on Mobile Systems, Applications, and Services*, (2017, June), pp. 56–67
17. J. Zhu, A. Pande, P. Mohapatra, J.J. Han, Using deep learning for energy expenditure estimation with wearable sensors, in *2015 17th International Conference on E-Health Networking, Application & Services (HealthCom)*, (IEEE, 2015, October), pp. 501–506
18. A.R. Lopez, X. Giro-i-Nieto, J. Burdick, O. Marques, Skin lesion classification from dermoscopic images using deep learning techniques, in *2017 13th IASTED International Conference on Biomedical Engineering (BioMed)*, (IEEE, 2017, February), pp. 49–54
19. W.J. Chang, L.B. Chen, C.H. Hsu, C.P. Lin, T.C. Yang, A deep learning-based intelligent medicine recognition system for chronic patients. IEEE Access **7**, 44441–44458 (2019)
20. A. Prasoon, K. Petersen, C. Igel, F. Lauze, E. Dam, M. Nielsen, Deep feature learning for knee cartilage segmentation using a triplanar convolutional neural network, in *International Conference on Medical Image Computing and Computer-Assisted Intervention*, (Springer, Berlin, Heidelberg, 2013, September), pp. 246–253
21. N.Y. Hammerla, S. Halloran, T. Plötz, Deep, convolutional, and recurrent models for human activity recognition using wearables. arXiv preprint arXiv:1604.08880 (2016)
22. Y. Gao, X. Xiang, N. Xiong, B. Huang, H.J. Lee, R. Alrifai, Z. Fang, Human action monitoring for healthcare based on deep learning. IEEE Access **6**, 52277–52285 (2018)
23. Y. Gu, Y. Chen, J. Liu, X. Jiang, Semi-supervised deep extreme learning machine for Wi-Fi based localization. Neurocomputing **166**, 282–293 (2015)
24. M. Mohammadi, A. Al-Fuqaha, M. Guizani, J.S. Oh, Semisupervised deep reinforcement learning in support of IoT and smart city services. IEEE Internet Things J. **5**(2), 624–635 (2017)
25. X. Wang, L. Gao, S. Mao, S. Pandey, CSI-based fingerprinting for indoor localization: A deep learning approach. IEEE Trans. Veh. Technol. **66**(1), 763–776 (2016a)

26. J. Wang, X. Zhang, Q. Gao, H. Yue, H. Wang, Device-free wireless localization and activity recognition: A deep learning approach. IEEE Trans. Veh. Technol. **66**(7), 6258–6267 (2016b)
27. B.A. Erol, A. Majumdar, J. Lwowski, P. Benavidez, P. Rad, M. Jamshidi, Improved deep neural network object tracking system for applications in home robotics, in *Computational Intelligence for Pattern Recognition*, (Springer, Cham, 2018), pp. 369–395
28. S. Levine, P. Pastor, A. Krizhevsky, J. Ibarz, D. Quillen, Learning hand-eye coordination for robotic grasping with deep learning and large-scale data collection. Int. J. Robotics Res. **37**(4–5), 421–436 (2018)
29. B. Wu, F. Iandola, P.H. Jin, K. Keutzer, Squeezedet: Unified, small, low power fully convolutional neural networks for real-time object detection for autonomous driving, in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*, (2017), pp. 129–137
30. M. Bojarski, D. Del Testa, D. Dworakowski, B. Firner, B. Flepp, P. Goyal, X. Zhang, End to end learning for self-driving cars. arXiv preprint arXiv, 1604.07316 (2016)
31. H. Xu, Y. Gao, F. Yu, T. Darrell, End-to-end learning of driving models from large-scale video datasets, in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, (2017), pp. 2174–2182
32. W. Huang, G. Song, H. Hong, K. Xie, Deep architecture for traffic flow prediction: Deep belief networks with multitask learning. IEEE Trans. Intell. Transp. Syst. **15**(5), 2191–2201 (2014)
33. Y. Lv, Y. Duan, W. Kang, Z. Li, F.Y. Wang, Traffic flow prediction with big data: A deep learning approach. IEEE Trans. Intell. Transp. Syst. **16**(2), 865–873 (2014)
34. Z. Zhao, W. Chen, X. Wu, P.C. Chen, J. Liu, LSTM network: A deep learning approach for short-term traffic forecast. IET Intell. Transp. Syst. **11**(2), 68–75 (2017)
35. A.K. Goel, R. Chakraborty, M. Agarwal, M.D. Ansari, S.K. Gupta, D. Garg, Profit or loss: A long short term memory based model for the prediction of share price of DLF group in India, in *2019 IEEE 9th International Conference on Advanced Computing (IACC)*, (IEEE, 2019, December), pp. 120–124
36. J. Zhang, Y. Zheng, D. Qi, Deep spatio-temporal residual networks for citywide crowd flows prediction. arXiv preprint arXiv, 1610.00081 (2016)

Internet of Everything: Applications

Rakhi Wajgi, Jitendra V. Tembhurne, Dipak Wajgi, and Tapan Jain

1 Introduction

Internet of Things (IoT) is defined in many ways by the different researchers due to indistinctness of two terms, namely, "*Internet*" and "*Things*". The "*Internet*" mainly focuses on the network perspective and "*Things*" describes objects in the surroundings [1]. IoT is oriented into three main visions such as *Things*, *Semantic*, and *Internet* [2]. Things includes those objects present in the environment, which can sense, store, and transfer data. Internet provides medium of communication between things and semantic vision deals with how information generated by things is interpreted and stored.

Since the past few years, IoT has created huge number of surprisingly new products, which are beyond our expectations. After the term IoT was coined by Kevin Ashton in 1999, it was never thought that IoT is going to become a bedrock for numerous applications belonging to diverse domains. It was never believed that IoT

R. Wajgi
Department of Computer Technology, Yeshwantrao Chavan College of Engineering, Nagpur, India

J. V. Tembhurne
Department of Computer Science & Engineering, Indian Institute of Information Technology, Nagpur, India
e-mail: jitendra.tembhurne@cse.iiitn.ac.in

D. Wajgi
Department of Computer Engineering, St. Vincent Pallotti College of Engineering, Nagpur, India

T. Jain (✉)
Department of Electronics & Communication Engineering, Indian Institute of Information Technology, Nagpur, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_9

is going to change the world by allowing devices to sense the surrounding and thereby provide ease of life. Initially, there was a lot of skepticism and objections raised by people regarding how computer is going to percept the environment, but all were invalidated by progressive applications and prototypes designed by researchers using IoT technology. It is a network of physical things, which communicate with each other in the environment [3]. Things includes a variety of smart sensing devices connected over the internet. These devices continuously monitor their surrounding parameters such as temperature, humidity, pressure, healthcare information, etc.; moreover, communication takes place among the devices thereby substantiating an intelligent IoT system. Because of the exceptional opportunities provided by IoT, many business sectors want to exploit this technology.

IoT is mainly characterized by extensive sensing, reliable transmission, and intelligent analysis. IoT sensory devices usually record temperature, humidity, biomedical information, etc. Single sensor is dedicated to seize one measuring parameter or more than one parameter. All sensors are permitted to store data on cloud storage, and it can be accessed from anywhere and at any time by the user. IoT provides facility of integrating a variety of devices to function together. It also helps in easy removal and addition of component with minimum impact, which makes IoT a flexible and robust technology [7]. These devices will be controlled remotely through specific application. The data collected by these devices are generally stored on the cloud storage through internet for further analysis. After analyzing the data on the cloud, appropriate decisions are taken. Network protocols are used by these smart sensing devices for the communication over the internet. It includes ZigBee, Wi-Fi, WiMAX, etc. After few years, numerous devices going to become a part of internet and the network will grow enormously to satisfy the requirements of people. The growth of IoT mainly depends on two technologies, i.e., Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN). RDIF is an electromagnetic technology used to track a tag associated with an object, whereas WSN is a group of spatially located diversified sensing devices, which monitor and record their surroundings. Presently, IoT is completely different and still in its babyhood. But in the future, the paradigm is going to shift from "*Things*" to "*Everything*" and it will be termed as Internet of Everything (IoE).

This chapter is organized as follows: Sect. 2 describes basic architecture of IoT, and Sect. 3 elaborates various applications of IoT from diversified domains. Section 4 explores challenges, future technology of IoE, and future opportunities. The chapter ends with summary mentioned in Sect. 5.

2 Architecture of IoT

Though there are different IoT systems available in the market, basic architecture of all IoT systems is nearly similar. Architecture of IoT mainly consists of four different layers, namely – sensor layer, network layer, processing layer, and application layer, which is shown in Fig. 1. The purpose behind working of all these layers is to

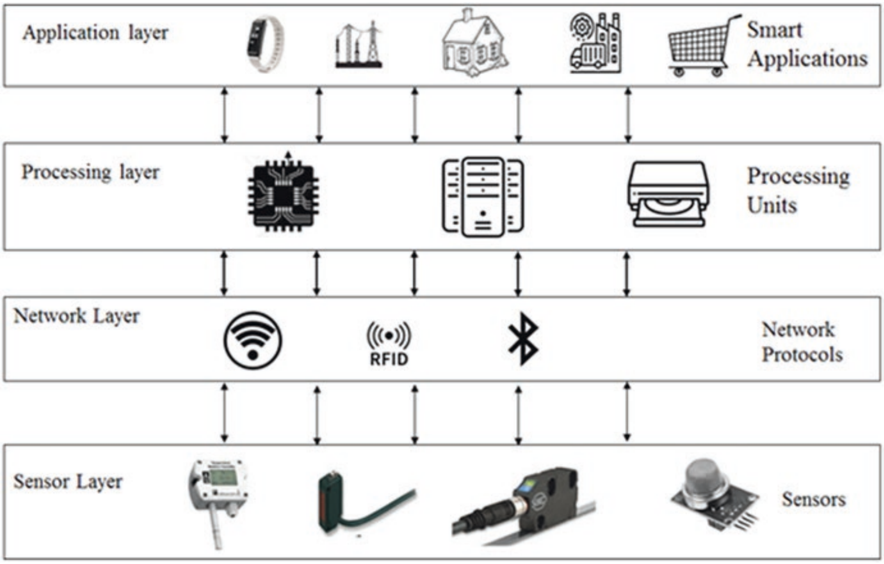


Fig. 1 Architecture of IoT

provide scalability, maintainability, ease of use, and dedication to single application. Smart sensing devices such as humidity, temperature, smoke sensors, biomedical sensors etc. are located at the bottommost layer known as sensor layer. Depending on the applications, different sensors are used at sensor layer, which are mainly classified into Motions sensors, Environmental sensors, and Position sensors. The purpose of sensor layer is to collect data from the surroundings through different sensing devices. These devices have the capability to sense the environment and convert it to analog form. Actuators are also mounted on sensor layer to act upon the environment if needed. Devices in this layer have the ability to switch off/on the lights, ACs, fire alarms, motors etc. based on the decision taken after data analysis.

Data Acquisition System (DAS) and network gateway are present at network layer. DAS converts analog data into digital form, and Gateway floats this digital data on the network through high speed gateways and routers. It also protects and filters data from malware. Networking protocols such as ZigBee, Wi-Fi, Bluetooth, RFID, WiMAX, etc. are the part of network layer. Devices at sensor layer will communicate with each other through these protocols. Based on the nature of applications, protocols are used. RFID and Bluetooth are used for limited area application; the contents of RFID tag are read by RFID reader. RFID will work like Barcode technology, but unlike conventional barcode, it does not require presence of reader in the proximity of tag. Similarly, for wide range applications, other protocols are utilized such as Wi-Fi and WiMax. The use of protocols depends on the kind of applications, speed requirements, network size, communication pattern, and power requirements. Based on this, various protocols work synergistically at different layers of IoT network.

Data sensed by sensing devices are processed at the processing layer to take suitable decisions. Various machine learning algorithms and visualization technologies are used at this layer to perform data analysis and visualization. Complete data and results of data analysis are stored on cloud server. This layer also shares processed data with other devices via network layer. The topmost layer is the application layer, which contains various applications of IoT such as smart homes, wearable devices, smart grid, etc. It's a user-oriented layer, which helps in implementing various applications based on users' requirements.

3 Applications of Internet of Things

Based on the types of sensors available in the market and their utility, we have classified IoT deployment into ten different domains of application. These domains are also indicated in clockwise direction in Fig. 2.

(i) Smart Home System
(ii) Wearable Devices
(iii) Smart Grid
(iv) Industrial IoT
(v) Medical IoT
(vi) Smart Vehicles
(vii) Smart Retailing
(viii) Supply Chain Management
(ix) Smart Farming
(x) Smart City

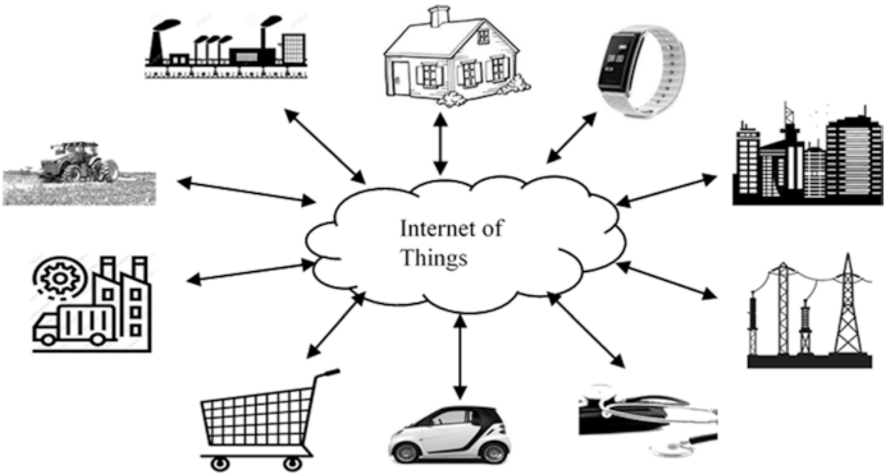


Fig. 2 Application domains of IoT

3.1 Smart Home System

Smart home has the highest ranking among all the IoT applications. It's a kind of intelligent system developed for the automation of home with the help of IoT and Cloud platform. Nearly, 256 companies are having their startup in this application. In smart home system, devices such as refrigerators, air conditioners, televisions, lights, etc. are connected to the internet through network protocols and are monitored and controlled remotely by the user.

There are multiple ways through which smart home system can be implemented such as Wi-Fi enabled devices controlled through android application, Arduino Kit having microcontroller embedded in it, which interacts with the devices tied with sensors located at nearby proximity. Apart from this, there could be smart devices like Alexa, which will follow voice command given by the user to control home appliances. Moreover, RDIF tags are also used for building wireless smart home. Different designs based on IoT and service component technologies can be utilized for the development of smart home [4]. There are different variants of smart home systems, which are developed with specific requirements. The basic architecture to design smart home system is presented in Fig. 3. In this, many devices are controlled remotely through the mobile application via internet.

Three different use-cases are implemented, namely, (1) monitoring condition of home, (2) controlling home appliances, and (3) tracking entry of users in the home by using Arduino Kit, RFID, and ZigBee protocols [5]. In first use-case, user can continuously monitor readings of temperature and humidity sensors from remote places. Second use-case allows to control appliances such as washing machine, lamps, televisions, fans etc. Moreover, third use-case helps in tracking the presence of user at home. Arduino Kit is utilized to program sensors and actuator, and ZigBee

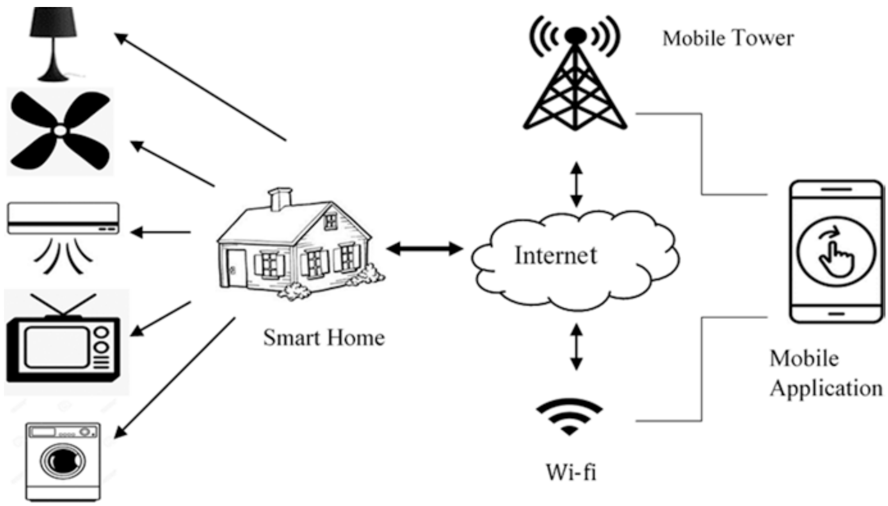


Fig. 3 Basic architecture of smart home system

is used for establishing communication between them. In the prototype, VCNL4000 is applied as proximity and light sensor and DHT22 is adopted as temperature and humidity sensor.

Another variant of smart home system based on knowledge-driven approach is simulated in [6]. It monitors Activities of Daily Living (ADL) such as *MakingTea*, *MakingHotDrink*, *TakeMedicine* etc. for elderly persons who have cognitive deficiency. The system assists and takes in-time decision through data collected by different sensors located at home. Rule-base knowledge representation system accompanied with IoT and cloud computing is employed to build fully functional classic smart home [7]. All the home appliances are fitted with sensors and cloud computing supports a scalable storage and computing power to monitor, access, and manipulate devices anywhere and at any time.

Low cost, energy-efficient and energy monitoring system for home appliances is proposed in [8]. It is a complete solution consisting of front-end to back-end modules for the home automation. Three-layered secured smart home system is designed to focus on the detection of vulnerabilities, avoiding monitory loss, and risk life, and these layers are hardware layer, control layer, and processing layer. Machine learning (ML) algorithm is applied at processing layer for detecting abnormal activities through video captured by smart cameras. ML model is built and trained on the data consisting of videos of daily leaving activities and utilized to provide security to home. In [9], a new developer-friendly library was developed in python for privacy preservation of IoT-enabled smart home. This library replaces standard networking functions to obscure the pattern of traffic generated by smart devices through integration of payload padding, fragmentation, and randomized cover traffic. Moreover, to secure the IoT-enabled smart home from fire and to avoid residential death, and property loss, WSN-based fire detection and prevention system is modeled in [10]. The system keeps energy consumption by sensor nodes at minimum level thereby detecting early fire.

3.2 Wearable Devices

Wearable devices are generally called as “*wearables*”, and it is the second most popular application of IoT. Wearables are small electronics devices, which are easily mounted on the human body anywhere at any time to facilitate hand-free operations. It is predicted that wearable technology will reach a market value of $57,653 million by 2022, which is almost three times more than that in 2016 (i.e., $19,633 million) [11]. This is the reason that the major giants like Google, Apple, Facebook, Amazon, and Microsoft are investing in this market. Wearable devices are classified into three types: (1) Accessories, (2) E-Textiles, and (3) E-Patches. Accessories include wrist bands, smart watches, head mounted smart devices, and smart ornaments. E-Textile comprises smart garments and foot/hand-worn. E-Patches consist of smart tattoo and skin patches with delicate circuitry in it. We have highlighted various types of wearables in Fig. 4. The

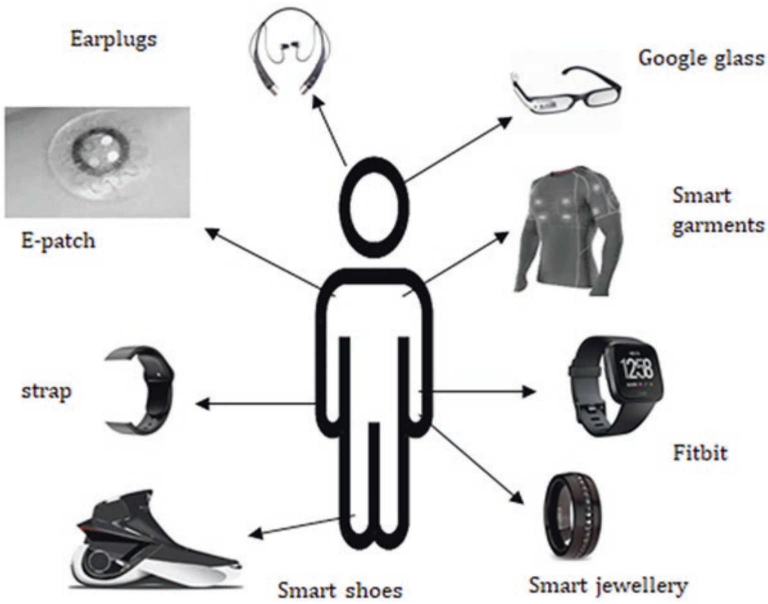


Fig. 4 Wearable devices

main purpose of wearables is to monitor health parameters. Some of the wearables with the functionalities are listed as follows:

(i) *Smart Eyewear*: Devices that can be mounted on the eyes come under this category of Eyewear. Google glass [12], Google lens [13], and Indoor Landmarks Identification Supporting Wearables [14] are some of the famous smart Eyewear. Google glasses are smart spectacles used for generating meeting, conference, and events' reminders by synching with calendar of phones and computers. They also help in capturing surrounding photos.

(ii) *Accessories*: These include smart rings, neck band, and kinds of jewelry in which sensors are embedded for monitoring health parameters [15]. Smart ring is used to measure arterial pressure and oxygen saturation level [16]. This artifact is used for ambulatory monitoring of elderly or unhealthy people.

(iii) *Wrist bands*: It includes fit-bit, smart watches, smart straps, honor bands, etc. They allow continuous monitoring of pulse rate, temperature, and blood pressure. The data captured by these devices are stored on cloud, and after analysis, if some unusual patterns are found, then emergency messages or signals are sent to doctors to take preventive actions.

(iv) *E-Patch*: It is a custom designed electronic circuitry fitted on the skin, which controls smart devices around the user. By rubbing the surface, tweaking the adjacent skin or skimming in specific direction of this circuit generates signals, which are sent to smart watch or wrist band. This E-Patch can be used for medical emergency and controlling devices like Alexa by people who can't speak.

Advancement in the technologies of smart phones and awareness towards healthcare will trigger the business of wearables, albeit costly one. Some wearable devices such as ingestible sensors and insulin pump need medical permission to inject them in the body [17–23].

In order to track psychological condition of human under stress condition, it is necessary to monitor bodily signals. To achieve this, wearable devices offer integrated sensors like accelerometers, gyroscopes, ISenesor, and elastic measuring units. These help in monitoring human behavior in terms of motion recognition, pressure sensing, and psychological behavior [24]. It is also applied in rehabilitation and behavioral therapy where doctors monitor patients remotely. To measure electrocardiogram (ECG), 3-axis motion, electrodermal activities, and temperature, a neoprene band is designed, which is discussed in [25]. In [26], a head mounted system is proposed by author to assess anxiety, mood, depression, and stress. The wearable social sensing watch is designed to continuously capture data from multiple sensors. This includes information on audio, environmental, and behavioral data. The correlation between physical information and psychological status is identified after analyzing the experimenter data [24]. Moreover, the detailed and critical survey of wearable devices along with challenges and working is discussed in [27]. Figure 5 shows various applications of wearables from monitoring of viable health parameters to controlling appliances of home.

3.3 Smart Grid

Due to the growing demand of electricity, heavy loads on power plant, and emerging challenges in power generation sectors [28], the concept of Smart Grid is originated. It is a network of all the devices, which are in the path of generation of electricity to the consumption of electricity by the consumers. As per the Government, smart

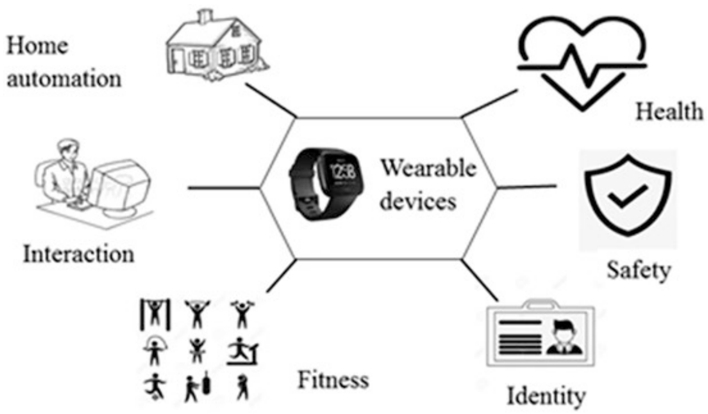


Fig. 5 Applications of Wearables

grids can overcome the problems faced by the conventional grids. Smart grid has capacity to deal with problems such as energy crises, climate change, and emergency recovery. Smart devices in IoT form network among power devices, charging stations, and storage devices. Primary components of smart grid are sensors or smart meters, charging stations, storage devices, and automated distribution centers. Smart meters keep track of the overall energy consumption by the customer. It keeps the summary of data of overall units consumed and electricity loads. Automated distribution centers are the units where IoT is exploited at maximum level. It automatically distributes electricity based on the loads on the grid lines and detects failures of grid lines, and also promises safety and economy. Charging and storage stations permit homes and residential areas to go off-grid in case of emergency or accidents. They also keep track of growing demands of electricity from independent residential areas.

In Germany, an integrated IoT setup is built for implementation of smart grids. Lumin is one such IoT-enabled smart grid project, which handles renewable source of energy thus helps in cost saving and efficient management of energy [29]. Basic architecture of smart grid is presented in Fig. 6. In this, smart devices are installed on grid to monitor flow of electricity, temperature, or natural calamities like flood or twister. An approach regarding how IoT can be used to design smart grid transmission lines is proposed in [30], and it mainly consists of two components. In the first part, smart devices are installed on transmission lines to inspect the status of conductor, and in the second part, other smart devices are configured on transmission towers to keep track of the surroundings and status of the tower. Such smart grids overcome the challenges of high operational cost and time, complex data transmission rate, and routine maintenance. Along with smart grids, substations and

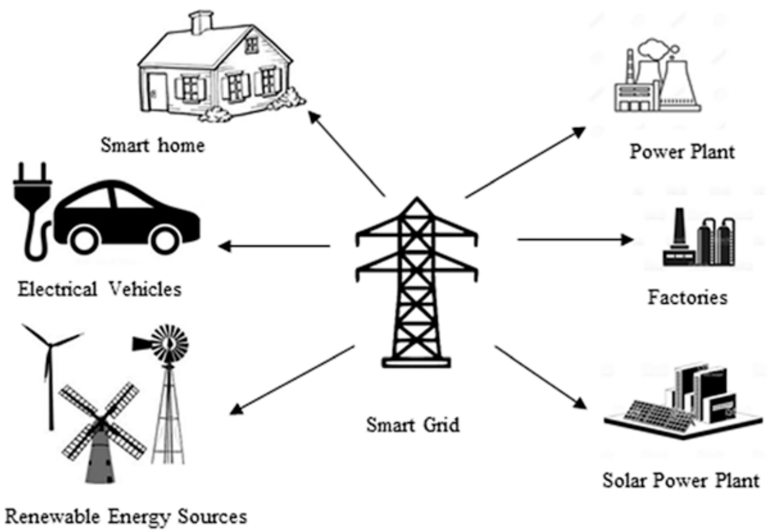


Fig. 6 Smart grid

equipments available at power station are needed to be monitored intelligently. To do so, IoT-based system is proposed in [31], which tracks all the equipment available at substations. Cabinet of substations is monitored by temperature and humidity sensors to protect it from overheating, smoke sensors are used to detect any kind of fire or smoke inside the substation, gas sensor for sensing harmful gases is produced inside the substation, and water sensors are applied for monitoring the immersions of floor or cable in the water.

3.4 Industrial IoT

Industrial IoT (IIoT) is a new stream of IoT where the focus is on automation of manufacturing industries using IoT. It's a result of ubiquitous computing and connectivity of smart devices. Initially, there are many challenges in IIoT, which are described and addressed in [32], namely, deadline of product delivery, labor availability, maintenance, and storage of products. IIoT is a network of smart devices configured in the industries to monitor whole cycle of product development, i.e., from procuring the raw materials to product delivery. Minimum human intervention due to the use of IoT in industry speeds up the process of product manufacturing. It lowers down the cost both in terms of time and money and also minimizes human-errors. One of the applications of IIoT discussed in [33] focuses on the testing of endurance of Motorcycle. This is the four-layered architecture that comprises data acquisition, cognitive layer, network layer, and control layer. IIoT has great opportunities in industrial automation of health equipment, medical equipment, and aerospace industry.

Subsequently, IIoT is applied in online monitoring of environmental conditions and determining the working status of equipment used for steel casting [34]. Unceasing steel casting is a critical process of steel making and shaping of steel in production industry. It represents unpleasant environment (i.e., high temperature, loud noise etc.) in the industry having the de facto great importance. Therefore, there is a growing demand for online tracking and Maintenance, Repair and Overhaul (MRO) service provider [35]. By applying IoT, MRO operations can be achieved with maximum chances of energy and manpower saving for industries having unpleasant environment. The basic aim of IIoT is not to replace humans but to create new opportunities of revenue generation.

IIoT leverages plenty of use-cases apart from manufacturing. These include streamline of operational efficiency, rationalization, maintenance, etc. [36]. It has the following advantages:

(i) Enhance work safety
(ii) Enhance product innovation process
(iii) Reducing asset life cycle cost
(iv) Reducing downtime
(v) Improving productivity

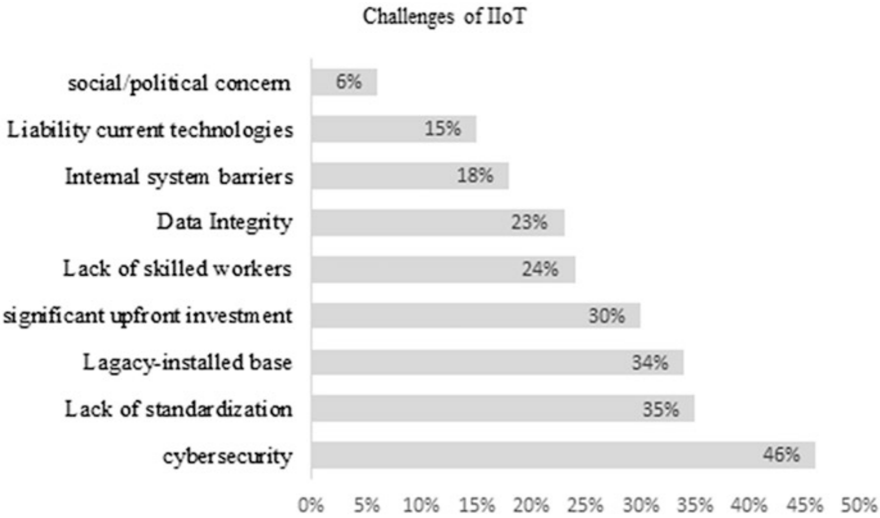


Fig. 7 Challenges in IIoT

Apart from the advantages of IIoT, there are challenges also while adopting IIoT, which are shown in Fig. 7.

In Fig. 7, we observed that cybersecurity is the main challenge in IIOT and hence we need to adopt the appropriate techniques to make the system secure against any cyber-attacks. Cybersecurity is the most challenging task faced by 46% of industries with other challenges such as lack of standardization and legacy-installed base that are equally important to be resolved.

3.5 Medical IoT

Medical IoT is the use of IoT in healthcare centers or hospitals. It is an allied branch of IoT basically known as Internet of Medical Things (IoMT). In healthcare, some patients required continuous monitoring or medication and it is necessary to take proactive decisions in critical conditions. Devices like fitness bands, glucometer, cuffs measuring heart rate, and blood pressure give personal attention to the people and can be manipulated as per requirements. It helps the physician in monitoring adherence of patient to treatment plan. IoT helps nurses in tracking the contents of IV bottle by generating alarm once bottle gets empty. It also helps in design of wheelchair tracking system used by physically disabled people. IoT-enabled sanitization devices, thermal scanner, are very useful during pandemic like COVID19. Insulin pen, Open APS (Artificial Pancreas System), glucometer, and oximeter are some of the smart devices that made diabetic life painless.

Various devices were proposed by the researchers, which are useful in the medical domain. One such device is built from energy efficient Wireless Body Sensor nodes [8]. These nodes continuously track Electrocardiogram (ECG) signals from patients' body outside the hospital environment and allow doctor to monitor patient remotely and also facilitate him to provide suggestions if need arises. Due to transfer of sensitive data through internet, there is possibility of compromising this data by the attacker. To avoid this, a web-based IoMT Security Assessment Framework (SAF) is developed by author [8]. To give utmost care to elderly person, wearables associated with sensors are fitted in assistive devices so that movements, vital signs of oldsters, are monitored, and alarm messages are sent to relatives in case of emergency.

In [37], IoT system is proposed for medical domain to monitor two types of anesthetics, namely, *paracetamol* and *propofol* in human serum. Prior to critical surgeries, anesthesia is given to the patients to make them unconscious so as to have painless surgery and graceful recovery of patient. To achieve this, anesthesiologist is armed with an application and smart wristwatch through which patients' condition will be monitored during the injection of anesthesia and they need not have to wait near the patient for hours. The generalized architecture of IoMT is shown in Fig. 8.

Continuous drug monitoring is one of the future standards for improving the health of individuals. Wearables and implantable biosensors may be utilized with IoT, which voluntarily changes medication dosing in response to patient health conditions, allowing risk control and improving individualized therapy [38]. Patients' suffering with diabetes requires continuous monitoring of blood glucose level. For them, IoT devices such as insulin pen, insulin pump, and wireless glucometer can be used. To give rapid response to data avalanche, fog computing or edge computing is applied with IoT as it requires less bandwidth and has greater privacy and security [39, 79].

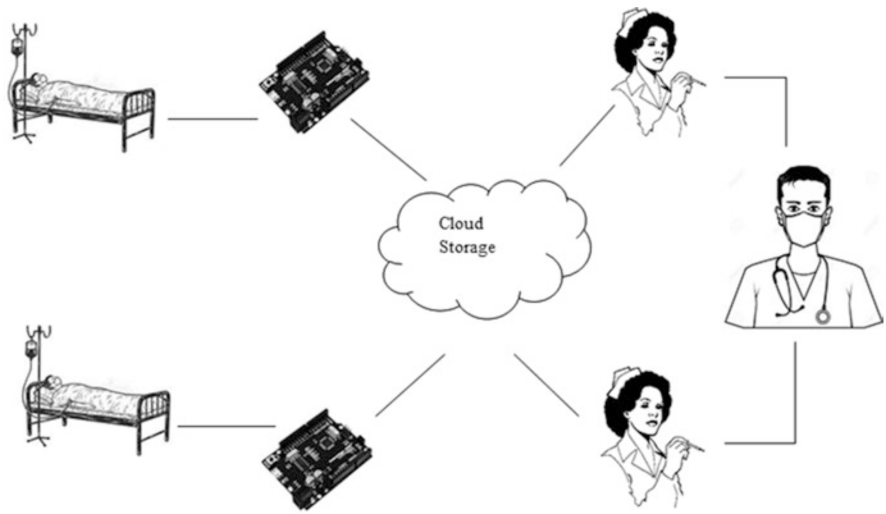


Fig. 8 Medical IoT

3.6 Smart Vehicles

As the number of vehicles on the road has been rising day-by-day over the last 10 years, road safety is a major concern and that needs to be pragmatically handled. With IoT growth, the automobile industry is no longer behind other industries that are opting for a smart solution. They are developing different solutions using IoT that assists drivers. These solutions aid with either navigation or sophisticated system to assist drivers on roads. The basic architecture of IoT-enabled smart vehicle is shown in Fig. 9. The system will help in monitoring different features in the vehicle such as security, smoke, navigation, etc.

In [40, 41], IoT-enabled vehicle safety and wellness models are presented to deter theft of vehicles. Moreover, a way to prevent cautionary road accidents is also suggested by the system. From the report of Ministry of Road Transport [42], the state that suffers with maximum number of fatalities due to drink and drive accidents is Uttar Pradesh, followed by Madhya Pradesh in India. The IoT-enabled module [42] will not allow the vehicle to start if the driver consumes an alcohol. In addition, a smart solution to calculate fuel levels in the vehicle is also suggested. In [43], a cost-effective approach is designed to make genuine cars safer than costly sedan vehicles that have built in smart monitoring framework. The system helps to identify the level of alcohol, amount of smoke in the car along with the distance of the object from the black spot, the rate of rain, and the level of light intensity. Hence, the system prevents the chances of road accidents. In [44], to avoid road accidents on highways due to poor visibility during night, a savvy system is designed, based on open source IoT platform NodeMCU and Ultrasonic sensor. These components work synergistically during night when visibility and ability to track exact position of vehicles is difficult.

Subsequently, another IoT-based smart solution to assist elderly people in safe driving is developed in [45]. There are some situations when elderly person cannot drive vehicle due to poor visibility and thus lead to fatal accident. To overcome this, a system is designed to form a network of sensors dedicated to monitor different

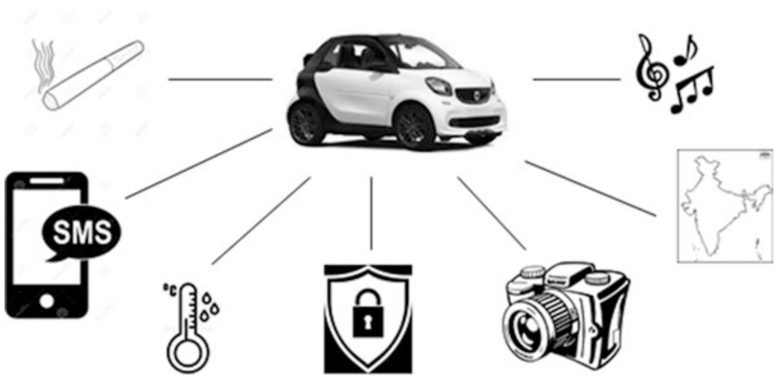


Fig. 9 Smart vehicle IoT architecture

aspects such as condition of road, weather, alcohol level, gas (in LPG vehicle), and surroundings. Depending on the data gathered by sensors and its analysis, commands are given to the driver or vehicle. In the worst case, if causality occurs, then instant message is sent to the relatives of driver or nearby hospitals for ambulatory action. Apart from security and accident prevention, there are other applications of IoT in design of smart vehicles such as fuel monitoring, drowsiness monitoring of driver, and reminder generation for vehicle servicing.

3.7 Smart Retailing

The days when individuals used to wait in line while buying goods at the supermarket are gone. Pantano and Timmermans [46] summarized the characteristics of a smart city such as wireless infrastructure, an effective online data transmission network facility, an innovation facility, competitiveness, governance, modern and sustainable transport facilities, and an atmosphere free of emissions. Integration of innovative network infrastructures and innovative sensor networks to achieve the growth and development of smart cities, along with cloud computing platforms is needed. Therefore, smart retailing emerges as a part of the broader concept of smart cities, by focusing on a new approach to retail management and adopting technologies as enablers of innovation and enhancements in consumers' quality of life. Thus, it starts from the same vision of the smart usage of modern technologies to improve retail management and services and improve consumers' journey [47].

To benefit the retailers and customers, IoT-based model is proposed in [48]. In this model, each product is associated with a RFID tag, which gets scanned using RFID scanner when user purchases it. User can see various pieces of information related to product such as expiry date, price, and quantity. Once purchasing of product is done, the status of the shelf in terms of availability of products will be updated on the database stored on the cloud. This will overcome the problem of frequent roaming around the supermarket by retailer. The overall availability status of all products is conveyed remotely to retailer so that he/she can refill the shelf well in advance with enough products to avoid economic loss. Hence, customers will never go empty hand from retail shops.

In [49], adoption of IoT-enabled system by two main companies in India for retail shopping, namely, Watasale and SPAR, is discussed. This shrewd way of retailing gives rich experience to people. It is more customer-oriented and takes care of intuitive demands of customers. A survey is conducted to 289 retailers to predict the customer attitude while retailing [50]. This helps in leveraging various opinions of customers to develop more smart system. In [51], an importance of smart retailing, benefits, and challenges arising in it are highlighted. Moreover, two models were proposed [52], namely, retail 4.0 IoT Consumer model and retail 4.0 IoT Retailer model to plan the marketing strategies from the data collected through RFIDs and sensors in order to have rich experience to customers while retailing.

3.8 Supply Chain Management (SCM)

The supply chain is a network of business processes, from the collection of raw materials to the production of refined goods. Under trembling conditions, all supply chain runs are vulnerable to hordes of disruptions at all stages. The supply chain mechanism is disrupted by several environmental factors at the global level [53], and customers have changing demands in terms of quality, price, and latest trends. Similar goods also differ due to the availability of raw materials, technology used, clock, etc. Therefore, in order to keep all the components of the supply chain to work synergistically, Christopher et al. suggested four pillars: responsiveness, reliability, resilience, and relationships [54]. Companies need to be very agile and have solution to mitigate all risks. IoT devices in the supply chain are efficient in monitoring and authenticating products and shipments using global positioning system (GPS) and other technologies. IoT can help supply chain in the following ways:

(i) Tracking of goods
(ii) Monitoring storage environment of goods
(iii) Estimating time of delivery of goods
(iv) Predicting delay in shipment

This can be achieved by attaching IoT device to specific containers. Based on the location and surrounding of IoT device, different types of data will be sensed, and information will be provided to suppliers, distributers, retailer, shopkeepers, and whole-sale dealers [55]. As warehouse plays a crucial role in SCM by storing raw data and managing inventory, a smart warehouse based on IoT system is proposed in [56]. This system utilized in knowing the conditions of all the goods prevents warehouse shortage and prohibits counterfeiting goods in inventory. An effective management of supply chain via RFID tags is presented in [57]. Author also discussed how different giants like Wall-marts, Chevrolet, and Procter and Gamble are exploiting RFID technology for automation purpose in supply chain management.

3.9 Smart Farming

The application where IoT is least exploited is farming albeit a lot of opportunities. For exponentially growing populations, countries depend on farming for food sources. Due to unpredictable climate condition and social challenges faced by the farmers, it is needed to bring revolution in farming using smart technologies, i.e., IoT. Use of technology will benefit farmer in mitigating risk of uncertain climate, environmental impact, and market requirements. It is predicted in the USA that IoT is going to have an investment of $4.3 billion by 2023 in order to feed enormous population [58]. IoT can be adopted in farming for the following purposes:

(i) Detecting humidity in soil with the help of humidity sensors
(ii) Detecting need of pesticide spraying through drones fitted with smart cameras

(iii) Detecting intrusion by animals in the farm
(iv) Detecting fire in the farm
(v) Weed removal
(vi) Water supply to plants
(vii) Detecting minerals in soil

Detailed survey of how to use IoT in farming is presented in [59]. The smart agro-architecture based on the IoT consists of five inter-connected sub-systems, i.e., sensing [60], data analysis [61], communication of data [62], visualization [59], and sub-system execution. The sensing sub-system is linked to the data analysis sub-system where each sensor's raw data is individually manipulated, processed, and analyzed using various algorithms implemented for visualization, and execution sub-system consists of microcontroller unit to perform computation.

In smart farming, all types of monitoring can be done through different types of sensors. Humidity in soil is monitored through soil sensor, water monitoring sensor will identify need of water to plants, and temperature sensor will keep track of surrounding temperature of crops. There are two more sensors that can be utilized for effective farming of animals, namely, gas sensor and pressure sensors [63]. Once all the sensors get assemble in the farm, they are operated through remote places via an android application installed on smart phone. Moreover, smart grid can also provide renewable energy to carry out several operations of farm. A sample prototype is developed for smart farming using Arduino as discussed in paper [64]. MIT media lab under the open agriculture initiative is treating growing crop as cooking some recipe under controlled environment. They are trying to control all farm related operations remotely and take appropriate action based on the data sensed by different sensors located in the farm [64]. In [60], how IoT can be deployed in all landscape to make farming more technology intensive than labor intensive is discussed. The overall design of IoT-based farming is shown in Fig. 10. Humidity sensor will detect humidity in soil, drones help in spraying fertilizers, and Agri-bots removes weed and also ploughs soil with the help of IoT and machine learning techniques. Soil sensors can detect mineral quantity in soil and facilitate to yield alternate crops in the same soil [78, 80].

Subsequently, IoT and artificial intelligence (AI) are used in various operations of farming, from ploughing of land till picking of the crops. Farm owners may use wireless IoT applications to collect information of livestock location, well-being, health through livestock monitoring, and geofencing. This data is utilized to avoid the spread of illness and decrease of labor costs as well. A smart greenhouse can be intelligently monitored and controlled remotely without human intervention by applying IoT. Crop prediction plays a vital role in assisting farmers to decide on a potential strategy for crop production, storage, marketing, and risk management techniques. In order to predict the production rate of the artificial crop network, information obtained by the farm sensors, which is based on the parameters such as soil, temperature, pressure, rainfall, and humidity, is utilized. Either via the dashboard or a personalized mobile application, farmers can get precise soil data [65] for further processing.

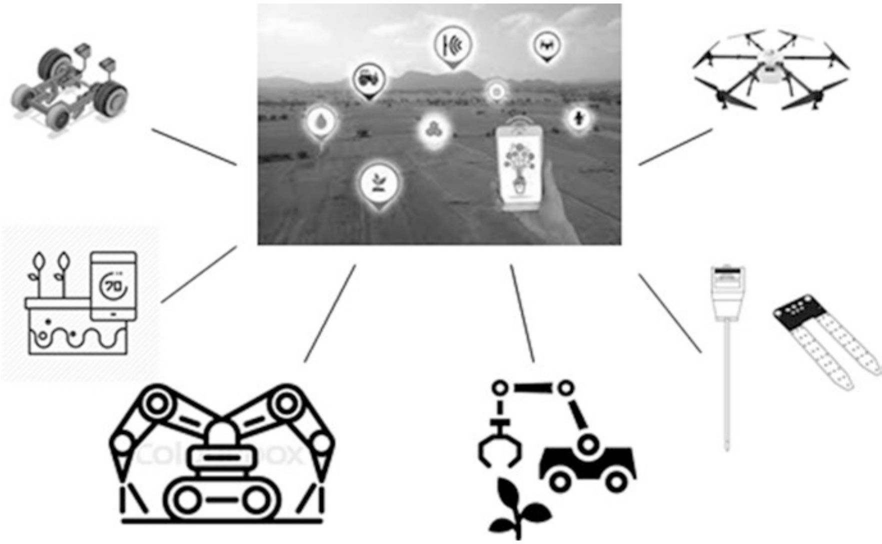


Fig. 10 Smart farming layout using IoT

3.10 Smart Cities

Growing population leads to scarcity of natural resources, which is a never ending process. There are various problems faced by urban citizens regarding insufficient parking, waste management, water management, electricity management, etc. Hence, all these problems lead to the poor standard of living. To overcome these issues, "*smart cities*" concept is originated. Smart cities pragmatically handle these issues by saving energy and using resources efficiently. Smart cities utilize IoT-enabled devices for lights, motors, parking, litter baskets, and traffic management and thereby improve the standard of living, public utilities, and infrastructures. Electricity is the most potential area of cost cutting. By the survey of IBM, it is found that in New York, people spend 22.5 years of their life waiting for elevators. Therefore, they doubled their investment in building smart elevators [66]. Smart Cities are second potential area where smartness and automation are required to save cost. To do so, New York, London, San Diago, and Copenhagen already alleviate problem of traffic congestion using smart sensing devices. These devices re-route the traffic to congestion free paths [66]. This supports in clearing the paths for two-wheelers as well as pedestrians. India is also no way behind implementing smart cities. Indian Government in 2015 decided to convert 100 non-smart cities into smart cities thereby providing lucrative facility to citizens leaving in those cities. In [67], a technology-mixed solution of smart cities using AI and IoT is proposed for smart traffic management.

Subsequently, main aspects, potential areas, and challenges of smart cities are described in [68]. How different locations are monitored and controlled remotely to make overall city smart is explained by the author. Sensors located at different places support in capturing data of corresponding location. Temperature, humidity, and smoke sensor assist in locating over polluted areas and areas where rain fall has occurred. This information is delivered to unhealthy people to take cautions. In [69], integration of IoT and cloud is proposed for smart parking system to tackle parking inconvenience and save the time spent in searching empty parking slot, which is an integral part of smart city. This smart parking system is controlled via mobile application, and its purpose is to find, allocate, reserve, and provide the best feasible parking slot to an individual driving in the specific area. Moreover, it is stated that more than 66% of the individuals are ready to pay for safe parking [70]. Hence, this idea triggers the concept of smart parking. The system can be deployed in the areas such as shopping mall, hotels, restaurants, streetcar parking areas, hospitals, multiplex, schools, colleges, and in residential areas. The required control centers can be established on highway, emergency centers, traffic control centers, and various police stations. Similarly, the smart parking system is implemented in [69] for the university campus.

Nevertheless, a framework of service in smart city for waste management is the latest requirement. It's a process of managing waste from its inception to its disposal. Pertinent way of waste management leads to imperishable development of country. Based on the case study of waste management in St. Petersburg, Russia, where average fuel consumption by trucks collecting waste is 1.8 million liters per year and cost spent in one year is $1 million, there is a need to do waste management in other parts of world also. This prompts to propose IoT-based waste management system [71] for an efficient collection of waste. A waste management model applied in the city of Wuhan is presented in [72]. This model highlighted the complete life cycle of handling waste management. For monitoring statistics of litter baskets and truck, an RFID-based model is proposed in [73].

The basic architecture of smart cities is demonstrated in Fig. 11. Smart sensing devices are installed at apartments, parking slots, streetlights, elevators, traffic signals, water tanks, and litter baskets. These devices communicate with environment and continuously sense the data and send it on cloud via internet. The stored data on cloud is utilized by different people and governing departments to take sagacious decisions.

Mostly, due to the absence of streetlights or loss of power, many road accidents such as theft, chain snatching, kidnapping, etc. occur. Indirectly, it creates those areas into heavens for the criminals. To deal with these problems, Smart lighting system can be adopted as a framework of smart city [74] [75]. Also, we can achieve energy saving up to 45% using such frameworks. Hence, it benefits in controlling streetlights remotely. Such system can be customized with additional feature of instinctively signals generation for electricity department, to take prompt action for resolving the issue, and crimes can thus be avoided. In [76], a system is developed for complete urban planning and smart city building using IoT and Big data. The system is implemented using Hadoop for handling unprecedented voluminous data generated by IoT devices. For designing complete urban planning based on IoT, the data related to vehicular network, weather, pollution, smart home, smart parking,

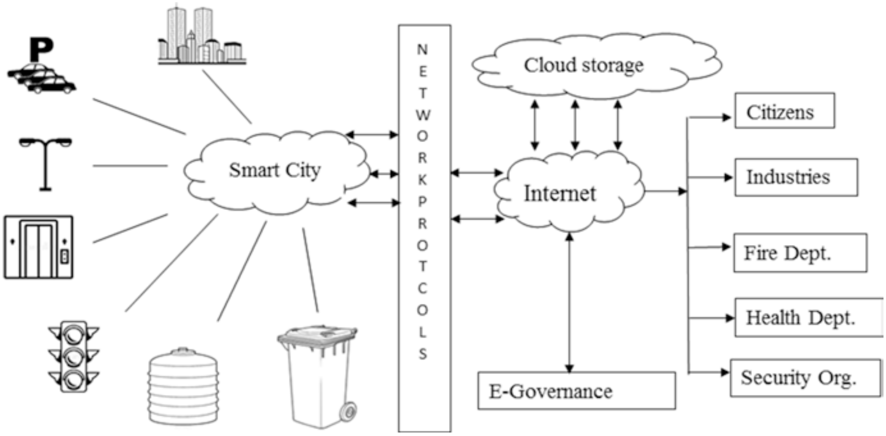


Fig. 11 Architecture of smart city using IoT

and surveillance system need to be analyzed. System performs well for the benefit of citizens, entrepreneurs, traffic authorities, and government, which results in taking wise decisions about nations at correct time.

4 Paradigm Shift from IoT to Internet of Everything (IoE)

CISCO, the major player in networking described in its report [77] that very soon the paradigm is going to shift from IoT to IoE. IoT is only connecting things (i.e., smart devices) in a mechanized way and the whole system gets operated from anywhere, at any time by anyone. It helps in making human task easier. But now, not only smart sensing devices but also other things, which are going to take part in communication, are people, process, and data. These are known as the four basic pillars of IoE, which is presented in Fig. 12. IoE is a broader perspective of IoT. IoE is a world of billions of objects with sensors glued with them, which communicate with each other through proprietary network protocols.

The four pillars of IoE enrich the set of experience for the users. CISCO predicts that $4.6 trillion will be at stake in the next decade [77], known as IoE value. IoE will create ground-breaking opportunities to the businesses. The theory of the IoE describes the world in which billions of sensors are inserted into billions of computers, machines, and ordinary objects, giving them extended possibilities for networking and making them smarter. Manufacturers are going to add sensors with devices. This supports them to detect malfunctioning of the device so that they can swap it out before complete damage occurs to them. IoE will connect unconnected things; as a result, there exist three different types of communication: people-to-people (P2P), machine-to-machine (M2M), and machine-to-people (M2P). CICSO predicted that there will be a 99.4% of things that will become part of internet and the

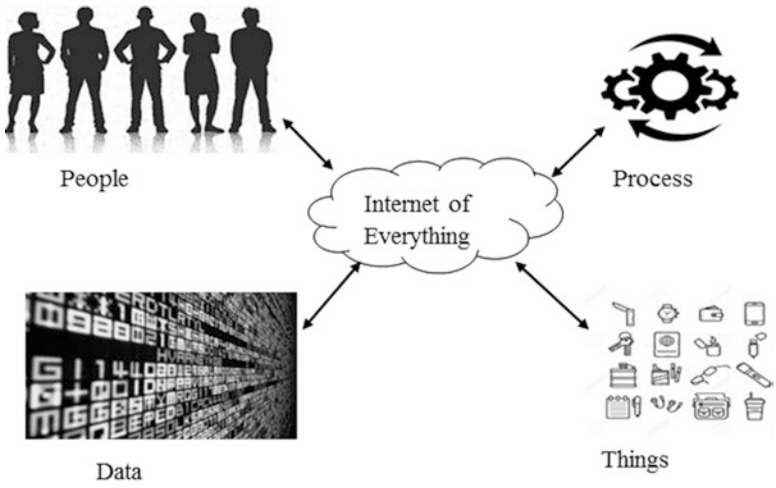


Fig. 12 Four pillars of IoE

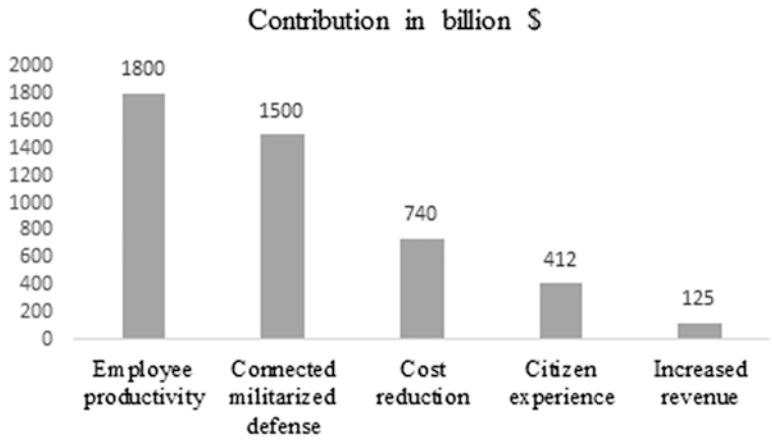


Fig. 13 IoE stake value at different sectors

$4.6 trillion value, which is at stake, will be spent in public sectors by giving benefits to agencies, citizens, and employees. IoE has tremendous potential to address issues of public sectors.

With the help of IoE, government can upgrade standard living for citizens of the country by leveraging M2M communication to deal with Big data and crowdsourcing. CISCO identified five sources on which $4.6 trillion will be spent, which is shown in Fig. 13. The highest amount that is at stake is from employee productivity sector. CISCO's IoE value at stake is calculated from different use-cases, which are classified into two types: Agency-specific and Cross-agency specific. Agency-specific includes use-cases such as Education, Culture and Entertainment,

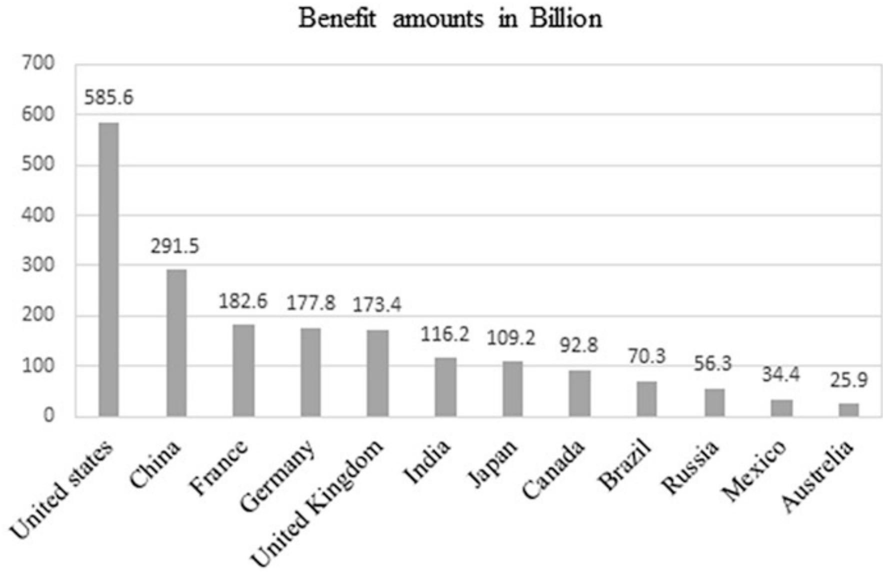


Fig. 14 Countries benefited from IoE stake value

Transportation, Safety and Justice, Energy and Environment, Healthcare, and Defense. Cross-agency use-cases include Next-generation Workforce and Operations. The countries that get benefitted from IoE stake value are shown in Fig. 14. The United States will be the most benefited country after deploying IoE, whereas Australia will be the least to benefit.

Out of the three different communications that are needed in IoE, P2P and P2M are going to have the highest stake value that is 69% and M2M is 31%. The essence of using IoE is that it will make human life agile, more prolific, regulatory, and luxurious.

Just to imagine a life using IoE, consider a day when you got up early in the morning, water heater at your home will start communication with sensor embedded in your body and get the hot water ready for your bath. Next, your coffee machine and sandwich maker will make a breakfast for you without letting you bother for availability of breads in your refrigerator. After breakfast, your smart watch will call the driver and order him to get your car ready for your office. While on the way to office, your schedule of the day will be given to your driver from your calendar so that you need not have to spend your time calling the driver and describing to him about your schedule of the day. While on the way back home, your car will remind you of purchasing a gift for your daughter on her birthday by stopping near the gift shop. In between, if some traffic jam occurred on your way due to some accident, you will not have to face the traffic congestion due to smart devices attached on the road or on the helmet of the person caught in an accident. This sensor on helmet or on the road would have already communicated with healthcare services and already avoided crowd and congestion at the accidental spot. This will make you reach home on time without mental tiredness. When you reach home, again the devices at your home start working as per your expectation without you operating them. This is the kind of comfort and standard of living, which will be provided to you through IoE. But, before heading towards IoE, we need to anticipate many exciting challenges, which are described in the next section.

4.1 Challenges and Issues in IoT/IoE

Before going to shift a landscape from IoT to a wider concept of IoE, the following challenges need to be addressed intelligently.

(i) How to achieve high interoperability among devices without human interventions at all
(ii) Provision of security mechanism for data, which is going to be available on the internet so that its misuse can be avoided
(iii) Global norms, policies, and laws for individual sector in order to maintain effective balance among economy, education, privacy, and security
(iv) Development of mechanism for repair or maintenance of smart devices and their alterative solution in case of failure during emergency conditions
(v) Facility for storage of voluminous data and its analysis
(vi) Upgradation of hardware and software
(vii) Creating awareness of technology among citizens

To overcome challenges of IoT devices, there are many solutions available in literature. Apart from them, we have identified possible solution for preventing data generated by IoT devices from being hacked. Many vendors in the market are having their own IoT infrastructure, devices, APIs, and data formats. This leads to the issue of interoperability due to vendor-lock and forced unveiling of IoT devices to work on cross platform. Hence, to deal with these issues, we need a standard infrastructure, APIs, and data formats to be developed. Another solution could be inclusion of one additional layer before application layer known as Web of Things (WoT) layer for seamless working of IoT devices. Mostly, in IoT applications, vendors and companies of the products are retaining their credentials and customers are not aware about its negative impact. Users don't realize the possibility of data being hacked. To avoid this, password and username should be updated at regular interval and strong password needs to be set for IoT network. Moreover, utilize only those features that are important and disable the remaining. Eventually, to boost the performance of IoT devices, regular maintenance and backups, and cleanup operations need to be performed on storage. To handle legal issues, cyber laws and rules, we need to design the preventive actions against data theft and misuse. To do so, we required a central facility or standard to update the software applied on IoT devices remotely. Also, keep track of updates available on firmware or product manufacturer's website. In addition, Over the Air (OTA) facility can be used to update firmware and software of IoT devices. Users need to be very cautious while handling

IoT devices' network. Installation of non-repudiation security software on computers, tablets, and smart phones can provide additional security to IoT devices from hackers.

5 Future Opportunities of IoE

As discussed earlier, the future will be of Internet of Everything where all objects around us will be assigned IP address and they will also participate in communication with surrounding objects. Data generated by these devices will be more informative, and connection between them will be of utmost importance. IoE is going to have strong potential through which gap between expectations by citizens and government practices will be fulfilled. Applications that were operating separately using IoT will now come under one umbrella. For example, Smart traffic, in which smart parking system will automatically get connected with Medical IoT and will help in saving many lives, casualties will be avoided, congestion due to traffic will be taken care of, and searching parking time will be saved.

To begin our journey towards IoE, government must work towards building strong economy, focus on policy making and regulations, and struggle for quality service delivery. There is a need of open platform where open discussion will be done on privacy, security, sustainability, and resilience of IoE. IoE will create groundbreaking opportunities for business. It will help enhance the capabilities of devices, which will grow beyond imagination. Today's fit bit not only monitors our health data but, in the future, will also call a doctor in case of sudden fluctuation of vital parameters without us being notified. Wearable smart tattoo by expectant mother will help in monitoring the health of fetus. In industry, IoE can do video analysis and help in optimizing productivity of stores. This is just a budding stage of IoE.

6 Summary and Future Direction

This chapter discussed about architecture of IoT and its applications. IoT-enabled wearable devices provide health-related information at our fingertips. Smart vehicles with IoT technology assist drivers and provide them safety on roads. IoT is used in smart farming to improve the yield of crops and enable intelligent farming, which is far away from conventional techniques. IoT has proven itself in supply chain management by removing uncertainties that pop outs in business. It created impact in retailing by providing customer-oriented services. Application of IoT in building smart home and city is a milestone. These two applications created many business opportunities. Smart home is the most explored domain of IoT, which is accepted by people around the world. It provides security to home, which is an asset for everyone. Apart from applications, architectures of various applications are also discussed in the chapter.

In the future, paradigm will shift to IoE. Government, researchers, academicians are trying to develop technology-based solutions where everything around us will communicate to each other and will improve the standard of living. Though IoE is in its embryonic stage, it has limitless potential that will automate our day-to-day life activities in the future. This chapter presents an indication about future technology of IoE so that researchers in the business sectors will develop prototypes and can convert them to final products as a part of business. Research is needed in the direction to provide single platform for all IoT devices to work on. More secure and scalable solution is needed for data security using a blend of IoT, deep learning, and AI. The scope of research in IoE comprises security, interoperability of IoT devices in cross platform, and development of energy-saving mechanism for sensing devices. Improving the life time of sensing devices is also one of the areas of research for sensing. In the future, IoE along with AI will steer varieties of use-cases at hyperscale.

References

1. L. Atzori, A. Iera, G. Morabito, The internet of things: A survey. Comput. Netw. **54**(15), 2787–2805 (2010)
2. D. Bandyopadhyay, J. Sen, Internet of things: Applications and challenges in technology and standardization. Wirel. Pers. Commun. **58**(1), 49–69 (2011)
3. A. Samuel, C. Sipes, Making internet of things real. IEEE Internet of Things Magazine **2**(1), 10–12 (2019)
4. B. Li, J. Yu, Research and application on the smart home based on component technologies and internet of things. Procedia Engineering **15**, 2087–2092 (2011)
5. M. Soliman, T. Abiodun, T. Hamouda, J. Zhou, C.H. Lung, Smart home: Integrating internet of things with web services and cloud computing, in *2013 IEEE 5th International Conference on Cloud Computing Technology and Science*, vol. 2, (IEEE, 2013, December), pp. 317–320
6. L. Chen, C.D. Nugent, H. Wang, A knowledge-driven approach to activity recognition in smart homes. IEEE Trans. Knowl. Data Eng. **24**(6), 961–974 (2011)
7. M. Domb, Smart home systems based on internet of things, in *Internet of Things (IoT) for Automated and Smart Applications*, (IntechOpen, 2019)
8. A. Ghosh, A. Raha, A. Mukherjee, Energy-efficient IoT-health monitoring system using approximate computing. Internet of Things **9**, 100166 (2020)
9. T. Datta, N. Apthorpe, N. Feamster, A developer-friendly library for smart home IoT privacy-preserving traffic obfuscation, in *Proceedings of the 2018 Workshop on IoT Security and Privacy*, (2018, August), pp. 43–48
10. F. Saeed, A. Paul, A. Rehman, W.H. Hong, H. Seo, IoT-based intelligent modeling of smart home environment for fire prevention and safety. J. Sens. Actuator Netw. **7**(1), 11 (2018)
11. Wearable technology market – global opportunity analysis and industry forecast, 2014–2022. http://www.prnewswire.com/news-releases/, 2017. Accessed on 11 Oct. 2020
12. Google Glass. https://en.wikipedia.org/wiki/Google_Glass, 2016. Accessed on 11 Oct. 2020
13. Google Contact Lens. https://en.wikipedia.org/wiki/Google_Contact_Lens, 2016. Accessed on 11 Oct. 2020

14. W. Ugulino, H. Fuks, Landmark identification with wearables for supporting spatial awareness by blind persons, in *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, (2015, September), pp. 63–74
15. Smarty ring. http://smartyring.com, 2016. Accessed on 11 Oct.2020
16. S. Rhee, B.H. Yang, H.H. Asada, Artifact-resistant power-efficient design of finger-ring plethysmographic sensors. IEEE Trans. Biomed. Eng. **48**(7), 795–805 (2001)
17. Proteus Discover. http://www.proteus.com/discover/. Accessed on 11 Oct.2020
18. Unilife. http://www.unilife.com. Accessed on 11 Oct.2020
19. Self injection systems. http://www.bd.com/pharmaceuticals/products/self-injection/patch-injectors.asp, Accessed on 11 Oct.2020
20. YDS delivery systems. http://www.ypsomed.com. Accessed on 11 Oct.2020
21. Omnipod System. https://www.myomnipod.com. Accessed on 11 Oct.2020
22. V-Go Insulin delivery device. http://www.go-vgo.com. Accessed on 11 Oct.2020
23. About PAQ. http://www.cequrcorp.com. Accessed on 11 Oct.2020
24. S. Yang, B. Gao, L. Jiang, J. Jin, Z. Gao, X. Ma, W.L. Woo, IoT structured long-term wearable social sensing for mental wellbeing. IEEE Internet Things J. **6**(2), 3652–3662 (2018)
25. R.R. Fletcher, S. Tam, O. Omojola, R. Redemske, J. Kwan, Wearable sensor platform and mobile application for use in cognitive behavioral therapy for drug addiction and PTSD, in *In 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, (IEEE, 2011, January), pp. 1802–1805
26. J.B. Wang, L.A. Cadmus-Bertram, L. Natarajan, M.M. White, H. Madanat, J.F. Nichols, et al., Wearable sensor/device (Fitbit one) and SMS text-messaging prompts to increase physical activity in overweight and obese adults: A randomized controlled trial. Telemedicine and e-Health **21**(10), 782–792 (2015a)
27. S. Seneviratne, Y. Hu, T. Nguyen, G. Lan, S. Khalifa, K. Thilakarathna, et al., A survey of wearable devices and challenges. IEEE Communications Surveys & Tutorials **19**(4), 2573–2620 (2017)
28. S. Bose, S.H. Low, Some emerging challenges in electricity markets, in *Smart Grid Control*, (Springer, Cham, 2019), pp. 29–45
29. Role of IoT in Smart Grid Technology. (2019). https://www.digiteum.com/iot-smart-grid-technology. Accessed on 11 Oct.2020
30. Q. Ou, Y. Zhen, X. Li, Y. Zhang, L. Zeng, Application of internet of things in smart grid power transmission, in *2012 Third FTRA International Conference on Mobile, Ubiquitous, and Intelligent Computing*, (IEEE, 2012, June), pp. 96–100
31. Y. Tian, Z. Pang, W. Wang, L. Liu, D. Wang, Substation sensing monitoring system based on power internet of things, in *2017 IEEE 2nd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC)*, (IEEE, 2017, December), pp. 1613–1617
32. H. Derhamy, *Architectural Design Principles for Industrial Internet of Things* (Doctoral dissertation, Luleå University of Technology, 2018)
33. S. Du, B. Liu, H. Ma, G. Wu, P. Wu, IIoT-based intelligent control and management system for motorcycle endurance test. IEEE Access **6**, 30567–30576 (2018)
34. F. Zhang, M. Liu, Z. Zhou, W. Shen, An IoT-based online monitoring system for continuous steel casting. IEEE Internet Things J. **3**(6), 1355–1363 (2016)
35. L.E. Redding, C.J. Hockley, R. Roy, J. Menhen, The role of maintenance, repair, and overhaul (MRO) knowledge in facilitating service led design: A nozzle guide vane case study, in *9th WCEAM Research Papers*, (Springer, Cham, 2015), pp. 379–395
36. Business guide to Industrial IoT. https://www.i-scoop.eu/internet-of-things-guide/industrial-internet-things-iiot-saving-costs-innovation/. Accessed on 11Oct 2020
37. F. Stradolini, A. Tuoheti, T. Kilic, S.L. Ntella, N. Tamburrano, Z. Huang, et al., An IoT solution for online monitoring of anesthetics in human serum based on an integrated fluidic bioelectronic system. IEEE Transactions on Biomedical Circuits and Systems **12**(5), 1056–1064 (2018)
38. S. Bian, B. Zhu, G. Rong, M. Sawan, Towards wearable and implantable continuous drug monitoring: A review. Journal of Pharmaceutical Analysis (2020)

39. D.C. Klonoff, Fog computing and edge computing architectures for processing data from diabetes devices connected to the medical internet of things. J. Diabetes Sci. Technol. **11**, 647–652 (2017)
40. F. Jabeen, S.R. Rupanagudi, V.G. Bhat, IoT based smart vehicle ignition and monitoring system, in *In 2019 International Conference on Advances in Computing, Communication and Control (ICAC3)*, (IEEE, 2019, December), pp. 1–7
41. B.G. Girish, A.D. Gowda, H. Amreen, Amit, K.M.A. Singh, IOT based security system for smart vehicle. International Research Journal of Engineering and Technology **05**(05) (2018, May)
42. More Drunk Driving Cases In `Dry' States Like Gujarat!. https://archive.indiaspend.com/viz-nomics/more-drunk-driving-cases-in-dry-states-like-gujarat. Accessed on 11 Oct. 2020
43. A.R. Chougule, K. Suganthi, IoT based smart car monitoring system, in *2018 Tenth International Conference on Advanced Computing (ICoAC)*, (IEEE, 2018, December), pp. 281–285
44. S. Nanda, H. Joshi, S. Khairnar, An IOT based smart system for accident prevention and detection, in *In 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA)*, (IEEE, 2018, August), pp. 1–6
45. K. Gupta, N. Rakesh, N. Faujdar, N. Gupta, D. Vaswani, K.S. Shivran, IoT-based smart car for safety of elderly people, in *Smart Systems and IoT: Innovations in Computing*, (Springer, Singapore, 2020), pp. 111–120
46. E. Pantano, H. Timmermans, What is smart for retailing? Procedia Environ. Sci. **22**, 101–107 (2014)
47. E. Pantano, C. Dennis, Smart Retailing (n.d.). https://doi.org/10.1007/978-3-030-12608-7_4
48. S.H. Kalange, D.A. Kadam, A.B. Mokal, A.A. Patil, Smart Retailing Using IOT. International Research Journal of Engineering and Technology **04**(11) (2017, Nov)
49. G. Singh, S. Srivastav, A. Gupta, V. Garg, Companies adoption of IoT for smart retailing in industry 4.0, in *In 2020 International Conference on Intelligent Engineering and Management (ICIEM)*, (IEEE, 2020, June), pp. 487–492
50. A.K. Tyagi, Building a smart and sustainable environment using internet of things, in *Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University Rajasthan, Jaipur-India*, (2019, February)
51. E. Pantano, C. Dennis, A smart retailing model, in *Smart Retailing*, (Palgrave Pivot, Cham, 2019). https://doi.org/10.1007/978-3-030-12608-7_4
52. A. Jayaram, Smart retail 4.0 IoT consumer retailer model for retail intelligence and strategic marketing of in-store products, in *Proceedings of the 17th International Business Horizon-INBUSH ERA-2017, Noida, India, 9*, (2017)
53. K. Butner, The smarter supply chain of the future. Strateg. Leadersh (2010)
54. Christopher, M. I. (2017). Logistics & Supply Chain Management
55. S. Chopra, P. Meindl, D.V. Kalra, *Supply Chain Management: Strategy, Planning, and Operation*, vol 232 (Pearson, Boston, MA, 2013)
56. N. Mostafa, W. Hamdy, H. Alawady, Impacts of internet of things on supply chains: A framework for warehousing. Soc. Sci. **8**(3), 84 (2019)
57. R. Angeles, RFID technologies: Supply-chain applications and implementation issues. Inf. Syst. Manag. **22**(1), 51–65 (2005)
58. Applications of IoT in Agriculture. https://www.biz4intellia.com/blog/5-applications-of-iot-in-agriculture/. Accessed on 11 Oct.2020
59. M. Dachyar, T.Y.M. Zagloel, L.R. Saragih, Knowledge growth and development: Internet of things (IoT) research, 2006–2018. Heliyon **5**(8), e02264 (2019)
60. N. Kaewmard, S. Saiyod, Sensor data collection and irrigation control on vegetable crop using smart phone and wireless sensor networks for smart farm, in *2014 IEEE Conference on Wireless Sensors (ICWiSE)*, (IEEE, 2014, October), pp. 106–112
61. D. Li, Y. Zheng, W. Zhao, Fault analysis system for agricultural machinery based on big data. IEEE Access **7**, 99136–99151 (2019)

62. P. Wang, R. Valerdi, S. Zhou, L. Li, Introduction: Advances in IoT research and applications. Inf. Syst. Front. **17**(2), 239–241 (2015b)
63. M. Mahbub, A smart farming concept based on smart embedded electronics, internet of things and wireless sensor network. Internet of Things **9**, 100161 (2020)
64. E.C. Ferrer, J. Rye, G. Brander, T. Savas, D. Chambers, H. England, C. Harper, Personal food computer: A new device for controlled-environment agriculture, in *Proceedings of the Future Technologies Conference*, (Springer, Cham, 2018, November), pp. 1077–1096
65. I. Charania, X. Li, Smart farming: Agriculture's shift from a labor intensive to technology native industry. Internet of Things **9**, 100142 (2020)
66. "How smart city technology & the Internet of Things will change our apartments, grids and communities" https://www.businessinsider.com/iot-smart-citytechnology?IR=T#:~:text=Smart%20cities%20use%20Internet%20of,utilities%20and%20services%2C%20and%20more. Accessed on 11 Oct.2020
67. S. Chatterjee, A.K. Kar, M.P. Gupta, Success of IoT in smart cities of India: An empirical analysis. Gov. Inf. Q. **35**(3), 349–361 (2018)
68. H. Arasteh, V. Hosseinnezhad, V. Loia, A. Tommasetti, O. Troisi, M. Shafie-khah, P. Siano, Iot-based smart cities: A survey, in *2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC)*, (IEEE, 2016, June), pp. 1–6
69. Z. Ji, I. Ganchev, M. O'Droma, L. Zhao, X. Zhang, A cloud-based car parking middleware for IoT-based smart cities: Design and implementation. Sensors **14**(12), 22372–22393 (2014)
70. V.P. Bilodeau, Intelligent Parking Technology Adoption (Doctoral dissertation, University of Southern Queensland) (2010)
71. T. Anagnostopoulos, A. Zaslavsky, K. Kolomvatsos, A. Medvedev, P. Amirian, J. Morley, S. Hadjieftymiades, Challenges and opportunities of waste management in IoT-enabled smart cities: A survey. IEEE Transactions on Sustainable Computing **2**(3), 275–289 (2017)
72. C. Tao, L. Xiang, Municipal solid waste recycle management information platform based on internet of things technology, in *2010 International Conference on Multimedia Information Networking and Security*, (IEEE, 2010, November), pp. 729–732
73. M.A. Hannan, M. Arebey, R.A. Begum, H. Basri, Radio frequency identification (RFID) and communication technologies for solid waste bin and truck monitoring system. Waste Manag. **31**(12), 2406–2413 (2011)
74. X. Ye, J. Huang, A framework for cloud-based smart home, in *Proceedings of 2011 International Conference on Computer Science and Network Technology*, vol. 2, (IEEE, 2011, December), pp. 894–897
75. L. Martirano, A smart lighting control to save energy, in *Proceedings of the 6th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems*, vol. 1, (IEEE, 2011, September), pp. 132–138
76. M.M. Rathore, A. Ahmad, A. Paul, S. Rho, Urban planning and building smart cities based on the internet of things using big data analytics. Comput. Netw. **101**, 63–80 (2016)
77. J. Bradley, J. Loucks, A. Noronha, J. Macaulay, L. Buckalew, Internet of everything (IoE). Survey Report (2013)
78. A. Vijayakrishna, G. Gopichand, M.D. Ansari, G. Suryanarayana, IOT based smart agriculture using LIFI, in *2022 5th International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT)*, (IEEE, 2022, November), pp. 1–7
79. Z.A. Jaaz, M.D. Ansari, P.S. JosephNg, H.M. Gheni, Optimization technique based on cluster head selection algorithm for 5G-enabled IoMT smart healthcare framework for industry. Paladyn, Journal of Behavioral Robotics **13**(1), 99–109 (2022)
80. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)

Artificial Intelligence and Machine Learning with IoT

Shailendra W. Shende, Jitendra V. Tembhurne, and Tapan Kumar Jain

1 Introduction

The Internet of Things is a blend of pervasive computing, including wired and wireless communication system, applications for sensors, actuators, and Internet-connected physical devices [29, 80]. It is a common term for smart interfaces with active communication technologies. If things connect and have smart interfaces, then they can have novel functionality outside their specific latest solutions [6]. With the growth of IoT, applications have grown smarter and interconnected devices are being used in all areas of various applications. Because the amount of data generated grows, ML approaches can be used to further improve the intelligence and effectiveness of applications [30].

S. W. Shende
Department of Computer Science & Engineering, Indian Institute of Information Technology, Nagpur, India

Department of Information Technology, Yeshwantrao Chavan College of Engineering, Nagpur, India

J. V. Tembhurne
Department of Computer Science & Engineering, Indian Institute of Information Technology, Nagpur, India
e-mail: jtembhurne@iiitn.ac.in

T. K. Jain (✉)
Department of Electronics & Communication Engineering, Indian Institute of Information Technology, Nagpur, India
e-mail: tapan.jain@iiitn.ac.in

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_10

1.1 Artificial Intelligence, Machine Learning, and Deep Learning

Firstly, when we discuss AI, what we are talking about must be clearly defined. Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are terms that are used interchangeably. What is their relationship? The relation between AI, ML, and DL is depicted in Fig. 1.

1.2 Artificial Intelligence

The term AI was coined in the 1950s by a group of pioneers in the field of computer science who wondered if computers could be programmed to "think" – an issue whose implications we are still discovering. A concise definition of AI is "the attempt to automate the intellectual tasks that humans normally perform." As a result, AI is a broad term that encompasses machine learning and deep learning, as well as a variety of other approaches that do not involve any learning at all. Early AI studies in the 1950s addressed issues such as symbolic processes and problem-solving methods. The US Department of Defense got interested in this type of work in the 1960s, and began teaching computers to mimic common human thinking.

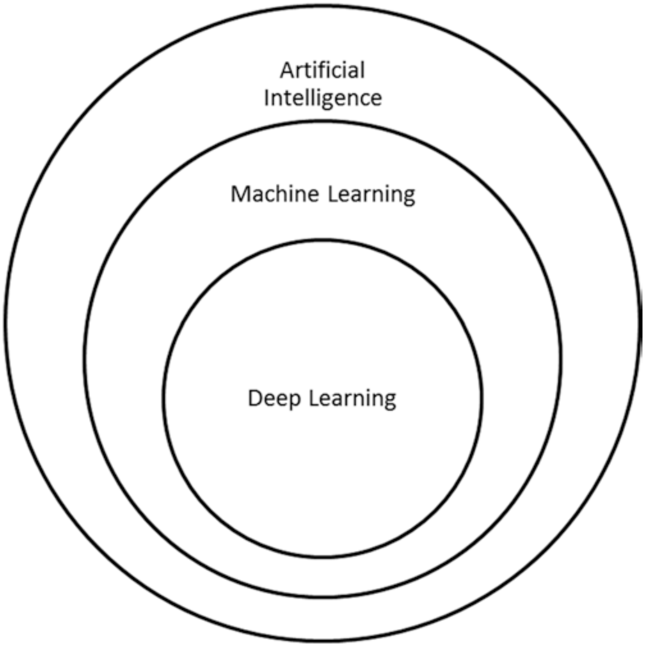


Fig. 1 Relationship between AI, ML, and DL

Long before Siri, Alexa, or Cortana became household names, the Defense Advanced Research Projects Agency (DARPA) conducted street mapping projects in the 1970s, and DARPA developed intelligent personal assistants in 2003. Automation and formal thinking, such as decision support systems (DSS) and intelligent detection systems, were paved by this early work that complement and increase human skills that we see on today's computers. Because of higher data volumes, complex algorithms, and advances in computational power and storage, AI has become more common in recent years.

1.3 What Are the Problems Involved Using AI?

The key restriction of AI is that it learns only from observations and input data, and there is no any alternative to it. That means if there is some error or inaccuracies in the input data, the same would be returned in the final outcomes. Modern AI technologies are prepared to take on a specific mission, i.e., the machine that plays chess is not capable of playing Go game or solitaire and the machine that are capable to discovers fraud cannot drive a vehicle or provide you with legitimate advice. In fact, AI applications that detect fraud in healthcare can't tell the difference between tax fraud and security claims. To put it another way, these systems are highly advanced and dedicated in nature. They are singularly concentrated on a single goal and do not behave in a human manner. Moreover, Self-learning systems are not always autonomous.

1.4 Machine Learning

ML emerges from the question: Is it possible for a machine to go above and beyond? "*What we are able to command it to do*" and learn to carry out a specific activity on its own? Is it possible for the machine to surprise us? Can a computer automatically learn data-processing rules instead of programmers hand-crafting them? This question paves the way for a new programming paradigm. In traditional programming, the input rules (a program) and data to be processed according to these rules are used as input to generate output responses and the same is presented in Fig. 2. With ML, humans input data, the predicted data responses, and the rules come out. To generate original responses, these rules can then be applied to the new data.

For more than a century, traditional computer programming has existed, with the first documented computer program dates from the mid-nineteenth century. Any manually created program that uses input as a raw data and generates output as meaningful information on a computer is referred to as traditional programming. Advanced programming, on the other hand, has transformed industry for decades,

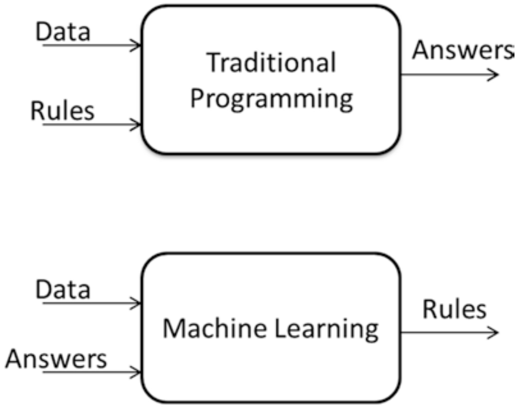


Fig. 2 Traditional and machine learning programming paradigm

especially in the context of intelligence and integrated analytics. To construct a program, the input data and the corresponding output are fed into a machine learning algorithm. This yields useful findings that can be used to predict future outcomes [2, 7].

In this part, we compare traditional programming to machine learning in greater detail. In traditional programming, the software is generated by an individual (or programmer). In this case, one must manually implement or code rules with some programming logic. We have the raw input data, and a set of instructions in the form of a program that uses that raw data and runs on a computer to generate the meaningful information as an output. Whereas, ML feeds the raw input data and the corresponding output to an algorithm to build a program or rules, which is very efficient. This is the main distinction between ML and traditional programming. Examples of ML includes: (1) the algorithm will formulate the software if you cater to the demographics of your target market, and (2) input transactions and observed output if they were previously churned or not, which will know how to predict whether anyone will churn or not.

1.5 Deep Learning

A particular subfield of ML is deep learning: a modern approach to the learning of data representations, which highlights the learning of successive gradually significant representations. The profound in-depth learning does not refer to the deeper understanding of a certain approach, but rather to the principle of following layers of representations. The depth of a model is determined by how many layers it contains. Layered representations of learning and hierarchical representations of learning may have been other suitable names for the field. In modern deep learning, hundreds or even more number of layers of representations can be stacked on top of one another, which will learn by their own from exposure to the training data.

2 Taxonomy of ML Algorithms

The objective of ML techniques is to teach computers without the need of human intervention to execute tasks. Typically, existing ML techniques are known as either supervised, unsupervised, or reinforcement learning as illustrated in Fig. 3.

Recently, AI techniques have greatly aided in the advancement of ML techniques. This chapter therefore includes fuzzy logic, evolutionary computation apart from the following ML strategies such as supervised learning, unsupervised learning, and reinforcement learning. Furthermore, in the sense of IoT, they have the most up-to-date algorithms. We briefly overview the various ML approaches.

2.1 Supervised Learning

In supervised learning, the input data is referred to as training data because it has a known label, such as approved/not approved or price of a house. In this learning, we have input variables (m) and an output variable (z). Supervised learning attempts to find a relationship or mapping function $f: m \rightarrow z$ using a training set {m, z}. The objective is to estimate the mapping function so very well, where we can forecast the output variables (z) for that data when we have new input data (m). It is called supervised learning since it is possible to consider the process of algorithm learning from the training dataset as a teacher guiding the learning process [51]. The algorithm models the training data iteratively and is updated by the teacher and here we know the correct answers. Learning stops when an appropriate output level is reached by the algorithm. The main supervised learning algorithms are illustrated in this section.

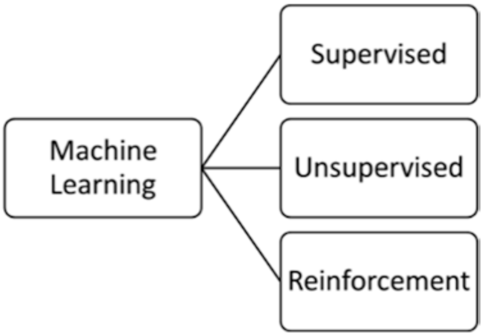


Fig. 3 Taxonomy of machine learning algorithms

2.1.1 k-Nearest Neighbors (k-NN)

In k-NN, the nearest k data points in the input training set or feature space are examined, and the goal is to identify a new given unseen data point that belongs to which class. As a result, in an attempt to locate the k-closest neighbors to the new unseen data point, we need to use different distance metrics such as Euclidean distance, Mahalanobis distance, Chi square, or Minkowsky.

Let m denote the new input data point, $N_k(m)$ denote its nearest k neighbors, l denote the expected class label for , and the class variable as a discreet random variable r. Furthermore, $L(.)$ denotes the indicator function: $L(s) = 1$ if s is true and $L(s) = 0$ otherwise. The form of the classification task is

$$p\left(r = c|,m|,k\right) = \frac{1}{k}\sum_{i \in N_k(m)} 1\left(r_i = c\right) \tag{1}$$

$$y = \arg_c \max_p \left(r = c|m,k\right) \tag{2}$$

i.e., the labels of its neighbors will be used to mark the input data point m [84].

In the context of IoT, k-NN is applied in indoor localization [3] wherein hardware platform is implemented using room impulse response for the localization of a low accuracy microphone, fault detection [52], and data aggregation approaches [53].

2.1.2 Naïve Bayes

In statistics, it is a classification technique based on applying Bayes' Theorem, assuming strong independence between features. A Naïve Bayes classifier, to put it simply, assumes that the existence of one feature in a class has no bearing on the occurrence of another feature. For instance, a fruit might be a mango if it is considered to be yellow in color, oval in shape, and measures about 4 inches in diameter. Even though these characteristics are dependent on one another or on the presence of several other characteristics, they all contribute to the probability that this fruit is a mango, which is why it is called "Naïve". In order to construct the problem, consider a vector $x = (x_1, \ldots, x_m)$, representing m features, a problem instance to be classified. Naïve Bayes classifiers classify x depending on applying Bayes' theorem with the "naive" implication of distinction among the feature values of x given the class variable z.

By using the Bayes' theorem, we have

$$p\left(z = c|x_1,\ldots,x_m\right) = \frac{\left(x_1,\ldots,x_m|z = c\right)p\left(z = c\right)}{p\left(x_1,\ldots,x_m\right)} \tag{3}$$

And by adding naïve distinction assumptions and certain generalizations, we have

$$p\left(z=c|x_1,\ldots,x_m\right) \propto \mathrm{p}\left(z=c\right)\prod_{i=1}^{\mathrm{M}} p\left(x_i|z=c\right) \tag{4}$$

Therefore, the classification task form is

$$y=\arg_c \max p\left(z=c\right)\prod_{i=1}^{\mathrm{M}} p\left(x_i|z=c\right) \tag{5}$$

where y stands for the expected class label for x. Distinct naive Bayes classifiers employ various methods and distributions for estimation $p(z = c)$ and $p(x_i| z = c)$ [85]. Although a minimal number of observations are needed to train a Nave Bayes classifier, it can handle a high-dimensional data space [31]. It is also a common model for application areas like, spam filtering [32], text classification, and automated medical diagnosis [33]. Naïve Bayes is adopted in IoT for the task of fault detection [52], cluster head selection [54], and localization [55–57] approaches. It is also useful in agriculture application for prediction of frost events [21].

2.1.3 Support Vector Machines (SVMs)

Classical SVMs are deterministic, binary classification algorithms built to locate a hyper-plane dividing the maximum margin range between any two training classes. The predicted classification of a different and unknown dataset is then calculated on the basis of which half of the hyper-plane it appears [34]. The purpose of the SVM is to find a hyper-plane in an N-dimensional space that separately classifies the data points. There are several possible hyper-planes that could be selected to distinguish the two classes of data points. The target is to find a plane that has the maximum margin, i.e., the maximum distance between the two classes' data points. Maximizing the gap from the margin offers some support so that further confidence can be classified in future data points.

Let v the normal vector of the hyperplane, and d the factor to adjust the deviation of the hyperplane. In addition, to ensure the SVMs can accommodate data outliers, for training point z_i, we use the variable ξ_i, also known as the "slack variable," which represents the distance by which this training point exceeds the margin in units of $|v|$. A bound optimization model is used to describe this binary linear classification task in the following form

$$\mathrm{f}(^{minimize}_{v,d,\xi}\, v,d,\xi)=\frac{1}{2}v^{\mathrm{T}}v+\mathrm{M}\sum_{i=1}^{1}\xi_{\mathrm{i}} \tag{6}$$

Subject to $z_i(v^T v_i + d) - 1 + \xi_i \geq 0; i = 1, \ldots. l$

$$\xi_i \geq 0; i = 1, \ldots. l$$

where the factor M > 0 indicates the severity of the penalty for a violation [34].

In various domains of IoT, the SVM is applied [4–6, 19, 58, 59] for the purpose of classification. In [4], SVM is adopted to improve the IoT Security System of Smart Home. Moreover, network slicing to tackle load balancing problems within a multi-tenant network system in IoT is handled by SVM [5]. Malware Detection for Reliable IoT services by applying SVM is investigated in [6]. Additionally, the number of security issues and the detection of malicious activity in IoT and wireless sensor networks (WSNs) can be handled with the help of localization [58, 59].

2.1.4 Logistic Regression (LR)

LR is a kind of regression analysis utilized in order to identify the relation of a dependent variable and one or more independent variables. LR shall be valid when binary variables are used for the dependent variable. As this is a regression analysis, it is reasonable to use logistic regression for the prediction tasks in ML [30]. Logistic Regression is applied for classification in prediction of frost events [21] in IoT ecosystem.

2.1.5 Decision Trees (DTs)

DTs are constructs that work with the classification problem and are therefore a decision process with many potential consequences. There are multiple nodes in a top down decision tree where each node may be a class or decision that moves a test item to a class. It's an easy alternative to classification problems. A new sub-process for classification takes place on each decision tree stage, splitting the main task into smaller sub-tasks [36]. The Random Forest (RF) algorithm is developed to improve the accuracy of decision trees. RF is an ensemble decision tree technique, which works by building multiple classifiers wherein each classifier is a tree for decisions.

An illustration of a decision tree is given in Fig. 4. Assume we want to identify whether a person is fit or not based on their age, dietary practices, regular exercise, and other factors. The decision nodes in this case are questions such as "How old he/she is?", "Does he/she work out??", "Is he/she a burger or pizza lover?", and the terminal nodes, resulting in status as either 'fit' or 'unfit' effects. DTs mostly deal with the binary classification problems.

There are numerous algorithms for creating decision trees, but the Iterative Dichotomiser 3 (ID3) Algorithm is one of the most efficient. The following is how it applies the concepts of entropy and information gain:

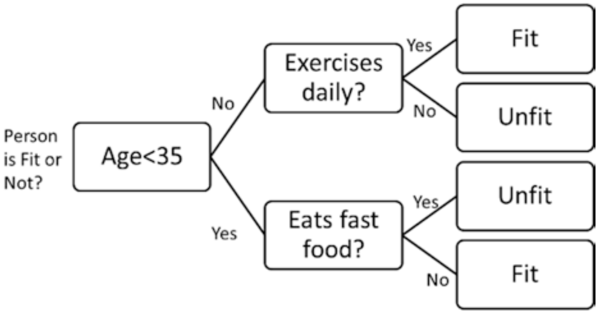


Fig. 4 An example of decision tree

Entropy is the measure of the amount of uncertainty or randomness in data and is denoted by H(S) for a finite set S.

$$H(S) = \sum_{x \in X} p(x) \log_2 \frac{1}{p(x)} \tag{7}$$

It shows intuitively how predictable a particular event is, e.g., consider a toss of a coin whose probability of both heads and tails is 0.5. Here, the entropy is as high as it can be, because there's no way of knowing what the outcome will be. Conversely, given a coin that has tails on both sides, it is entirely possible to estimate the entropy of such a case when we know in advance that it will be tails. To put it another way, there is no randomness in this case, because its entropy is 0. Lower values, in particular, denote less uncertainty, while higher values denote a high level of uncertainty.

The successful entropy change after agreeing on a specific attribute *Z* is denoted by IGain(*S*, *Z*) for a set *S*. It's the difference in entropy between the independent variables.

$$\text{IGain}(S,Z) = H(S) - H(S,Z)$$

Alternatively,

$$\text{IGain}(S,Z) = H(S) - \sum_{i=0}^{n} P(x) * H(x) \tag{8}$$

IGain(*S*, *Z*) denotes the information gain by employing feature vector *Z*. The first term, *H*(*S*), is the Entropy of the entire set *S*, while the second term calculates the Entropy after employing the feature vector *Z*, where *P*(*x*) is the probability of event *x*.

Decision tree can be applied in IoT for intrusion detection [60] and prediction of traffic congestion [35].

2.1.6 Linear Regression

Linear regression seeks to model the correlation between two variables by a adapting a linear equation to the observed data. Applying a linear regression to the system will reveal the association among the target variable and the predictor variables. The data will be modeled to match a straight line in linear regression. For example, a random variable, y (called a response variable), may be modeled as a linear function of another random variable, x (called a predictor variable), using an equation.

$$y = mx + b \tag{9}$$

Here, the parameters m and b define the line's slope and y-intercept, respectively. The technique of least squares, which minimizes the difference between the actual line separating the data and the approximation of the line, can be used to solve for these parameters. A variety of methods exist for model training: Bayesian Linear Regression (BLR), Ordinary Least Square (OLS), Least-Mean-Squares (LMS), and Regularized Least Squares (RLS). Among these, LMS is the fastest, scalable to big datasets, and by the technique of stochastic gradient descent, it learns the settings online [37, 38]. By using acceptable basic functions, it can be seen that by mapping the input vector to the output vector, it is able to represent arbitrary nonlinearities. Fixed base theory functions, however, leads to major flaws in this approach. Rising the size of the source space, for example, is correlated with significant increase in the number of base functions [37, 39, 40].

The application of Linear Regression in the IoT ecosystem is identified in [25, 41]. In [25], linear regression is employed to handle data imputation for restoring missing values in real-time streaming of data from the Internet of Things. As linear regression can process data quickly [41], it can be used to measure and forecast the electrical consumption of houses.

2.1.7 Support Vector Regression

A method named Support Vector Regression (SVR) is an extension of SVM model discussed in Sect. 2.1.3 to address regression problems. The underlying SVR model relies only on a few testing areas to sustain vectors in SVMs, because testing points near the model estimation are not approximated [81].

On the basis of a training set, the aim of regression is to discover a function that resembles the mapping from an input domain to real numbers. As illustrated in Fig. 5, decision boundary is represented by two parallel thin lines and the middle thick line represents the hyperplane. When we move forward with SVR, the aim is to essentially include the points that are inside the decision boundary line. The hyperplane with the most points is the best fit line. Consider the decision boundaries, i.e., thin lines to be at any distance, say '*d*', from the hyperplane. So, at a distance of '+*d*' and '-*d*' from the hyperplane, we draw these lines.

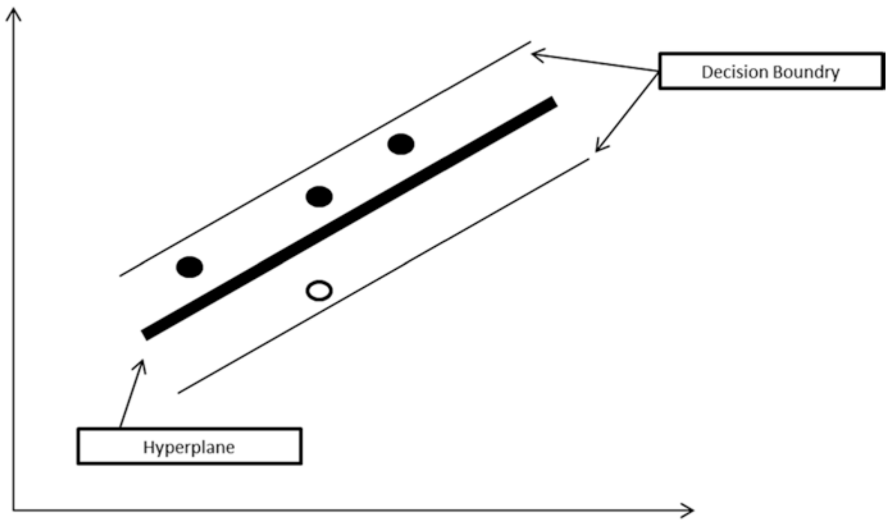


Fig. 5 An idea of SVR

Assume the hyperplane has the following equation:

$$Y = mx + c \tag{10}$$

The decision boundary equations are then as follows:

$$mx + c = +d \tag{11}$$

$$mx + c = -d \tag{12}$$

As a result, every hyperplane that satisfies our SVR must fulfill the following conditions:

$$-d < Y - mx + c < +d \tag{13}$$

There are several SVR implementation schemes, such as epsilon-SVR and nu-SVR [82], and the application of SVR in IoT [83] is to acquire precise temperature and relative humidity data forecasts.

2.2 *Unsupervised Learning*

In comparison to supervised learning, this learning algorithm does not need test data to be labeled. The objectives of this form of learning is to recognize unknown trends of corresponding samples in input data to form the groups of similar data points or predict future values. This technique is commonly used in product recommendation

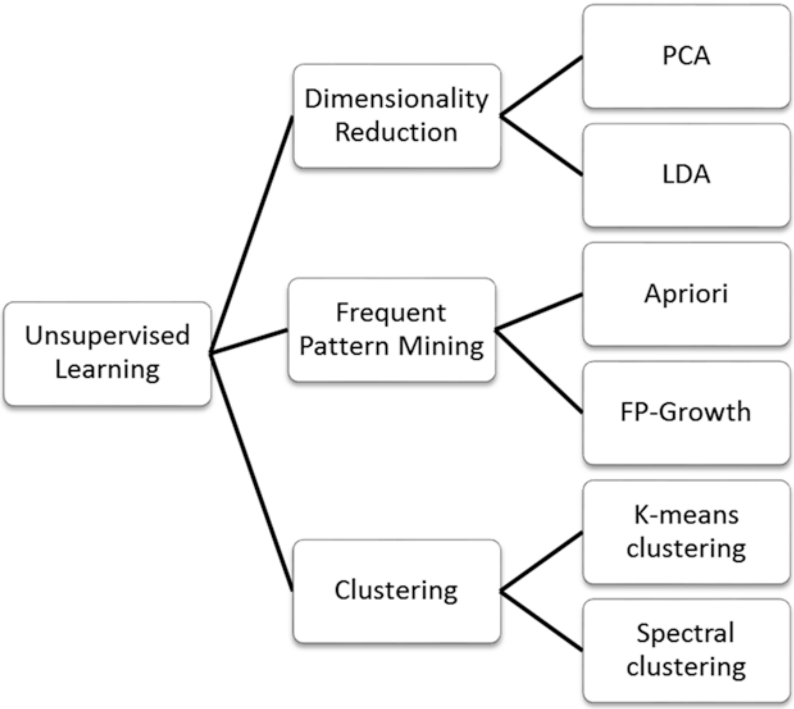


Fig. 6 Taxonomy of unsupervised algorithms

systems, consumer segmentation, and targeted marketing campaign. Moreover, it also addresses issues involving dimensionality reduction used for big data representation and feature extraction [42, 43]. The taxonomy of unsupervised learning is shown in Fig. 6.

2.2.1 Dimensionality Reduction

Techniques for reducing the number of input variables in training data are referred to as dimensionality reduction techniques. When working with high-dimensional data, it is often beneficial to minimize the dimensionality by projecting the data to a lower-dimensional subspace that captures the important features of the data.

When making a prediction for the final model, any reduction in dimensionality of training data, for example test data or validation datasets, also needs to be made to new data [55].

In Fig. 7, two dimensions are shown, $x1$ and $x2$, which are the measurements in cm ($x1$) and inches ($x2$) for some objects. Now, in machine learning, if we were to use all of these dimensions, they will transmit identical knowledge and add a lot of noise, so it's easier to use only one dimension. We have transformed the 2D (from

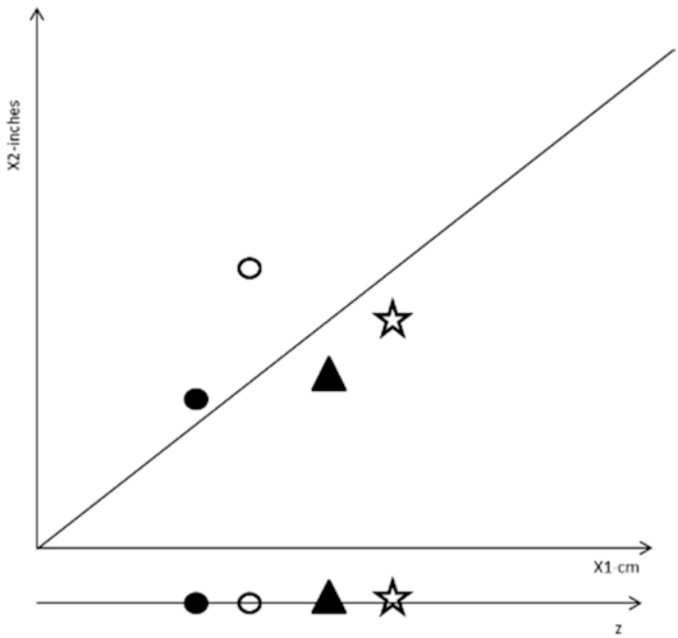


Fig. 7 Dimensionality reduction

$x1$ and $x2$) to 1D (z) data dimension here, which has made the data relatively easy to understand. For dimensionality reduction, there are several algorithms; here, we discuss the two main algorithms.

Principal Component Analysis (PCA) It is a dimensionality reduction technique used as one of the preprocessing techniques in ML. PCA is motivated by the orthogonal projection theorem wherein data points are mapped into the L linear dimension subspace, called the main subspace, having the greatest number of anticipated discrepancies [45].

Likewise, the goal is being viewed as finding an entirely orthonormal group of L linear M -dimensional base vectors $\{w_j\}$, and the corresponding linear data point projections $\{z_{nj}\}$ are designed in such a way that the mean reconstruction error is reduced, where x denotes the average of all data points [17, 44]. We identify the application of PCA in IoT in the reduction of data dimensionality at either the level of the sensor or the cluster head, which is used in Structural Health Monitoring on Low-Cost IoT Gateways [8], and reduction in the communication overhead [71]. It is also used to aggregate the redundant data [70] and detect the outliers and IoT network traffic anomaly [9, 10].

$$J = \frac{1}{N}\sum_{n}\left(\overline{X_n}\right)-\left(X_n\right)^2 \tag{14}$$

$$X_n = \sum_{j=1}^{L} Z_{nj} W_j + \overline{X} \tag{15}$$

Linear Discriminant Analysis (LDA) LDA is a dimensionality reduction approach that is commonly used to solve supervised classification problems. It is being used to transform higher-dimensional feature space into a lower-dimensional feature space, which can be used to represent group distinctions, such as separating two or more classes. For example, if we have two sets, and we are interested in separating them. These sets may have different characteristics. Just using one feature to classify them will result in some overlapping. So, for proper classification, we can keep increasing the number of features [72]. LDA is applied in IoT [13] wherein dimensionality reduction is performed for intrusion detection.

2.2.2 Frequent Pattern Mining

Frequent pattern mining is used to find the association among the item-sets, frequent patterns, i.e., subsets, subsequences, or substructures in datasets with certain frequency of occurrences.

Apriori The idea of association rule mining was first suggested in order to identify frequently purchased classes of items. The problem of learning association rules [73] is described as follows:

Consider $T = \{t_1, t_2, \ldots, t_n\}$ denotes a database, which consists of set of n-transactions and $I = \{i_1, i_2, \ldots, i_m\}$ denotes the universal set of all m-items present in the database. A unique identification will be assigned to each and every transaction in T, denoted by *id*, and it contains a subset of the items in I. The fraction of transactions with in dataset that contain the item set is known as the support *sup(A)* of a set of item A. Only those patterns $P \subset I$ that appear across at least a subset S of the transactions are to be determined by frequent pattern mining. This fraction S is called as minimum support, which can be defined either as an absolute number or a percentage of total transactions in the database. An association rule is established as:

$$a \to b, \text{for } a, by \subseteq I, a \cap b = \varnothing \tag{16}$$

Here the item set '*a*' is called as antecedent and '*b*' is called as consequent of the association rule. The conditional likelihood, $P(b|a)$, is used to express the confidence of an association rule, which is expressed as

$$\text{conf}\left(a \Rightarrow b\right) = supp\left(a \cup b\right) / \, supp\left(a\right) \tag{17}$$

Rules that meet both the minimal threshold for *minimum support (S) and confidence (C)* are deemed strong in order to select among the set of all possible interesting rules. In general, the learning of association rules can be carried out using the following phases:

1. *Finding Frequent item-sets*: Every item-set will meet the minimum support requirement, i.e., it happens as often as minimum support *S*.
2. *Generation of strong association rules:* All the frequent item-sets found in phase-1 are used to derive the association rules provided it must satisfy a minimum confidence constraint.

In [46], Apriori algorithm is applied in IoT for predictive analytics and maintenance of numerous smart home appliances including air cooling, water filters, ventilation, etc.

FP-Growth Initial step in the learning of the association rule involves looking for all possible combinations of items in a power set, as the quantity of items increases the size of this set grows at an exponential rate. The so-called Apriori property is the secret to a successful search algorithm: "All nonempty subsets of a frequent item set must be frequent as well". Thus, all of its supersets must also be infrequent for an infrequent item collection. The frequent pattern creation (FP-growth) algorithm is among the quickest and most popular algorithm for finding frequent item sets [61–63]. It is based on a prefix tree's representation of the specified datasets. Using a prefix tree data structure called FPtree, it can save a significant amount of memory when storing transactions. The FP-growth algorithm is built around a recursive elimination mechanism. It is stated as follows:

1. Initially, find all the set of frequent items and their support counts. Discard those items in the transactions that do not comply with the minimum support count, in a header table.
2. Store all frequent items in the list in descending order of frequency, called Frequent-list (F-list).
3. Sort the frequent items in transaction according to the items listed in F-list.
4. Construct the FP-tree by introducing instances into a tree with an 'empty' root node. To speed up FP-tree processing, items in every transaction are arranged in the same sequence as in the F-list. A list is used to index all nodes relating to the same object, making it possible to display and count all transactions involving the item by traversing the list.
5. Unlike Apriori algorithm, candidate items generation and checking them against the entire dataset, recursive mining of the FP-tree will directly expand large item sets. From F-list, it constructs the dependent item base with length-1-pattern that combines a variety of prefix paths in the FP-tree co-occurring with the suffix item. The result is a conditional FP-tree, including sums derived from original tree relative to the subset of features that are dependent on the feature, and each node counting the number of its children.
6. Recursive growth stops when the minimum support threshold is not reached by any specific items conditional on the attribute, and the remaining header items of the original FP-tree continue to be processed.

7. All item sets that satisfy the minimum support criteria are selected to generate the association rules, at the end of the recursive process.

In [47], FP-Growth is adopted in IoT system to figure out the patterns of IoT malware attempts from the data stream. By looking for patterns about operation types, sender's and receiver's port address, and size of TCP window, it is helpful to identify the behaviors of malware attacks.

2.2.3 Clustering

Clustering is an unsupervised approach for classifying components according to similarity or uncovered patterns in discrete groups [11, 48]. Clustering involves no identified labels to develop a model in contrast to the methods of classification.

k-means Clustering The goal of the *k*-means algorithm is to classify unlabeled data among *k* clusters (groups) where there must be some similarities in the data points of the same cluster. Disparity among the data points in the similarity of match is observed in classical *k*-means algorithm. *k*-means try to identify a set of cluster seed points, defined as $\{s_1, ..., s_k\}$, in order to minimize distances among data points and their closest centers [49]. The *k*-means is applied in IoT systems for localization, network sub-slicing, location privacy, and detection of the presence of multimedia traffic [3, 5, 12, 23, 27]. Network slicing is a basic technology used to solve load balancing problems in multi-tenant network systems. In [5], it is applied to form groups of certain services such as application-based, platform-based, and infrastructure-based services. The protection of location privacy in WSNs for IoT is investigated in [23]. A dummy sender and receiver nodes are used to protect the location of the real sender and the real receiver. The use of a k-means cluster can then be used to increase the routing path and thus the safety time.

Spectral Clustering (SC) Mainly, clustering is utilized to group all spectrums of unorganized data points into multiple groups based on their uniqueness. Spectral clustering is the common style of multivariate statistical analysis. Spectral clustering uses a clustering connectivity approach where node communities (i.e., data points) that are linked or directly next to each other are described in a graph. The mapping of nodes are performed corresponding to a low-dimensional space, which is effortlessly separated to construct the clusters. SC utilizes the knowledge from the eigenvalues (spectrum) of the special matrices (i.e., Affinity Matrix, Degree Matrix, and Laplacian Matrix) extracted from the graph or dataset. Spectral clustering methods are attractive, simple to implement, and relatively fast, particularly for the limited dataset up to a few thousand. SC handles data clustering in the form of graph partitioning without taking the form of data clusters' Expectation Maximization [24, 74].

How to apply SC in IoT is demonstrated in [16, 50, 75, 76]. In [16], spectral clustering is employed to optimize overlap degree related to user requests, and hence, resource utilization is improved in edge computing. Moreover, spectral clustering is applied to diminish the disparity degree between every two classes in wireless sensor network for the intrusion detection, which is presented in [50]. In [75], disconnected segments are detected in sensor network affected by the depletion of power battery or any physical tempering performed on the nodes. In contrary, SC is adopted in the detection and elimination of sensor nodes, which misbehave in IoT ecosystem [76].

2.3 Reinforcement Learning

Reinforcement learning (RL) is utilized as a technique amid supervised learning and unsupervised learning. It is neither supervised, since it doesn't depend solely on the collection of labeled data, nor unsupervised learning, since the reward are optimized by the agent. The agent require to identify "*right*" actions to be performed in various circumstances in order to achieve its ultimate objective [51]. Moreover, the aforementioned style of learning is practiced in Artificial Neural Networks (ANN) and Deep Learning (DL). Primarily, RL is useful in applications such as AI-based gaming, gaining skills, direction-finding using robot, and decision making in the real-time scenarios. For instance, in [14], RL algorithm is adopted for building autonomous IoT (AIoT). Further, RL is utilized in IoT systems to design routing protocols, and network performance is improved in WSNs along with reduction in energy consumption, which is witnessed by applying RL technique [64].

2.4 Artificial Neural Networks

ANN is described as a composition of neural network and process of learning at the time of handling the problem. In neural network, we have weighted connections between neurons, which is shown in Fig. 8. In neural network, an input layer takes the input variables to process in the network. Every neuron consists of variable values at the time of computation. The output layer comprises labels, which will be match for the processed input. There are some hidden layers between these layers, i.e., input and output layers.

Although ANNs offer solutions to complex as well as non-linear problems, the complexity lies in the computations performed in neural network. ANNs can be easily applied in IoT domain, and related work is presented in [1, 65–68]. In [1], a kind of ANN Reinforcement Neural Network (RNN) is modeled for track forecasting and routing. Eventually, ANN is developed to improve the efficiency of IoT localization [65, 66]. Detecting faulty nodes [67] and establishing routing in IoT system [68] are also proposed. Notice that since neural networks are compact models, they

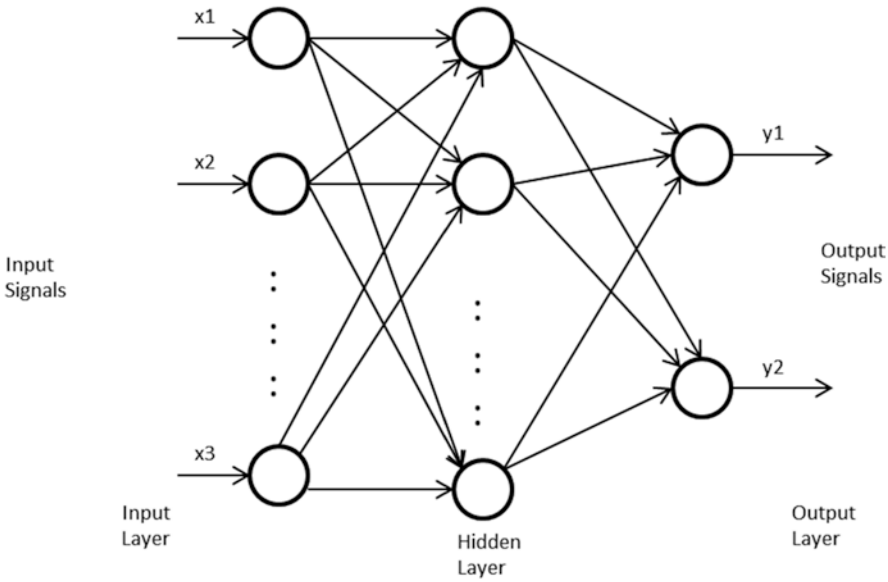


Fig. 8 Neural network architecture

are quick to process new data. However, in contrary, they usually need significant computation time for training the model. In addition, they are readily adaptable to the problems of classification and regression.

2.5 Fuzzy Logic

Traditionally, ML methods are utilized to work on binary values, i.e., 1 (True) or 0 (False). Fuzzy Logic (FL) comprises the type of reasoning wherein we can mimic human thinking; moreover, FL also mimics the human decision-making process, which includes the possibilities, i.e., 1 or 0. Fuzzy Logic is incorporating the idea of the degree of truth, i.e., the real value closer to 1 (value between 0 and 1) [69]. Exploitation of FL in IoT for various domains is designed and implemented in [18, 20, 22, 28, 69]. In [69], FL is applied to offer solution to localization wherein various issues are addressed such as residual energy of node, distance between data-sink nodes to elect the prominent cluster heads, and centrality. In [18], fuzzy logic along with reinforcement learning is applied to identify high reliable route in IoT. In [20], genetic algorithm and FL are adopted in opportunistic networks, which is based on IoT devices wherein the problem is resolved to select and place the IoT devices in underline network. In [22], neural network and FL are synthesized to equalizer – (1) optimal cluster heads selection and (2) uniform load distribution among the sensors. Further, navigation system is designed under smart home for blind person to be assisted in day-to-day activities using FL, which is presented in [28].

2.6 *Evolutionary Computation*

Contrary to other ML methods, evolutionary computation methods solve problems by applying computational models, which emulate humans or animals' biological actions in underlying problem.

2.6.1 Genetic Algorithms

Genetic algorithms (GAs), which belong to a large proportion of evolutionary algorithms, are adaptive heuristic search algorithms. Genetic algorithms remain derived from natural selection and genetics principles. The use of random searches, delivered with historical knowledge and guiding the search for better performing region under solution space, is intelligent. GA is also applied for high-quality solutions for search and optimization issues.

The process of natural selection is simulated by genetic algorithms, which ensures that those individuals changing in the environment can survive, reproduce, and pass on to the next generation. Thus, the "*survival of the fittest*" is observed among the individual in the successive generation to solve the problem. Moreover, population is preserved for an individual in the search space. Here, each entity represents a solution obtained for the problem in the search space and represented in the form of vector with finite length (i.e., chromosome) of the components. The aforementioned components are similar to the genes used. Accordingly, an individual chromosome is composed of many genes, i.e., variable components.

In [15, 20], genetic algorithm is developed for IoT application where it is found to be suitable to perform the tasks such as data aggregation and optimal clusters search. In [15], genetic algorithms are developed to build a decision fusion technique based on soft computing to find the optimal coefficient vector from sensing reports, which is collected from various secondary users to provide higher detection and lower probabilities of error and false alarm, in the context of malicious users and nodes.

2.6.2 Ant Colony Optimization

Ant Colony Optimization (ACO) is a meta-heuristic technique based on the population. ACO is generally applied on the complex optimization problems to determine the approximate solutions. In the search of suitable solution for underline optimization problem, a set of artificial ants (software agent) in ACO is utilized. Hence, optimization problem becomes optimal path finding problem in a weighted graph in order to apply ACO. The agents incrementally construct solutions from the graph by making certain movements. The solution construction process is stochastic as well as biased under pheromone model, i.e., the associated parameters with the components of the graph wherein parameter values are changed by ants at runtime [77].

Mostly, in IoT applications, the data sensed by the sensory devices are collected, and to perform further operations on the data, it is directed to the specialized nodes, namely, *manager*. To do so, trustworthy routing protocols are utilized, which faces two targets, i.e. – (1) improving data transmission as well as scalability and (2) minimizing energy consumption. These targets are the main challenges in WSNs and also considered vital issues in the IoT ecosystem. Both of this issues addressed to find efficient routing is presented in [26, 86, 87].

2.6.3 Particle Swarm Optimization

Particle swarm optimization (PSO) is a stochastic optimization strategy based on the population. It is influenced from the flocking birds or schooling fish based on their social behavior. The algorithm begins with a random pool of solutions consisting particles. Fitness function is employed to measure a fitness value of the particle that is optimized for each generation [78]. In PSO, particles obtained the potential solutions, and this is accomplished by traversing in problem space and following an optimum particle that leads to determining the global optimal solution.

In this paper [79], the PSO-based implementation used for path planning of WSNs and performance improvement for IoT clustering is useful, wherein the virtual clustering is applied at the time of routing to offer less energy consumption, prolonged lifetime of network, and reduction in transmission delay.

3 Conclusions

The IoT model has been an important part of our everyday lives. Nevertheless, the peculiar existence of IoT systems leaves one no alternative but to overcome their problems and shortcomings by adequate tools and specialized techniques. The requirement for machine learning approaches emerges from supervised-, unsupervised-, augmented learning, and fuzzy logic or evolutionary computing. These strategies provide various solutions to most of the problems. In this chapter, we have discussed the various machine learning techniques and applications of ML in IoT for solving a various problems such as data aggregation, data imputation, routing, node localization, network slicing, cluster formation, etc. In addition, we addressed the role of ML in protection, resource management, congestion control, and fault detection to improve the performance. Thus, we propose the use of supervised learning for performance-hungry problems (e.g., classification and forecast). Here, SVM and linear regression are the most suitable techniques for the aforementioned learning algorithm. However, for solving basic IoT operations, Evolutionary algorithms are more suitable. Fuzzy structures are capable of addressing uncertainties, hence adopted in IoT ecosystem for node localization and routing. IoT systems consist of heterogeneous computing devices, therefore, it is necessary to handle the various resources; so to manage the resources, the reinforcement learning is the best match.

The way businesses and industries work and the manner in which consumer reacts to the market is rapidly changed with the increasing adoption of IoT and AI. Studies and projections suggest that IoT, AI, and ML will still be there and will be a crucial part of our lives. Several domains need the intervention of IoT and AI in depth like power and energy sector, healthcare, smart home, and smart transport. Healthcare is the broadest sector allowing IoT and AI to intervene extensively. It is also the quickest realm to accept the IoT. Integrating IoT functionality with medical digital instruments greatly increases the service quality and performance. The formulation provides a high benefit to chronic patients and those who need constant care. According to Gartner Forecast, IoT health expenditure will reach $1 trillion in a century and reach a level for highly customized, reliable, and affordable health services for everyone. The digital health revolution will accelerate the development of several IoT-based start-ups that offer patient care, clinical information, and biometrics services. Moreover, the forthcoming IoT will consist of tremendous economic and social effect on the life of peoples. In IoT networks, connected devices are mostly resource-constrained, and become the soft targets for cyber attackers. Hence, comprehensive attempts are initiated to resolve the issues of secrecy and security in IoT, mainly adopting recent security schemes. The specific features of IoT nodes, however, make current solutions inadequate to protect the IoT networks' entire security spectrum. This is relative to resource limitations, diversity, highly dynamic network behavior, and vast real-time data. ML and DL are therefore used to deal with various security issues, and are capable of delivering built-in intelligence within IoT devices and networks. To allow IoT devices to fit under complex environment, AI and, more precisely, ML and DL techniques can be applied. By learning and analyzing statistical data from the underlining environment, the aforementioned techniques offer self-organizing operations and improvised system performance.

References

1. Celino, D. Dell'Aglio, E. Dell Valle, R. Grothmann, F. Steinke, V. Tresp, Integrating machine learning in a semantic web platform for traffic forecasting and routing, in *Proc. 3rd Int. Work. Inductive Reason. Mach. Learn. Semant. Web*, (IRMLES 2011, 2011), pp. 1–12
2. L.M. Gladence, V.M. Anu, R. Rathna, E. Brumancia, Recommender system for home automation using IoT and artificial intelligence. J. Ambient. Intell. Humaniz. Comput. **no. 0123456789** (2020). https://doi.org/10.1007/s12652-020-01968-2
3. M. Dziubany et al., Machine learning based indoor localization using a representative k-nearest-neighbor classifier on a low-cost IoT-hardware. Eur. Signal Process. Conf. **2018-September**, 2050–2054 (2018). https://doi.org/10.23919/EUSIPCO.2018.8553155
4. H.T. Hsu, G.J. Jong, J.H. Chen, C.G. Jhe, Improve IoT security system of smart-home by using support vector machine. 2019 IEEE 4th Int. Conf. Comput. Commun. Syst. ICCCS 2019, 674–677 (2019). https://doi.org/10.1109/CCOMS.2019.8821678

5. S.K. Singh, M.M. Salim, J. Cha, Y. Pan, J.H. Park, Machine learning-based network sub-slicing framework in a sustainable 5G environment. Sustain. **12**(15), 1–22 (2020). https://doi.org/10.3390/SU12156250
6. H.-S. Ham et al., Linear SVM-based android malware detection for reliable IoT services. J. Appl. Math. **2014**, 594501 (2014)
7. E. Adi, A. Anwar, Z. Baig, S. Zeadally, Machine learning and data analytics for the IoT. Neural Comput. Appl. **32**(20), 16205–16233 (2020). https://doi.org/10.1007/s00521-020-04874-y
8. A. Burrello, A. Marchioni, D. Brunelli, L. Benini, Embedding principal component analysis for data reduction in structural health monitoring on low-cost IoT gateways. ACM Int. Conf. Comput. Front. 2019, CF 2019 – Proc, 235–239 (2019). https://doi.org/10.1145/3310273.3322822
9. T. Yu, X. Wang, A. Shami, Recursive principal component analysis-based data outlier detection and sensor data aggregation in IoT systems. IEEE Internet Things J., 1–1 (2017). https://doi.org/10.1109/JIOT.2017.2756025
10. D.H. Hoang, H.D. Nguyen, A PCA-based method for IoT network traffic anomaly detection. Int. Conf. Adv. Commun. Technol. ICACT **2018-February**(February), 381–386 (2018). https://doi.org/10.23919/ICACT.2018.8323766
11. H. Bangui, M. Ge, B. Buhnova, Exploring big data clustering algorithms for internet of things applications. IoTBDS 2018 - Proc. 3rd Int. Conf. Internet Things, Big Data Secur **2018-March**(IoTBDS 2018), 269–276 (2018). https://doi.org/10.5220/0006773402690276
12. Z. Yu, Big data clustering analysis algorithm for internet of things based on K-means. Int. J. Distrib. Syst. Technol. **10**(1), 1–12 (2019). https://doi.org/10.4018/IJDST.2019010101
13. D. Zheng, Z. Hong, N. Wang, P. Chen, An improved LDA-based ELM classification for intrusion detection algorithm in IoT application. Sensors (Switzerland) **20**(6), 1–19 (2020). https://doi.org/10.3390/s20061706
14. L. Lei, Y. Tan, K. Zheng, S. Liu, K. Zhang, X. Shen, Deep reinforcement learning for autonomous internet of things: Model, applications and challenges. IEEE Commun. Surv. Tutorials **22**(3), 1722–1760 (2020). https://doi.org/10.1109/COMST.2020.2988367
15. M.S. Khan, N. Gul, J. Kim, I.M. Qureshi, S.M. Kim, A genetic algorithm-based soft decision fusion scheme in cognitive IoT networks with malicious users. Wirel. Commun. Mob. Comput. **2020** (2020). https://doi.org/10.1155/2020/2509081
16. G. Li, S. Xu, J. Wu, H. Ding, Resource scheduling based on improved spectral clustering algorithm in edge computing. Sci. Program. **2018** (2018). https://doi.org/10.1155/2018/6860359
17. M.H. Alsharif, A.H. Kelechi, K. Yahya, S.A. Chaudhry, Machine learning algorithms for smart data analysis in internet of things environment: Taxonomies and research trends. Symmetry (Basel). **12**(1), 1–17 (2020a). https://doi.org/10.3390/SYM12010088
18. Y. Akbari, S. Tabatabaei, A new method to find a high reliable route in IoT by using reinforcement learning and fuzzy logic. Wirel. Pers. Commun. **112**(2), 967–983 (2020). https://doi.org/10.1007/s11277-020-07086-8
19. F. Alam, R. Mehmood, I. Katib, A. Albeshri, Analysis of eight data mining algorithms for smarter internet of things (IoT). Procedia Comput. Sci **58**(DaMIS 2016), 437–442 (2016). https://doi.org/10.1016/j.procs.2016.09.068
20. M. Cuka, D. Elmazi, R. Obukata, K. Ozera, T. Oda, L. Barolli, An integrated intelligent system for iot device selection and placement in opportunistic networks using fuzzy logic and genetic algorithm, in *Proc. - 31st IEEE Int. Conf. Adv. Inf. Netw. Appl. Work. WAINA 2017*, (2017), pp. 201–207. https://doi.org/10.1109/WAINA.2017.178
21. A.L. Diedrichs, F. Bromberg, D. Dujovne, K. Brun-Laguna, T. Watteyne, Prediction of frost events using machine learning and IoT sensing devices. IEEE Internet Things J. **5**(6), 4589–4597 (2018). https://doi.org/10.1109/JIOT.2018.2867333
22. P.K. Kashyap, S. Kumar, U. Dohare, V. Kumar, R. Kharel, Green computing in sensors-enabled internet of things: Neuro fuzzy logic-based load balancing. Electron. **8**(4) (2019). https://doi.org/10.3390/electronics8040384

23. G. Han, H. Wang, M. Guizani, S. Chan, W. Zhang, KCLP: A k-means cluster-based location privacy protection scheme in WSNs for IoT. IEEE Wirel. Commun. **25**(6), 84–90 (2018). https://doi.org/10.1109/MWC.2017.1800061
24. C. Guyeux, S. Chrétien, G.B. Tayeh, J. Demerjian, J. Bahi, Introducing and comparing recent clustering methods for massive data management in the internet of things. J. Sens. Actuator Networks **8**(4), 1–25 (2019). https://doi.org/10.3390/jsan8040056
25. T. Peng, S. Sellami, O. Boucelma, IoT data imputation with incremental multiple linear regression. Open J. Internet Things **5**(1) (2019)
26. O. Said, Analysis, design and simulation of internet of things routing algorithm based on ant colony optimization international journal of communication systems. Wiley **30**, e3174 (2016)
27. J. Stewart, R. Stewart, S. Kennedy, Dynamic IoT management system using K-means machine learning for precision agriculture applications. ACM Int. Conf. Proceeding Ser. (2017). https://doi.org/10.1145/3018896.3036385
28. S. Tayyaba, M.W. Ashraf, T. Alquthami, Z. Ahmad, S. Manzoor, Fuzzy-based approach using iot devices for smart home to assist blind people for navigation. Sensors (Switzerland) **20**(13), 1–13 (2020). https://doi.org/10.3390/s20133674
29. M. Mahdavinejad, M. Rezvan, M. Barekatain, P. Adibi, P. Barnaghi, A. Sheth, Machine learning for internet of things data analysis: A survey. Digit. Commun. Netw. (2017). https://doi.org/10.1016/j.dcan.2017.10.002
30. F. Zantalis, G. Koulouras, S. Karabetsos, D. Kandris, A review of machine learning and IoT in smart transportation. Future Internet, (2019) 11(4), p.94.
31. A. McCallum, K. Nigam, et al., A comparison of event models for naive bayes text classification, in *AAAI-98 Workshop on Learning for Text Categorization*, vol. 752, (Citeseer, 1998), pp. 41–48
32. V. Metsis, I. Androutsopoulos, G. Paliouras, Spam filtering with naive Bayeswhich naive Bayes? CEAS, 27–28 (2006)
33. G.I. Webb, J.R. Boughton, Not so naive bayes: Aggregating one dependence estimators. Mach. Learn. **58**(1), 5–24 (2005)
34. C. Cortes, V. Vapnik, Support-vector networks. Mach. Learn. **20**(3), 273–297 (1995)
35. S. Devi, T. Neetha, Machine learning based traffic congestion prediction in a IoT based Smart City. Int. Res. J. Eng. Technol. **4**, 3442–3445 (2017)
36. P.E. Utgoff, Incremental induction of decision trees. Mach. Learn. **4**, 161–186 (1989)
37. C.M. Bishop, *Pattern Recognition and Machine Learning* (Springer, 2006)
38. G.A. Seber, A.J. Lee, *Linear Regression Analysis*, vol 936 (John Wiley & Sons, 2012)
39. K.P. Murphy, *Machine Learning: A Probabilistic Perspective* (MIT press, 2012)
40. J. Neter, M.H. Kutner, C.J. Nachtsheim, W. Wasserman, *Applied Linear Statistical Models*, vol 4 (Irwin, Chicago, 1996)
41. W. Derguech, E. Bruke, E. Curry, An autonomic approach to real-time predictive analytics using open data and internet of things, in *Ubiquitous Intelligence and Computing, 2014 IEEE 11th Intl Conf on and IEEE 11th Intl Conf on and Autonomic and Trusted Computing, and IEEE 14th Intl Conf on Scalable Computing and Communications and its Associated Workshops (UTC-ATCScalCom)*, (IEEE, 2014), pp. 204–211
42. T.D. Buskirk et al., An introduction to machine learning methods for survey researchers. Surv. Pract. **11**(1), 2718 (2018)
43. M.H. Alsharif, A.H. Kelechi, K. Yahya, S.A. Chaudhry, Machine learning algorithms for smart data analysis in internet of things environment: Taxonomies and research trends. Symmetry **12**, 88 (2020b)
44. H. Hotelling, Analysis of a complex of statistical variables into principal components. J. Educ. Psychol. **24**(6), 417 (1933)
45. H. Abdi, L.J. Williams, Principal component analysis. Wiley Interdiscip. Rev Comput. Stat. **2**(4), 433–459 (2010)
46. Vasiliy et al., Association rules Mining for Predictive Analytics in IoT cloud system. https://doi.org/10.1007/978-3-319-99316-4_14

47. Ozawa et al., *A Study of IoT Malware Activities Using Association Rule Learning for Darknet Sensor Data International Journal of Information Security*, vol 19 (Springer Science and Business Media LLC, 2019), pp. 83–92
48. A.K. Jain, M.N. Murty, P.J. Flynn, Data clustering: A review. ACM Comput. Surv. (CSUR) **31**, 264–323 (1999)
49. A. Coates, A.Y. Ng, Learning feature representations with K-means, in *Neural Networks: Tricks of the Trade*, Lecture Notes in Computer Science, ed. by G. Montavon, G.B. Orr, K.R. Müller, vol. 7700, (Springer, Berlin, Heidelberg, 2012)
50. An intrusion detection algorithm for sensor network based on normalized cut spectral clustering Gaoming Yang, Xu Yu, Lingwei Xu, Yu Xin, Xianjin Fang Published: October 4, 2019. https://doi.org/10.1371/journal.pone.0221920
51. M. Kubat, *An Introduction to Machine Learning* (Springer, Cham, Switzerland, 2017)
52. E. Warriach, K. Tei, A comparative analysis of machine learning algorithms for faults detection in wireless sensor networks. International Journal of Sensor Networks **24**(1), 1–13 (2017)
53. Y. Li, L. Parker, Nearest neighbor imputation using spatial–temporal correlations in wireless sensor networks. Information Fusion **15**, 64–79 (2014)
54. V. Jafarizadeh, A. Keshavarzi, T. Derikvand, Efficient cluster head selection using naïve bayes classifier for wireless sensor networks. Wirel. Netw **23**(3), 779–785 (2017)
55. B. Sun, Y. Guo, N. Li, D. Fang, Multiple target counting and localization using variational Bayesian EM algorithm in wireless sensor networks. IEEE Trans. Commun. **65**(7), 2985–2998 (2017)
56. Z. Wang, H. Liu, S. Xu, X. Bu, J. An, Bayesian device-free localization and tracking in a binary RF sensor network. Sensors **17**(5), 1–21 (2017a)
57. Y. Guo, B. Sun, N. Li, D. Fang, Variational bayesian inference-based counting and localization for off-grid targets with faulty prior information in wireless sensor networks. IEEE Trans. Commun. **66**(3), 1273–1283 (2018)
58. J. Kang, Y. Park, J. Lee, S. Wang, D. Eom, Novel leakage detection by ensemble CNNSVM and graph-based localization in water distribution systems. IEEE Trans. Ind. Electron. **65**(5), 4279–4289 (2018)
59. S. Zidi, T. Moulahi, B. Alaya, Fault detection in wireless sensor networks through SVM classifier. IEEE Sensors J. **18**(1), 340–347 (2018)
60. S. Varsha, P. Shubha, T. Avanish, Intrusion detection using data mining with correlation, in *2nd International Conference for Convergence in Technology (I2CT)*, (2017)
61. J. Han, J. Pei, Y. Yin, Mining frequent patterns without candidate generation. ACM SIGMOD Rec. **29**(2), 1–12 (2000)
62. J. Han, P.Y. Mao, Mining frequent patterns without candidate generation: A frequent-pattern tree approach. Data Min. Knowl. Discov. **8**(1), 53–87 (2004)
63. C. Borgelt, Frequent item set mining. Data Min. Knowl. Discov. **2**(6), 437–456 (2012)
64. A. Habib, M. Arafat, S. Moh, Routing protocols based on reinforcement learning for wireless sensor networks: A comparative study. Journal of Advanced Research in Dynamical and Control Systems **14**, 427–435 (2018)
65. S. Banihashemian, F. Adibnia, M. Sarram, A new range-free and storage-efficient localization algorithm using neural networks in wireless sensor networks. Wirel. Pers. Commun. **98**(1), 1547–1568 (2018)
66. A. El Assaf, S. Zaidi, S. Affes, N. Kandil, Robust ANNs-based WSN localization in the presence of anisotropic signal attenuation. IEEE Wireless Communications Letters **5**(5), 504–507 (2016)
67. P. Chanak, I. Banerjee, Fuzzy rule-based faulty node classification and management scheme for large scale wireless sensor networks. Expert Syst. Appl. **45**(C), 307–321 (2016)
68. A. Mehmood, Z. Lv, J. Lloret, M. Umar, ELDC: An artificial neural network based energy-efficient and robust routing scheme for pollution monitoring in WSNs. IEEE Trans. Emerg. Topics. Comput., 1–1 (2017)

69. A. Umarikar, *Fuzzy Logic and Brief Overview of its Applications* (University Västerås Suecia, 2003)
70. S. Liu, L. Feng, J. Wu, G. Hou, G. Han, Concept drift detection for data stream learning based on angle optimized global embedding and principal component analysis in sensor networks. Comput. Electr. Eng. **58**, 327–336 (2017)
71. J. Wang, Y. Gao, W. Liu, A. Sangaiah, H. Kim, An improved routing schema with special clustering using PSO algorithm for heterogeneous wireless sensor network. Sensors **19**(3), 671 (2019)
72. G.J. McLachlan, *Discriminant Analysis and Statistical Pattern Recognition* (Wiley Interscience, 2004) ISBN 978-0-471-69115-0. MR 1190469
73. R. Agrawal, T. Imielinski, A. Swami, Mining association rules between sets of items in large databases. ACM SIGMOD Rec. **22**(2), 207–216 (1993)
74. U. Von Luxburg, A tutorial on spectral clustering. Stat. Comput. **17**, 395–416 (2007)
75. H. Hu, X. Wang, Z. Yang, B. Zheng, A spectral clustering approach to identifying cuts in wireless sensor networks. IEEE Sensors J. **15**, 1838–1848 (2015)
76. Kung, H.T.; Vlah, D. A spectral clustering approach to validating sensors via their peers in distributed sensor networks. In Proceedings of the 18th International Conference on Computer Communications and Networks, San Francisco, CA, USA, 3–6 August 2009a; pp. 1–7
77. R.S. Parpinelli, H.S. Lopes, A.A. Freitas, Data mining with an ant colony optimization algorithm. IEEE Trans. Evol. Comput. **6**(4), 321–332 (2002). https://doi.org/10.1109/TEVC.2002.802452
78. J. Kennedy, R.C. Eberhart, Particle swarm optimization, in *Proc. IEEE int'l Conf. On Neural Networks*, vol. IV, (IEEE service center, Piscataway, NJ, 1995), pp. 1942–1948
79. J. Wang, Y. Cao, H. Kim, S. Lee, Particle swarm optimization based clustering algorithm with mobile sink for WSNs. Future Gener. Comput. Syst. **76**, 452–457 (2017b)
80. L. Atzori, A. Iera, G. Morabito, The internet of things: A survey. Comput. Netw. **54**(15), 2787–2805 (2010)
81. A. Smola, V. Vapnik, Support vector regression machines. Adv. Neural Inf. Process. Syst. **9**, 155–161 (1997)
82. A.J. Smola, B. Scholkopf, A tutorial on support vector regression. Statistics Comput. **14**(3), 199–222 (2004)
83. P. Ni, C. Zhang, Y. Ji, A hybrid method for short-term sensor data forecasting in internet of things, in *2014 11th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, (2014)
84. T. Cover, P. Hart, Nearest neighbor pattern classification. IEEE Trans. Inf. Theory **13**(1), 21–27 (1967)
85. H. Zhang, The optimality of naive bayes. AA **1**(2), 3 (2004)
86. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
87. V.K. Gunjan, S. Kumar, M.D. Ansari, Y. Vijayalata, Prediction of agriculture yields using machine learning algorithms, in *Proceedings of the 2nd International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications: ICMISC 2021*, (Springer, Singapore, 2022), pp. 17–26

Performance Analysis of Cellular Internet of Things Using Cognitive Radio

Priyanka Mishra, Prabhat Thakur, and G. Singh

1 Introduction

Spectrum is a natural source and there is very limited availability of spectrum. There is a fixed spectrum assignment and bandwidth is also found to be very expensive. Some frequency bands like radio and TV are unutilized while the other frequency bands are overutilized. This shows that there is inefficiency in the utilization of the spectrum. This necessitates to exploit the spectrum opportunistically; therefore, we need to dynamically utilize the spectrum, which is called dynamic spectrum access [1]. To achieve this dynamic spectrum access, we need a clever radio or clever system. Such a clever system or radio is known as cognitive radio. It is an intelligent, adaptive, aware radio model that senses its functional surroundings and dynamically adapts its radio operating parameter to update systems like mitigating interference, facilitating interoperability, and maximizing throughput. Spectrum scarcity is one of the major problems as most of the spectrum is left unused leaving behind spectrum holes. So, cognitive radio makes use of their spectrum hole in an efficient manner, thus leaving very less spectrum holes.

Recent studies show that in the integration of cognitive radios with IoT-based wireless communication technologies, multiantenna systems [1–3] offer better

P. Mishra · G. Singh
Department of Electrical and Electronics Engineering Science, Auckland Park Kingsway Campus, University of Johannesburg, Johannesburg, South Africa
e-mail: ghanshyams@uj.ac.za

P. Thakur (✉)
Department of Electrical and Electronics Engineering Science, Auckland Park Kingsway Campus, University of Johannesburg, Johannesburg, South Africa

Symbiosis Institute of Technology, Symbiosis International (Deemed University), Pune, India
e-mail: prabhatt@uj.ac.za

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_11

results in terms of data rates, efficiency, availability, complexity, robustness and solve the spectrum scarcity issues even in coming age of the Internet of Things [4–7]. Improved intelligent radio systems efficiently work with fifth generation wireless networks by employing the licensed spectrum with the primary user and unlicensed spectrum combined with different application bands [8]. As it is an effective tool to mitigate various issues wirelessly, its smart sensing technique regulates the ability of spectrum resources [9].

The predominant characteristics of cognitive radio are its capability and reconfigurability. The capability of the cognitive radio to sense its radio environment by noting down the variations is called cognitive capability whereas the ability of the cognitive radio to change the functional elements according to the need of the radio surroundings is called reconfigurability. Achieving these characteristics in cognitive radio can be well explained in the "cognitive cycle" as shown in Fig. 1.

The primary role of cognitive radio is spectrum sensing, spectrum management, spectrum sharing, and spectrum mobility. The process of detecting an unused part of the spectrum or spectrum hole, that is, detecting whether the primary user is present or absent. Occupying the efficient part of the spectrum to obtain the user's requirement is spectrum management. In addition, the cognitive radio provides fair spectrum scheduling method among Cognitive radios users and distributes spectrum among the scheduled users is known as spectrum sharing. Further, spectrum mobility performs transition to a better spectrum, that is, to empty the channel, where the licensed user is identified.

Further, this chapter is structured as follows. Section 2 comprises the system model of the IoT-based cognitive radio network. Section 3 comprises the spectrum sensing phenomenon and layer-wise structure of the cognitive radio cycle. Further, Sect. 4 illustrates the IoTs-based cognitive radio network structure. Section 5

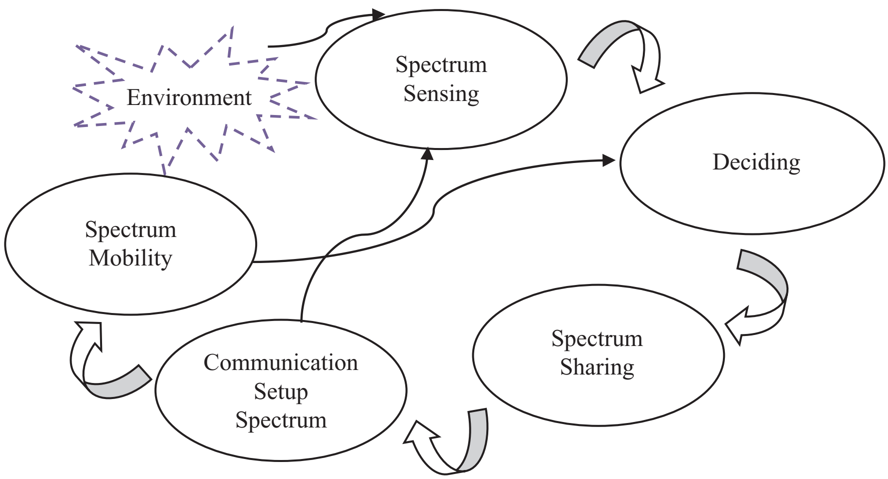


Fig. 1 Cognitive radio cycle

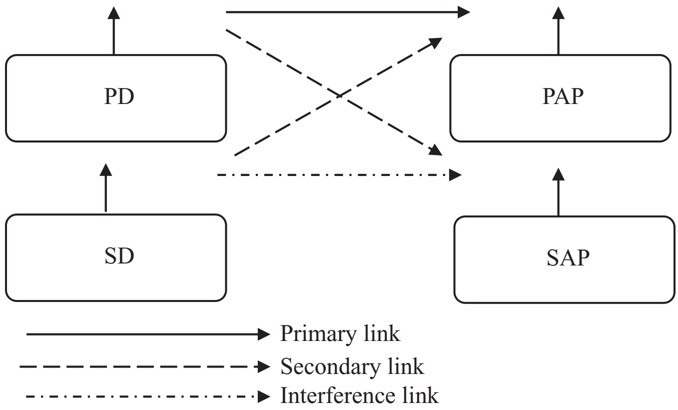


Fig. 2 IoT-based cognitive radio network

presents the complete process of spectrum sensing using MATLAB. Section 6 comprises the simulation results and discussion followed by the conclusion in Sect. 7.

2 System Model for IoT-Based Cognitive Radio

Considering an IoT-based cognitive radio network consisting of a primary IoT device (PD), primary access point (PAP), secondary IoT device (SD), and secondary access point (SAP) as shown in Fig. 2. It is assumed PD and SD transmit information to their respective access point. The spectrum has been divided into licensed primary IoT (P-IoT) and unlicensed secondary IoT (S-IoT). Assuming that primary access point (PAP) and the secondary access point (SAP) are unbuffered, thus there is no possibility of the combination of signals received from earlier transmissions. If an error occurs during the transmission, we adopt an automatic repeat request (ARQ) protocol to correct the error. When new information is generated at the PD or SD, while the primary IoT and secondary IoT users are busy in the current transmission, the PD and SD discard the current information and start to transmit new information or packet of data.

3 Potentials of Cognitive Radio

Cognitive radio is a dynamic spectrum access that improves spectrum utilization. It gives better interoperability and improved vertical handoff by selecting the best network. Link optimization is done with respect to modulation, power and topology, better usage of other resources, increased capacity and high data rates, improved coverage, service quality, and link reliability by intelligently identifying the channels for communication.

In spectrum management, the use of radio frequency for efficient use and gain benefits of cognitive radio is regulated [10]. It has three processes such as cycle sensing, deciding, and acting. The measurements are taken in first process and spectrum sensing is performed, which is affected by various wireless limitations. Because the measurements may be uncertain in first process, a decision needs to be made by the secondary, which is knowledge based and observation. Eventually, in the last step of the cycle, because of the uncertainty, wrong actions are taken. So, it is important to acknowledge the uncertainty by sensing the spectrum optimally by making right decisions and taking correct action.

Spectrum sensing is a very eminent method in cognitive radio system because it allows secondary users to acknowledge about the environment by finding the availability of primary user. It is formulated as follows:

$$y(k) = \begin{cases} N_0 & \mathrm{H}_0 \ : \mathrm{PU} \quad \text{Absent} \\ h * x(k) + N_0, & \mathrm{H}_1 \ : \mathrm{PU} \quad \text{Present} \end{cases} \tag{1}$$

where $k = 1 \ldots. K$, K is the number of samples, $y(k)$ is the SU received signal, $x(k)$ is the PU signal, N_0 is the additive white Gaussian noise (AWGN) with zero mean and variance δ_w^2, and h is the complex channel gain of the sensing channel. H_0 and H_1 show the presence and absence of the PU signal.

The PU signal detection is achieved using one of the spectrum sensing method to take decisions among the two hypotheses H_0 and H_1. At the receiver end, the test statistic (T), is then correlated to a threshold (γ) to sense the presence or absence of PU signal. The Hypothesis H_1 and H_0 refer to the presence and absence of the PU signal respectively and decided as follows:

$$\begin{cases} T \geq \gamma, & \mathrm{H}_1 \\ T < \gamma, & \mathrm{H}_0 \end{cases} \tag{2}$$

where γ denotes the sensing threshold. Absence of PU signals enables the SU to get access to the PU channel.

3.1 Generic Flow Diagram of Cognitive Radio

The fundamental objective of cognitive radios is spectrum sensing, spectrum sharing, and spectrum access. They work in PHY and MAC layers [11]. Further, cognitive radios influence the functioning of upper protocol layer. For quality of services observation, learning and decision-making must also be performed at the network, transport, and application layers [12]. Figure 3, shows the generic flow diagram of cognitive system.

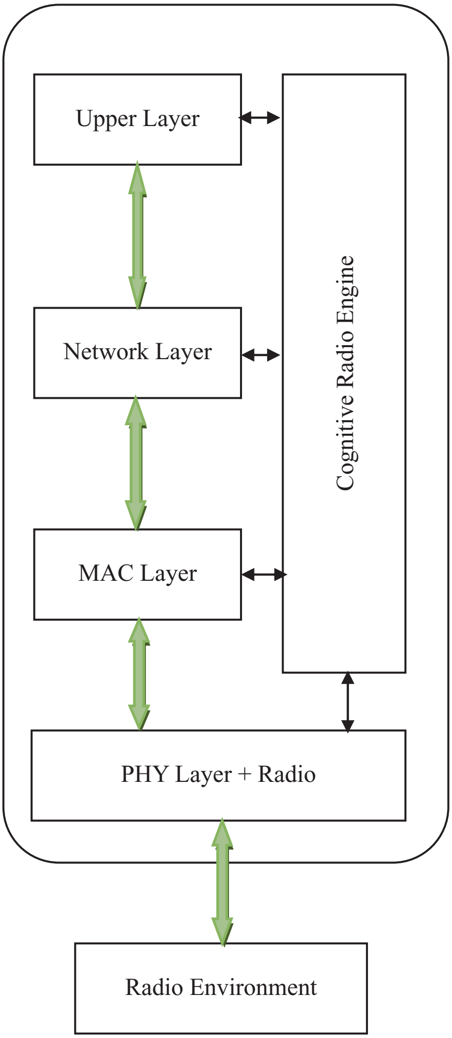


Fig. 3 Generic cognitive radio flow diagram

4 IoT-Based Cognitive Radio

4.1 Need for Cognitive Radio in IoT

The exponential growth of internet traffic, count of licensed users will increase accordingly. This will make an issue to the unlicensed users. Therefore, it is very difficult to manage the expenses of obtaining spectrum from these unauthorized users. Cognitive radio networks are the feasible choice to combat this issue. Second, the expanding of internet will increase the count of IoT tools connected to the network. This will cause interference in the network due to device-to-device communication. IoT-based cognitive radio can assign channels that are interference free.

Huge payload of information generated by individual users will require enormous bandwidth for transmission. Efficient spectrum utilization using cognitive radio technology will cater to this challenge.

4.2 Cognitive Architecture for IoT

The cognitive architecture structure for the cellular IoT is shown in Fig. 4 [13]. The framework consists of three levels of enablers. Each layer consists of fabrics that are used for the mechanism of various functionalities. The virtual object (VO) levels create the virtual description of real-world and digital objects are used for the exchange of the information with the real-world object (RWO).

The VOs can be further used for the generation of composite virtual objects (CVOs). Thus, the combination of these layers and structure together will create a cognitive network which can be used for power optimization, energy efficiency, reduced computational time, and increased reliability.

The service function includes translation of service request, real world knowledge, and request information down to the CVO level in order to create meaningful mashups to serve the request. The real-world knowledge will help us decision-making necessary for cognitive radio cycle [14].

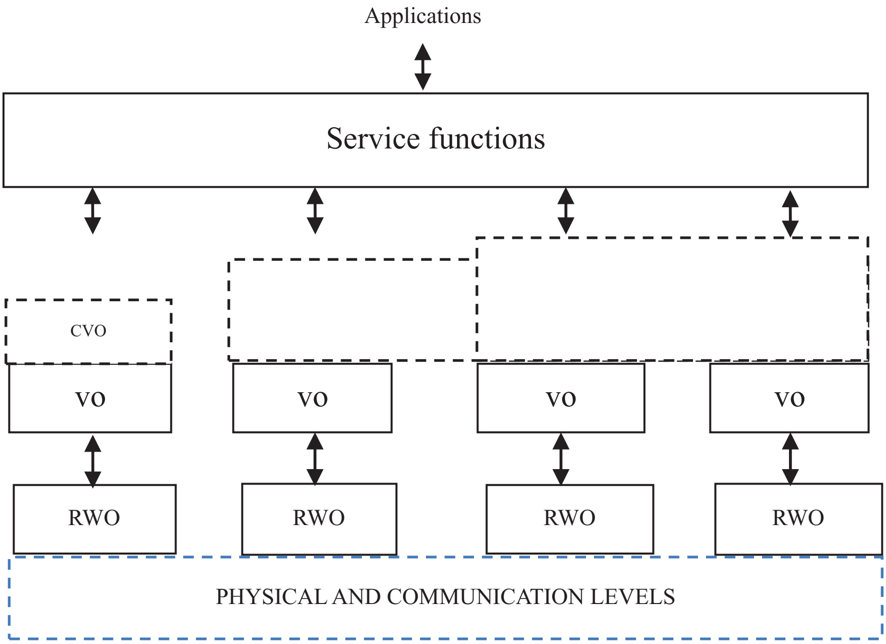


Fig. 4 Cognitive radio IoT-based architecture

5 Flowchart for Spectrum Sensing in Cognitive Radio

In this section, a brief flowchart for spectrum sensing in cognitive radio is discussed. We considered five different combinations for primary users with different transmission signal frequencies of 1 KHz, 2 KHz, 3 KHz, 4 KHz, and 5 KHz, respectively as shown in Fig. 5. Different cases have been considered describing various combinations of primary users. We calculate the sum of all primary users and plot the power versus frequency graph of the resultant signal. Further, the spectrum is checked for any empty slot and secondary user is supposed to occupy the empty slot. After the secondary user has entered in the spectrum, we calculate the sum of

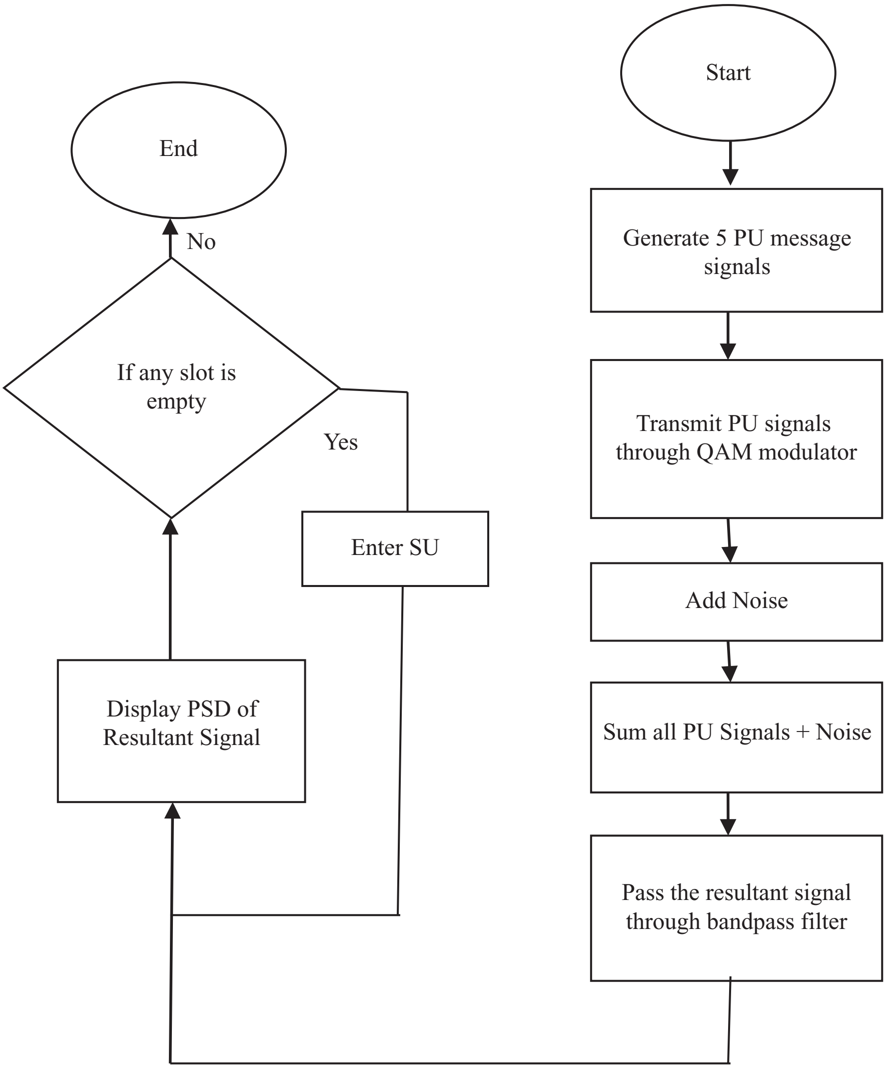


Fig. 5 Flowchart for Spectrum Sensing

the primary user signal and secondary user signal and plot the power spectral density. The sampling frequency is chosen to be 12 KHz. The noise affects the spectrum sensing process; accordingly, we consider the signal-to-noise ratio (SNR) is equivalent to 15 dB in each case.

6 Results and Discussion

This section covers all the results simulated in MATLAB software using efficient spectrum sensing algorithm for cognitive radio. Figure 6 shows the presence of one primary user keeping channel capacity minimum and probability is less. Second, empty slots are occupied by secondary user as shown in Fig. 8, by improving channel capacity and deduction in probability. Secondary user fills the third and fourth slots in the iteration as shown in Figs. 10 and 12, respectively.

In fifth iteration, due to the presence of one primary user, all slots are occupied as shown in Fig. 14, having maximum channel capacity and spectrum probability.

Case 1:
Figure 6 shows the power spectral density graph for the cognitive radio system when only one primary user is present. Only one slot is occupied, which is shown in graph by the spiky peaks on the both sides of 1 KHz frequency spectrum. The power in this frequency range is almost 1 dB, that is, most of the signal power is confined within this spectrum. Figure 7 shows the probability of detection of empty slots due to the presence of only primary user. The detection probability of vacant slot is maximum in this case.

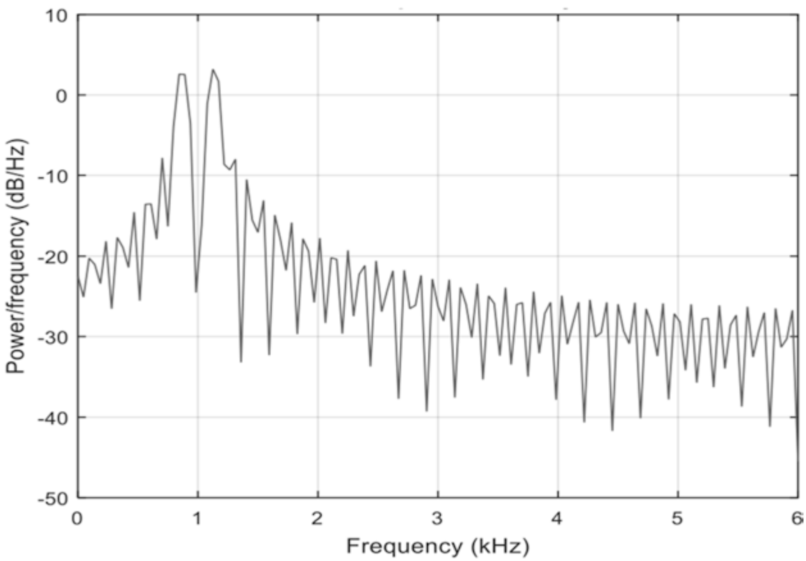


Fig. 6 Only one primary user is present in spectrum

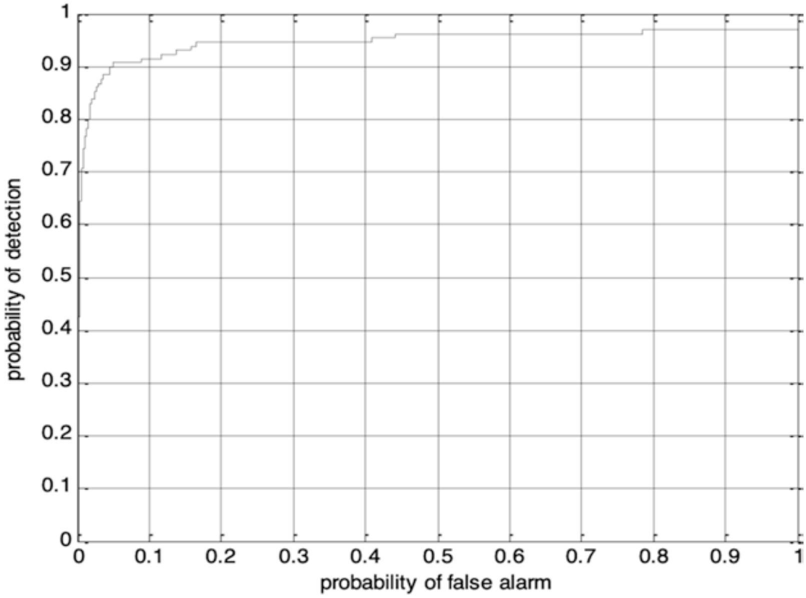


Fig. 7 Detection Probability of holes in presence of one PU

Case 2:
Secondary user senses the spectrum and occupies the second slot. Now, two slots are present in the spectrum. This is shown in graph by two spiky peaks ranging between 1 and 2 KHz frequency spectrum. Power in these two bands is almost equal to 4 dB as shown in Fig. 8.

Figure 9 shows the probability detection of unoccupied slots when only two slots are in use. The detection probability of empty slots somehow decreases as compared to case 1, because one more slot gets occupied in this case.

Case 3:
In Fig. 10, secondary user again senses the spectrum and finds three empty slots, thereby, occupying the third slot. The spiky peaks at 1, 2, and 3 KHz band frequency demonstrate the occupancy of three slots. Again, the power at these frequency bands is 4 dB. Figure 11 shows the detection probability when three slots are occupied. Again, it can be seen that with the occupancy of one more slot, the detection probability of empty slot decreases.

Case 4:
Figure 12 shows the power spectral density graph when four slots are occupied. This is shown with four spiky peaks at 1, 2, 3, and 4 KHz frequency bands. Figure 13, demonstrates the decrease in the detection probability of empty slots. Now, only one slot is left unoccupied.

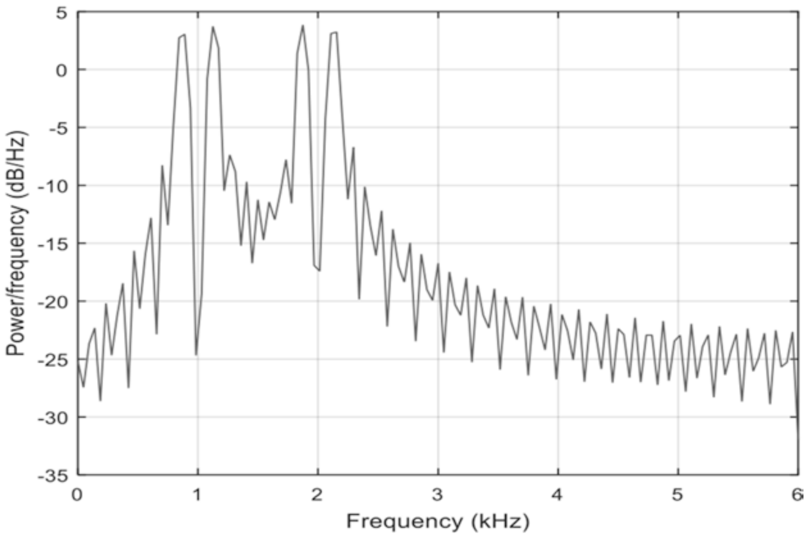


Fig. 8 Secondary primary user is present in spectrum

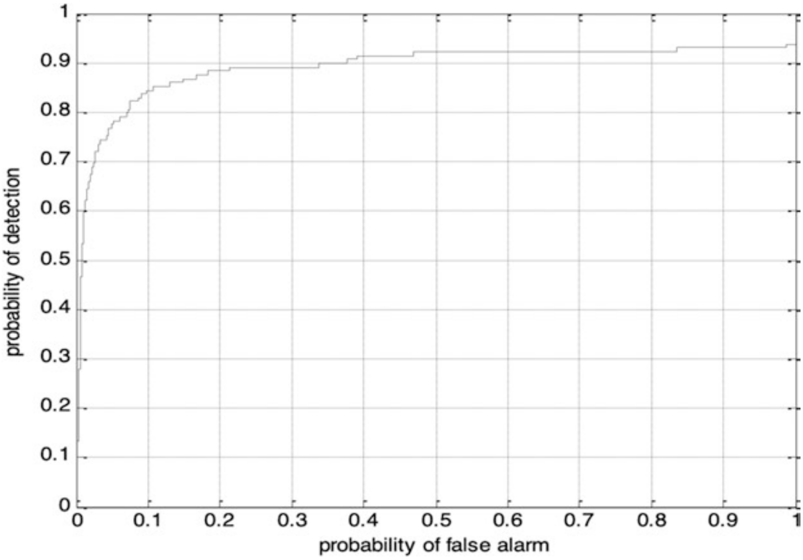


Fig. 9 Detection Probability of holes in presence of second PU

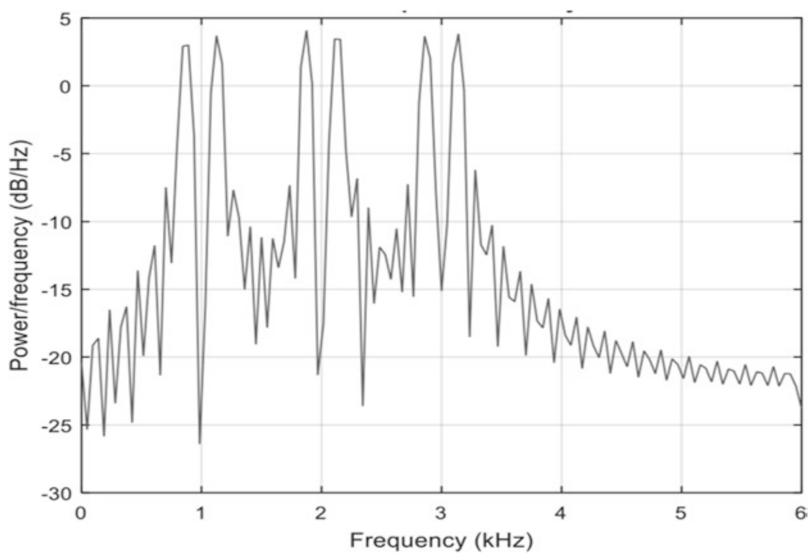


Fig. 10 Third primary user is present in spectrum

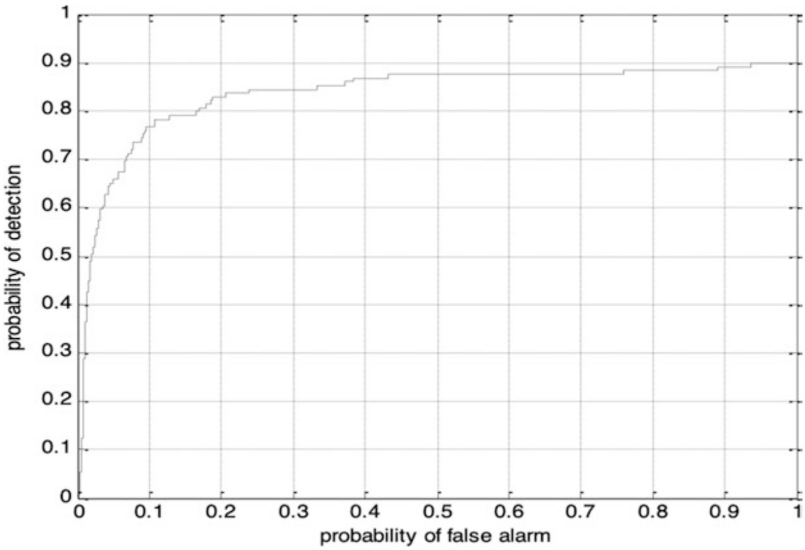


Fig. 11 Detection Probability of holes in presence of third PU

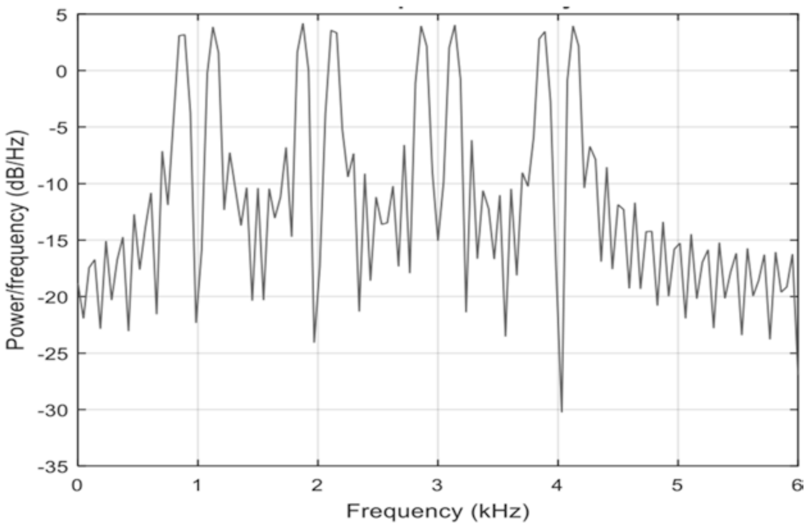


Fig. 12 Fourth primary user is present in spectrum

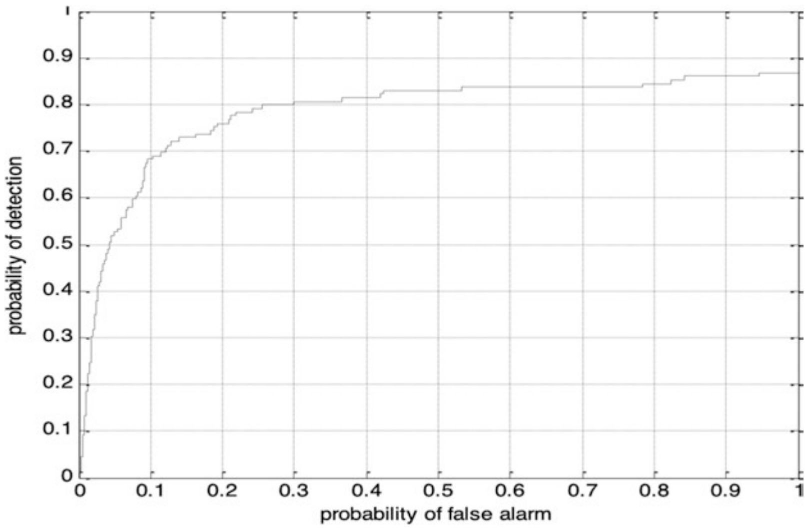


Fig. 13 Detection Probability of holes in presence of fourth PU

Case 5:
Secondary user once again senses the spectrum in the fifth repetition and fills the fifth slot. Figure 14 shows the full spectrum with all slots being occupied. Now, there is no scope for any spectrum hole. The slots are occupied at 1, 2, 3, 4, and 5 KHz frequency bands. Most of the signal power is confined in the spectrum over these bands. The bandwidth requirement for the transmission of all primary users

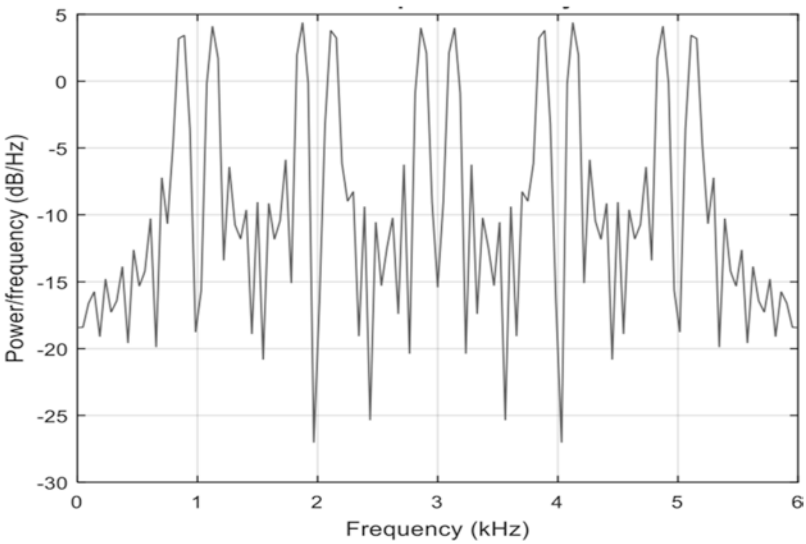


Fig. 14 All five primary users present in the spectrum

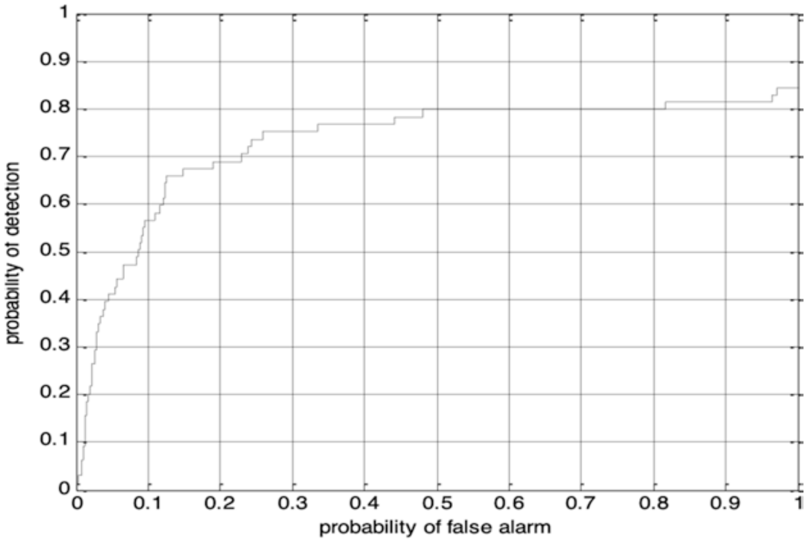


Fig. 15 Detection Probability of holes in presence of fifth PU

will be 4 KHz. In this way, efficient spectrum sensing is being done by the cognitive radio algorithm. Figure 15 shows the detection probability when all slots are occupied. The detection probability of empty slots is the least.

Table 1 Detection Probability versus false alarm probability

Sr. No.	Cases	PF	PD
1.	Only one PU is present	0.91	0.1
2.	One PU and SU are present	0.85	0.1
3.	Two PUs and one SU are present	0.78	0.1
4.	Three PUs and one SU are present	0.69	0.1
5.	Four PUs and one SU are present	0.59	0.1

Table 1 lists the detection probability (PD) of vacant slots versus probability of false alarm for different occupancy. The probability of false alarm (PF) has been taken as 0.1 for each case.

7 Conclusion

This chapter presents the insight and innovative ideas of cellular IoT-based cognitive radio networks. The need of cognitive radio in IoT and IoT-based cognitive radio architecture has been briefly discussed in this chapter. We also present efficient spectrum sensing algorithm depending on spectrum sensing. The algorithm takes five iterations to make the spectrum completely occupied. In each and every iteration, secondary user occupies the slot left vacate by the primary user. Thus, minimum resources are getting wasted and full occupancy of channel is obtained in the last iteration. The last iteration, that is, when all the slots get occupied are having highest detection probability and spectral efficiency. In this way, the channel goes from the worst to the best case. Simulation results validate our analysis. Cognitive radio can be used for 4G and 5G technology for better spectrum sensing and spectrum sharing.

References

1. T. Alam, S.R. Thummaluru, R.K. Chaudhary, Integration of MIMO and cognitive radio for Sub-6 GHz 5G applications. IEEE Anten. Wirel. Propag. Lett **18**(10), 2021–2025 (2019)
2. A. Das, N. Das, A.D. Barman, S. Dhar, Energy incentive for packet relay using cognitive radio in IoT networks. IEEE Commun. Lett. **23**(9), 1581–1585 (2019)
3. P. Thakur, P. Thakur, P. Patiyal, Cognitive radio with internet of things: A new revolution. 5th IEEE International conference on Parallel, Distributed and Grid Computing, Waknaghat, 2018, Dec, pp. 1–6
4. P. Thakur, G. Singh, Cognitive inspired internet-of-medical-things: Security and interference management, in *Intelligent Data Security Solutions for e-Health Applications*, (Elsevier, 2020a), pp. 131–149
5. P. Thakur, G. Singh, Performance analysis of MIMO based CR-NOMA communication systems. IET Commun **14**(16), 2677–2686 (2020b). https://doi.org/10.1049/iet-com.2019.0988

6. F. Hu, B. Chen, K. Zhu, Full spectrum sharing in cognitive radio networks toward 5G: A survey. IEEE Access **6**, 15754–15776., ISSN: 2169-3536 (2018)
7. A. Sabbah, M. Ibnkahla, O. Issa, B. Doray, Control Channel selection techniques in cognitive radio networks: A comparative performance analysis. J. Commun. Netw **20**(1), 57–68 (2018)
8. W. Zhang, X.W. Cheng, X. Ge, Y. Chen, Enhanced 5G cognitive radio networks based on spectrum sharing and spectrum aggregation. IEEE Trans. Commun. **66**(12), 6304–6316 (2018)
9. X. Tianheng, H. Honglin, M. Zhang, Sliced sensing system: Toward 5G cognitive radio applications under fast time-varying channels. IEEE Syst. J. **13**(2), 1297–1307 (2019)
10. P. Thakur, G. Singh, Power management for spectrum sharing in cognitive radio communication systems. J. Electromagn. Waves Appl **34**(4), 407–461 (2020c). https://doi.org/10.1080/09205071.2020.1716858
11. P. Thakur, G. Singh, Energy and spectrum efficient SMC-MAC protocol in cognitive radio networks. IET Commun **13**(17), 2705–2713 (2019). https://doi.org/10.1049/iet-com.2019.0212
12. Y.C. Liang, K.C. Chen, G.Y. Li, P. Mahonen, Cognitive radio networking and communications: An overview. IEEE Trans. Veh. Technol. **60**(7), 3386–3407 (2011)
13. S. Sasidharan, A. Somov, A.R. Biswa, R. Giaffrede, Cognitive management framework for Internet of Things: -a prototype implementation. 2014 IEEE World Forum on Internet of Things(WF-IoT) (2014)
14. P. Thakur, A. Kumar, S. Pandit, G. Singh, S.N. Satashia, Spectrum mobility in cognitive radio network using spectrum prediction and monitoring techniques. Phys. Commun **24**, 1–8 (2017). https://doi.org/10.1016/j.phycom.2017.04.005

IOT for Healthcare

G. Suryanarayana, L. N. C. Prakash K, Mohd Dilshad Ansari, and Vinit Kumar Gunjan

1 Introduction

In today's world, it is in need of a grid of linked computers, people, time, locations, and networks, which itself are fully integrated into what is known as the Internet of Things (IoT). The convergence of various technologies as well as connectivity strategies is the primary enabler of this exciting framework. The most important are recognition and monitoring systems, wired and wireless sensing and actuation platforms, improved networking protocols, and decentralized technology for smart things. The fundamentals of IoT are a blend of the Internet and new technologies. The word "Internet of Things (IoT)" has increasingly achieved popularity in the field of information technologies. This one has been established in a variety of forms and is referred to as the next phase. The IoT is intended to change certain facets of our lives, and it is changing the world. The number of IoT devices is estimated to skyrocket in the coming decades. IoT has a total presence of many more than 12 billion users that could access the internet; however, by 2020, it is projected that there would be 26 times extra interconnected objects with the Internet than humans. Currently, all around us, including kitchen lighting and various household

G. Suryanarayana (✉)
Department of Information Technology, Vardhaman College of Engineering, Hyderabad, India

L. N. C. Prakash K
CVR College of Engineering, Hyderabad, India

M. D. Ansari
Computer Science and Engineering, SRM University Delhi-NCR, Sonepat, Haryana, India

V. K. Gunjan
CMR Institute of Technology, Hyderabad, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_12

appliances to vending machines and automobiles can connect to the internet and communicate with several other devices. IoT refers to computers or structures that can communicate with the Internet by using hardware components, detectors, microcontrollers, and network access to capture and share data. A vast quantity of information is processed and stored securely on thousands of computers. Frameworks would become more effective and intelligent as a result. IoT generates smart objects that serve as future basic components in the advancement of cyber-physical digital systems. It is designed for millions of physical items or things, which will be outfitted through various types of detectors and actuators and would be connected to the Internet through various communication systems aided by various technologies including wireless communication, radio frequency identification (RFID), and semantic web facilities.

IoT enables people to communicate with various devices including health monitors, surveillance cameras, domestic appliances, and many more. Keeping all of this in mind, we are all aware of many IoT applications that have been created, in which each and every physical object is linked to the Internet through sensor devices. The sensors mounted in the participating systems assist in contact. Sensors are also used in a wide range of applications, such as smart devices (mobile phones, laptops, and so on), transportation networks, temperature management, industrial safety, and healthcare.

IoT has increasingly become more competitive in the field of healthcare services. IoT in healthcare, in particular, incorporates sensors, integrated circuits, and other devices to process and transmit sensor information to the cloud, and then to clinicians (doctors). Combining IoT functionality into diagnostic instruments increases the quality and efficiency of treatment for both aged and pediatric patients. IoT in healthcare could store thousands of medical records in a computerized format, allowing patients to access medical records at any time.

Many portable health-detecting products have also been established, allowing patients to carry them for observation. The health tracking unit is attached to the patient, allowing the doctor to track the condition of the patient at all moments. Since IoT-assisted patients can be reached via the network, the sufferer's medical status could be monitored at the appropriate time, and appropriate action should be taken. The article's main goal could be to know how real-time medical information about the patient is obtained through IoT, analysis, and categorization of collected data concerning the patient, and interpreting and forecasting every illness or condition at a provisional level using data analysis technologies will also have a method beneficial for strategic decisions, to have healthcare dependent on the IoT remedies at any moment and from any location. In this article, the concepts, objectives, and background knowledge of IoT are discussed. Then, we also present challenges and key scientific problems involved in IoT development.

1.1 IoT Principles and Strategies

The primary concept of IoT was introduced by MIT Auto-ID Labs there at the ending of the 1990s (http://www.autoidlabs.org/) that arose from one logistical need. According to the ITU Web Studies 2005 [18], we are moving toward a "ubiquitous network society," wherein networks and networked computers are ubiquitous. Anything from tires to toothbrushes would be able to communicate in the future, ushering in a new age wherein today's modern Internet (of information and human beings) brings benefits to future IoT. At the moment, the "stuff" term in IoT was being generalized to common devices, and interconnected transmission functionality has been expanded to all network technology, like RFID (radio frequency identification). The IoT is inextricably linked to the Internet, mobile phone networks, and wireless communications. We describe IoT as described after contrasting it to WSNs, the Internet, ubiquitous networks, and further research. The IoT is a network that connects various regular electronic components with recognizable domains in order to deliver smart services. It is compared with existing methods known such as the Internet and telecommunication networks. The IoT provides three key characteristics as follows:

(1) Ordinary objects are *instrumented*: Ordinary items are outfitted with sensors, and it ensures that everyday items like cups, chairs, screws, meats, and car tires can be individually handled by just being integrated with a chip, RFID, smart card, or other technologies.
(2) Autonomic terminals are *interconnected*. Autonomic terminals are connected together. That is, those designed to operate technological devices are linked as autonomic network terminals.
(3) Pervasive services are *intelligent*. As such, a vastly integrated network that allows any element to engage in the service in order to make the ubiquitous service intelligent sensor nodes in an automobile network or a human-carrying network, for example, will track the state of the road or even the driver's body in live time to guide driving behaviors.

As a result, IoT is a complex multi-disciplinary application, containing various disciplines including computer science, communications, sensing technologies, and microelectronics. We split the framework of an IoT device into four layers for clarification like entity sensing layer, data sharing layer, information integration layer, and application service layer. Figure 1 depicts the four-layer construction. The object sensing layer is in charge of detecting physical things and collecting data. The data sharing layer is in charge of data transfer transparency. The information integration layer performs the replication, processing, and convergence of ambiguous information obtained through networks, as well as the incorporation of the incomplete data into functional knowledge. The application service layer delivers content to a variety of customers. Having worked on interconnected devices is what IoT architecture is all about. Detectors, IoT gateways, cloud servers, and smartphone apps are the four fundamental building blocks. Cross-site authentication and

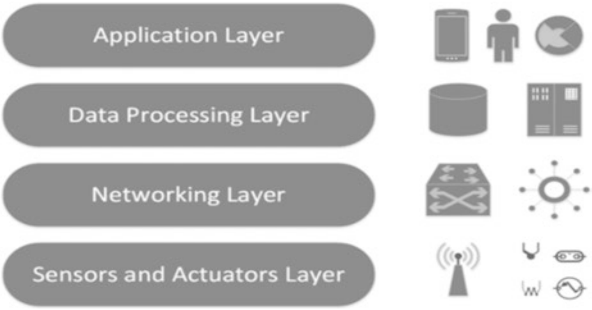


Fig. 1 Four-layer architecture of IoT

malicious software attacks are typical application layer problems including risks. DoS attacks and unauthorized malicious attacks are persistent mistakes and risks of something like the information processing framework. The network layer's most potential complications as well as vulnerabilities include Man-in-the-Middle Assault, Database Inflict damage, and Vulnerability Attack. As a result, the majority of sensor-related risks are Snooping, Privilege Escalation, and Scheduling Attack.

Detectors, as when the name implies, detect information. This information is recorded on a remote server, where informed choices are made. Eventually, an access point serves as a carrier for that kind of information, and smartphone apps allow users to view and monitor it [32].

The conventional Internet, in terms of strategy, lacks sensing capability and only connects intelligent machines. In comparison, the IoT has an external sensing layer that decreases the specifications of interface functionality and allows connectivity of pseudo or shallowly systems. In the meantime, it adds many additional criteria and barriers to data sharing, process integration, and utilities, as well as increasing the network's sophistication. A positive development in clinical governance is the relocation of regular patient tests as well as other healthcare facilities from the clinic to the domestic setting [25]. Patients can also access medical services quite quickly, particularly in an emergency. Furthermore, clinics might reduce their workload by delegating practicable and simple roles to the home environment. One significant benefit is the lack in spending. Patients might stop paying medical expenses any day they go to see a specialist. As a result, it is critical that an emerging development be adopted in the medical sector in the recent future to improve new healthcare procedures and applications to use them for simple tracking of patients from somewhere else. Patient care entails reviewing the patient's medical status as well as their prescription information.

There is little risk of a patient's illness worsening if the right medications are provided at the correct time. Taking medicine at the correct time is extremely hard for the aged. It is possible that they will forget about it from time to time. As a result, inadequate patient management is a significant issue for both the general public and healthcare monitors. In 1999, the notion of the IoT initially gained popularity. Whenever all things besides individuals in everyday natural life had identifiers,

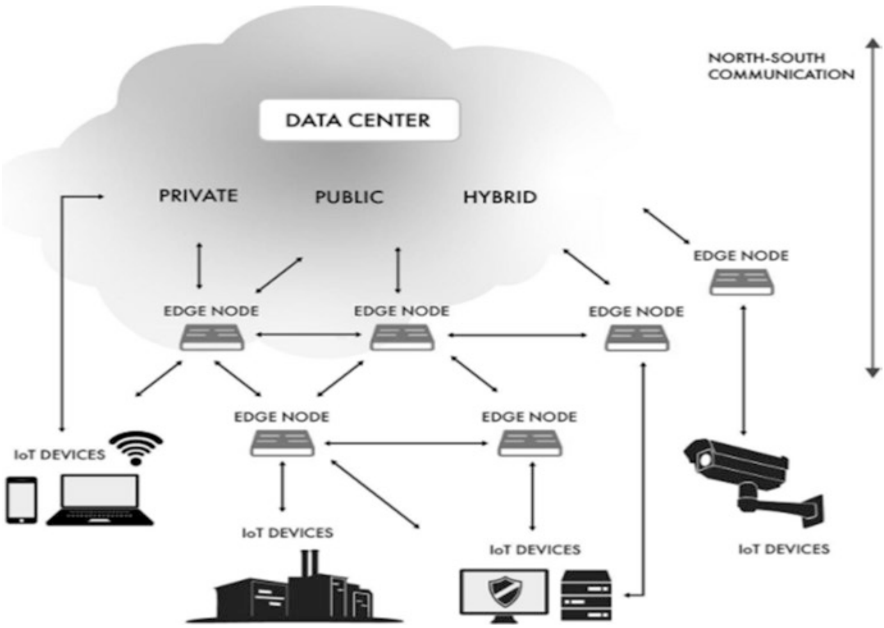


Fig. 2 The networking protocol used by IoT computers and cloud service providers

machines possibly will handle and maintain them. The IoT is a mechanical and digital machine-like computers, cars, and houses, as well as additional objects implanted through electronics, apps, and detectors besides wireless connectivity that capture and share data [32]. The IoT enables devices to be detected and managed directly through current infrastructure networks [25], allowing for added straight incorporation of the real environment with computer-based processes and subsequent increased performance, precision, in addition, reliability. As IoT is enhanced with sensing devices and actuators, it is really a subset of the broader category of cyber-physical devices, which also includes smart grids, smart buildings, intellectual mobility, and smart cities. Fig. 2 represents the networking protocol used by IoT computers, boundary nodes, and cloud service providers. Each item is individually detectable by its integrated computer device, but it can interact with network Infrastructure.

Experts predict that the IoT will have nearly 50 billion artifacts by means of 2020. The usage of IoT has resulted in the accelerated development of integrated sensors, identifiers, and other devices. Sensing devices may be combined with IoT to provide more precise information. To make the device more user-friendly, an Android program may be used in conjunction with the medicine box. The implementation of various technologies, such as IoT, at the right moment may make a significant difference in any area, particularly the healthcare field. The use of the IoT technology (IoT) in medical (manufacturing sector, personal healthcare, and healthcare payment implementations) has skyrocketed across a wide range of diverse IoT use cases. Simultaneously, healthcare monitoring use cases are gaining in popularity, and the patient-centric environment is speeding up, even though obstacles exist. By 2019, 87% of healthcare institutions will have implemented IoT technologies. The market across the globe healthcare industry is projected to hit $169.30 billion by 2020, with remote control playing a significant role.

2 Literature Review

A variety of investigators have formulated different designs for IoT in healthcare including illness forecasting through specific methodologies. This section reflects upon work that has been completed in the same location.

Ahn et al. [2] proposed a method for calculating biomedical parameters in a seated position, including such Electrocardiogram (ECG) as well as Ballistocardiogram (BCG), while using a digital chair that detects non-constrained bio-signals and can be tracked using a control method similar to that which they established, offering a perfect illustration of the use of IoT in healthcare. Almotiri et al. [4] suggested the m-health scheme, which uses smartphones to capture real-time information from patients and storing this on computer systems linked to the internet, allowing for unique recipient access. This information could be used for clinical medical diagnosis and is obtained through the use of a combination of smart technologies as well as a body sensor network. Barger et al. [7] developed a smart home system that uses network architecture to detect and recognize the patient's behavior in the home, and a version of each is going to be implemented. The main goal of their study is to see if their approach is efficient of outwitting behavioral habits, and they have addressed this in their research.

Chiuchisan et al. [8] suggested a method for preventing patient risks in smart ICUs. The suggested device notifies the patient's family and physicians of any changes in the health conditions or body movements, as well as the mood of the environment, so that appropriate precautionary changes can be made. Dwivedi et al. [10] proposed a multi-layered healthcare communications system architecture that is a mix of authentication scheme, cryptographic signature, and biometric identification technology to protect diagnostic data that must be shared over the entire internet for electronic patient record (EPR) schemes. Gupta et al. [12] suggested a framework that takes Raspberry Pi to quantify and track Electrocardiogram (ECG) and many other important health measurements of patients, which could be very useful for clinics and patients, including families.

Gupta et al. [13] proposed a solution based on the Intel Galeleo development agency, which gathers different data and accesses it to a repository where it could be used by physicians, as well as reducing the discomfort experienced by patients who must attend the hospital on a regular basis to verify their health parameters. Lopes et al. [24] suggested an IoT-based platform for people with disabilities to research and identify IoT applications in the healthcare sector that can support them and their society. They choose two use cases to investigate the most recent IoT inventions and their applications, which are mostly aimed at the challenged. Nagavelli and Rao [26] presented a novel model for estimating the seriousness of illness from some kind of medical database that used a mining-based mathematical technique known as the level of disease probability threshold. And, in today's highly competitive environment, they have redesigned an approach that is primarily used to calculate the hyperlink strength of websites. Sahoo et al. [6] investigated the medical monitoring system and the massive volume of medical data provided by numerous publications. They then evaluated the health metrics to forecast the patient's or subject's predicted health outcomes. They have used a cloud-based big data analytic tool to do the same thing utilizing likelihood. Tyagi et al. [20] investigated the function of patient monitoring and researched its technological implications in order to make it a realization and identify resources, about which they suggest a cloud-based theoretical structure wherein patients' health records and knowledge can be safely shared with the consent of the patient including their families by constructing a network among patient, clinic, physicians, laboratories, and so on. The primary explanation to this would be to alleviate hospitals of costly health treatment and solve the lack of physicians, thereby providing better treatment and service to patients.

Xu et al. [31] proposed a novel template for collecting and analyzing IoT data. They created a resource-based distributed data obtaining system to gather and publish data sets internationally so that they can be viewed instantly, at any time. They also demonstrate an IoT-based emergency care service, as well as how to capture and then use IoT data on various networks. Ilkko et al. [17] introduced A Drug Dosage Regulator of Abundant Home Setting [17], smart household and wireless sensor network, which has also improved the eminence of life expectancy by offering safety, intelligence, and convenience. We have spoken about a centered home server through three key functions: usage of existing interfaces on registered devices for controlling the operation, acting as a data portal for the relevant device. The uphill expedient had deployed to make persons aware (older person) as well as for nursing drives uphill. The household server designed and efficiently track the medication container operation by providing material compatible interface design augmented, also by belongings of end customer computers. Kliem et al. [21] proposed a protection and connectivity framework for network-connected medical equipment in mobility conscious e-healthcare ecosystems. Telemedicine is a cost-effective and location-independent surveillance system in which appropriate and reliable patient information can be transmitted with various devices while keeping protection and privacy in mind. Emergency conditions necessitate on-the-fly network connectivity and also data transfer through fields such as patients' homes, private practices, emergency vehicles, and clinics, in which each domain might be concurrent to a separate authority. As a result, a movement conscious methodology enabling out-of-the-box medicinal system incorporation besides authorization, and meeting the standard protection and confidentiality standards in e-health environments are required.

Parida et al. [27] suggested radio frequency identification (RFID aimed at Home Medication Organization Solution. RFID built technology has been hand-me-down to render medication recognition scheme moreover this type of Monitoring of medication is achieved like urgent or daily medication through deprived of RFID tag. The High frequency (HF) tag has been assigned to the user, and the user is being tracked using an RFID scanner, a webcam, and a web-based device. This scheme could be useful to the elderly and the less educated.

Clifton et al. [9] proposed a self-powered wireless environment surveillance system powered by soil energy. An automated surveillance device in the emergency room was clinically validated on a broad scale [9]. The automated healthcare management, which includes electronic medical data, that normally has more difficulties to obtain, deals through artifact information in the form of algorithms, analyzes, and communicates the proper valuation for presentation to clinicians, and this illustrated the machine learning algorithms incorporated across healthcare organizations provide clinical benefits for impoverished patients.

Hamida et al. [14] suggested an in-home wearable insomnia monitoring and diagnostic device that is both effective and stable [14]. Because of technological advancements, it should be necessary to identify timing. Supervision in this section provides an empirical assessment of connectivity in addition to safety measures that would be hand-me-down in house patient specialist attention and medical care, highlighting the greatest appropriate procedure in relations of safety and directly above. Following that, protocols for the delivery of appropriate in-home health information systems are established.

Home Health Hub Internet of Things (H3IoT) was introduced by Ray et al. [28] in 2014. Healthiness is an essential portion of natural life; in addition, it is important to prioritize healthiness associated issues where digitalization can help while using a number of devices via the development of IoT. But, due to the variation and information sharing, the principle of digital transformation for healthcare insurance is being overlooked. Here, the best emphasis has been given to architecture system for significant clinical hub, which has a vision of someone using real-time data.

Sawand et al. suggested development of dynamic symbol display grounded on wireless sensor networks besides telehealth technology [29]. The dynamic sign display will remain integrated through Bluetooth expertise that remains integrated via a sensor device, and the transmission would also consist of the application driven mobile telephone that is enabled by means of 3G otherwise 802.11 of IEEE that is Wi-Fi based communication. The information again on or after transmission will be sent toward the cloud meant for centralized one-to-one care; an analyst in a distant location would be able to access the medical data and, in the event of an emergency, will be able to take immediate measures.

Ajmal Sawand et al. [29] suggested interdisciplinary methods to developing effective and reliable e-healthcare surveillance solutions [29], The digital revolution of IoT, wireless frame part networking, and cloud computation has contributed significantly toward e-medical care, improving the quality of clinical services. Specifically, patient-centric monitoring acts a significant part in e-healthcare system, including clinical data gathering, processing, information transmission, and predictive analytics.

Huang et al. [16] designed the selection and implementation of the pill box while keeping the difficulties of elderly people in mind in order to have maximum drug protection. The pill box will educate the user on the importance of timing, and by doing so, drug abuse will be reduced.

Al-Majeed et al. [3] introduced IoT-based residential telemedicine services [3], and actual tracking is achievable with IoT, which aids in the advancement of low-cost medical processing, connectivity, and cognitive systems that improve quality of life. Where there is a higher concentration of communications, there is a risk of information loss, but with the right software, it could resolve the issue and create low-cost computing, detecting, and human–computer interface technologies.

Lin et al. [23] presented a self-powered mobile environmental surveillance system powered by soil energy. The surveillance system will be using a self-powering network ecosystem powered by green energies that can be useful in isolated places whereby electricity is a concern. Throughout this method, soil energy is used with carbon and zinc electrodes.

Integrated framework aimed at web-grounded management and surveillance of a digital homegrown provides a small price integrated framework aimed at web-related management besides surveillance, with a decentralized sensing and control network as well as a touchpad to provide an easy-to-use interface to such user and wireless internet access [5, 11, 19, 22, 30].

H. Baek et al. [26] presented a digital health tracking chair for noninvasive bio indication analysis, though these systems are nearly entirely built from standard materials. A. J. Jara et al. [6] suggested Zigbee technology for wireless drug control in order to obtain sensor values. Zigbee can easily transmit sensor values, but it cannot be used for uninterrupted transmitting data. Trying to reduce the sampling frequency addresses the above issue but has an effect on signal efficiency.

3 Advantages of IoT

3.1 Concurrent Reporting and Tracking

Actual stretch surveillance via connected devices has the potential to reduce the risk in the case of a medical emergency such as heart disease, diabetes, and bronchitis. With legitimate tracking of the situation in position by a digital healthcare system attached to a mobile application, smart sensors can gather clinical and perhaps other essential medical file and transmit it toward a provider via the smartphone's information link. Research performed by the Center for Interconnected Healthcare Strategy found that remote patient control reduced 30-day readmission rates by 50% of patients with heart failure. Figure 3 represents description of a traditional IoT and cloud-based healthcare infrastructure.

This information is hosted in the cloud and can also be accessed by an authorized individual, a doctor, an affiliate, or an external expert, in order to enable them to

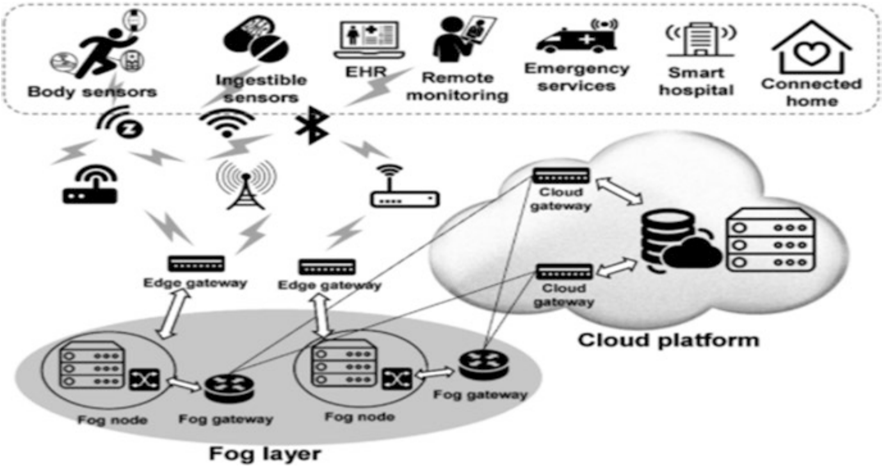


Fig. 3 A high-level description of a traditional IoT and cloud-based healthcare infrastructure

view the data gathered irrespective of their location, times, and system. This information is hosted in the cloud.

3.2 End-to-End Connectivity and Affordability

By using a method of versatility in healthcare services as well as other emerging technology and next-generation health services, IoT will simplify clinical care process. IoT facilitates compatibility, mechanical connectivity, sharing of information, and flow of data that allows the distribution of health services successful. Connectivity procedures are Bluetooth LE, Wi-Fi, Z-wave, and Zig Bee in addition to new protocols, and healthcare professionals will improve the method they detect patients' sicknesses and illnesses as well as innovative approaches to treatment. Out of them, Zigbee is really a moderate cost and has reduced power mesh network that is commonly used for managing and tracking systems, with just a scope of 10–100 m. This networking system becomes less costly and easier to implement than those of other established relatively brief wireless communication such as Bluetooth and Wi-Fi. Consequently, the technology-based setup thus reduces costs, cuts unwanted trips, uses higher performing services, and improves distribution and scheduling data mixture and investigation (Fig. 4).

A large number of information that a medical system transmits is difficult to maintain and handle, due to its real-time use, if cloud storage is inaccessible. Even healthcare professionals have to make a tough gamble on the acquisition and analysis of data from numerous instruments and bases. IoT systems will in actual time capture and examine the data and diminish the necessity for raw data storage. All this may be done across the cloud with only final reports with diagrams available for

Fig. 4 Zigbee technology and modem

providers. Moreover, clinical operations enhance decision-making and are less susceptible to mistakes by providing health analytics and information perspective.

3.3 Tracking and Alerts

In an instance of life-threatening circumstances, an appropriate cautioning is significant. Medicinal IoT systems collect vital information and send the situation to doctors for immediate one-to-one care, while notification about essential components is sent to users via smartphone apps besides other related strategies. Reports and warnings express a strong view around the health of a patient, regardless of location also period. It also helps to decide well and with time. IoT allows alarming, recording, and reporting in real time, enables practical therapies, greater precision, and doctors' adequate intervention, and improves full patient care outcomes.

3.4 Remote Medical Assistance

Patients can reach a physician from a distance of several kilometers using a smart smartphone application in emergency situations. Medics will immediately check patients and recognize their problems on the move through mobility options for healthcare. Many healthcare supply chain companies are now planning the production of robots for distributing medicines on the basis of prescribed and dysfunctional data available on interconnected computers. Patient treatment will be improved in the hospital by IoT. In fact, this reduces the expansion of people's health services. Some of the benefits of remote medical assistance are increased efficacy of drug therapy, therapeutics, and treatment. Consultations are arranged as soon as possible, with no lengthy waits, significantly reduced costs in primary treatment, including patients and nurses would appreciate the importance, patient understanding from their own wellness has increased, and health facility congestion has been minimized.

4 Research Opportunities

IoT would correspondingly remain used for experimental resolutions on healthcare analysis as IoT allows us toward gather a large volume of information on the disease of the patient that we might have gathered manually for several years. These gathered data will also be used to promote clinical research in statistical analyses. IoT then reduces not only time but also resources to study. In the area of medical science thus, IoT seems to have a significant influence. It allows greater and improved therapies to be introduced. IoT remains used in a wide range of instruments to improve the excellence of patients' healthcare amenities. Old smartphones are now upgraded with IoT by only using smart computer built-in chips. This chip improves the patient's help and treatment. As a step in research, smart card technology is introduced, which resembles a standard digital wallet but what distinguishes it as "smart" is the tiny semiconductor chip inserted into card. The chip is a high-performance small computer, which can be configured in a number of different ways. Chip locks allow safe information exchange by safely storing and accessing data and software upon chip. Smart card technique enables high standards of authentication and confidentiality safeguards, providing a mechanism for processing confidential data such as identification and medical records.

4.1 Challenges

4.1.1 Data Security and Privacy

Data security and confidentiality are also one of the main encounters posed by IoT. In actual time, IoT systems gather and communicate data. Maximum of IoT computers, data configurations, and standards do not exist. Furthermore, the law on data possession has some uncertainty. Many of these aspects make the information extremely vulnerable toward cybercriminals that break interest in the process besides negotiating both patients' and physicians' personal health information (PHI). Cyber criminals will exploit patient information for creating false IDs so that they can then purchase pharmaceutical and medical appliances. Cybercriminals may also submit an insurance claim false on behalf of the patient. Fig. 5 represents security and privacy of the healthcare data.

4.1.2 Multi-device and Protocol Incorporation

Incorporation of various instruments correspondingly impedes IoT deployment in the medical industry. The explanation for this stumbling block is that computer vendors have yet to reach an agreement on connectivity protocols and standards. So, even though a variety of technologies are related, the differences in their interaction

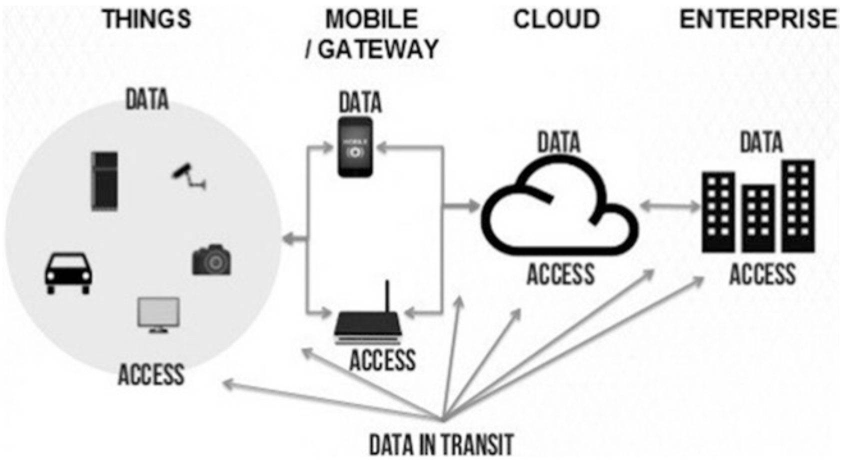


Fig. 5 security and privacy of the healthcare data

protocols confuse and impede the cluster formation method. The non-uniformity of the protocols used by connected devices delays down an entire procedure and limits the spectrum of optimization of IoT systems in healthcare.

4.1.3 Consistency and Data Overload

By means of previously said, data accumulation is complicated owing to the usage of various communication procedures and specifications. IoT computers, on the other hand, continue to generate a massive amount of results. Data obtained by IoT systems are used to obtain critical perceptions. Though the volume of information is so vast, it is extracting information and transforming the information into more problematic for physicians, affecting the consistency of decision-making. Furthermore, as more computers are linked and record increasing amounts of data, this problem is growing.

4.1.4 Cost

The price of such IoTs is primarily determined by the volume of information contained in repositories. The lower maintenance cost and Low-power WAN (wide area network) (LPWAN) technologies make for cost savings in the network portion. Under the scope of IoT issues, engineering economics receives particular attention. The software for analyzing cost control considerations aimed at determining an appropriate simulation model, which would include estimates that use the dynamic system development methodology, allowing a conclusion to be drawn more about expense of the IoT application. As previously said, data computation is complicated owing to the practice of various communication procedures and specifications. IoT computers, on the other hand, continue to generate a massive number of results. Data obtained by IoT systems are used to obtain critical understandings. Though the volume of information is so vast, it is extracting information and transforming the information into more problematic for physicians, affecting the consistency of decision-making. Furthermore, as more computers are linked and record increasing amounts of data, this problem is growing.

5 Internet of Things (IoT) Advancements in Healthcare

The growth of IoT is thrilling designed for everyone because of the issue diverse range of applications in numerous industries. It has many uses in healthcare. IoT in healthcare aids in the following areas:

- Minimizing urgent care wait times
- Tracking patients, nurses, and supplies
- Improving prescription management
- Maintaining vital equipment supply

IoT has since launched a range of smart devices and accessories that have enabled doctors' life easier. These are the instruments mentioned below:

(a) Hearables

Hearables remain cutting-edge hearing aids that have been radically altered the method persons with audible range impairment interrelate with the media. Just about everywhere, hearables are Bluetooth-enabled, able to communicate with your smartphone. It allows anyone to process, standardize, and add actual world noises. In-ear technologies are used in several hearables' devices being developed by manufacturers including larger corporations. Any programmers simply perform best in this manner: measurements of the heart rhythm and body temperature, for instance, are still more reliable from an in-ear system than those from anything close to the body, such as a cuff or chest band. The easiest example is done in Doppler Laboratories.

(b) Sensors that can be ingested

Ingestible detectors remain indeed a wonder of advanced technology. They are pill-sized detectors that track the drug in our bodies that notify us before any anomalies are detected. The above detectors may be a lifesaver for diabetic patients by reducing symptoms and providing early notice of disorders. However, one illustration is Proteus Digital Health, which is the miniature detector, manufactured by Proteus, and is around the scale of a grain of sand. It becomes active when it comes into communication with stomach fluid. The sensor senses and tracks the time and date when the pill is swallowed. The sensor sends the data to a device carried by that

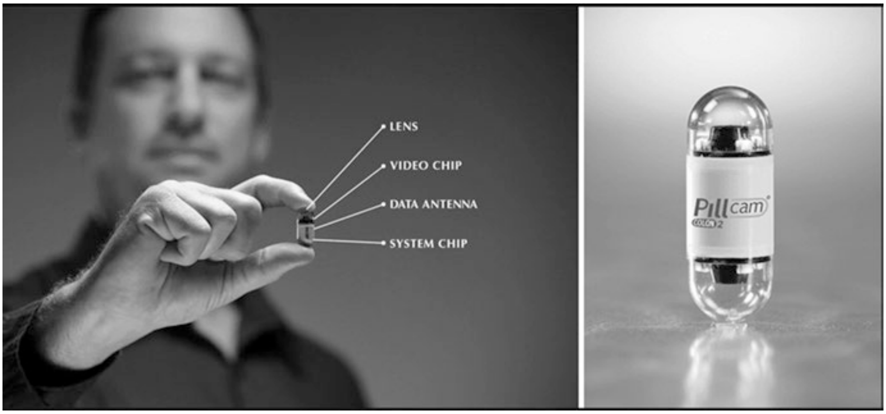


Fig. 6 PillCam COLON 2. [1]

of the patient. Fig. 6 represents the pillCam COLON sensor. The PillCam COLON would enable more patients to be tested in a more efficient and accessible way, reducing the financial burden on the health process and increasing the mortality rate among those treated.

(c) Moodables

Moodables provide mental state gadgets that make us feel better all through the day. This could sound like science fiction, and it is really close to the truth. Thync and Halo Neurosciences have also been research on it and have made significant strides. Moodables are head-mounted wearables that provide small power to the brain, elevating our mindset. The moodable strategy has the potential to have some significant advantages. For starters, mobile users will no further be forced to interact via their phones for the next two weeks. Second, moodable's prospective data collection approach could improve the probability of capturing impartial, digitally expressed mood disorders produced by the participant prior to processing the responses or being conscious that their mental wellbeing was being evaluated. Most interestingly, textcolorcyan moodable model promises an almost simultaneous monitoring rating of the subject's mental condition until the machine learning models are properly educated.

(d) Computer vision technology

The use of computer vision technologies, in conjunction with AI, also greatly contributed to drone technological innovation, which seeks toward imitate viewing experience and, as a result, strategic thinking can be done. Drones like Skydio use machine vision systems to spot and avoid obstacles. This technology will also help visually blind individuals move more effectively. Handling drug trial maintenance, computer vision in operation, quicker lab research outcomes, and therapy are a few uses of computer vision technologies. Trend analysis and studies providing a precise measuring instrument, automatic processing of 3D radiological images, diagnostic implementations irregularities in the heart, lungs, and liver are discovered. Computer Vision for Diagnosis Of cancer and Detecting Pneumonia. Diagnosis Of cancer, Detecting Pneumonia.

(e) Healthcare charting

IoT instruments like Audemix eliminate a lot of the human labor that a clinician needs to prepare while patient recordkeeping. The thing is regulated by means of voice recognition and collects information from the patient. It allows the sufferer's details available for analysis. It helps physicians with about 15 h of work every week.

6 Conclusion

In this chapter, we discussed and demonstrated the concepts for automated devices that ensure continuous tracking of different health variables and forecasting of any disease, which is important to predict serious diseases at an early stage. It is also discussed about how the IoTs-enabled remote health management system has many advantages over traditional health monitoring systems. From this chapter, anyone can understand that it is critical to collect accurate raw data in an effective manner; however, it is much more important to explore and mine the raw data to extract more valuable knowledge such as links between objects and facilities to allow the concept of IoT or industrial IoT. In this chapter, we explored the use of IoT in healthcare systems, the complexities of IoT in healthcare structures, and a study of numerous studies done in this research field.

From the standpoint of healthcare, this chapter evaluates various IoT protection and privacy functions, such as privacy criteria, vulnerability templates, and risk classifications. Furthermore, this chapter presents an innovative collective authentication scheme to reduce potential threat, explores how impressive results including such data analytics, intelligent systems, and wearable technology could be advantageous in a healthcare environment, and addresses various IoT and electronic health records laws and regulations from around the world to experience how they would help social and economic development in order to achieve sustainable development.

References

1. S.N. Adler, Y.C. Metzger, PillCam COLON capsule endoscopy: recent advances and new insights. Therap Adv Gastroenterol. **4**(4), 265–268 (2011). https://doi.org/10.1177/1756283X11401645. PMID: 21765870; PMCID: PMC3131168
2. B.G. Ahn, Y.H. Noh, D.U. Jeong, *Smart Chair Based on Multi Heart Rate Detection System* (2015 IEEE Sensors, 2015), pp. 1–4
3. S.S. Al-majeed, *Home Telehealth by Internet of Things (IoT)* (2015), pp. 609–613

4. S.H. Almotiri, M.A. Khan, M.A. Alghamdi, *Mobile Health (m-Health) System in the Context of IoT* (2016 IEEE 4th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW), 2016), pp. 39–42
5. M.D. Ansari, V.K. Gunjan, E. Rashid, On security and data integrity framework for cloud computing using tamper-proofing, in *ICCCE 2020*, (Springer, Singapore, 2021), pp. 1419–1427
6. H. Baek, G. Chung, K. Kim, K. Park, A smart health monitoring chair for nonintrusive measurement of biological signals. IEEE Trans. Inf. Technol. Biomed. **16**(1), 150–158 (2011)
7. T.S. Barger, D.E. Brown, M. Alwan, Health-status monitoring through analysis of behavioral patterns. IEEE Trans. Syst. Man Cybern. A Syst. Hum. **5**(1), 22–27 (2005) ISSN 1083-4427
8. I. Chiuchisan, H.N. Costin, O. Geman, *Adopting the Internet of Things Technologies in Health Care Systems* (2014 International Conference and Exposition on Electrical and Power Engineering (EPE), 2014), pp. 532–535
9. D.A. Clifton, D. Wong, L. Clifton, S. Wilson, R. Way, R. Pullinger, L. Tarassenko, A large-scale clinical validation of an integrated monitoring system in the emergency department. IEEE J. Biomed. Heal. Informatics **17**(4), 835–842 (2013)
10. A. Dwivedi, R.K. Bali, M.A. Belsis, R.N.G. Naguib, P. Every, N.S. Nassar, *Towards a Practical Healthcare Information Security Model for Healthcare Institutions* (4th International IEEE EMBS Special Topic Conference on Information Technology Applications in Biomedicine, 2003, 2003), pp. 114–117
11. P. Gautam, M.D. Ansari, S.K. Sharma, Enhanced security for electronic health care information using obfuscation and RSA algorithm in cloud computing. International Journal of Information Security and Privacy (IJISP) **13**(1), 59–69 (2019)
12. M.S.D. Gupta, V. Patchava, V. Menezes, *Healthcare Based on IoT Using Raspberry Pi* (2015 International Conference on Green Computing and Internet of Things (ICGCIoT), 2015), pp. 796–799
13. P. Gupta, D. Agrawal, J. Chhabra, P.K. Dhir, *IoT Based Smart Healthcare Kit* (2016 International Conference on Computational Techniques in Information and Communication Technologies (ICCTICT), March 2016), pp. 237–242
14. S.T.-B. Hamida, E. Ben Hamida, B. Ahmed, A. Abu-Dayya, *Towards Efficient and Secure In-home Wearable Insomnia Monitoring and Diagnosis System* (13th IEEE Int. Conf. Bioinforma. Bioeng, 2013), pp. 1–6
15. http://www.autoidlabs.org/ (Aug 2011)
16. S. Huang, H. Chang, Y. Jhu, G. Chen, *The Intelligent Pill Box – Design and Implementation* (IEEE International Conference on Consumer Electronics, 2014), pp. 235–236
17. L. Ilkko, J. Karppinen, UbiPILL a medicine dose controller of ubiquitous home environment. 2009 Third Int. Conf. Mob. Ubiquitous Comput. Syst. Serv. Technol., 329–333 (2009)
18. International Telecommunication Union. *ITU Internet Reports 2005: The Internet of Things* (November 2005).
19. Z.A. Jaaz, M.D. Ansari, P.S. Joseph Ng, H.M. Gheni, Optimization technique based on cluster head selection algorithm for 5G-enabled IoMT smart healthcare framework for industry, Paladyn. J. Behav. Robot. **13**(1), 99–109 (2022)
20. A.J. Jara, M.A. Zamora-Izquierdo, A.F. Skarmeta, Interconnection framework for m-health and remote monitoring based on the Internet of Things. IEEE J. Sel. Areas Commun. **31**(9), 47–65 (2013)
21. A. Kliem, M. Hovestadt, O. Kao, *Security and Communication Architecture for Networked Medical Devices in Mobility-Aware eHealth Environments* (IEEE First Int. Conf. Mob. Serv, 2012), pp. 112–114
22. A. Ksibi, H. Mhamdi, M. Ayadi, L. Almuqren, M.S. Alqahtani, M.D. Ansari, et al., Secure and fast emergency road healthcare service based on blockchain technology for smart cities. Sustainability **15**(7), 5748 (2023)
23. F.-T. Lin, Y.-C. Kuo, J.-C. Hsieh, H.-Y. Tsai, Y.-T. Liao, H. C., Lee A Self-Powering Wireless Environment Monitoring System Using Soil Energy. IEEE Sens. J. **15**, 1–15 (2015)

24. N.V. Lopes, F. Pinto, P. Furtado, J. Silva, *IoT Architecture Proposal for Disabled People* (2014 IEEE 10th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), 2014), pp. 152–158
25. J. Morak, H. Kumpusch, D. Hayn, R. Modre-Osprian, G. Schreier, Member, IEEE design and evaluation of a telemonitoring concept based on NFC-enabled mobile phones and sensor devices. IEEE Trans. Inf. Technol. Biomed **16**(1), 17–23 (2012)
26. R. Nagavelli, C.V. Guru Rao, *Degree of Disease Possibility (ddp): A Mining Based Statistical Measuring Approach for Disease Prediction in Health Care Data Mining* (International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2014), 2014), pp. 1–6
27. M. Parida, H.-C. Yang, S.-W. Jheng, C.-J. Kuo, *Application of RFID Technology for In-House Drug Management System* (15th Int. Conf. Network-Based Inf. Syst, 2012), pp. 577–581
28. P. Ray, Home Health Hub Internet of Things (H 3 IoT): An architectural framework for monitoring health of elderly people. Sci. Eng. Manag. Res. **3**, 3–5 (2014)
29. A. Sawand, S. Djahel, Z. Zhang, F. Na, *Multidisciplinary Approaches to Achieving Efficient and Trustworthy eHealth Monitoring Systems* (Commun. China (ICCC), 2014 IEEE/CIC Int. Conf, 2014), pp. 187–192
30. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
31. B. Xu, L.D. Xu, H. Cai, C. Xie, J. Hu, F. Bu, Ubiquitous data accessing method in IoT-based information system for emergency medical services. IEEE Trans. Industr. Inform. **10**(2), 1578–1586 (2014) ISSN 1551-3203
32. G. Yang, L. Xie, M. Mäntysalo, X. Zhou, Z. Pang, X. Li Da, S.K.-W. Senior, Q. Chen, L.-R. Zheng, A health-IoT platform based on the integration of intelligent packaging, unobtrusive bio-sensor, and intelligent medicine box. IEEE Trans. Industr. Inform. **10**(4), 2180–2191 (2014)

Landslide Monitoring System Using an IoT Wireless Sensor Network

Gian Quoc Anh, Tran Binh Duong, Vijender Kumar Solanki, and Duc-Tan Tran

1 Introduction

Landslides are a slow or fast motion of a large landmass and rocks down a hill or ridge. Little or no flow occurs over a particular slope until heavy rain, resulting in rainwater facilitating the movement causing landslides. Landslides are significant threats to people, seriously affecting infrastructure, property, and people's lives. According to a summary of the SafeLand (http://www.safeland-fp7.eu), Europe is the region with the second-highest number of deaths and the highest economic loss from landslides compared to other continents in the twentieth century with a statistic of 16,000 people, deaths from landslides and physical damage amounted to more than $1.7 billion. The findings were made using factors related to landslides, estimating a landslide's likelihood, thereby establishing a relationship between the factors involved, and the landslide can predict future landslide risk and give the most sensible warning.

Some constructive solutions warn systems such as landslide warning information based on rainfall, based on slope displacement monitoring, and analysis model permeability. However, based on observation and statistics, the warning threshold

G. Q. Anh
Nam Dinh University of Technology Education, Nam Dinh, Vietnam

VNU – University of Engineering and Technology, Hanoi, Vietnam

T. B. Duong
Vietnam Paper Corporation, Hoan Kiem, Hanoi, Vietnam

V. K. Solanki
Department of Computer Science & Engineering, CMR Institute of Technology, Hyderabad, TS, India

D.-T. Tran (✉)
Faculty of Electrical and Electronic Engineering, Phenikaa University, Hanoi, Vietnam
e-mail: tan.tranduc@phenikaa-uni.edu.vn

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_13

shows the limits of the influencing factors that are likely to occur landslides [51]. Therefore, the method is based on rain information using real-time data monitoring at rain gauging stations [9, 34, 38, 40, 41, 46, 48]. This system's advantage is simple, but elements of topography, geology, cover, drainage that reflect pore-water pressures of specificity are ignored, leading to low accurate warnings.

Many devices and techniques have been applied to monitor slope displacement, including geotechnical sensors and remote sensing technology [13]. The method of monitoring the slope's displacement is limited; the tension sensor cannot track the displacement inside the ground at different depths. Inclinometers are often used to overcome this obstacle. The inclinometer is usually connected in series and placed in boreholes at different depths. Tilt measurement data are converted to displacement distance.

GPS and radar technologies are also applied to monitor shifts over large areas [4, 23]. Ground radars are installed in a safe location to track and digitally map the slope. This method can calculate the actual surface displacement with an accuracy of millimeters. However, this technology does not allow monitoring of underground displacement under the slope surface.

Studies have shown displacement and acceleration; at the same time, the slope's foot shows an 80–90% water saturation ratio before a landslide occurs. Integrated systems of monitoring data and physical or numerical modeling are evaluated as effective systems for the early prediction of landslides. In this case, the sensor network monitors the factors causing the slide built. Several successful integrated models have been published, such as the seepage model [12, 15, 26], the slope equilibrium model [54], and the slip transmission model [39, 60].

In 2005, Towhata's team proposed a soil slip warning system based on soil slip identification, including a moisture meter [56]. Data from the measuring equipment are sent to the central station for processing and alarming if necessary. However, the use of an inclinometer is energy inefficient. To overcome this obstacle, it is possible to use a three-dimensional accelerometer module based on micro electro-mechanical system (MEMS) technology to measure the accurate angle of inclination while a compact, more efficient configuration. In addition, in this system, the processing of alarm information is not automated yet.

In 2006, Terzis et al. announced to build a warning using wireless sensor networks [53]. In this system, sophisticated sensor boxes can detect small soil deformation, and sensor position information is fed into the finite element model. The system cost is too high to be implemented in practice.

In 2010, Huggel Christian's team initially integrated the finite element method into the warning model and conducted experiments in Colombia [30]. However, the finite element method's disadvantage is that the volume of computation is huge; it is challenging to implement in practice on a large scale. The article goes into depth analysis of landslide monitoring system using a wireless sensor network from the above research.

In this chapter, Sect. 2 discusses landslide events and Sect. 3 presents Wireless sensor network (WSN) Technologies. Section 4 introduces the landslide mapped to sensors. Section 5 reviews related work and shows the research issues and challenges, whereas Sect. 6 concludes the conclusion.

2 Landslide Events

Landslide refers to the geological phenomenon in which the rock and soil on the slope slide down the slope in a whole or scattered manner along a specific weak surface or weak zone under the action of gravity. Landslides mostly occur on slopes with a slope of less than 50. According to the composition, landslides' stratum lithology characteristics are divided into soil landslides and rock landslides. According to the landslides' structural features and the sliding surface's relative positions, and the rock (soil) layer, soil landslides can be divided into homogeneous landslides and bedding landslides. According to the landslide's structural characteristics and the sliding surface's exposed position, rock landslides can be divided into landslides on the slope, landslides at the foot of the slope, and landslides at the bottom of the slope. Landslide formation conditions and predisposing factors are divided into the following.

2.1 Landslide Formation Conditions

1. Topography. The formation conditions of landslides can only occur on slopes with a particular slope in a specific landform. The terrain and landforms prone to landslides can be summarized into three categories: rivers, lakes (reservoirs), and seas, which are eroded by flowing water. Bank slope; artificial side slope for railway, highway, and engineering buildings; the upper and lower slopes are steep, and the middle part is gentle, and the upper part is a belt-shaped slope.
2. Formation lithology conditions. Rock and soil are the material basis for landslides. Generally, all kinds of rocks and soils may constitute landslides, in which the structure is soft, the shear strength and weathering resistance are low, and they are affected by water. Rocks and soils prone to change in nature, such as loose overburden, shale, mudstone, coal-measure strata, schist, slate, phyllite, tuff, and other soft and hard rock layers, are prone to landslides.
3. Geological structural conditions. The slope rock and soil can only slide down when they are cut and separated into discontinuous states by various structural surfaces. At the same time, the structural surfaces provide channels for rainfall to enter the slope. Therefore, multiple joints, fractures, bedding planes, lithological interfaces, and slopes with developed faults, especially when the steeply inclined structural surfaces of parallel and vertical slopes and the gently inclined structural surfaces develop, are most prone to landslides.
4. Hydrogeological conditions. Groundwater activities play an essential role in the formation of landslides, which are mainly manifested in softening of rock and soil, reducing the shear strength of rock and soil, especially the softening effect and reducing the strength of the sliding (belt) protruding; generating or increasing hydrodynamic pressure and pore water pressure, eroding rock and soil, increasing rock and soil bulk density, causing floating force on permeable rocks, etc. Below is a brief description of some of the more common types of landslides.

2.2 Swivel Slides

Swivel slides are the most common type of skidding, occurring mostly along pavement walls with a gradient of over 60 degrees, a few milled on steep slopes above 35 degrees, and occurring in the weathered rock portion of all walls create geology. Slides have a rather diverse morphology, but the most common is the arc shape, the inverted funnel shape, and the trapezoidal shape. The slip surface is mainly a convex surface developed according to the weathering layers.

Rotation sliding mainly occurs according to the sliding-slip mechanism, sliding from outside to inside to decrease the slope's slope angle or sidewall. Slip material in the form of soil, clay powder, weathered rock chips. Swivel mainly occurs during or immediately after heavy rains.

2.3 Translational Slide

A translational slide occurs along the road's slope, where the rock is intensely layered and in the same direction as the terrain slope. Simultaneously, the fracture systems are perpendicular to or near perpendicular to each other, resulting in almost separated rock blocks.

2.4 Streamflow or Slip Flow

Streamflow or slip flow occurs in areas where tectonic destruction exists—characterized by discrete, weakly bonded materials that only maintain equilibrium on the slopes. On the slopes with high slopes or slippage, landslides can happen at any time under the impact of factors such as rain and vibration. The material mass moves very quickly and has great destructive power.

2.5 Mixed Slip

In some areas with relatively thick weathered crust covered on the rock with the cracked structure under the developed ground, it will form an intermediate slide between translational and rotating shear. The sliding wall has a high slope; when moving downward, the sliding block controlled by the intermediate sliding surfaces suddenly changes the slope angle. Then, the sliding body will move almost flat to the bottom.

3 WSN Technologies

WSN is a network of devices called sensor nodes distributed in space and collaborating to exchange the information obtained from the surveillance environment over a wireless connection. Data obtained from the sensor networks are sent wirelessly to a central station (also called a sink node) in accordance with a predetermined protocol over a single-hop or multi-hop link for internal use or to connect to other networks for remote access through the gateway [50]. Sensor network (SN) and the central station's connection is bidirectional for data exchange, and SN operation can be reestablished. WSN combines devices to collect (monitor), exchange, and process information, thereby making results and meaningful decisions corresponding to the monitoring environment's phenomena and events. WSN is designed to be application-oriented, with solutions tailored to a specific application. WSN includes three main types: event detection, query-based monitoring, and continuous monitoring and tracking [17]. WSN is often connected to other networks such as the Internet and telephones to expand operational capabilities and exchange information.

WSN is widely used in industry, agriculture, smart home, mining, medical, military, etc. due to remote monitoring's advantages, a large number of sensor nodes, low cost, and easy deployment. Specifically, WSN has been successfully applied in food and agriculture monitoring [61], flash flood warning [14], soil moisture monitoring [32], civil structure monitoring [16], underground monitoring structure [36], and underground coal mine monitoring [37].

WSN has desirable features such as small SN size, low energy consumption, flexible large-scale deployment, and scalability. In addition, WSN is limited by low bandwidth, short transmission distance (for PAN technology), and low ability to process data and store information at nodes. Another critical issue is that SNs are often deployed in hazardous, inaccessible environments, while battery power is used to power all SN operations.

Some WSN applications in landslide studies have been made, specifically detect landslides [49], predicting landslides [52], early warning systems landslide [5, 31]. The SN is designed to operate continuously for months or even years without replacing the battery in the ground slip warning system. Due to technological advances, research and application of WSNs for ground slip early warning systems are still ongoing. WSN is recommended for precipitation landslide warning and monitoring systems. With the advantage of its collection flexibility, its real-time data transmission has been proven in environmental monitoring applications [8, 19, 50].

The monitoring and warning system of landslides caused by rain enables the sensors in the sensor nodes to measure ground slip parameters (such as pore water pressure, inclination, and vibration) and transmit data received and get to the central station via wireless links. The environmental parameters are measured at the sensor nodes and then sent to the central station via the wireless link. The central station provides data to users connecting to the Internet through a gateway. The data are then passed to a data server connected to the Internet or other networks through a gateway [1, 11, 20, 21, 25, 33, 43, 45, 57, 59].

4 Landslide Mapped to Sensors

The early warning system's design and successful implementation for landslides caused by rain are highly dependent on the sensors and networks used. A large amount of monitoring data is collected, processed, and transmitted by sensors and networks [40]. Therefore, it is necessary to determine the correct type of sensor, the number and position of the monitoring point, and the monitored parameter sampling rate [10].

For the landslide warning system, the sensor selection depends on the slide trigger parameter. One type of sensor cannot provide enough information to predict a slide, so it is necessary to combine different sensors to collect information. Observed information includes environmental/weather conditions affecting slides and displacement to varying positions on the slope and slope parameters. The parameter is monitored according to (i) rainfall, groundwater level, humidity, and pore-water pressure in sliding mass at different depths are indirect parameters; (ii) the amplitude, speed, and direction of landslide displacement of the slope are direct parameters. For landslides due to rain, catastrophes are mainly influenced by groundwater conditions, rainfall intensity, and soil properties of the slope [47]. Water seeps into the slope during rain, increases pore water pressure, and reduces shear resistance, reducing Factor of Safety (FoS) [7]. Therefore, pore water pressure sensors and soil moisture sensors are used to collect and monitor the slope's soil properties, determining the unstable state. The acceleration sensor monitors slope surface motion.

Sensors placed close to the surface and buried under a slope are selected based on accuracy, response time, energy consumption, and long-term use. A wireless data transmission protocol connects sensor nodes.

The wireless sensor network uses sensors that have direct contact to collect information. Figure 1 illustrates the diagram of a WSN assembled at a field site, and Fig. 2 presents a photo of a sensor node.

Deformation Measurement

There are many ways to track deformation and measure deformation in geotechnical applications, vibratory wire gage, resistance type measuring device, and fiber optic sensors. A robust, durable technology commonly used for geotechnical applications is vibrating wire strain gauges.

The vibrating wire strain gage works on the following principle: a tension wire, when pulled, vibrates at a frequency proportional to the wire's strain. The resonant frequency of the wire is the basis for determining the strain frequency. The resonance frequency (f) and tension force (T) depend on length (L), cross-sectional area

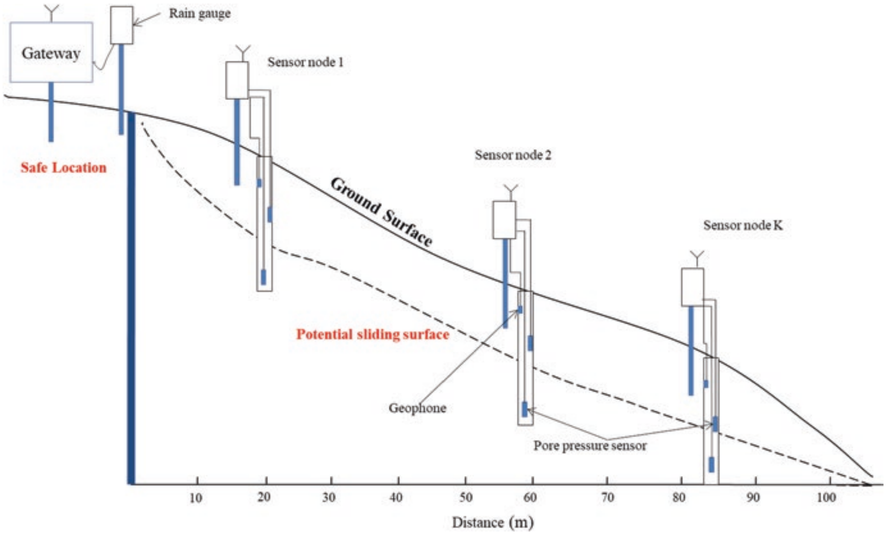
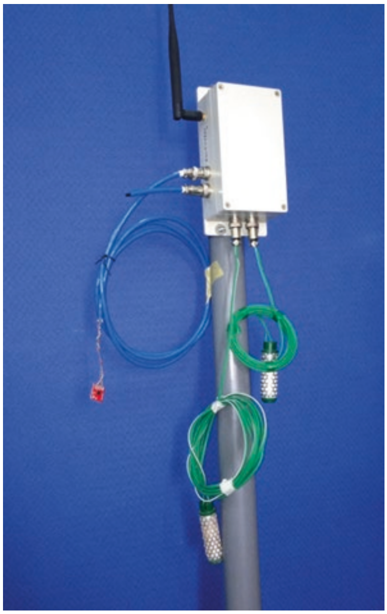


Fig. 1 WSN is deployed in the field site

Fig. 2 A photo of a sensor node



(A), and wire material density (ρ), which are related and expressed by the following formula:

$$f = \frac{1}{2L}\sqrt{\frac{T}{\rho A}} \tag{1}$$

The strain can be calculated using the following formula:

$$\varepsilon = GF\left(f^2 - f_0^2\right) \tag{2}$$

where ε is the strain, G and F are the coefficients depending on the material properties, length, and tension.

Resistance strain gage works on the dependence of conductivity on the shape of conductors under strain.

Inclination Measurement

Tilt measurement is the measure of the angle deviation from the vertical gravity vector. In geotechnics, tilt is one of the versatile measurements due to calculating deviation or displacement. In fact, there are many types of inclinometers that are classified based on the measuring mechanism, such as electrolytic inclinometer, accelerometer, and vibrating wire.

Electrolytic tilt sensors include a conductive liquid glass vial, and a wheatstone circuit type is applied to connect three electrodes. As the device tilts, bubbles in the vial move, increasing the resistance between the two electrode pairs and decreasing the opposite electrode pair's resistance. A constant voltage is supplied to the sensor, and tilt is correlative to the voltage change.

Tilt is measured by accelerometer type inclinometer using a force-balance servo. Anatomy of the device includes a block of steel pendulum hanging on a hollow precisely detector, while pairs of moment coils surround the pendulum. As the device tilts, the pendulum moves and the hollow detector activates the feedback control circuit to excite the torque coils to push the mass back to zero. The current flowing through the coil, which exerts the magnetic field to push the pendulum back to zero, is adjusted by the servo amplifier. The power required to push the pendulum to a hollow position is adjusted for inclination.

Vibrating wire inclinometer includes a mass of pendulum that moves under the effect of gravity. Attached to the pendulum is a vibrating wire strain gage. Mass fluctuations can alter the tension in the strain gage.

Tilt sensors are based on MEMS technology in which the sensor is packaged in a semiconductor base together with a signal-processing circuit. MEMS-based sensor size components are approximately 1–100 microns, with sensors typically less than a millimeter in size. Tilt is usually measured based on gravity's effect on a small mass suspended in an elastic support structure. As the device tilting, mass moves, causing the capacitance changes between it and the supporting structure. The angle of inclination is calculated from the measured capacitance. MEMS is low cost and impact resistant and has good frequency response and low power requirement, so it is becoming more and more popular in many applications related to inclination and acceleration monitoring. The need for constant monitoring of strain events leads to the need for high-performance and low-cost measurement systems for on-site installation. The use of MEMS technology is a viable solution.

Vibration Measurement
Stress reduction is effectively partly due to vibration that increases the pore water pressure in the ground. Granular soils lose stiffness when the effective stress is close to zero (total stress deduct pore water pressure). The hardness of granular soils is directly related to the effective stress of the surrounding environment.

The geophones and accelerometers are often used to monitor vibrations. Typically, the geophones, the device that converts ground-to-voltage displacement speed, are used to analyze the displacement speed of landslides, as in Ramesh's study, Maneesha Vinodini [40]. A geophone is the motion sensor of choice because it does not need a power source to operate and detect extremely small ground displacements. Vibrate wire strain gages are also commonly used for measuring strain. The vibrating wire device's principle is based on the relationship between the vibration frequency and the string tension. The two ends of the wire are attached to the structure under supervision. When there is a change, displacing the distance between these two points will result in a change in the string tension, resulting in a change in the vibration frequency. A magnetic core, surrounded by an electrical coil, is placed in the device. The casing and magnetic core are tied together and move together, while springs are used to attach the coil. When the ground shakes, the cabinet moves but the coil tends to stand still. Movement of the magnet in the coil creates an electric current that corrected follow speed of oscillation.

To measure and record, the accelerometer was used. The most popular application in geotechnical is an accelerometer of piezoelectric type. The instantaneous charge is generated by piezoelectric quartz when under load or pressure. Signals dissipate rapidly over time, even when load or pressure is maintained. An accelerometer comprises a piezoelectric crystal that supports a vibrating mass. A spring and a damping device are used to adjust the properties of the accelerometer. The accelerometer can only monitor accelerations at lower frequencies than its natural frequency; this is an important characteristic. The natural frequency is common in the 5000–20,000 Hz range. Hence, the accelerometer is more flexible than the geophone and is often used to measure velocity by integrating acceleration time records. In recent years, accelerometers based on MEMS technology have been developed and applied.

5 Research Issues and Challenges

In recent years, many authors have applied WSN in the monitoring and early warning system of landslides because of its outstanding advantages [24].

System Constraints Need Design Continuous operation time should last at least one rainy season. The sensor button is deployed at a fixed position on the track slope and is not continuously accessible. The communication range is around several hundred meters. The system is designed on the assumption that the sensor button is provided by limited battery power, which must be active for a long time. Calculation speed and memory capacity at the sensor node are limited. Therefore, the algorithm deployed at the sensor node must have low computational volume. Sensors are pre-grouped according to geospatial, and the center cluster is pre-selected based on position and distance to the central station. The center cluster is supplemented with energy from the solar energy source.

Installation and commissioning are factors to consider when designing a monitoring system. If the system is complex, requiring technicians to have high installation and operation techniques will increase the system's investment and operating costs. The system works in a harsh, risky environment, so the network's lifetime must be large enough to reduce human intervention. Many solutions have been implemented to optimize the sensor node's energy, such as optimizing the hardware design and choosing to use MEMS sensors. Adopting an adaptive network configuration ensures system reliability even when some sensor nodes are not working correctly. Remote, automatic algorithm updates are also one of the requirements for WSN.

Typically, WSN is deployed in harsh environments in energy constraints, computational capabilities, sensor node storage, communication range, and bandwidth. On the other hand, many influencing factors in the analysis and prediction of landslides are nonlinear, with changes over time. There is no clear boundary on the threshold, so deciding based on the hard threshold can lead to inappropriate warnings. Furthermore, the quality of information obtained from the sensor is usually not high due to sensor limitations and operating conditions. Therefore, it requires algorithms to adapt to each factor. The adaptive algorithm is applied to optimize the system's resource and energy efficiency while enhancing system flexibility.

One of the Bottlenecks of WSN Application Is the Energy Limitation It affects system design decisions such as sampling frequency and type of sensor to be used. Battery power, with limited energy, is often used to power all SN operations. Depending on the deployment environment, the battery supplied to the SN can be replaced or recharged. When deployed in harsh or dangerous environments, battery power replacement is not always possible.

Many solutions have been proposed, such as harnessing energy from the surrounding environment (solar energy, wind, oscillation, sound, heat, etc., converted into electrical energy for direct use or storage) [2]. However, the solution in a specific project is not always feasible. For example, they are harnessing solar energy during the rainy season or where the mountainous terrain, the slope direction is not suitable, while this time SN uses the most energy. In addition, this energy source is not stable depending on the time of day and the season.

Recently, wireless charging technology has also been studied to apply to WSN [3, 18, 42, 47, 58]. It is a potential technology because the energy is transmitted without contact between the transmitting and receiving equipment with many advantages of water resistance and the device's dust resistance due to no direct connection [18]. However, there are still many obstacles to implementing this technology due to technical factors such as topographical conditions, distance, and transmission efficiency [3].

Many scientists use the research direction to optimize SN's energy consumption to prolong the operating time of SN [62]. Energy consumed at the sensor node is due to three parts: sensor, processing, and communication. The energy-saving solution at SN can focus on three parts: (i) data collection (adaptive sampling, reduced data collection, sensor hierarchy in which the sensor has high energy consumption. Works only under defined conditions); (ii) data processing (compressing data by encoding data at SN and decoding at the central station, predicting data based on time and space correlation, the central station only sends data if any differences between obtained data and predicted data, group data processing); and (iii) data transmission over the network (grouping, network protocol, network coding, etc.) [6, 28]. In particular, communication is generally assumed to have much greater energy consumption than processing energy. The wireless transmission takes a large amount of power; the transmission energy is proportional to the transmission distance's square. The power to transmit one bit is equivalent to the energy to execute several thousand instructions [48]. Communication operation mode consists of receiving data, transmitting data, and idle state with the same power consumption.

Meanwhile, in sleep mode, energy consumption is reduced. Therefore, the transmitter should be turned off when possible [6]. The SN returns to operating mode only when there is a request to transmit information from another SN or is scheduled to work (the SN is programmed to return to the operating mode at the same time). One solution is used to let the sleeping SN know when another SN is required to use different communication frequencies for data (high speed, energy-consuming) and signal (low speed, less energy saving) [6]. Solutions are given at SN to solve energy problems such as design optimization and adaptive sampling in Nguyen et al. [44]; compressing and arranging data based on the time and spatial correlation of the data obtained at SN in Liao et al. [38]; using low-power communication standard, optimizing network configuration, and dividing the operation process of SN into states in Nguyen et al. [44]. There are many solutions to reduce energy consumption and extend the lifetime of WSN, including data compression [35]; combine data in central clusters; low architectural SN design; optimal routing configuration [27, 34]; vary the sampling rate and the rest (duty cycle) in which the system switches between the active and idle states [27]. The sensor consumes a large amount of energy to collect data, the sensor's choice must be considered. Sensors manufactured using MEMS technology are preferred due to their very low power consumption. A solution to change the sampling frequency is also used. Sensors are also stratified, in which sensors with a large power consumption only operate when the SN detects a specific event [22]. In addition to the grouping solution, SN also needs to set up an appropriate sampling algorithm and schedule to limit energy consumption. Different solutions can be combined to extend network lifetime. The solutions are a trade-off between SN lifetime and application requirements, including processing capacity, speed, and data transmission.

Processing data at the sensor node or in the central cluster helps reduce data transmission energy while also reducing congestion in the network as the number of sensor nodes in the network increases. A popularly applied direction is to use technology and techniques to optimize the sensor node's operation and reduce the amount of data transmitted. The principles that have been applied and presented in the document include data compression and duty circle.

WSN Customization and Reliability Issues WSN is typically deployed in a variable environment. Button positions can be predictable or random, fixed, or mobile. The SN quantity is customizable and extensible. SN has limited energy, computing power, storage capacity, and communication bandwidth. The WSN must also satisfy the SN's scalability, independent operability condition if another SN goes wrong. Therefore, the design should consider common issues such as data arrangement, positioning, node grouping, routing, scheduling, anomaly detection, and error. For optimal routing, the SN needs to know the location. The solution used can either use GPS to determine the absolute position or estimate the reference position by calculating the reference point's propagation time.

Data Processing Problem (Congestion Reduction) in WSN Network WSN includes many SNs and tends to increase, data are collected in large quantities, and operation time is extended. Information needs to be processed before transmission to reduce congestion. The purpose of data processing at the source is to reduce the amount of SN data to be transmitted. Data processing is essential in reducing latency, reducing congestion, reducing transmission power, and increasing SNs in the network. The basis for data processing is based on the characteristic that the data obtained at MEMS sensors are not very accurate compared to large measuring equipment. On the other hand, the time and spatial correlation data between the SNs are arranged close together.

The distribution processing model at SN is studied to solve the problem of data processing in WSN networks. Distributed data processing at SN is used very limitedly with simple decisions. The reason is due to SN limitations in processing speed, memory capacity, and power. Furthermore, the node's data processing does not promote data correlation between the SNs, which is the WSN network's strength. The time correlation between data obtained in the past cannot be exploited due to memory capacity limitations. The implementation algorithm must have low complexity consistent with the limited capabilities of SN [32, 55]. Decision accuracy is limited only by the computational power of SN. The advantage of distributed processing is exploiting the computing power of SN, reducing the amount of data to be transmitted in the network.

The centralized data processing model at the central station or central cluster is also deployed. A commonly used solution is to divide the SN group according to the spatial deployment relationship or measurement data object correlation. Within each group, there is a central cluster. The center cluster can be fixed or alternately selected according to different criteria, for example, based on the remaining energy at each SN. The SNs send the data to the central cluster. In the central cluster, the data is processed by discarding redundant data, sorting it, and sending it to the central station. Because the SN's data accuracy is not high, they need to be synthesized at the central cluster to find the data's correlation to make a general decision. Assuming that the energy, computation, and memory resources at the central cluster are higher than that of SN, this model supports a more complex and powerful algorithm than performing distributed computation at SN.

On the other hand, due to obtaining information from many SNs, the model of environmental information exploitation is more extensive. Data mining and development trends in the spatial and time scale are predicted [59]. The grouping also reduces energy because the SN does not have to transmit/receive data directly with the central station but through the central cluster and acts as a routing function. Furthermore, transmitting data directly to the central station will require large bandwidth and energy consumption at SN. Concentrating data to the central cluster and sorting and pre-processing will reduce the communication bandwidth between the central cluster and the central station while reducing SN's energy consumption.

Data prediction solution. SN predicts received data to reduce the amount of data to be transmitted. In the case the obtained data are different from the predicted data, the newly acquired data are sent. The predictive method is based on data series measured in the past or on the correlation of data obtained at SN close together.

Synchronization Issue in WSN Synchronization in the WSN network is necessary to ensure smooth coordination between nodes, the relationship of the information obtained at the nodes over time is shown [9]. For example, to save energy, each button can put itself in sleep mode (sleep mode or idle mode) but must switch to active mode at the right time so as not to miss information. The center station has to know when each node has acquired information to coordinate communication between these nodes. The synchronous solution must take into account the limited energy problem of the WSN. Solve the problem of density and the increasing number of nodes in the network. Accuracy depends on the application. The solution must also ensure reliability in the event of some node failure.

Anomaly Detection Network security is also a significant problem with WSN. Due to wireless transmission, various types of data retrieval and hijacking attacks have been performed. Many proposed solutions are proposed, such as data encryption and decoding, anomaly detection algorithms. However, this solution also contributes to greater computation volume for SN.

Quality of Service (QoS)

- Ability of extension.
- Energy usage is limited by battery sources.
- Resources in SN are limited: processing speed, memory capacity, battery power.
- Ability to operate when buttons do not work properly.
- Scope of supervision.

Positioning Problem in WSN Positioning in WSN to determine the position of SN, from there can detect wrong SN location, where abnormality happens, etc.

For the application using WSN, the above-mentioned problems should be considered. However, for a particular application, some issues are considered acceptable, while others need evaluation.

6 Conclusion

This chapter presents systems for monitoring and early warning of landslides due to rain applied on a slope scale using wireless sensor networks. We discuss the slope surface monitoring solutions using accelerometers, pore pressure sensors, rain gage, soil parameters, rain information, etc. Next, wireless sensor networks are proposed for use in surveillance and alarm systems due to the advantages of deployment capacity, flexibility, low energy consumption, etc. Besides, challenges and constraints when applying wireless sensor networks in landslide monitoring systems.

References

1. S. Ahmed, S. Gupta, A. Suri, S. Sharma, Adaptive energy efficient fuzzy: An adaptive and energy efficient fuzzy clustering algorithm for wireless sensor network-based landslide detection system. IET Network **10**(1), 1–12 (2021)
2. G. Anastasi, M. Conti, M. Di Francesco, A. Passarella, Energy conservation in wireless sensor networks: A survey. Ad Hoc Netw. **7**, 537–568 (2009)
3. M.-G. Angeli, A. Pasuto, S. Silvano, A critical review of landslide monitoring experiences. Eng. Geol. **55**, 133–147 (2000)
4. G. Antonello, N. Casagli, P. Farina, D. Leva, G. Nico, A. Sieber, et al., Ground-based SAR interferometry for monitoring mass movements. Landslides **1**, 21–28 (2004)
5. C. Arnhardt, K. Asch, R. Azzam, R. Bill, T. Fernandez-Steeger, S. Homfeld, et al., Sensor based landslide early warning system-SLEWS. Development of a geoservice infrastructure as basis for early warning systems for landslides by integration of real-time sensors. Geotechnologien Sci. Rep. **10**, 75–88 (2007)
6. S. Asano, H. Ochiai, H.D. Vinh, TXT-tool 4.081-8.1: landslide monitoring for early warning in the Hai Van Station landslide in Vietnam, in *Landslide Dynamics: ISDR-ICL Landslide Interactive Teaching Tools*, (Springer, 2018), pp. 785–792
7. M. Barla, F. Antolini, An integrated methodology for landslides' early warning systems. Landslides **13**, 215–228 (2015)
8. P. Baronti, P. Pillai, V.W. Chook, S. Chessa, A. Gotta, Y.F. Hu, Wireless sensor networks: A survey on the state of the art and the 802.15. 4 and ZigBee standards. Comput. Commun. **30**, 1655–1695 (2007)
9. R.L. Baum, J.W. Godt, Early warning of rainfall-induced shallow landslides and debris flows in the USA. Landslides **7**, 259–272 (2010)
10. M. Berti, M. Martina, S. Franceschini, S. Pignone, A. Simoni, M. Pizziolo, Probabilistic rainfall thresholds for landslide occurrence using a Bayesian approach. J. Geophys. Res. Earth Surf. **117** (2012)

11. C. Buratti, A. Conti, D. Dardari, R. Verdone, An overview on wireless sensor networks technology and evolution. Sensors **9**, 6869–6896 (2009)
12. G. Capparelli, P. Versace, FLaIR and SUSHI: Two mathematical models for early warning of landslides induced by rainfall. Landslides **8**, 67–79 (2010)
13. N. Casagli, S. Morelli, W. Frodella, E. Intrieri, V. Tofani, TXT-tool 2.039-3.2 ground-based remote sensing techniques for landslides mapping, monitoring and early warning, in *Landslide Dynamics: ISDR-ICL Landslide Interactive Teaching Tools*, (Springer, 2018), pp. 255–274
14. M. Castillo-Effer, D.H. Quintela, W. Moreno, R. Jordan, W. Westhoff, Wireless sensor networks for flash-flood alerting, in *Devices, Circuits and Systems*, (Proceedings of the Fifth IEEE International Caracas Conference on, 2004, 2004), pp. 142–146
15. B.-G. Chae, M.-I. Kim, Suggestion of a method for landslide early warning using the change in the volumetric water content gradient due to rainfall infiltration. Environ. Earth Sci. **66**, 1973–1986 (2011)
16. K. Chintalapudi, T. Fu, J. Paek, N. Kothari, S. Rangwala, J. Caffrey, et al., Monitoring civil structures with a wireless sensor network. IEEE Internet Comput. **10**, 26–34 (2006)
17. G.M. Dias, B. Bellalta, S. Oechsner, A survey about prediction-based data reduction in wireless sensor networks. ACM Comput. Surv. (CSUR) **49**, 58 (2016)
18. M.J. Dong, K.G. Yung, W.J. Kaiser, *Low Power Signal Processing Architectures for Network Microsensors* (Proceedings of the 1997 International Symposium on Low Power Electronics and Design, 1997), pp. 173–177
19. C. Fosalau, C. Zet, D. Petrisor, Implementation of a Landslide Monitoring System as a Wireless Sensor Network, in *Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, (IEEE Annual, 2016), pp. 1–6
20. A. Gian Quoc, C. Nguyen Dinh, N. Tran Duc, T. Tran Duc, S. Kumbesan, Wireless technology for monitoring site-specific landslide in Vietnam. Int. J. Electr. Comput. Eng. **8**(6), 4448–4455 (2018)
21. Q.A. Gian, D.C. Nguyen, D.N. Tran, D.T. Tran, Monitoring of landslides in mountainous regions based on FEM modelling and rain gauge measurements. Int. J. Electric. Comput. Eng. **6**(5), 2106 (2016)
22. Q.A. Gian, D.T. Tran, D.C. Nguyen, V.H. Nhu, D. Tien Bui, Design and implementation of site-specific rainfall-induced landslide early warning and monitoring system: A case study at Nam Dan landslide (Vietnam). Geomatic. Nat. Hazards Risk **8**(2), 1978–1996 (2017)
23. J.A. Gili, J. Corominas, J. Rius, Using global positioning system techniques in landslide monitoring. Eng. Geol. **55**, 167–192 (2000)
24. P. Giri, K. Ng, W. Phillips, *Wireless Sensor Network System for Landslide Monitoring and Warning* (IEEE Transactions on Instrumentation and Measurement, 2018), pp. 1–11
25. J. Goswami, A. Saha, IoT sensor network based implementation for rainfall induced landslide monitoring, in *International Conference on Computational Intelligence, Security and Internet of Things*, (Springer, Cham, 2020), pp. 304–316
26. R. Greco, A. Guida, E. Damiano, L. Olivares, Soil water content and suction monitoring in model slopes for shallow flowslides early warning applications. Phys. Chem. Earth, Parts A/B/C **35**, 127–136 (2010)
27. J.A. Gutierrez, M. Naeve, E. Callaway, M. Bourgeois, V. Mitter, B. Heile, IEEE 802.15. 4: A developing standard for low-power low-cost wireless personal area networks. IEEE Netw. **15**, 12–19 (2001)
28. M. Hons, R. Stewart, D. Lawton, M. Bertram, G. Hauer, Field data comparisons of MEMS accelerometers and analog geophones. Lead. Edge **27**, 896–903 (2008)
29. http://www.safeland-fp7.eu
30. C. Huggel, N. Khabarov, M. Obersteiner, J.M. Ramírez, Implementation and integrated numerical modeling of a landslide early warning system: A pilot study in Colombia. Nat. Hazards **52**, 501–518 (2010)
31. E. Intrieri, G. Gigli, F. Mugnai, R. Fanti, N. Casagli, Design and implementation of a landslide early warning system. Eng. Geol. **147–148**, 124–136 (2012)

32. B. Kerkez, S.D. Glaser, R.C. Bales, M.W. Meadows, Design and performance of a wireless sensor network for catchment-scale snow and soil moisture measurements. Water Resour. Res. **48** (2012)
33. S. Kumar, S. Duttagupta, V.P. Rangan, M.V. Ramesh, Reliable network connectivity in wireless sensor networks for remote monitoring of landslides. Wirel. Netw **26**(3), 2137–2152 (2020)
34. D. Lagomarsino, S. Segoni, R. Fanti, F. Catani, Updating and tuning a regional-scale landslide early warning system. Landslides **10**, 91–97 (2013)
35. J. Landes, J. Begley, G. Clarke, American society for testing and materials. STP **590**, 128–148 (1976)
36. M. Li, Y. Liu, *Underground Structure Monitoring with Wireless Sensor Networks* (Proceedings of the 6th International Conference on Information Processing in Sensor Networks, 2007), pp. 69–78
37. Li, Y. Liu, Underground coal mine monitoring with wireless sensor networks. ACM Trans. Sensor Network (TOSN) **5**, 10 (2009)
38. Z. Liao, Y. Hong, J. Wang, H. Fukuoka, K. Sassa, D. Karnawati, et al., Prototyping an experimental early warning system for rainfall-induced landslides in Indonesia using satellite remote sensing and geospatial datasets. Landslides **7**, 317–324 (2010)
39. R. Macciotta, C.D. Martin, N.R. Morgenstern, D.M. Cruden, Quantitative risk assessment of slope hazards along a section of railway in the Canadian Cordillera—A methodology considering the uncertainty in the results. Landslides **13**, 115–127 (2016)
40. A. Manconi, D. Giordan, Landslide early warning based on failure forecast models: The example of the Mt. de La Saxe rockslide, northern Italy. Nat. Hazards Earth Syst. Sci. **15**, 1639–1644 (2015)
41. J. Mathew, D.G. Babu, S. Kundu, K.V. Kumar, C. Pant, Integrating intensity–duration-based rainfall threshold and antecedent rainfall-based probability estimate towards generating early warning for rainfall-induced landslides in parts of the Garhwal Himalaya, India. Landslides **11**, 575–588 (2014)
42. A. Menció, M. Galán, D. Boix, J. Mas-Pla, Analysis of stream–aquifer relationships: A comparison between mass balance and Darcy's law approaches. J. Hydrol. **517**, 157–172 (2014)
43. D.C. Nguyen, D.N. Tran, N.H. Le, D.T. Ta, A.T. Pham, D.T. Tran, Multi-sensors integration for landslide monitoring application. VNU J. Sci. **30**(6S-B), 202–210 (2014)
44. C.D. Nguyen, T.D. Tran, N.D. Tran, T.H. Huynh, D.T. Nguyen, Flexible and efficient wireless sensor networks for detecting rainfall-induced landslides. Int. J. Distrib. Sens. Netw. **2015**, 235954 (2015a)
45. D.C. Nguyen, T. Duc-Tan, D.N. Tran, Application of compressed sensing in effective power consumption of WSN for landslide scenario, in *Asia Pacific Conference on Multimedia and Broadcasting*, (IEEE, 2015b), pp. 1–5
46. M. Papa, V. Medina, F. Ciervo, A. Bateman, Derivation of critical rainfall thresholds for shallow landslides as a tool for debris flow early warning systems. Hydrol. Earth Syst. Sci. **17**, 4095–4107 (2013)
47. Y. Peng, Z. Li, W. Zhang, D. Qiao, *Prolonging Sensor Network Lifetime Through Wireless Charging* (IEEE Real-Time Systems Symposium, 2010), pp. 129–139
48. L. Piciullo, S.L. Gariano, M. Melillo, M.T. Brunetti, S. Peruccacci, F. Guzzetti, et al., Definition and performance of a threshold-based regional early warning model for rainfall-induced landslides. Landslides **14**, 995–1008 (2016)
49. M.V. Ramesh, Design, development, and deployment of a wireless sensor network for detection of landslides. Ad Hoc Netw. **13**, 2–18 (2014)
50. P. Rawat, K.D. Singh, H. Chaouchi, J.M. Bonnin, Wireless sensor networks: A survey on recent developments and potential synergies. J. Supercomput. **68**, 1–48 (2014)
51. S. Segoni, L. Piciullo, S.L. Gariano, A review of the recent literature on rainfall thresholds for landslide occurrence. Landslides **15**, 1–19 (2018)
52. A. Sheth, K. Tejaswi, P. Mehta, C. Parekh, R. Bansal, S. Merchant, et al., *Senslide: A Sensor Network Based Landslide Prediction System* (Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems, 2005), pp. 280–281

53. A. Terzis, A. Anandarajah, K. Moore, I. Wang, *Slip Surface Localization in Wireless Sensor Networks for Landslide Prediction* (Proceedings of the 5th International Conference on Information Processing in Sensor Networks, 2006), pp. 109–116
54. B. Thiebes, R. Bell, T. Glade, S. Jäger, J. Mayer, M. Anderson, et al., Integration of a limit-equilibrium model into a landslide early warning system. Landslides **11**, 859–875 (2013)
55. H. Thirugnanam, M.V. Ramesh, V.P. Rangan, Enhancing the reliability of landslide early warning systems by machine learning. Landslides **17**, 2231–2246 (2020)
56. I. Towhata, T. Uchimura, C. Gallage, On early detection and warning against rainfall-induced landslides (m129), in *Landslides*, (Springer, 2005), pp. 133–139
57. D.T. Tran, D.C. Nguyen, D.N. Tran, D.T. Ta, Development of a rainfall-triggered landslide system using wireless accelerometer network. Int. J. Adv. Comput. Technol. **7**(5), 14 (2015)
58. UN-ISDR, *Developing Early Warning Systems: A Checklist* (Third International Conference on Early Warning (EWC III), Bonn, 2006)
59. L. Xiang, J. Luo, C. Rosenberg, Compressed data aggregation: Energy-efficient and high-fidelity data collection. IEEE/ACM Trans. Network (TON) **21**, 1722–1735 (2013)
60. Y. Yin, H. Wang, Y. Gao, X. Li, Real-time monitoring and early warning of landslides at relocated Wushan town, the three Gorges reservoir, China. Landslides **7**, 339–349 (2010)
61. X. Yu, P. Wu, W. Han, Z. Zhang, A survey on wireless sensor network infrastructure for agriculture. Comput. Stand. Interfaces **35**, 59–64 (2013)
62. X. Zhu, Q. Xu, M. Tang, W. Nie, S. Ma, Z. Xu, Comparison of two optimized machine learning models for predicting displacement of rainfall-induced landslide: A case study in Sichuan Province, China. Eng. Geol. **218**, 213–222 (2017)

Precision Livestock Farming Systems Based on Accelerometer Technology and Machine Learning

Duc-Nghia Tran, Phung Cong Phi Khanh, Tran Binh Duong, Vijender Kumar Solanki, and Duc-Tan Tran

1 Introduction

In the past, cow raising was very popular with households and farms all over the world. With small-scale farming, monitoring of health status and animal reproduction would be simple by the experience of the breeder. It becomes difficult for large farms or livestock businesses to apply traditional methods such as manual monitoring.

Cows alter their behavior to allow them to cope with stress factors such as infections, feelings of fullness or changes in their living conditions, and environment [32]. Therefore, behavior also demonstrates the health and well-being of the cow. Detecting daily cow behavior changes can aid in issuing warnings to improve farm management and improve livestock welfare [5, 7, 17, 27, 31, 51].

There are many techniques that help monitor the health, performance, and reproductive problems of livestock on a large scale. These techniques help farm owners,

D.-N. Tran
Institute of Information Technology, Vietnam Academy of Science and Technology, Hanoi, Vietnam

P. C. P. Khanh
University of Education, Caugiay, Hanoi, Vietnam

T. B. Duong
Vietnam Paper Corporation, Caugiay, Hanoi, Vietnam

V. K. Solanki
Department of Computer Science & Engineering, CMR Institute of Technology, Hyderabad, TS, India

D.-T. Tran (✉)
Faculty of Electrical and Electronic Engineering, Phenikaa University, Hanoi, Vietnam
e-mail: tan.tranduc@phenikaa-uni.edu.vn

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_14

companies, or businesses to control their animals, thereby helping to improve livestock production. However, the currently applied techniques are still quite manual and require human intervention. Researching new technologies and equipment has always been a topic of intense interest [5, 7, 17, 27, 31, 32, 51].

Precision livestock farming (PLF) systems support farmers in managing the performance of management. The PLF concept encapsulates the use of data to assist in managing the welfare and health of animals. Data capture technology has developed rapidly, and PLF systems can use data efficiently for productivity enhancement. A good PLF system from farmers' point of view should be easy to use and financial benefits, thus, it varies depending on the technology.

There has been a large increase in the use of remote surveillance devices such as global position trackers (GPS), position sensors, and accelerometers to automatically record animal behavior [8]. In [1], the categorization of cow behaviors was designed and performed using video data using a camera. Behavior events of interest in this study included lying, standing, walking, and feeding.

The benefits and potentials of remote tracking of cattle behavior using a variety of methods have been described by many authors including clinical disease, visual monitoring, using accelerometer, measuring footsteps and food intake, and behavior tracking using real-time global positioning system. Recent advances in high sensitivity sensing electronics provide new scenarios for recording cow activity [18]. The selection of sensors and technologies will depend on concerned information, and several existing systems based on sensor technology have been developed to automatically analyze dairy behavior [50, 52]. Up to now, PLF systems based on accelerometer technology and machine learning (ML) are very promising for behavior monitoring [3, 5, 7, 8, 17, 21, 26, 27, 31, 33–35, 38, 49, 51]. With the advantages of small size, lightweight, and low power consumption, the accelerometer provides an objective method of measurement that does not affect cows, objectively classifying cow behavior under farm conditions [3, 21, 26, 33–35, 38, 49].

Interpreting the data collected by accelerometer sensors when describing behavior remains a major challenge for developers, regarding the complexity of the operation, and extracting characteristics. It allows distinguishing the behavior, loss of characteristic data caused by the wireless transceiver, and the complex data processing required to handle the interference inherent in the collected measurements. This has led to a need for more efficient and accurate methods for analyzing a large amount of movement and behavior data being collected [4].

Machine learning (ML) provides a good approach to improving model accuracy, based on flexible variable data structures while processing large and complex datasets obtained from one environment [36]. In general, studies usually use a strain accelerometer on the cow neck and foot or use a pressure sensor on the cow cheek. Less common behaviors are usually just walking, standing, lying down, and eating. Many studies even manually recorded data on memory cards. The wireless sensor platform needs to be studied and applied more effectively. Besides, the algorithms also need to be improved to improve the classification efficiency. In studies [3, 8, 19, 49] that demonstrated the potential of using ML in categorizing cow behavior, they only classified two or three behaviors [3, 8], The positive predictive value of the classification is not high [19] and lacks analysis of the data characteristics [19, 20, 49]. The fact is the performance of the classification method will depend closely on the features and data window.

To classify cow's behavior based on using accelerometer and ML, two common kinds of acceleration data were analyzed: data measured from the leg and data measured from the neck [2, 11, 14, 15, 30, 45]. The ML algorithms for this problem are quite diverse such as decision tree (DT) algorithm, k-means, hidden Markov model (HMM), and support vector machine (SVM). Behavior of interest in this kind of study may include lying, standing, walking, and feeding. The benefits and potential of PLF systems based on accelerometer technology and machine learning are discussed as the future of livestock.

2 Machine Learning Algorithms for Animal Monitoring

ML is an area of artificial intelligence (AI) that involves the research and construction of techniques that allow systems to "learn" automatically from data to solve specific problems. For example, machines can "learn" how to classify e-mails for spam or not and automatically classify them into their respective folders. ML is very close to statistics as both fields are studying data analysis. However, unlike statistics, ML focuses on the complexity of algorithms in performing the computation.

Machine learning is now widely applied including data tracing, medical diagnostics, detection of fake credit cards, stock market analysis, DNA sequencing, handwriting and speech recognition, automatic translation, play game, robot locomotion, and cattle behavior classification.

The availability of large datasets on farms is providing the potential for the application of ML in livestock. The development of PLF systems relies on exploiting such data [12]. Data capture technology such as using sensors [28, 29, 39–43, 48] improves rapidly nowadays. Along with the support of ML and powerful computing platforms, new insights (such as disease phenotypes) can be revealed from these data [46].

PLF systems in livestock (such as dairy farms) have been discussed for many years. Searching on the Web of Science database using the keywords "machine learning" and "dairy," the results show that automatic behavior classification can be considered as one of the most important research topics in the context of livestock management in the last 10 years.

Groups of machine learning algorithms by their learning style are as follows:

- Supervised learning is a machine learning technique for building a function from a training data set. The training data consist of pairs of input objects (usually vector form) and desired output. The output of a function can be a continuous value (called regression), or it can be a prediction of a classification label for an input object (called a classification) [16]. This method is used for classification problems.

- Unsupervised learning is a method of machine learning that aims to find a model that matches observations. Given a sample of only objects, it is necessary to search for the interesting structure of the data and to group the same objects [47]. This method is used for clustering and clustering problems.
- Semi-supervised learning is a class of machine learning that uses both labeled and unlabeled data for training—typically a small amount of labeled data along with a large number of unsigned data labels. Semi-supervised learning stands between unsupervised learning (without any labeled data) and supervised (all data are labeled) [53].
- Reinforcement learning: Computers make action decisions and receive feedback from the environment. The computer then sought to correct the way in which its decision to act. The k-means algorithm is unsupervised learning, whereas SVM and decision-tree are supervised learning [37].

A diverse range of ML algorithms exists, and for this review, only some basic algorithms are discussed in the context of their use in livestock science research, in particular for cow behavior classification problems.

2.1 The General Concept

The actual demand is that from a database with a lot of hidden information, we can extract business intelligence decisions. Classification and prediction are two forms of data analysis to derive a model that describes important data classes or predicts future data trends. The subclass predicts the values of certain labels or discrete values, which means that the subclass deals with data objects whose tuples are known. Meanwhile, the prediction builds the model with continuous value functions. For example, the weather forecast classification model can tell whether tomorrow's weather is rainy or sunny based on the humidity, wind, temperature, etc. of today and the previous days. Thanks to the laws about customer buying trends in supermarkets, salespeople can make the right decisions about the number of items and types of sale. A predictive model can determine the amount of money spent by potential customers based on information about the customer's income and occupation.

Over the years, data classification has attracted the attention of researchers in many different fields such as machine learning, systems specialists, and statistics. This technology also applies in many other fields such as commercial, bank, advertising, market research, insurance, health, and education. Most of the previous generation algorithms use data mechanisms that reside in memory and often manipulate small amounts of data. A number of later algorithms have used disk-based techniques to significantly improve the scalability of the algorithm with large datasets of up to billions of records.

The data classification problem is the process of classifying a data object into a given class or classes, thanks to a classification model built on a set of labeled data objects that have been pre-labeled known as a learning data set (training set). The classification process is also known as the labeling of data objects.

Thus, the task of the data classification problem is to build a classification model so that when there is new data entered, the classification model will tell which class that data belongs to.

There are many problems with data classification, such as binary classification, multi-class classification, and multivalent classification. Binary classification is the process of classifying data into one of two different classes based on whether or not that data has some of the properties specified by the classifier. Multi-layer layering is the process of layering with a number of layers greater than two. Thus, the data set in the consideration domain is divided into many classes, not just two classes as in the binary classification problem. In essence, the problem of binary classification is a separate case from the problem of multi-class classification [10, 13, 22, 23, 25].

2.1.1 The General Data Classification Process

Learning Process

The learning process is intended to construct a model that describes a set of predefined data classes or concepts. The input to this process is a structured data set described by attributes and generated from the set of tuples of those properties. Each tuple is collectively referred to as a data element, which can be patterns, examples, objects, records, or instances. In this data set, each data element is assumed to belong to a predetermined class, and the class here is the value of an attribute selected as the class tag or class attribute. The output of this step is usually classification rules in the form of if-then rules, DTs, logic formulas, or neural networks. Figure 1 shows the process of building a classification model.

Classification Process

Classification is using the model built in the previous step (learning process) to classify new data. First, the predictive accuracy of the newly generated classification model is estimated. The holdout is a simple technique for estimating that precision. This technique uses a test dataset with class labeled samples. These samples were randomly selected and independent of those in the training data set. The accuracy of the model on the test data set given is the percentage of samples in the test data set correctly classified by the model (compared to reality). If the accuracy of the model is estimated based on the training data set, the results obtained are very positive because the model always tends to "over-fit" the data. Over-fit is the phenomenon that the classification results coincide with the actual data because the process of building the classification model from the training data set may have incorporated specific features of the data set. It is therefore necessary to use a test data set that is independent of the training data set. If the accuracy of the model is acceptable, then the model is used to classify future data or those for which the value of the classification attribute is unknown [12].

Figure 2 shows the estimate of the classification model on test data. Using the model trained from the previous step, test data will be labeled behavior classes.

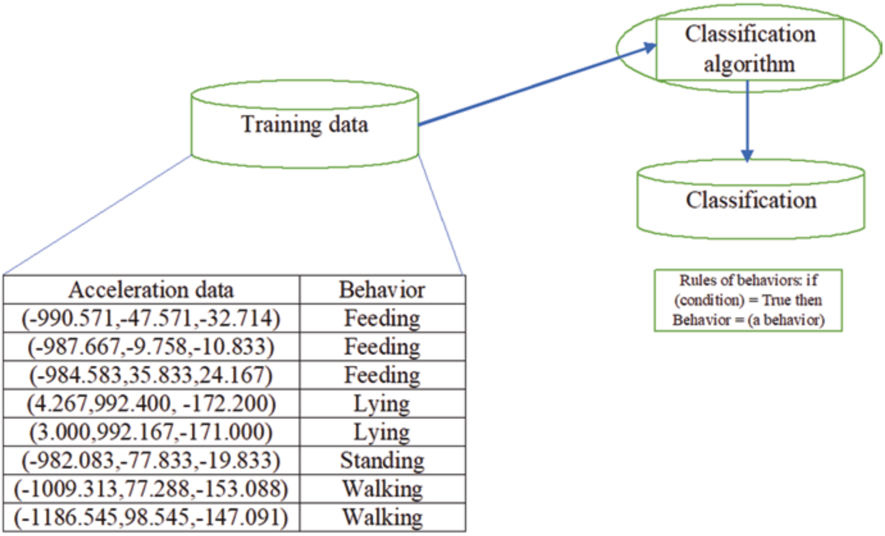


Fig. 1 The process of building a classification model

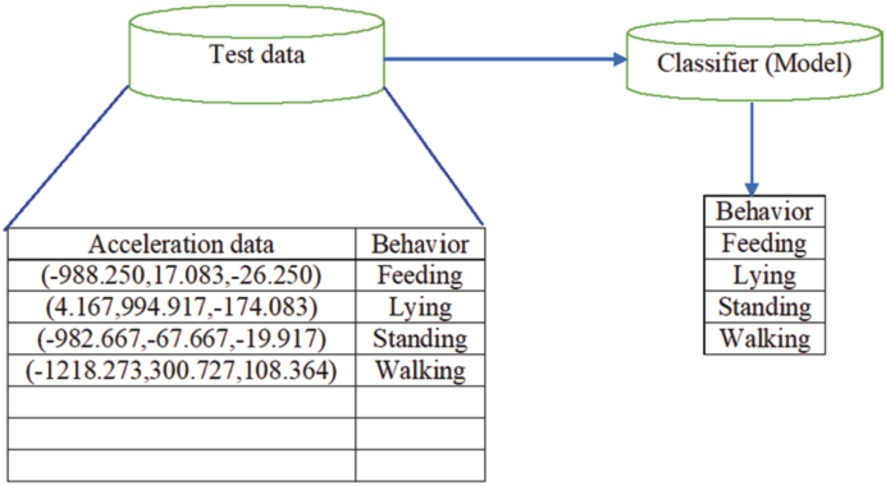


Fig. 2 Estimate of the model on test data

These labeled data will be compared with the observed data from real behavior to check the performance of the training model in step 1. For example, if the labeled data is labeled as feeding, which according to feeding observation, then this labeled data is labeled correctly. If the condition is not satisfied, then this labeled data are labeled wrongly. The performance of the model is evaluated by indicators (more detail about indicators at the end of this section).

Figure 3 shows the new data classification. For models that have a good performance on test data, they can be applied in practice. In this case, we do not know the

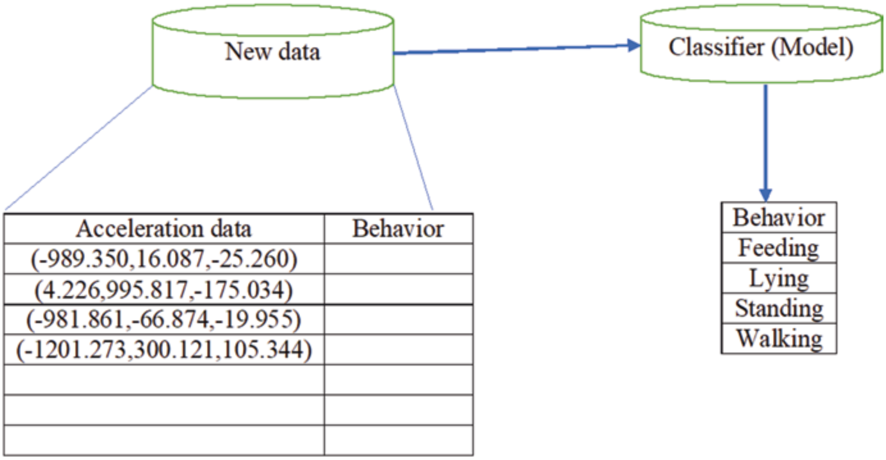


Fig. 3 New data classification

label of the data in advance. Using the evaluated model in the previous steps, new behaviors can be labeled correctly. The reliability of the evaluated model depends on the values of indicators.

2.1.2 Data Classification Process for Behavior Classification Problem

Section 2.1.1 describes the general concept to build a classification model. However, with the behavior classification problem, it is usually not possible to use only the available data (x-axis, y-axis, and z-axis data) to build a good classification model. The quality and the performance of the model rely on many factors such as features, data windows length, and amount of data. The whole process of behavior identification is shown in Fig. 4.

Figure 5 outlines the construction of the classifier, and some of the data were randomly selected as training data set and the remaining was used as test data set. The division of [training data, test data] in the literature usually is [60%, 40%] or [70%, 30%] for good model performance, and the choice varies on the method and the data [45]. The classifier has been trained with features calculated from measurements of acceleration (input) and matching behavior (output). The resulting classification model was tested and the model's performance indicators were calculated from the independent test data set.

Feature Engineering

Feature engineering techniques are applied to create a suitable feature set from raw dataset. Features can take many forms such as binary or numeric, and they can increase the dataset dimensionality. Features can be mean, standard deviation (SD), root mean square (RMS), etc., and they are computed for every windowing data. The model will learn which behavior class conditions are satisfied based on the features. A behavior (the output) is a label of behavior class, and it results in one of

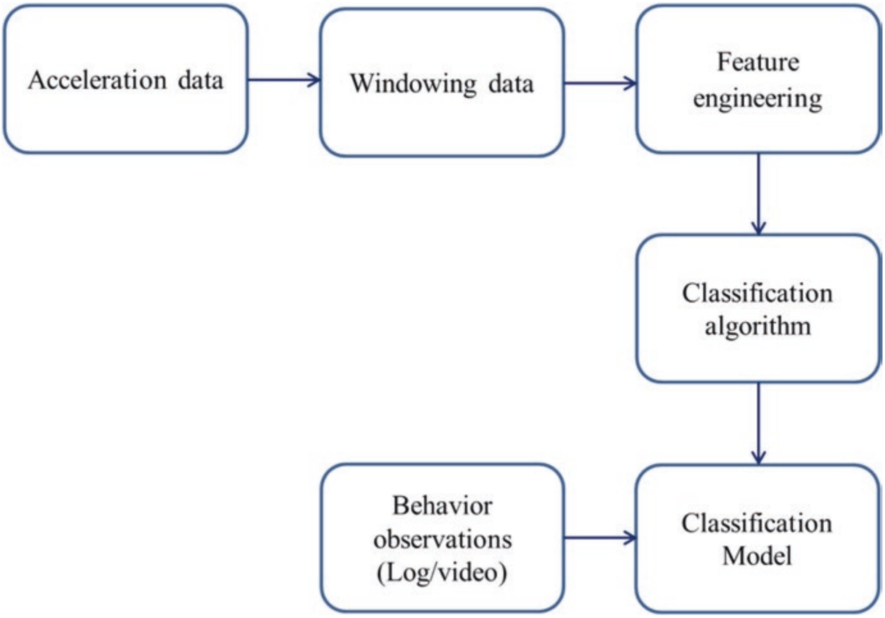


Fig. 4 Behavior identification process

the behaviors such as feeding, standing, and lying (Table 1). The classification algorithm studies the data (including new features) to learn how to distinguish behavior classes and then build the classification model based on the knowledge it has studied.

Data Windows Length

Data windows length is important since it affect directly features and the number of behavior [14, 45]. If data windows length is short, then it is difficult to see the differences between each behavior since the data are not significant. Vice versa, more than one activity can be contained in a large data window, and the number of training data in this case also reduces, leading to the decrease in classification performance [14]. Hence, the data window length has been a focal point in numerous studies [3, 14, 19, 45, 49, 50]. Table 2 listed some examples of lying acceleration data samples, using leg-mounted device. The unit of acceleration data is *mg*.

Evaluation Indicators

Indicators evaluate the performance of the model. Indicators are calculated from classification results. Table 3 lists an example of classification results.

A true positive (TP) is a classification result where the model predicts the positive behavior class correctly. In the example, it is when the model predicts lying for lying observation/data. A true negative (TN) is a classification where the model predicts the negative behavior class correctly. In the example, it is when the model predicts non-lying for non-lying observation/data. A false positive (FP) is a

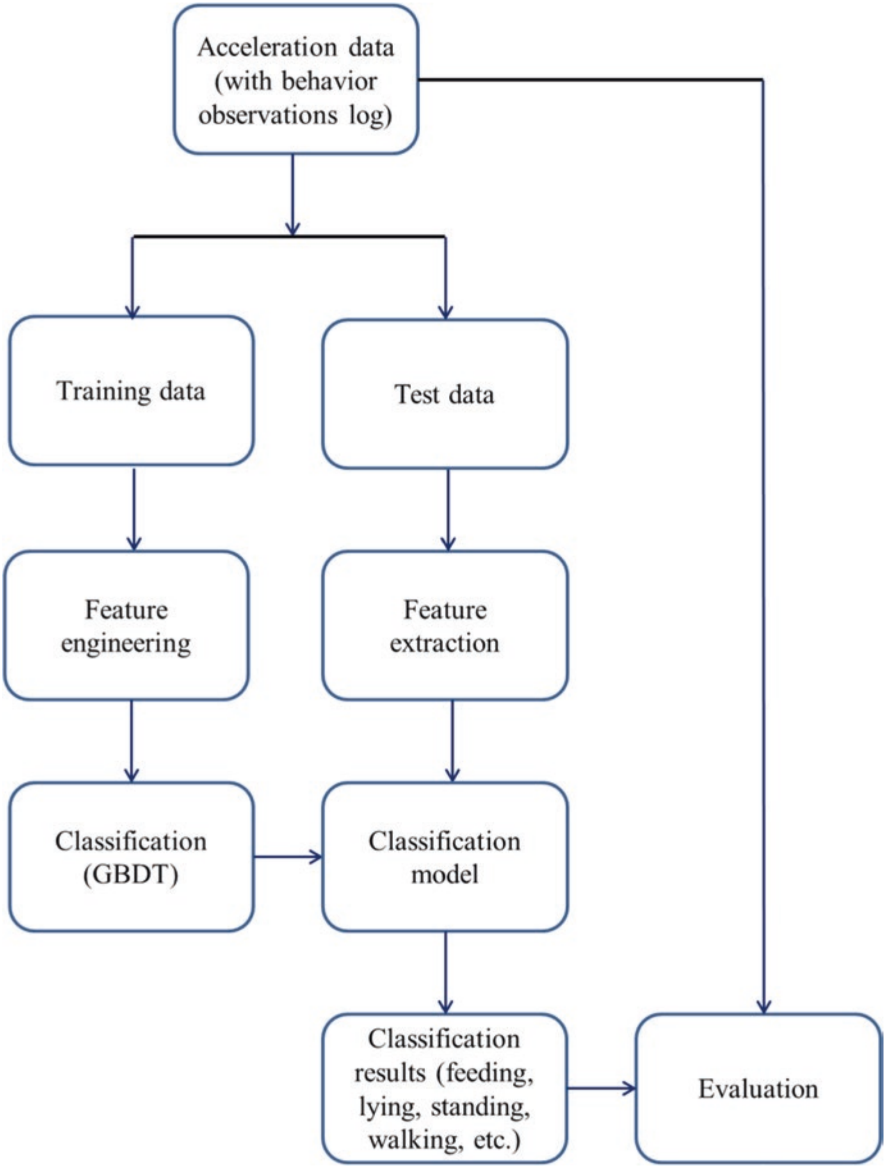


Fig. 5 Construction process flowchart of the classifier

classification result where the model predicts the positive behavior class incorrectly. In the example, it is when the model predicts non-lying for lying observation/data. A false negative (FN) is a classification result where the model predicts the negative behavior class incorrectly. In the example, it is when the model predicts lying for non-lying observation/data.

Table 1 Description of some basic behaviors of cow

Behavior	Definition
Feeding	The cow is at feeding zone and searches for or masticates the feed.
Lying	The cow is in a cubicle in a lying down position.
Standing	The cow stands entirely on its four legs.
Lying down	The cow bents one foreleg, lowers its forequarters, then hindquarters, and settles down in a state of lying.
Standing up	The cow rises from a lying state to stand on all four feet.

Table 2 Examples of lying acceleration data samples, using leg-mounted device

Acc in *x* (mg)	Acc in *y* (mg)	Acc in *z* (mg)
4.75	990.67	−176.25
5.42	990.33	−174.33
4.17	990.83	−177.42
3.75	990.67	−176.92
3.50	991.67	−176.50
4.83	991.17	−174.00
0.73	991.36	−174.73
8.75	991.42	−204.25
3.75	991.42	−167.25
3.58	992.33	−179.75
3.67	990.92	−179.17
4.75	990.67	−172.42
4.42	991.83	−173.92
0.82	990.91	−172.55
5.25	990.67	−176.42
2.58	992.25	−176.83

Table 3 Classification results, an example of lying prediction

Behavior		Observed	
		Lying	Non-lying
Predicted	Lying	TP	FN
	Non-lying	FP	TN

Sensitivity, accuracy, and positive predictive value (PPV) are some important indicators to evaluate the performance of the model. The below formulae shows the calculation of these indicators:

$$\text{Sensitivity} = \frac{TP}{TP + FN} \tag{1}$$

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + FN + TN} \tag{2}$$

$$PPV = \frac{TP}{TP + FP} \tag{3}$$

2.2 Potential and Simple Algorithms for Behavior Classification Problem

2.2.1 K-Means Clustering

Clustering is a very important technique in data mining, it belongs to the class of "Unattended Learning" methods in Machine Learning. There are many different definitions of this technique, but in essence, we can understand clustering is the process of trying to group given objects into clusters, such that objects in the same cluster. Are similar and objects of different clusters are not similar.

The purpose of clustering is to find nature within the groups of data. Clustering algorithms all generate clusters. However, there is no one that is considered the best criterion for the validation of clustering analysis, depending on the purpose of clustering such as data reduction, "natural clusters", "useful" clusters, outlier detection.

Unlike object classification, the class label is unknown. This happens often with large databases because assigning class labels to large numbers of data objects is an expensive process. Clustering is very helpful in giving an overview of all the data.

K-means is a very important algorithm and is commonly used in clustering technique. The main idea of the k-means algorithm is to find a way to group the given objects into K clusters (K is the number of predefined clusters, K positive integers) such that the sum of the squares of the distance between the objects to the center group is the smallest.

The k-means algorithm works through the following main steps:

(a) Randomly select K centers for K clusters. Each cluster is represented by the cluster centers.
(b) Calculate the distance between objects to K center (usually use Euclidean distance).
(c) Group the subjects into the nearest group.
(d) Redefine the new center for the groups.
(e) Repeat step (b) until there is no group change of objects [27].

Figure 6 shows the k-means algorithm.

The k-means algorithm is a simple, recursive algorithm (repeated many times), so the computation cost will be large.

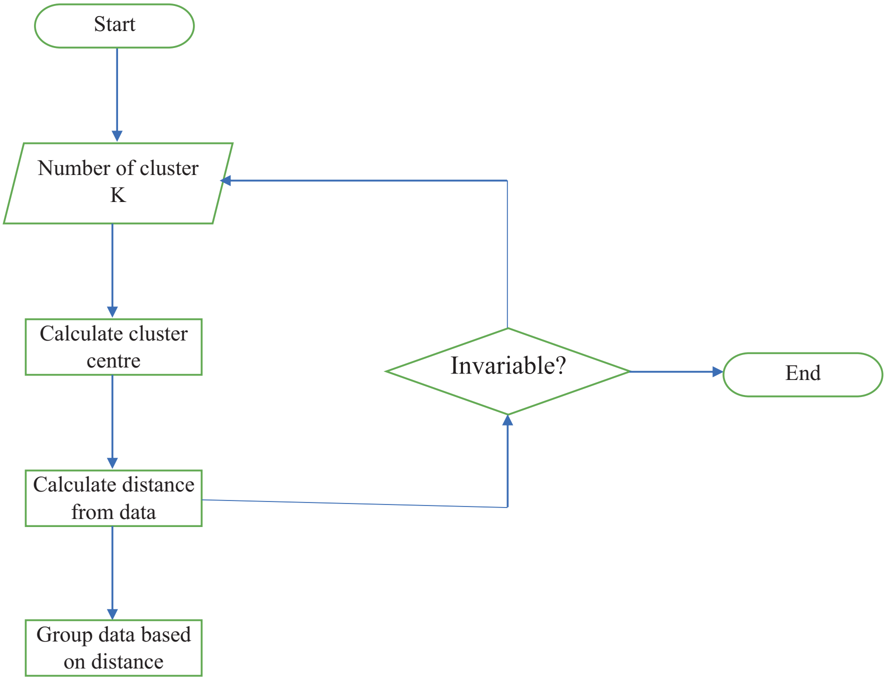


Fig. 6 Diagram of the algorithm k-means

2.2.2 Support Vector Machine (SVM)

As a method based on statistical theory, SVM is a strong mathematical foundation to ensure that the results found are correct. The supervised learning algorithm is used for data classification. As an experimental method, it is one of the most powerful and accurate methods among well-known data classification algorithms. SVM is a highly generalized method, so it can be applied to many types of identification and classification problems. Figure 7 shows finding the maximum boundary of the SVM algorithm:

The idea of the SVM method is to give a training set, represented in vector space, where each document is a point, and this method finds the best decision superspace that can divide the overhead points. This space into two separate classes, respectively, class + and class o. A superspace is a function similar to the equation for the line $y = ax + b$. In fact, if we need to subclass a data set with only two features, the super-flat is now a straight line. The quality of this hyperplane is determined by the distance (called the boundary) of the nearest data point of each layer to this plane. Then, the larger the boundary distance, the better the decision plane, and the more accurate the classification. The purpose of the SVM method is to find the maximum boundary distance.

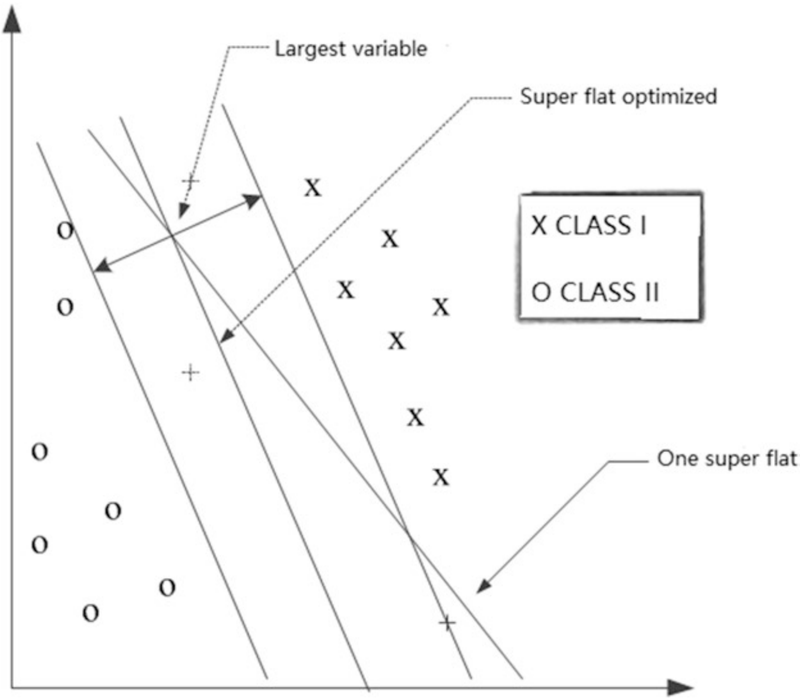


Fig. 7 SVM algorithm

SVM algorithm is performed through the following steps:

- Convert input data to the digital format of SVM.
- Data preprocessing. Performing data transformation suitable for the calculation process and avoiding too large numbers describing attributes. It is advisable to scale the data to convert it to [−1, 1] or [0, 1].
- Choosing the kernel function. Selecting the appropriate kernel function for each specific problem to achieve high accuracy in the classification process.
- Cross-checking to determine the parameters for the application. This also determines the accuracy of the classification process.
- Using parameters for training with the sample set. In the training process, we will use an algorithm to optimize the distance between the superstars in the classification process, determine the classification function in the feature space by mapping data into feature space by description the resolution for both cases is that the data is split and non-linearly split in feature space.
- Testing dataset check.

2.2.3 Decision Tree Algorithm

In the field of machine learning, DTs are a kind of predictive model, that is, a mapping from observations of an object/phenomenon to conclusions about the objective value of the thing/phenomenon. Each node corresponds to a variable; the line between it and its child nodes represents a value specific to that variable. Each leaf node represents the predicted value of the target variable, given the values of the variables represented by the path from the root node to that leaf node. The machine learning technique used in DTs is called DT learning, or just called a DT.

The DT is also included in the classification problem (supervised learning). In order to build a DT, it also takes two steps, "learning" and "classification".

DT learning is also a popular method in data mining. The DT then describes a tree structure, in which the leaves represent the classifications and the branches represent the combinations of attributes that lead to the class. A DT can be learned by dividing the source set into subsets based on an attribute value test. This process is repeated recursively for each derived subset. The recursion is complete when splitting is no longer possible, or when a single classification can be applied to each element of the derived subset. A random forest classifier uses a number of DTs in order to improve the classification ratio.

DTs are also a descriptive means for the computation of conditional probabilities.

Figure 8 shows an example of classification using a DT:

In the DT,

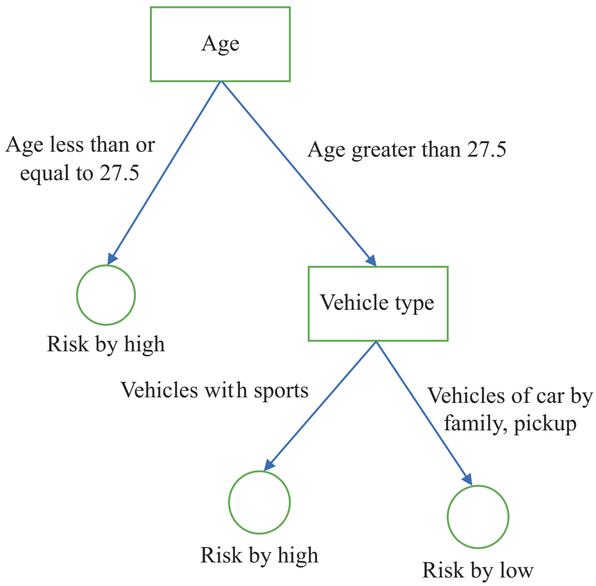


Fig. 8 Decision tree example

- Root. It is the top node of the tree.
- Internal node. It represents a check on a single property (rectangle).
- Branch. It shows the results of the test on the inner node (arrow).
- Leaf node. It is a class representation or class distribution (circle).

To classify the unknown data sample, the attribute values of the sample are examined in the DT. Each corresponding sample has a path from the root to the leaf and the leaf represents that sample classification value prediction [18].

In this chapter, DTs are used to process continuity properties such as the data values of x, y, and z three-dimensional acceleration sensors. Meanwhile, with continuous properties (numerical properties), the set of values is not predetermined. Therefore, during tree development, it is necessary to use binary test: value (A) $\leq \theta$, where θ is the threshold constant determined in turn based on each individual value or each pair of contiguous values (in sorted order) of the continuity being considered in the training data set. That means if the continuity attribute A in the training data set has d distinct values, then d−1 check value (A) $\leq \theta - i$ with i = 1...d−1 is needed to find the best threshold corresponding to that property.

Advantages of DT:

- Easy to convert

The DT has the ability to generate rules that can be converted to English, or SQL statements. This is the outstanding advantage of this technique. Even with large datasets that make DTs large and complex, following any path in the tree is easy in a common and clear sense. Classification or prediction is relatively transparent.

- Enforcement ability in rule-oriented fields

This may sound obvious, but inductive rules in general and DTs, in particular, are the perfect choice for areas where real rules are. Many fields from genetics to industrial processes actually contain hidden, ambiguous rules due to their complexity and ambiguity by error data. DTs are a natural choice when we suspect the existence of obscure, hidden rules.

- Easy to calculate while classifying

Although as we all know DTs can contain many formats, in practice, the algorithms used to generate DTs often produce trees with low branching numbers and simple checks. at each node. Typical tests are number comparison, considering the elements of a set, and simple joins. When executed on a computer, these tests convert into logical functions and integers, which are fast and inexpensive to execute. This is an important advantage because in commercial environments, predictive models are often used to classify millions or even billions of records.

- The ability to deal with both continuous and discrete attributes

DTs process "good" equally with the continuum and the discrete attribute. However, with continuous properties, more computational resources are needed. The discrete properties caused problems with neural nets, and statistical techniques are really easy to manipulate with the division criteria in the DT; each branch corresponds to each separate data set according to the value of the attribute chosen to grow at that node. Continuity properties are also easily divided by selecting a threshold number from the ordered set of values. After choosing the best threshold, the dataset divides according to the binary test of that threshold.

- Clearly demonstrates the best properties

  DT building algorithms provide the property that best divides the training data set starting from the root node of the tree. From there, it can be seen which attributes are most important for prediction or classification.

- Disadvantages of DT

  Despite these outstanding strengths, DTs still inevitably have weaknesses. It is a DT that is not very suitable for problems with the goal of predicting the value of continuity attributes such as income, blood pressure, or bank interest. DTs are also difficult to deal with continuous-time data if otherwise spend a lot of effort in making data representations in continuous patterns.

- It is easy to error when there are too many layers

  Some DTs only deal with classes of binary values of yes/no or agree/reject. Others can assign records to any number of classes, but error-prone when the number of training examples corresponding to a class is small. This happens more quickly with trees that have many layers or have many branches on a node.

- Expensive computational cost to train

  This may seem contradictory with the DT's affirmation above. But DT development is computationally expensive. Because the DT has a lot of inner nodes before going to the last leaf. At each node, it is necessary to calculate a measure (or division criterion) on each attribute, and with a continuous attribute, it is necessary to add the manipulation of reordering the data set according to the value order of that attribute. Then, it is possible to select a development attribute and a corresponding best division. Some algorithms use a combination of weighted combinations of attributes to develop DTs. Amputation is also "expensive" as many candidate seedlings have to be generated and compared.

2.2.4 Comparison of some Simple Classification Algorithms

The classification and clustering methods can be compared against the following criteria:

- Prediction accuracy

  Accuracy is the model's ability to accurately predict the class label of new or unknown data.

- Speed

  Speed is the computational costs associated with process creating and using the model.

Table 4 Comparison of some basic classification algorithms

Algorithm	Properties
K-means	High prediction accuracy Slow execution speed. Clustering required Weak strength Khả năng mở rộng thấp Good comprehension Simple, easy to use
Support vector machines	Highest prediction accuracy Slow execution speed Good strength High scalability Good comprehension High complexity
Decision tree	High prediction accuracy Fast execution speed Good resistance to interference High scalability Perspicuous Low complexity

- Strength

  Strength is the ability of the model to make correct predictions from noisy data or data with missing values.

- Ability of extension

  Scalability is the ability to effectively execute large amounts of data of the learned model.

- Comprehension

  Comprehension is the degree of understanding and thoroughly of the results generated by the model learned.

- Simplicity

  Simplicity is related to the size of the DT or the curvature of the rules. Table 4 lists the comparison of the classification algorithms based on the above attributes.

3 Design of a PLF System Based on Accelerometer Technology

The core of a PLF system concept is usually based on the wireless sensor network [9, 10, 24, 44] with the automated data collection function. Thus, the devices of a PLF system include:

- Devices that are mounted on cows, typically one device per cow, can be affixed to various locations such as the legs, neck, nose, or cheek. These devices serve as sensor network nodes, collecting data for monitoring services and wirelessly transmitting revenue-related information.

- One central device functions as a network node, receiving data from the devices mounted on the cow. Its primary purpose is to store and process data, and it can also be connected to the internet to provide advantages over mobile devices.

3.1 System Block Diagram

This review only discusses PLF systems using neck/leg devices. The main idea of these PLF systems is to monitor the cow through the wireless sensor network model. The general system is divided into two main parts: the first part is the equipment mounted on the cow to measure the movement at the neck/leg position, and the second part is the signal reception, storage, and processing of the received signal, to classify predict behavior (Fig. 9).

For the first part, each network node is a cow neck/leg device (mounted on the cow's neck or cow's leg). These nodes are wirelessly interconnected and developed based on 3-axis accelerometer for more accurate behavior determination. The second part consists of devices acting as the central node, receiving data from the network nodes through wireless communication in the 433 MHz frequency band. The central node is connected to the computer and the data are sent to the computer. Computers store data in records for storage, processing, and analysis of cow's behavior.

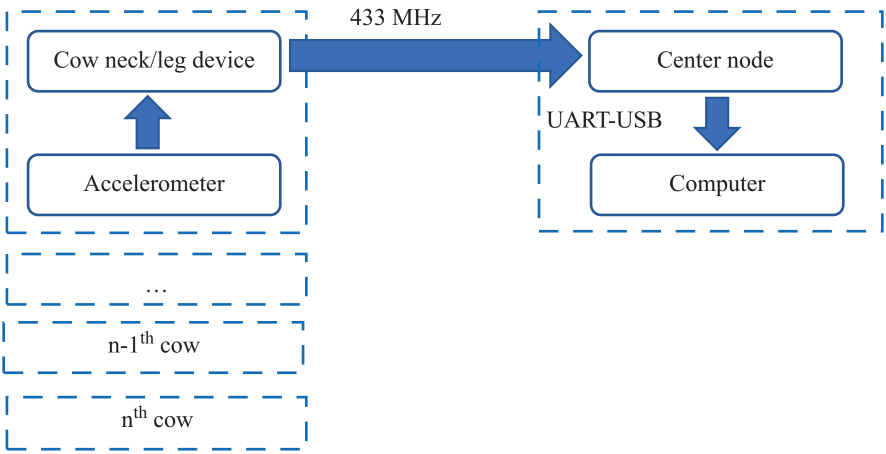


Fig. 9 A PLF system concept based on wireless sensor network

3.2 Block Diagram of Motion Measuring Equipment Attached to the Cow Neck/Leg

The neck/leg-mounted device is designed to measure movements at the cow's neck/leg. Data collected from this device are 3-axis acceleration data of the neck/leg relative to the ground reference system. From these data, it is possible to determine the movement of the cow's neck/leg, which will determine its current behavior. Figure 10 shows the system integration diagram example of a neck/leg motion measuring device.

The example design of the device on the neck/leg includes an Atmega328 microprocessor to receive data, process data, and coordinate data flow. Acceleration sensor MPU-6050 receives data of 3-axis acceleration, and communication module RF24L01 enables devices to communicate and receive data from each other. The Lora module acts as the end device, and together with the central node, the Lora module forms a wireless sensor network. A battery of 3.7 V–4000mAh will power the device on the neck.

The accelerometer is used to obtain acceleration data for dimensions X, Y, and Z, each with a range of ±8 g and a sampling frequency of 1 Hz. It integrates a 12-bit A/D converter to change the analog voltage into digital data.

3.3 Central Node to Collect and Process Data

The design of the center node includes the Atmega328 processor to receive data, process them, and transmit them to the computer. The Lora module acts as the end device, and together with the neck motion measuring device, the Lora module forms the wireless sensing network. Figure 11 shows the design diagram of the central node.

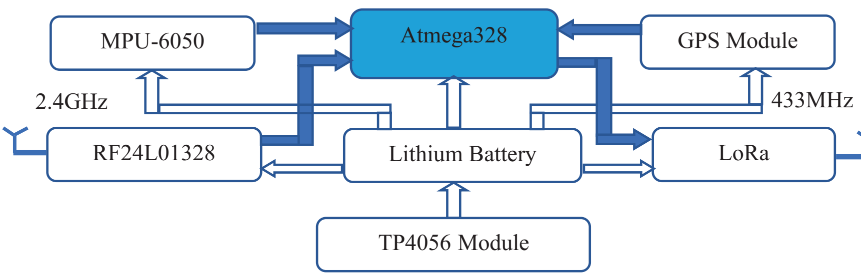


Fig. 10 The neck/leg-mounted device

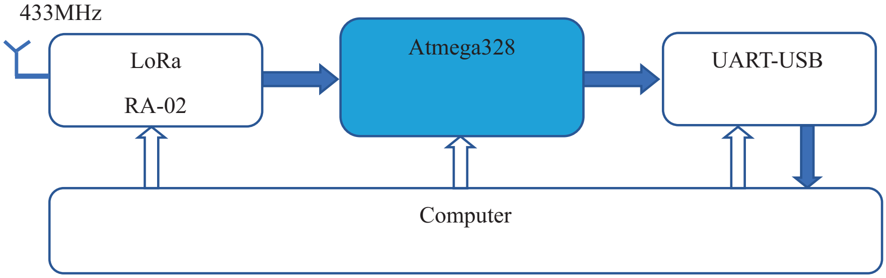


Fig. 11 Center node

Data obtained from Lora via Serial peripheral interface (SPI) protocol transmitted to the Atmega328 processor. Process transmission to the module converts the serial communication protocol to a USB transmission to a computer. On a computer, install software captures data from USB and packs it into records. The power supply for the center node is from the computer.

4 Potential PLF Systems Based on Accelerometer Technology and Machine Learning

Table 5 presents some potential PLF systems based on accelerometer technology and machine learning in the literature. P. Martiskainen and M. Jarvinen [19] used SVM, Arcidiacono et al. [3] used thresholds comparison (DT based), Wang et al. [26] used AdaBoost, Barwick et al. [6] and D. N. Tran et al. [45] used RF. All these works aimed to recognize behaviors based on neck/leg-mounted acceleration data. The length of data window varied from 3 to 16 s.

P. Martiskainen and M. Jarvinen [19] classified eight behaviors such as standing, feeding, lying, and walking. They used eight features, including SD, mean, max value, and min value. Some classification performance of their model is provided in terms of accuracy, sensitivity, PPV: feeding (0.96, 0.75, 0.81), lying (0.84, 0.80, 0.83), and walking (0.99, 0.79, 0.79). These results are not good to compare to recent works, but it was an impressive result in the year of its publishment [19].

Arcidiacono et al. [3] used a simple classifier based on accelerometer thresholds to distinguishing between feeding and standing. Their system is very simple since it only uses x-axis accelerometer data for analysis. It is a good idea when the concerned behavior focuses on feeding, one of the most important behavior.

Wang et al. [26] classified seven behaviors of cow: standing, feeding, lying, walking, active walking, standing up, and lying down. The overall performance in terms of (accuracy, sensitivity, PPV) is (0.86, 0.85, 0.80). They used location sensors to support recognition of feeding for free-stall barn cows. So, the solution is not suitable for grazing cows. And if the cow is standing but not feeding at the fixed feeding position, then it will make confusion for the classification model.

Table 5 Summary of some PLF systems based on accelerometer technology and machine learning

Research group	Sensor technology	Length of data window (second)	Algorithm base
P. Martiskainen and M. Jarvinen [19]	Accelerometer (collar-mounted)	10	SVM
Arcidiacono et al. [3]	Accelerometer (collar-mounted)	5	DT
Wang et al. [26]	Accelerometer (leg-mounted), location sensor	6	AdaBoost
Barwick et al. [6]	Accelerometer (leg-mounted, collar-mounted, ear-mounted)	3, 5, 10	RF
D. N. Tran et al. [45]	Accelerometer (leg-mounted, collar-mounted)	16	RF

SVM Support vector machines, *DT* Decision tree, *RF* Random forest

Barwick et al. [6] identified sheep behavior, including standing, feeding, lying, and walking. Three experiments used accelerometers (leg-mounted, collar-mounted, ear-mounted). The standing accuracy is 0.69–0.97, walking is 0.85–1, feeding is 0.58–0.95, and lying is low. These results are worse compare to the works with cows.

D. N. Tran et al. [45] classified four cow behavior: standing, feeding, lying, and walking. They used synchronized acceleration data (from neck sensor and leg sensor on each cow) to archive better performance compare to the recent works. The classification performance of their model in terms of (accuracy, sensitivity, PPV) is up to (0.99, 0.99, 0.99). The reason is this system has advantages of both neck and leg accelerometer to recognize behavior.

All the works above aimed to develop PLF systems based on accelerometer technology and machine learning for monitoring the animal. These systems are using Internet of Things (IoT) technology, which is the key to smart and precision livestock and other fields [45].

5 Conclusion

The future livestock will include sensor systems for effective management. These sensors are sources of large quantities of data that impact the way of management. Behavior data are one of the important indicators, which reflects animal welfare. The literature shows that accelerometers are sensitive even to small perturbations in the behavior of animals, thus they are highly valuable for the recognition of the behavior.

This review provided a detailed methodology to implement PLF sensor systems based on accelerometer technology and machine learning. The main focus of these systems is the behavior classification of pasture-based cattle. Various ML classification algorithms that are suitable to deal with this problem have been reviewed. In particular, important elements of behavior classification algorithms such as the feature set, the data window, and the evaluation method were discussed. These PLF sensor systems will provide benefits for farmers by contributing to the improvement of the quality of livestock and reducing the costs for management.

Acknowledgement This research is funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number: 02/2022/TN. Duc-Nghia Tran was funded by the Postdoctoral Scholarship Programme of Vingroup Innovation Foundation (VINIF), code VINIF.2022.STS.38.

References

1. K.M. Abell, M.E. Theurer, R.L. Larson, B.J. White, D.K. Hardin, R.F. Randle, Predicting bull behavior events in a multiple-sire pasture with video analysis, accelerometers, and classification algorithms. Comput. Electron. Agric. **136**, 221–227 (2017)
2. M. Alsaaod, J.J. Niederhauser, G. Beer, N. Zehner, G. Schuepbach-Regula, A. Steiner, Development and validation of a novel pedometer algorithm to quantify extended characteristics of the locomotor behavior of dairy cows. J. Dairy Sci. **98**, 6236–6242 (2015)
3. C. Arcidiacono, S.M.C. Porto, M. Mancino, G. Cascone, Development of a threshold-based classifier for real-time recognition of cow feeding and standing behavioural activities from accelerometer data. Comput. Electron. Agric. **134**, 124–134 (2017)
4. L. Atallah, B. Lo, R. King, G. Yang, Sensor positioning for activity recognition using wearable accelerometers. IEEE Trans. Biomed. Circ. Syst **5**, 320–329 (2011)
5. N. Bareille, F. Beaudeau, S. Billon, A. Robert, P. Faverdin, Effects of health disorders on feed intake and milk production in dairy cows. Livest. Prod. Sci. **83**, 53–62 (2003)
6. J. Barwick, D.W. Lamb, R. Dobos, M. Welch, D. Schneider, M. Trotter, Identifying sheep activity from tri-axial acceleration signals using a moving window classification model. Remote Sens. **12**, 646 (2020)
7. M.R. Borchers, Y.M. Chang, A validation of technologies monitoring dairy cow feeding, ruminating, and lying behaviors. J. Dairy Sci. **999**, 7458–7466 (2016)
8. Diosdado, J.A. Vázquez, et al., Classification of behavior in housed dairy cows using an accelerometer-based activity monitoring system. Anim. Biotelemetry **3** (2015)
9. D.D. Do, H.V. Nguyen, N.X. Tran, T.D. Ta, T.D. Tran, Y.V. Vu, Wireless ad hoc network based on global positioning system for marine monitoring, searching and rescuing (MSnR), in *Asia-Pacific Microwave Conference 2011*, (IEEE, 2011), pp. 1510–1513
10. A. Gian Quoc, C. Nguyen Dinh, N. Tran Duc, T. Tran Duc, S. Kumbesan, Wireless technology for monitoring site-specific landslide in Vietnam. Int. J. Electr. Comput. Eng. **8**(6), 4448–4455 (2018)
11. Q.T. Hoang, C.P.K. Phung, T.N. Bui, T.P.D. Chu, D.T. Tran, Cow behavior monitoring using a multidimensional acceleration sensor and multiclass SVM. Int. J. Mach. Learn. Networ Collab. Eng. **2**, 110–118 (2018)
12. A. Kamilaris, A. Kartakoullis, F.X. Prenafeta-Boldú, A review on the practice of big data analysis in agriculture. Comput. Electron. Agric. **143**, 23–37 (2017)
13. S. Kapil, M. Chawla, M.D. Ansari, On K-means data clustering algorithm with genetic algorithm, in *2016 Fourth International Conference on Parallel, Distributed and Grid Computing (PDGC)*, (IEEE, 2016), pp. 202–206
14. P.C.P. Khanh, D.-T. Tran, V.T. Duong, N.H. Thinh, D.-N. Tran, The new design of cows' behavior classifier based on acceleration data and proposed feature set. Math. Biosci. Eng. **17**, 2760–2780 (2020)
15. P.C.P. Khanh, T.T. Long, N.D. Chinh, T. Duc-Tan, Performance evaluation of a multi-stage classification for cow behavior, in *2018 2nd International Conference on Recent Advances in Signal Processing, Telecommunications & Computing (SigTelCom)*, (IEEE), pp. 121–125

16. K. Liakos, P. Busato, D. Moshou, S. Pearson, D. Bochtis, Machine learning in agriculture: A review. Sensors **18**, 2674 (2018)
17. F. Mahmoud, B. Christopher, A. Maher, H. Jürg, S. Alexander, S. Adrian, H. Gaby, Prediction of calving time in dairy cattle. Anim. Reprod. Sci. **187**, 37–46 (2017)
18. C.W. Maina, *IoT at the Grassroots – Exploring the Use of Sensors for Livestock Monitoring* (Ist-Africa Week Conference, 2017), pp. 1–8
19. P. Martiskainen, M. Jarvinen, Cow behavior pattern recognition using a three-dimensional accelerometer and support vector machines. Appl. Anim. Behav. Sci. **119**, 32–38 (2009)
20. G. Mattachini, E. Riva, C. Bisaglia, J.C.A.M. Pompe, G. Provolo, Methodology for quantifying the behavioral activity of dairy cows in free-stall barns. J. Anim. Sci. **10**, 4899–4907 (2013)
21. E.S. Nadimi, H.T. Søgaard, Observer Kalman filter identification and multiple-model adaptive estimation technique for classifying animal behavior using wireless sensor networks. Comput. Electron. Agric. **68**, 9–17 (2009)
22. S.C. Nayak, M.D. Ansari, COA-HONN: Cooperative optimization algorithm based higher order neural networks for stock forecasting. Recent Adv. Comput. Sci. Commun. **14**(7), 2376–2392 (2021)
23. S.C. Nayak, S. Das, M.D. Ansari, Tlbo-fln: Teaching-learning based optimization of functional link neural networks for stock closing price prediction. Int. J. Sensor. Wirel. Commun. Control **10**(4), 522–532 (2020)
24. D.C. Nguyen, T. Duc-Tan, D.N. Tran, Application of compressed sensing in effective power consumption of WSN for landslide scenario, in *2015 Asia Pacific Conference on Multimedia and Broadcasting*, (IEEE, 2015a), pp. 1–5
25. C.D. Nguyen, T.D. Tran, N.D. Tran, T.H. Huynh, D.T. Nguyen, Flexible and efficient wireless sensor networks for detecting rainfall-induced landslides. Int. J. Distrib. Sensor Network **11**(11), 235954 (2015b)
26. K. O'Driscoll, L. Boyle, A brief note on the validation of a system for recording lying behavior in dairy cows. Appl. Anim. Behav. Sci. **111**, 195–200 (2008)
27. G.M. Pereira, J. Heins Bradley, I. Endres Marcia, Validation of an ear-tag accelerometer sensor to determine rumination, eating, and activity behaviors of grazing dairy cattle. J. Dairy Sci. **101**, 2492–2495 (2018)
28. V.T. Pham, D.A. Nguyen, N.D. Dang, H.H. Pham, V.A. Tran, K. Sandrasegaran, D.T. Tran, Highly accurate step counting at various walking states using low-cost inertial measurement unit support indoor positioning system. Sensors **18**(10), 3186 (2018)
29. V.T. Pham, Q.B. Le, D.A. Nguyen, N.D. Dang, H.T. Huynh, D.T. Tran, Multi-sensor data fusion in a real-time support system for on-duty firefighters. Sensors **19**(21), 4746 (2019)
30. K.P.C. Phi, K.T. Nguyen, D.-N. Tran, D.-C. Nguyen, T.H. Quang, T. Van Nguyen, D.-T. Tran, Classification of Cow's Behaviors Based on 3-DoF Accelerations from Cow's Movements. Int. J. Electr. Comput. Eng. **9**, 1656–1662 (2019)
31. S.M.C. Porto, C. Arcidiacono, Localization and identification performances of a real-time system based on ultra wide band technology for monitoring and tracking dairy cow behavior in semi-open free-stall barn. Comput. Electron. Agric. **108**, 221–229 (2014)
32. D.V. Rahman, Smith, cattle behavior classification from collar, halter, and ear tag sensors. Inf. Process. Agric. **5**, 124–133 (2018)
33. B. Robert, B.J. White, D.G. Renter, R.L. Larson, Evaluation of three-dimensional accelerometers to monitor and classify behavior patterns in cattle. Comput. Electron. Agric. **67**(1-2), 80–84 (2009)
34. B.D. Robért, B.J. White, D.G. Renter, R.L. Larson, Determination of lying behavior patterns in healthy beef cattle by use of wireless accelerometers. Am. J. Vet. Res. **72**, 467–473 (2011)
35. M.S. Shahriar, D. Smith, Detecting heat events in dairy cows using accelerometers and unsupervised learning. Comput. Electron. Agric. **128**, 20–26 (2016)
36. M. Sugiyama, M. Kawanabe, *Machine learning in Non-Stationary Environments* (MIT Press, 2012)
37. R.S. Sutton, A.G. Barto, *Introduction to Reinforcement Learning*, vol 135 (MIT Press, Cambridge, 1998)

38. J.M. Talavera, L.E. Tobón, J.A. Gómez, M.A. Culman, J.M. Aranda, D.T. Parra, L.E. Garreta, Review of IoT applications in agro-industrial and environmental fields. Comput. Electron. Agric. **142**, 283–297 (2017)
39. T.D. Tan, N. Van Tinh, Reliable fall detection system using an 3-DOF accelerometer and cascade posture recognitions, in *Signal and Information Processing Association Annual Summit and Conference (APSIPA), 2014 Asia-Pacific*, (IEEE, 2014), pp. 1–6
40. T.D. Tan, L.M. Ha, N.T. Long, N.D. Duc, N.P. Thuy, Integration of inertial navigation system and global positioning system: Performance analysis and measurements, in *2007 International Conference on Intelligent and Advanced Systems*, (IEEE, 2007), pp. 1047–1050
41. T.D. Tan, L.M. Ha, N.T. Long, H.H. Tue, N.P. Thuy, Novel MEMS INS/GPS integration scheme using parallel Kalman filters, in *2008 IEEE/SICE International Symposium on System Integration*, (IEEE, 2008), pp. 72–76
42. T.D. Tan, L.M. Ha, N.T. Anh, *A real-time vibration monitoring for vehicle based on 3-DOF MEMS accelerometer* (Proc. 2010 Int. Conf. Computational Intelligence and Vehicular System, 2010), pp. 160–164
43. T.D. Tan, N.T. Anh, G.Q. Anh, Low-cost structural health monitoring scheme using MEMS-based accelerometers, in *2011 Second International Conference on Intelligent Systems, Modelling and Simulation*, (IEEE, 2011), pp. 217–220
44. D.T. Tran, D.C. Nguyen, D.N. Tran, D.T. Ta, Development of a rainfall-triggered landslide system using wireless accelerometer network. Int. J. Adv. Comput. Technol. **7**(5), 14 (2015)
45. D.N. Tran, T.N. Nguyen, P.C.P. Khanh, D.T. Tran, An IoT-based Design Using Accelerometers in Animal Behavior Recognition Systems. IEEE Sensor. J. (2022). https://doi.org/10.1109/JSEN.2021.3051194
46. S. Tsairidou, A. Allen, G. Banos, M. Coffey, O. Anacleto, A.W. Byrne, R.A. Skuce, E.J. Glass, J.A. Woolliams, A.B. Doeschl-Wilson, Can we breed cattle for lower bovine TB infectivity? Front. Vet. Sci **5**, 310 (2018)
47. J.J. Valletta, C. Torney, M. Kings, A. Thornton, J. Madden, Applications of machine learning in animal behaviour studies. Anim. Behav. **124**, 203–220 (2017)
48. P. Van Thanh, A.N. Thi, Q.T.T. Thuy, D.C.T. Phuong, V.H. Mau, D. Tran, *A Novel Step Counter Supporting for Indoor Positioning Based on Inertial Measurement Unit* (2017 7th International Conference on Integrated Circuits, Design, and Verification (ICDV), Hanoi, 2017), pp. 69–74. https://doi.org/10.1109/ICDV.2017.8188641
49. J. Wang, Z. He, Development and validation of an ensemble classifier for real-time recognition of cow behavior patterns from accelerometer data and location data. PLoS One **13** (2018)
50. J. Wang, Z. He, J. Ji, K. Zhao, H. Zhang, IoT-based measurement system for classifying cow behavior from tri-axial accelerometer. Ciência Rural **49**, 1–13 (2019)
51. H.C. Weigele, L. Gygax, A. Steiner, B. Wechsler, J.B. Burla, Moderate lameness leads to marked behavioral changes in dairy cows. J. Dairy Sci. **3101**, 2370–2382 (2018)
52. N. Zehner, C. Umstatter, System specification and validation of a noseband pressure sensor for measurement of ruminating and eating behavior in stable-fed cows. Comput. Electron. Agric. **136**, 31–41 (2017)
53. X. Zhu, A.B. Goldberg, Introduction to semi-supervised learning. Synth. Lect. Artif. Intell. Mach. Learn. **3**, 1–130 (2009)

Smart IoT-Based Greenhouse Monitoring System

Agilesh Saravanan. R, Gowri Priya, Sai Nishanth, Praveen Sai, and Vasanth Kumar

1 Introduction

The greenhouse is the location where we can grow fruit and vegetables. Every plant or crop has a specific environment to grow. Nowadays, the environment, temperature, and humidity are changing every day. As a result, plants do not grow well, and few crops end without any benefit. I think it is the main reason to lose a crop by farmers. As a result, this project can reduce damage to crops/plants and help plants to live for a long time.

In this chapter, we observe the surrounding environment of plants and crops like temperature, humidity, light intensity, and soil moist by using DHT11, light dependent resistor (LDR), and soil moisture sensors, respectively. Here, we use a DC fan to cool down the temperature, light bulbs, and a water pump to wet the soil [4]. Here, we add a WI-FI module ESP8266 to monitor parameters and notification when the fan or blub or water motor is switched on/off. Earlier instead of Wifi Azevedo et al. [1] use the Zigbee network for Application layer.

Temperature, humidity, soil moisture, and light intensity will be collected by project till the end of the project. In today's greenhouses, the monitoring of parameters is important for the good quality and productivity of plants. However, certain parameters such as temperature, humidity, soil moisture, and light intensity are required for higher plant growth in order to achieve the stated consequence [13]. Thus, Node MCU has been developed primarily as a greenhouse control unit using sensors. The Node MCU is used for this project. Node MCU can receive feedback from a wide range of sensors and can control generators, lights, and various actuators. Few sensors are used to measure few parameters. DHT11 sensor is used to

Agilesh Saravanan. R (✉) · G. Priya · S. Nishanth · P. Sai · V. Kumar
Department of ECE, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India
e-mail: agilesh@kluniversity.in

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_15

measure temperature and humidity values. The soil moisture sensor tests the water content of the soil [10]. The LDR sensor is used at a modest depth. The exhaust fan, water pump, and artificial light are also connected to the Node MCU.

All environmental parameters are dispatched to android cell phone via offline. A cloud is used to ship environmental parameters to server. As a result, when less than 50% of the soil loses its moisture, the motor pump will immediately turn on to sprinkle the water and start sprinkling the water until the moisture drops to 55% and the pump is turned off after that. At a given time, sensor information will be sent to the ThingSpeak Server so that it can be monitored from anywhere in the world [14]. ThingSpeak enables instant viewing of the data that the computers have transmitted to ThingSpeak. With the power to execute MATLAB programming in ThingSpeak, you will do online data interpretation and processing because it comes in. ThingSpeak is additionally used for prototyping and proof of IoT concept applications involving analytics. When the temperature is raised to or greater than 40 degrees, the fan is switched on and when the temperature is a smaller amount than 28 degrees, the fan is transitioned. Similarly, where the light level is less than the normal amount, the electric lights are switched on automatically and off when there is enough sunlight. So, a person can track the parameters with an Android phone. This device is very useful for farmers to observe and monitor environmental parameters in their fields. Farmers do not need to head to their farms. Any variance within the environmental criteria may result in monetary losses in the agricultural and pharmaceutical industries and may pose a life-threatening danger to consumers of biomedical industries. These losses can be stopped by managing them instantly.

2 Literature Review

In Vimal and Shivaprakasha [16], the project is about a system using GSM and Ethernet, which reduces the power consumption, maintenance, and complexity. That project can be used in agricultural field, in nursery, and in botanical garden. Used technologies are GSM module and Ethernet. Easy to communicate and monitor are the advantages. System costs high is a drawback. In Chen & Liu et al. [2] introduced the CAN Transport Based Intelligent Greenhouse Control System, this creates a great advance and revolution in Green house Monitoring. The author S.Li. [9] introduce the STM32 for monitor CO_2 concentration in the Green house which help in stabilization of Oxygen level in greenhouse .

In Geng et al. [3], a four-layer device architecture was developed with outstanding motion control functions using mobile acquisition. Layers used are perceptual (physical) layer, control layer, transmission layer, and application layer. Raspberry pi and Arduino chip were combined to work as data server. Due to compact size, Raspberry pi and sensors were integrated into mobile system. Cycle redundancy check (CRC) was used to reduce data loss at transmission layer. Advantage of this project is that it monitors the highest and lowest values at a given point in time.

In [15] authors Subahi et al. devoloped the advance intelligent system for controlling and monitoring the temperature of Green house condition with advanced sensor interface and cotrolling system. A hybrid wired/wireless networking infrastructure for greenhouse management is developed by Mirabella et al. in [11].

In [6], authors said that "Some complications arose during field experiments. Because of the EMI power source, some incorrect records were recorded. Salt deposition and thus incorrect measurements were observed on the soil wetness sensor probes. The total SMS loss was 0.5%." According to Tseng et al. (2006), this amount of SMS loss is appropriate. The missing records were not consecutive and were insignificant on the remote server (1.8%). R.L. Njinga et al. [12] undergone the research in Examination of essential elements for plants development utilizing instrumental neutron activation analysis at extreme level of outcome.

In paper [17] the author D. Visser et al used the Advancing light system in which the nursery used a 3D model of tomato and a beam tracer. In Xia et al. [19], authors had designed monitoring of greenhouses and a framework focused on MSP430. The CC2530 module is introduced in this article. The method has the benefits of stable service, low power consumption, durability, and convenient usage, thus meeting a great deal with modern requirement for greenhouse production.

Kitpo et al. [7] provided a survey report on agricultural problems. Many tools have been used to boost words of the farmers. This paper reflects on a major irrigation crisis. There are a lot of irrigation schemes and they are automated. The study allows us to learn about different IOTs GSM related methods used in the irrigation system. This paper contains a section-wise explanation of the previous work. So that, we will hear more about the problems of agriculture. This report is helpful to learn about the developments in agriculture for 10 years to enable a detailed survey to be undertaken to help farmers.

Xing et al. [20] aimed at the greenhouse in facility agriculture and developed intelligent knowledge monitoring system, and the conclusion can be made as follows:

(i) The star network control structure was constructed.
(ii) Used ZigBee to set up wireless sensor network.
(iii) A kind of cooperative control method based on time control, manual control, automatic control, intelligent control, and remote control was proposed.

3 Design of Greenhouse Monitoring

3.1 Greenhouse

Growing plant is the combination of both art and science. Due to the modern development in technology, it creates newer dimension in growing the plant. Greenhouse technique is unique method to affording such an environment to the plants. Even though the man faced a lot of challenges in growing plant, he learned how to grown

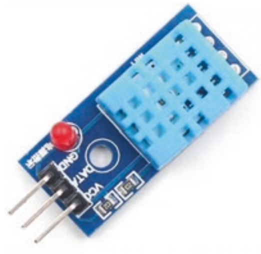


Fig. 1 DHT11 sensor module

plant not only in normal condition but also in extreme adverse condition with the help of advanced technology, which is called as "green house monitoring."

In the green house monitoring to maintain the environment and increase the productivity, some sensors are used. They are magnetic sensor, humidity sensor, temperature sensor, light sensor, and moisture sensor.

Many supportive components are used to control the environment in the green house such as bulb, fan, motor, and heater, and all these get control with respect to the collecting data from the sensor. Sensors are the basic components to sense various physical parameters such as light, heat, pressure, and humidity. The above are the basic factors controlled in green house for the better production.

A. Humidity and temperature

Temperature and humidity are measured using the DHT11 sensor and it is shown in Fig. 1. If the humidity of green house is below the defined level, water is sprayed to maintain humidity level. If it is less than the defined value, the spray will switch off the water. For the temperature of more than critical value, the fan has to switch on and value of the sensor is transmitted using Node MCU and the data is maintained in cloud and monitored through ThingSpeak.

B. Soil moisture

For the irrigation, the water supply is the major concern, and for that purpose, we use water pump, and soil moisture sensor shown in Fig. 2 is used for detecting the moisture in soil. If moisture is less than threshold value, water pump is switched on until the soil moisture attained the threshold level, and value of the sensor is transmitted using Node MCU and the data is maintained in cloud and monitored through ThingSpeak.

C. Light intensity

Light is the important factor for plant growth. The intensity of the light is provided by 100-watt bulb and it is controlled by sensor called light dependent resistor (LDR) as shown in Fig. 3. It turned on/off depending on threshold level. If light intensity is more, it turned off the bulb. If not, it switched on the bulb. The sensor value is monitored through ThingSpeak.

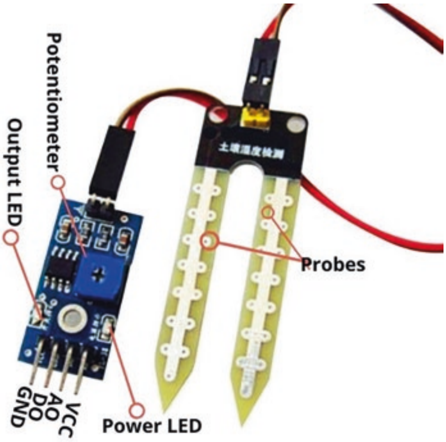


Fig. 2 Soil moisture sensor module

Fig. 3 LDR sensor Module

The ultimate aim of green house monitoring is to improve efficiency and effectiveness of your management, save money, and provide better crop.

The method for monitoring and controlling the green house is focused on the calculation of the light intensity, soil moist, temperature, and humidity of the sensor situated at the locations. The result can be seen in ThingSpeak.

3.2 IoT Technology

Nowadays, Internet is an adequate thing to this world. In that, we knew Internet of Things (IoT) is more attractive and expanding technology. We are very closed or controlled by internet. The advantage of the internet is the hyper connected technology as we use on mobile and laptop. It is an adequate and helpful connection with sensor application. The way it helps is to connect the device from the farther distance to communicate and get connected. It is a very great achievement compared to other contrasting and communicating devices.

IoT will support a huge amount of development in our day-to-day lives. We can enable a device in public and private places. It helps to adapt our situations such as environment, education, safety, commercial, comfort, and personal well-being.

The IoT network can manage the following application such as medicare, smart automation maintenance, security surveillance, transportation, and industrial purpose. The IoT devices transform our lives in many aspects. New IoT products such as internet operated appliances can be controlled by Internet such as home automation, and energy management devices are turned toward the innovation of “Smart Home,” giving more security, highly controllable through security locks and alarm even controlled by home appliance too.

In addition, there are several personal Internet of Things (IoT) gadgets available, including wearable fitness trackers and medical surveillance tools, such as health monitoring monitors.The utilization of monitoring devices and networkconnected medical devices has become integral to the provision of healthcare services, offering enhanced and intensive monitoring capabilities for patients. The utilization of Internet of Things (IOT) facilitates seamless and expeditious connectivity to patients, enabling continuous monitoring of healthcare conditions.

Even IOT systems like networked vehicle advanced traffic system which helped to turned toward a metropolitan as “Smart Cities” help to minimize the congestion and consumption. With the help of the IoT, the huge development in the agriculture industry products development is done by providing Internet to agro-based application and giving access and controlling remotely by the mobile application such as thingSpeak.

3.3 Green House Monitoring Using IoT Technology

As compared to open field cultivation, the greenhouse will produce more crop per square meter. The microclimatic parameters are monitored and controlled to maintained an optimum temperature in greenhouse. The automated green house system is controlled by a sensors and actuators that are controlled by microcontroller driving a computer program.

The two important stations in a system are remote monitoring station and actuator/sensor station. The controller with the help of sensor checks if the climatic condition in the greenhouse is in predefined values programmed in Node MCU. The sensor values are transmitted through the Node MCU to Cloud and it is monitoring through thingSpeak all over the time.

Block diagram of IoT-based greenhouse monitoring is shown in Fig. 4. The change in environment is sent to Node MCU by different sensors such as soil moisture sensor, LDR, and DHT11 and it analyzes the data and sends commands to respective controlled devices such as water motor, artificial light, and exhaust fan. This data is uploaded to cloud-based platform called ThingSpeak using in-built Wi-Fi module called Node MCU.

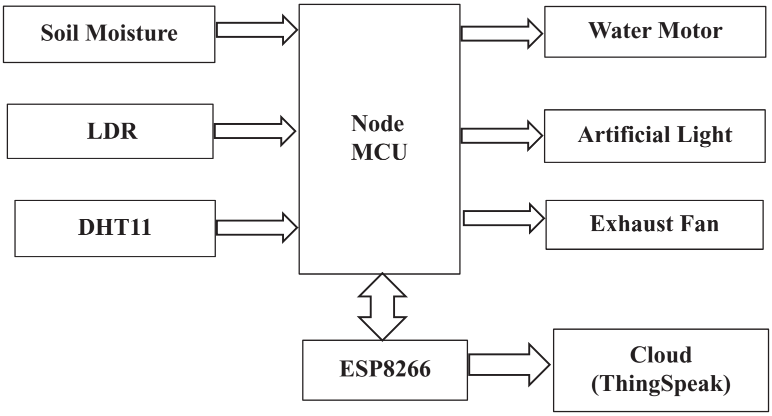


Fig. 4 Block diagram of greenhouse monitoring

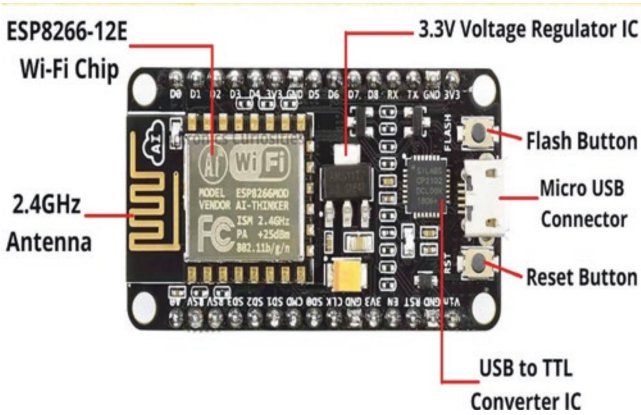


Fig. 5 Node MCU

3.4 Hardware Description

Today, due to the development of IOT application, the sensor that interfaces with the microcontroller is getting more and more critical. Node MCU is the open source platform which helps to connect sensors and allow the sensors to transfer the data through the WiFi Protocol and it is shown in Fig. 5. It also includes the basic feature of basic microcontroller such as GPIO, PWM, and ADC. It has capability to control many application separately.

The unique feature of this Node MCU board is as follows:

1. Having internal antenna
2. Feasible in event driven API application
3. Containing 13 GPIO pins, 10 PWM channels, I2C, SPI, ADC, UART, and 1-Wire
4. Offered as access point or station

Greenhouse monitor hardware is designed to monitor all the data that come from various sensors, which have different parameters like light intensity, soil moisture, humidity, and temperature. Every sensor senses the change in their respective domain and transfers this change to the Node MCU that is shown in Fig. 5. For example, soil moisture sensor senses the moisture level in the soil and transfers the information to the microcontroller. As Node MCU itself consists of Wi-Fi module, it can be used to upload all the data to the ThingSpeak, a cloud-based platform.

3.5 Software Description

The software is designed to process the humidity, temperature, light intensity, and soil moist value from sensor to Node MCU microcontroller. Then, it continues to monitor the parameters from microcontroller. The microcontroller Node MCU is to convert analog to digital, send the value of sensor through serial communication to computer, and control the water motor, artificial light, and exhaust fan according to the parameter's values.

It is very convenient to schedule part of this project. The DHT library is used in this software to read the humidity and temperature sensor (DHT11 basic) from the humidity and temperature sensor, which can be monitored using ThingSpeak.

4 Methodology

The key purpose of this research work is to focus on monitoring the greenhouse and acting on soil moist, and air and lighting services. The components used are as follows:

- Node MCU
- ESP8266 Wi-Fi module
- Soil moisture sensor
- LDR
- DHT11

Node MCU is an open source IoT platform. The Node MCU is a platform for Internet of Things (IoT) that is open source in nature. The system comprises firmware that operates on the Espress IC Systems ESP8266 Wi-Fi SoC, as well as hardware that is built upon the ESP-12 Module. The sensors employed in this study are the temperature and humidity sensor (DHT11), soil moisture sensor, and light-dependent resistor (LDR). The exhaust fans, water pump, and artificial light can be classified as the terminal devices or end equipment. The exhaust fans, the water pump, and the artificial light are the end equipment.

In the event that the dirt dampness esteem is underneath the expressed level, the motor turns on and siphons the water through the tubing [5]. It very well may be performed consequently and constantly until the characterized edge esteem has been met. Here, all limit esteems are taken from the perception of the rancher. It is utilized to decide the power of the light inside the nursery. In the event that the sunshine level is like the sting, the LED activates consequently and off within the event that it is not equivalent.

DHT11 screen detects temperature and mugginess. In the event that the temperature esteem is higher than or equivalent to the limit esteem, the fumes fan turns on consequently and off in the event that it is not exactly the edge esteem. In the event that the dampness esteem is not exactly or equivalent to the limit esteem, the fan turns on consequently and draws the ventilate of the nursery and off in the event that it is more than the edge.

The suggested method fits well and has shown effective outcomes. End equipment such as light source, water pump, and fans within the greenhouse have been triggered according to the threshold conditions of parameters such as temperature, humidity, and soil moisture values. The data obtained from the MCU Node is sent to the ThingSpeak server and the data is reflected on the server.

Here, the data is read from the different sensors that the sensed data is sent to the ThingSpeak IoT network through the internet using the ESP8266 module installed on the unit [8].

The framework portrays the assortment of exercises completed by the various modules, for example, temperature, humidity, LDR, and soil wetness. It tests whether the estimations of the boundaries are underneath or over the edge esteems [18]. The actuators are set off and deactivated considering the present situation.

5 Result

ThingSpeak is an IoT platform that helps to capture, interpret, and visualize data. It has TCP/IP to send and receive data. That is why we build channels in ThingSpeak. The sensed data is seen in the generated channels. Here, we use ThingSpeak as a cloud platform.

Finally, we have created a webpage in ThingSpeak. We gathered all sensors data and uploaded in ThingSpeak website using Node MCU, and it analyzes the data and represents it in graphical format as shown in Fig. 6. Here are some of the data such as temperature, humidity, soil moisture, and light intensity gathered from sensors and displayed in ThingSpeak. Here, the data may be varied from time to time so that we get up and down in the graphical representation of data.

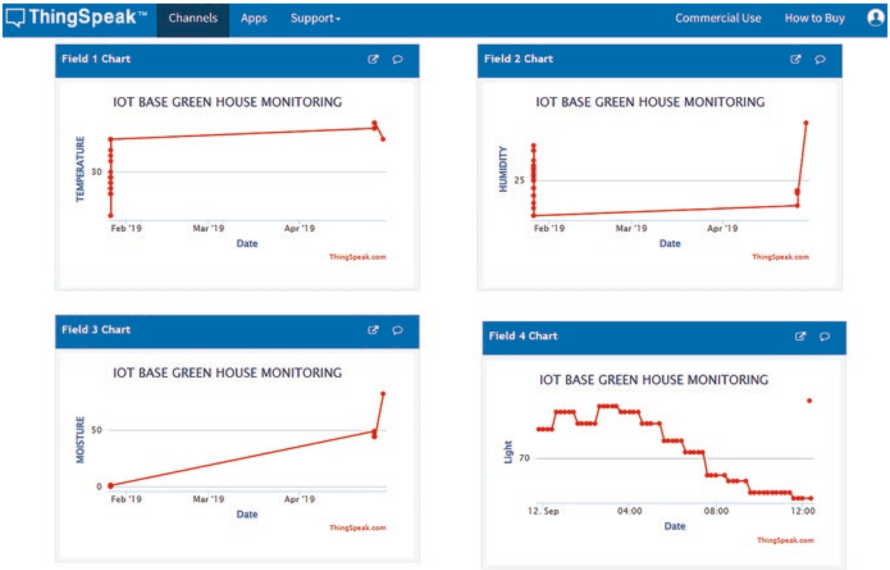


Fig. 6 Sensors data shows on the ThingSpeak dashboard

6 Conclusion

The key benefit of this project is that all tasks to be done by controlling devices such as exhaust fan, artificial lights, and water motor and to monitor climatic conditions such as temperature, relative humidity, light intensity, and soil moisture levels in the greenhouse atmosphere, which are automated and do not require human intervention. We can also add GSM module to send SMS to the user's phone to reduce the expense of the internet and users can get alerts without internet access to their phone.

References

1. J. Azevedo, F. Santos, M. Rodrigues, L. Aguiar, Dozing ZigBee networks at the application layer. IET Wirel. Sens. Syst. **4**(1), 35–41 (2013)
2. P. Chen, B. Liu, *Advancement of the CAN Transport Based Intelligent Greenhouse Control System[C]* (2010 International Conference on Computer Application and System Modeling, 2010), pp. V10-631–V10-644
3. X. Geng et al., A Mobile greenhouse environment monitoring system based on the internet of things. IEEE Access **7**, 135832–135844 (2019). https://doi.org/10.1109/ACCESS.2019.2941521
4. X.Y. Gong, S. Rudi, C.A. Lehmeier, Atmospheric CO_2 mole portion influences stand-scale carbon use effectiveness of sunflower by invigorating breath in light. Plant Cell. Environ. **40**(3), 401–412 (2017)

5. M. Hanggoro, A. Putra, R. Reynaldo, R.F. Sari, *Green House Monitoring and Controlling Using Android Mobile Application* (2013 International Conference on QiR, Yogyakarta, 2013), pp. 79–85. https://doi.org/10.1109/QiR.2013.6632541
6. https://www.researchgate.net/publication/306066391_Design_of_a_Greenhouse_Monitoring_System_Based_on_GSM_Technologies
7. N. Kitpo, Y. Kugai, M. Inoue, T. Yokemura, S. Satomura, *Internet of Things for Greenhouse Monitoring System Using Deep Learning and Bot Notification Services* (2019 IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, 2019), pp. 1–4. https://doi.org/10.1109/ICCE.2019.8661999
8. K.G. Kumar, K.N. Rao, *Autonomous Greenhouse using Internet of Things with ThingSpeak* (International Research Journal of Engineering and Technology (IRJET), 2019) e-ISSN: 2395-0056, p-ISSN: 2395-0072
9. S. Li, *Research on Intelligent Monitoring System of Greenhouse Intensity and CO_2 Concentration Based on STM32*, vol 2018 (IEEE International Conference on Mechatronics and Automation (ICMA), Changchun, 2018), pp. 666–670. https://doi.org/10.1109/ICMA.2018.8484450
10. Z. Lihong, S. Lei, *Estimation and Control System of Soil Moisture of Large Greenhouse Group Based On Twofold CAN Bus* (IEEE Conference Publications, 2011), pp. 518–521
11. O. Mirabella, M. Brischetto, A hybrid wired/wireless networking infrastructure for greenhouse management. IEEE Trans. Instrum. Meas. **60**(2), 398–407 (2011). https://doi.org/10.1109/TIM.2010.2084250
12. R.L. Njinga, M.N. Moyo, S.Y. Abdulmaliq, Examination of essential elements for plants development utilizing instrumental neutron activation analysis. Int. J. Agron **2013**, 156520 (2013)
13. K. Rangan, T. Vigneswaran, *An Embedded Systems Way to deal with Monitor Green House* (IEEE Meeting Publications, 2010), pp. 61–65
14. N.N.Y. Sang, N.K. Hlain, Smart Greenhouse using ThingSpeak IoT Platform. J. Comput. Appl. Res. **1**(1) (2020)
15. F. Subahi, K.E. Bouazza, An intelligent IoT-based system design for controlling and monitoring greenhouse temperature. IEEE Access **8**, 125488–125500 (2020). https://doi.org/10.1109/ACCESS.2020.3007955
16. P.V. Vimal, K.S. Shivaprakasha, *IOT Based Greenhouse Environment Monitoring and Controlling System Using Arduino Platform* (2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), Kannur, 2017), pp. 1514–1519. https://doi.org/10.1109/ICICICT1.2017.8342795
17. D. Visser, H.B. Pieter, G.H. Buck-Sorlin, G.W.A.M. van der Heijden, Advancing light in the nursery utilizing a 3D model of tomato and a beam tracer. Front. Plant Sci. **5**(48) (2014)
18. G. Wenchuan, C. Hanjie, L. Ruiming, L. Jian, Z. Haihui, Nursery Monitoring System Based on Wireless Sensor Networks[J]. Trans. Chin. Soc. Agric. Mach. **41**(7), 181–185 (2010)
19. L. Xia, L. Wenhui, S. Yixin, *Greenhouse Monitoring System Design Based on MSP430 and King View* (2017 32nd Youth Academic Annual Conference of Chinese Association of Automation (YAC), Hefei, 2017), pp. 111–114. https://doi.org/10.1109/YAC.2017.7967388
20. X. Xing, J. Song, L. Lin, M. Tian, Z. Lei, *Development of Intelligent Information Monitoring System in Greenhouse Based on Wireless Sensor Network* (2017 4th International Conference on Information Science and Control Engineering (ICISCE), Changsha, 2017), pp. 970–974. https://doi.org/10.1109/ICISCE.2017.205

Automatic Water Irrigation System Using IoT

P. Sanjan Miller, B. Sai Bhaskar Reddy, M. Govardhan Reddy, M. Sridhar, and Surendra Kumar Bitra

1 Introduction

A brilliant agriculture model is a framework that is constantly observed. It monitors soil parameters such as temperature, stickiness, soil wetness, PH, and so on, and may be used to control multiple activities in the field remotely from anywhere, at any time [3, 9, 12]. It provides a cutting-edge lifestyle in which an individual may operate his electronic devices using an upgraded cell phone, as well as efficient energy usage [10, 18]. It is used in a variety of industries, including astute agribusiness, brilliant halting, keen structure natural checking, medical services transportation, and others.

The keen agriculture model is a framework for continual observation. It monitors soil parameters such as temperature, moisture, soil wetness, and pH. The IoT allows for remote control of multiple field jobs from any location, at any time [13, 19]. It provides a cutting-edge lifestyle in which an individual may operate his electronic devices using an advanced mobile phone, as well as efficient energy use. It is used in many aspects of the industry, including clever agribusiness, sharp halting, astute structure ecological monitoring, and medical care transportation [2, 15].

Irrigation is the most important thing in agriculture for 5000 years and it is used to increase the yield of crops. Applying water to the crops is known as irrigation. Nowadays, the mechanization of irrigation plays a crucial role as well as progressing rapidly due to groundwater depletion. The amount of irrigation is increased due to the increased groundwater depletion [6]. In Bangladesh, flood irrigation technology is implemented due to its simplicity and low cost. For improving irrigation efficiency, an intelligent irrigation system was introduced by Gutiérrez et al. [5]).

P. S. Miller · B. S. B. Reddy · M. G. Reddy · M. Sridhar (✉) · S. K. Bitra
Department of ECE, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India
e-mail: sridhar.m@kluniversity.in

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_16

Nowadays, the smart irrigation system (SIS) becomes an interesting topic for next-generation research [1, 16].

Recently, Kinjal et al. [8] developed an irrigation system consisting of soil conditions, plant water usage, evaporation, and climate monitoring system [17]. The customized water schedules and run-time are more concentrated on intelligent systems. The SIS controllers and the moisture sensors worked based on climate changes. The best SIS is based on the geographical situation as well as the surrounding terrain [7].

Evapotranspiration (ET) is the combination of soil evaporation and the transpiration of plants. ET is the time-based controller used for changing the irrigation schedules based on the local available meteorological data. In the present global technology, automation is the technology used to process all processes without human interaction. In this work, importance is given for the irrigation process controlled by electronic components and relevant materials which can be done without human interaction.

The most extensive automation system is designed and deployed based on the sensor systems. Due to this system, the people are very much benefited from their regular activities, saving time and effort. The sensor systems include microcontroller, DC motor, relays, and battery. The soil moisture levels are sensed by the switching system and the plants are irrigated. The motor ON/OFF is controlled automatically by soil dryness level. The sensor data is analyzed using a personal computer based on the graphs. The PC is used to monitor and operated using the SIS. This technique is very much useful in large as well as small gardens, greenhouses, nurseries, and green roofs of the houses. It saves the loss of water, time, and energy of the people. The SIS assists the farmers in benefitting the plantation without irrigation issues.

The moisture levels of the ground are correctly analyzed by the sensor and transmitted the data for reading by the controller. The sensor is buried in the root region of a plant or tree on the lawn or bushes. The SIS is configured using traditional times with irrigation start time, duration, and stop time using the controlled programs to the moisture sensor. If the sufficient moisture is available in the ground, the SIS will hold the next watering schedule. In the SIS, irrigation time is not scheduled because it operates on the demand of water supply.

The operation of a large-scale water system structure with fewer manual intercessions is referred to as automation. The cost–benefit ratio is improved by simplifying the single distribution which is a representation of the fully regulated water system. Understanding the water system's planning is required for the mechanization of the structure of the small-scale water system. Plant irrigation systems that are automated estimate and measure the current plant and then give the desired amount of water, which reduce the amount of water used and keep the plants healthy. The economy is mostly focused on agriculture, with isotropic climatic conditions and full utilization of agricultural resources [4, 8].

Increasing the use of current data innovation in agribusiness will address a number of difficulties that ranchers are facing. The disaster is underway due to a lack of meticulous documentation and correspondence. Our paper aims to solve these problems. This framework provides an astute observation stage structure and framework structure for an IoT-dependent office farming setting. This will act as a catalyst for the transition from traditional to modern agriculture [11, 14].

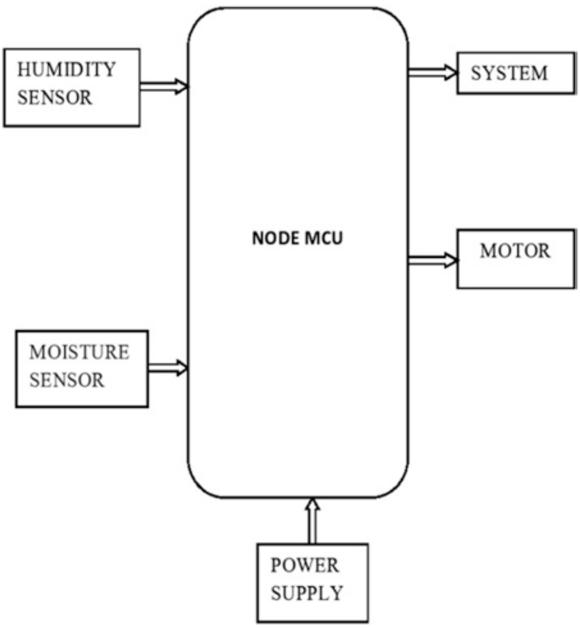
2 Proposed System

The shrewd farming model principle expects to dodge water wastage in the water system measure. It is minimal effort and productive framework is demonstrated as follows. It incorporates NodeMCU, Arduino Nano, soil sensors for dampness, and Dht11, solenoid valves, and transfers. The proposed system is shown in Fig. 1.

The NodeMCU ESP8266 contains the ESP-12E module and ESP8266 chip with Tensilica Xtensa 32-bit LX106 RISC chip. The microchip operates at 80–160 MHz clock recurrence with upholds RTOS. The ESP8266 of Fig. 2 has RAM of 128 KB and flash memory of 4 MB. The power module is in-assembled with Wi-Fi, Bluetooth, and ideal deep sleep operations for IoT module.

Moistness sensors distinguish the overall dampness of the prompt conditions where they are set. They measure both the dampness and temperature noticeable all around and express relative mugginess as a level of the proportion of dampness noticeable all around to the most extreme sum that can held noticeable all around at the present temperature. As the air gets more sizzling, holds more dampness, so that the overall mugginess changes with temperature. The most dampness sensors utilize the capacitive estimation to decide the measure of dampness noticeable all around. This kind of estimation depends on the electrical channels with a non-conductive

Fig. 1 Proposed schematic of irrigation system



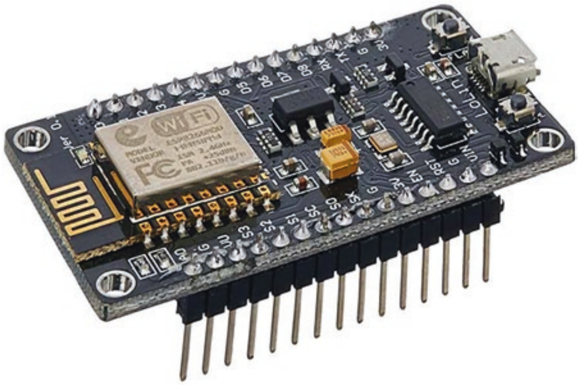


Fig. 2 Hardware module of node MCU ESP8266

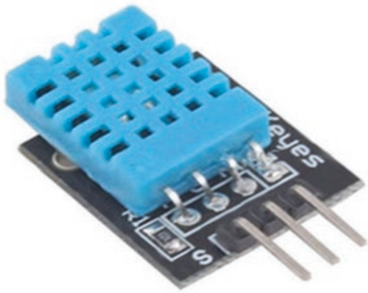


Fig. 3 Humidity sensor module

polymer film lying between them to make the electrical field. The air dampness on the film changes the corresponding voltage levels between the two plates changes. This change is then changed over into a computerized estimation of the air's relative dampness subsequent to considering the air temperature and the hardware module of humidity sensor used in this work is presented in Fig. 3.

A straightforward soil dampness sensor is used for ground-keepers. Soil sensors measure the soil volumetric content of water. Moistness sensors distinguish the overall dampness of the prompt conditions where they are set. They measure both the dampness and temperature noticeable all around and express relative mugginess as a level of the proportion of dampness noticeable all around to the most extreme sum that can held noticeable all around at the present temperature. As the air gets more sizzling, it holds more dampness, so that the overall mugginess changes with temperature. The most dampness sensors utilize the capacitive estimation to decide the measure of dampness noticeable all around.

The electric engine converts the electrical energy in to the mechanical energy. By the association between engine attractive field and flow of electricity in a twisting wire, power is produced as a force is applied to engine shaft. The electrical engines are fueled by the direct current sources such as batteries, rectifiers, or AC sources. The electric generator is indistinguishable from electric engine, yet works with a switched stream of intensity, converting the mechanical energy into electrical energy. The hardware modules of motor and moisture sensor are shown in Fig. 4.

(a) (b)

Fig. 4 Hardware module of (**a**) moisture sensor and (**b**) motor

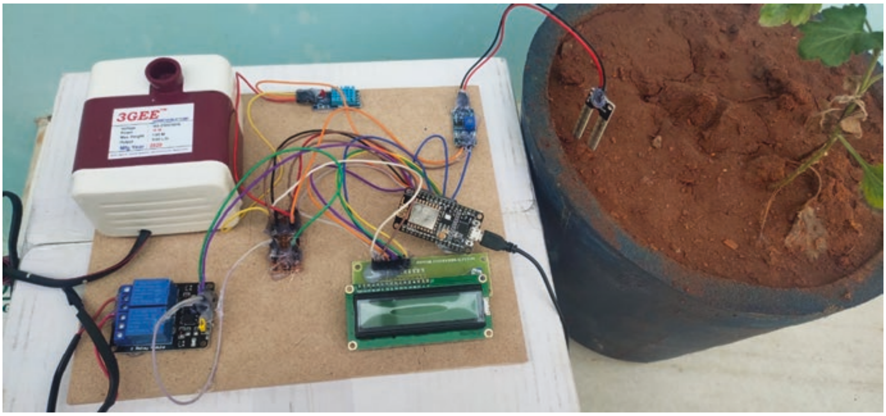


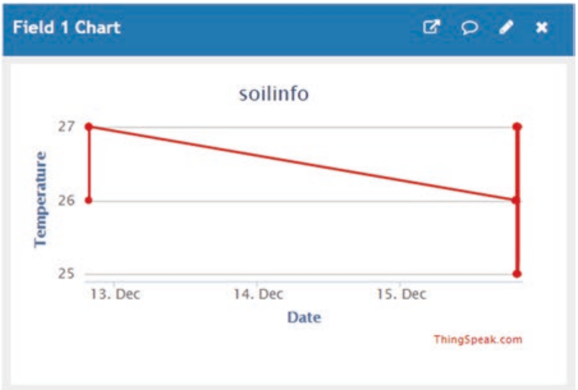
Fig. 5 Developed hardware module of irrigation model using IoT

3 Results

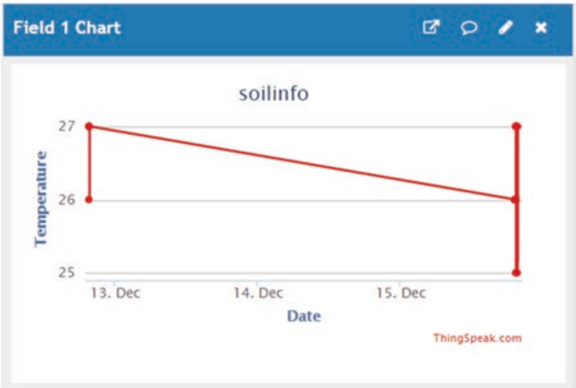
In this venture, the engine is controlled in the field dependent on stickiness, the temperature, and the dampness level. The moisture level in the soil is measured or detected by the sensors. The qualities are changed over the advanced structure and it is given to Arduino Nano. On and off of engine are carried out according to the dampness levels of the soil without human collaboration. The hardware implementation of proposed irrigation system is shown in Fig. 5.

We utilize a single engine for two unique homesteads. The solenoid valve controls the progression of the water, by estimating dampness levels of the dirt. For two homesteads, two dampness sensors are utilized, and these are associated with microcontroller and send dampness levels ceaselessly. Fig. 6 shows two modes in the framework, programmed manually. The program can control the engine naturally and is dependent on the sensor information.

Fig. 6 Results of proposed system (**a**) temperature (**b**) humidity (**c**) soil moisture



(a)



(b)

(c)

4 Conclusion

The keen farming utilizing IoT has been tentatively demonstrated to work acceptably by checking estimations of the stickiness and the temperature effectively through web control of the engine in the field. It additionally stores the sensor boundaries in the opportune way. This assists the client with dissecting the states of different boundaries in the field whenever anyplace. Under this condition, either control or use the boundaries of the field appropriately. At last, we presume that the programmed water system framework is more productive than the planned water system.

References

1. M. Agarwal, V.K. Bohat, M.D. Ansari, A. Sinha, S.K. Gupta, D. Garg, A convolution neural network based approach to detect the disease in corn crop, in *In 2019 IEEE 9th International Conference on Advanced Computing (IACC)*, (IEEE, 2019), pp. 176–181
2. S.M. Ahmed, B. Kovela, V.K. Gunjan, IoT based automatic plant watering system through soil moisture sensing—A technique to support farmers' cultivation in rural India, in *Advances in Cybernetics, Cognition, and Machine Learning for Communication Technologies*, (Springer, Singapore, 2020), pp. 259–268
3. U. Anchalia, K.P. Reddy, A. Modi, K. Neelam, D. Prasad, V. Nath, Study and Design of Biometric Security Systems: Fingerprint and Speech Technology, in *Proceedings of the third international conference on microelectronics, computing and communication systems*, (Springer, Singapore, 2019), pp. 577–584
4. V.K. Gunjan, S. Kumar, M.D. Ansari, Y. Vijayalata, Prediction of agriculture yields using machine learning algorithms, in *Proceedings of the 2nd International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications*, (Springer, Singapore, 2022), pp. 17–26
5. J. Gutiérrez, J.F. Villa-medina, A. Nieto-garibay, M.Á. Porta-gándara, *Automated Irrigation System Using a Wireless Sensor Network and GPRS Module* (IEEE transactions on instrumentation and measurement, 2013), pp. 1–11. https://doi.org/10.1109/TIM.2013.2276487
6. M.K. Haider, M.S. Islam, S.S. Islam, M.N.I. Sarker, Determination of crop coefficient for transplanted Aman rice. Int. J. Nat. Soc. Sci. **2**(23), 34–40 (2015)
7. B. Keswani, A.G. Mohapatra, A. Mohanty, A. Khanna, J.J.P.C. Rodrigues, D. Gupta, V. Hugo, Adapting weather conditions based IoT enabled smart irrigation technique in precision agriculture mechanisms. Neural Comput. & Applic. **30**(6), 1–16 (2018). https://doi.org/10.1007/s00521-018-3737-1
8. A.R. Kinjal, B.S. Patel, C.C. Bhatt, *Smart irrigation: Towards Next Generation Agriculture* (Internet of Things and Big Data Analytics Toward Next-Generation Intelligence, 2018), pp. 265–282. https://doi.org/10.1007/978-3-319-60435-0_11
9. A. Lakra, K. Gupta, K. Murmu, D. Prasad, V. Nath, Study and development of solar-powered water pumping system, in *Proceedings of the Third International Conference on Microelectronics, Computing and Communication Systems*, (Springer, Singapore, 2019), pp. 655–660
10. S.K. Nagothu, Weather based smart watering system using soil sensor and GSM, in *In 2016 World Conference on Futuristic Trends in Research and Innovation for Social Welfare (Startup Conclave)*, (IEEE, 2016), pp. 1–3

11. G.S. Narayana, M.D. Ansari, V.K. Gunjan, Instantaneous approach for evaluating the initial centers in the agricultural databases using K-means clustering algorithm. J. Mob. Multimed. **43**, 43–60 (2022)
12. N. Nidhi, M. Kumari, D. Prasad, A. Pandey, S.S. Solanki, A. Kumar, et al., Design of Low-Power 3-Bit CMOS Flash ADC for Aerospace Applications, in *Proceedings of the Third International Conference on Microelectronics, Computing and Communication Systems*, (Springer, Singapore, 2019), pp. 585–594
13. G. Parameswaran, K. Sivaprasath, Arduino based smart drip irrigation system using internet of things. Int. J. Eng. Sci. **5518**(5), 5518–5521 (2016)
14. A.S. Prodhan, M.N.I. Sarker, A. Sultana, M.S. Islam, Knowledge, adoption and attitude on banana cultivation technology of the banana growers of Bangladesh. Int. J. Hortic. Sci. Ornam. Plant **3**(1), 47–52 (2017)
15. R. Raut, H. Varma, C. Mulla, V.R. Pawar, Soil monitoring, fertigation, and irrigation system using IoT for agricultural application, in *Intelligent Communication and Computational Technologies*, (Springer, Singapore, 2018), pp. 67–73
16. A. Reche, S. Sendra, R.D. Juan, J. Lloret, A smart M2M deployment to control the agriculture irrigation, in *ADHOC-NOW Workshops 2014*, vol. 2, (Springer-Verlag, Berlin Heidelberg, 2015), pp. 139–151. https://doi.org/10.1007/978-3-662-46338-3_12
17. A.M. Reddy, K.R. Rao, An android based automatic irrigation system using a WSN and GPRS module. Indian J. Sci. Technol. **9**(29), 1–6 (2016)
18. S.K. Surshetty, S. Anwer, Y. Deep, M. Gandhi, V. Nath, Smart irrigation system using custom made PCB, in *International Conference on Nanoelectronics, Circuits and Communication Systems*, (Springer, Singapore, 2018), pp. 85–94
19. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)

Development of Safety Monitoring for an IoT-Enabled Smart Environment

A. Harshitha, Ch. Manikanta Uma Srinivas, M. Eswar Sai, Krishnaveni Kommuri, and P. Gopi Krishna

1 Introduction

Reconnaissance mission cameras are available in a wide range of styles and features, and they are an basic component of a security system. Web security structures or internet protocol (IP) cameras use the Internet by organizing frameworks to send and receive data. They are truly easy to present and interface with your structure, and you can see live camera deals with at whatever point with free adaptable applications for cutting edge cells phones and tablets. IP cameras can be presented in essentially any region and can screen within an office as well as outside of an office. Cameras can also be used to alert the security/protection authorities to respond to questionable activities or individuals. Video perception incorporates the exhibit of watching a scene or scenes and looking for express practices that are unseemly or that may show the turn of events. Essential businesses of video observation combine watching individuals at the entry to games, public transportation (train platforms, air terminals, etc.), and around the edge of secure workplaces, especially those that are restricted by network spaces. The endeavor then widens to the library of Open CV. It is a library of Python attachments expected to handle PC vision issues. Open CV-Python uses NumPy, which is an highly progressive library for numerical assignments with a MATLAB-style etymological construction. All the Open CV s are changed over to and from NumPy displays.

A. Harshitha · C. Manikanta Uma Srinivas · M. Eswar Sai · K. Kommuri (✉) ·
P. Gopi Krishna
Department of ECM, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India
e-mail: krishnavenikommuri@kluniversity.in

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_17

1.1 Video Processing

Computer vision may be a huge piece of the data science/artificial intelligence (AI) space. Currently, and once more, computer vision engineers should manage the recordings. Here, we hope to uncover understanding of video preparation—, clearly. This could be evident for some, but all things considered, video real time is under no circumstances a standardized cycle; nonetheless, it is a distinct one. That means, anytime to manage recordings, area unit manage the succession of edges themselves. Every unit is simply an image that can be addressed as an $m \times n$ exhibit of pixels, where (m, n) is the image size. Each element is also addressed as a contingent upon that shading model we intend to area unit utilizing (grayscale, red green blue, or maybe multispectral). The elemental video handling equipment for Python is OpenCV. OpenCV is an associated degree ASCII text file library that supplies the USA with the gadgets to primarily perform such a picture and video handling. OpenCV is written in C++ and its essential interface is in C++. cv2.waitKey() may be a necessary structure block for OpenCV video handling. Stand by secret is a technique that shows the casing for the indicated milliseconds. The '0xFF == Ord ('q')' within the 'if' proclamation is a rare punctuation to offer the 'while' circle break, by a console key squeeze occasion. cap. Delivery () and cv2.destroybAllWindows () area unit the methods to shut video documents or the catching gismo, and extinguish the window, that was created by the show technique. That is, presently we intend to notice a way to release recordings in Python, and we notice a way of getting to every casing of a video. From here, we add any style of image handling within this cycle, either object identification, or human posture assessment model, or both. The additional jump into OpenCV for video making is up to the reader. There square measure a group of useful instruments that will meet any necessity, from the smallest amount hard-to-please assignment (resize, crop, shading/splendor change), through image separation to triangulation.

1.2 OpenCV and NumPy

OpenCV-Python may be a library of Python attachments planned to cope with laptop vision problems. Python is an extremely useful programming language started by Guido van Rossum that quickly became commonplace, essentially by virtue of its straightforwardness and code clarity. It engages the designer to convey musings in fewer lines of code while not decreasing heaviness.

Compared with languages such as C/C++, Python is much slower. In light of everything, Python is viably disentangled with C/C++, which allows the USA to build to create computationally raised code in C/C++ and make Python coverage that are used as Python modules. This provides the USA with two positive conditions: first, the code is almost as quick because of the principal C/C++ code (since it is the real C++ code operating in establishment) and second, it is easier to code in

Python than in C/C++. OpenCV-Python may be Python coverage for the principal OpenCV C++ execution. OpenCV-Python uses NumPy, which is also an unbelievably improved library for numerical exercises with a MATLAB-style history. All the OpenCV bunch structures area unit modified over to and from NumPy shows. This also makes it easier to consolidate with numerous libraries that use NumPy, for instance, SciPy and Matplotlib.

2 Related Work

In this paper various weakening models such as ITU-R, RH, surface-to-air missiles, and Mapfumo area unit are contemplated and also the results area unit differentiated and calculable qualities and poor down to deciding the affordable model for one [1]. During this paper, we intend to review the potential attacks with reference to the Cisco Seven-Layer model. Also, preparing force, energy verge of collapse, and cut-off limits of very small enrolling gadgets have been essentially overhauled whereas their sizes have diminished as a whole [2]. These sensible conditions create them to be force in towards the new mechanical rise within the field of ineluctable registering. Middleware assumes a basic half in building the ineluctable applications. The inevitable gadgets act obsessed on the setting of the circumstance, that is, they are doing their activities as indicated by the climate of the application. They answer the circumstances intelligently as they make their own selections obsessed on the setting created for that individual application [3]. Here, the protocol execution problems come about for the foremost half owing to blunders in transmission and handoffs. The paper presents an intensive study of various methodologies with reference to the development in protocol execution in remote organizations. It sums up the various planned procedures and presents the benefits and downsides of these methodologies [4]. Another channel that might satisfy an oversized portion of the wants of a current when administrative official was created during this half. Healthy assessment area unit procedures are created for a few regular problems, for example, assessing space and scale [5].

A basic piece of home robotization is to provide every home with checking frameworks to computerize homes. Here comes the requirement of a stripped-down effort Wi-Fi authorized regulator to assemble information and distribute it to employees. The MCU hub is one such unimaginable alternative. Utilizing this framework, home natural conditions are checked, and also the information is sent using the Message Queuing Telemetry Transport (MQTT) convention and it is distributed through employees to customers [6]. This paper concerns the checking of ecological boundaries systematically to conjecture the climate expectation. These days, prognosis assumes an essential half for residents living within the city district regions. Typically, the boundaries of the climate forecast amendment to varied fields and regions that hip to the horticultures and travelers.MSP430. It is employed for manufacturing plant management and automation applications [7]. This paper proposes an associate degree approach to assembling a financially intelligent ecological checking framework utilizing the MCU node. The environment in which individuals, creatures, or plants live is termed surroundings. Recognition of climate boundaries such as temperature, stickiness, greenhouse emissions, etc., these variables assume a large part, because they are directly connected to the medical issues of people within the climate [8]. Deep convolution neural networks with another double characterization layer, that is reinvigorated on the online. This cycle empowers net-based mostly following by ill the ROI windows discretionarily tested near to the past ROI state. It helps to accomplish constant vehicle following abundant below impediment and dynamic foundation conditions [9]. In this paper a couple of general surveys on wearable and advantageous sturdy devices for externally weakened people are discussed. There are various procedures but all of the gadgets cannot acknowledge the speed of the vehicle and partition between the individual and vehicle. During this association we provide a theoretical system on new IoT authorized coordinated convenience to assist externally debilitated people. The planned device will notice the speed and distance of a vehicle that is coming back toward the consumer [10].

The idea of recognizing a moving item from a comparative foundation is called coverage. During this audit study, numerous methods for moving factor identifying proof with some highlights planned by totally different scientists were examined [11]. Article affirmation in innovative photos is finished exploitation grammar. This paper advocates a completely unique system for removing information concerning the states of assorted things and components during a high level image and for seeing articles employing a neural association [12]. Downy principle may be thanks to affect reckoning obsessed on “levels of truth” rather than the quality factor “valid or bogus”. Numerous sorts of nonlinear channels such as the expanded Kalman channel, the cross-breed expanded Kalman channel, firefly 0.5 breed extended Kalman filter are tried to figure out the perfect arrangement. Goof-based mostly feathery reasoning has been the rationale for calibration of the methodology [13]. TensorFlow bundles along various AI and important learning models and counts and makes them accommodating using a technique for a run-of-the-mill likeness. In this paper, the count or moving article in static institution based mostly on circumstance has been planned. This assignment is by and large performed by institution allowance procedure and factor finder [14]. TensorFlow a begin to complete ASCII text file AI stage for everyone. In this paper they give article acknowledgment utilizing the Keras Library with backend Tensor stream to remain off from troubles in acknowledgment of things in photos the deep neural organizations notably Tensor stream below the Keras Library is employed [15].

We can show that the planned cross-selection model accomplished a better f-extent of 76.7% appeared otherwise with respect to that of different existing models, for example, the nearest- neighborhood algorithmic model and the spatial-exponential weighted moving average model [16]. Presently, on a daily basis, crowd investigation has become associate degree arising field in exploration. The safety issue is attended to by way of mechanized examination of cluster exercises utilizing management videos. The principle components of crowd analysis viz. assessment of the size of the cluster, social following, and development assessment area unit are discussed in this paper [17]. One important advance is 3D scenes age from second photos. One of the tough tasks is the age of the Depth Map from a single-read Image. Deep learning is used here for seeing from the image and also the significance map created [18]. The system connected to object acknowledgment fuses division, plan, and collection of articles that are associated with numerous designs. In this paper, a completely unique portrayal framework known as wealth-based mostly image classification (Akaike Information Criterion) is planned employing a wavelet neural framework [19]. This paper has the objective of proposing a groundbreaking atom channel subject to modified Grey Wolf Optimization, which can beat the impoverishment of the model issue within the normal particle channel [20].

Radio Frequency Identification is a remote development used for following a reputation related to a factor and remarkably basic cognitive process it. associate degree alpha examination of the created model of the overhauled show gathering device is performed and also the results affirm its unimaginable introduction [21]. The examination of the website Diversity Gain Model dependent on the known precipitation information has been finished. The radio waves multiplying through the Earth's surroundings is tightened on account of the presence of measuring device particles, as an example, water smolder, storm drops, and also the ice particles that absorb and scatter the radio waves and on these lines degenerate the introduction of the microwave interface [22]. These assumption models have the key information, the geologic zone, the repeat of the sign used, and also the proportion of precipitation in that zone. By applying these models in totally different geographical territories, the enervating of the association for level of the time and with numerous frequencies within the Unq band vary, i.e., 10.99 rate to 14.2 rate area unit expected [23].

Radio wires performing at gigahertz frequencies area unit being planned and dead for satellite correspondences. Yet, the microwave signals area unit encountering loss of signal strength once meddled with totally different layers of the surroundings, precipitation, mists so on pelter drop circulation supplanted this tough work with disentangled investigation for a selected scene [24]. During this examination, distinctive existing bunch based mostly, EM grouping and game arrange based mostly on irregularity acknowledgment systems in video observation area unit talked concerning. The new methodologies such as the mixture of convolution neural network and repeated neural network and of course deep learning area unit the powerful calculations for immense datasets [25].

3 Safety Monitoring for Smart Environment System Overview

After associate degree audit of the connected works, the principle goals that we have set for the projected framework are released: (a) endlessly screen the climate for boundaries, for instance, separation of the centered object, soaker water recognition, object location; (b) ultrasonic detector and soaker detector module need to be related to the Raspberry Pi to screen the IoT climate; (c) camera will interface simply by utilizing the OpenCV strategy or by we {will|we are able to} interface with Raspberry Pi through the OpenCV technique; (d) and GSM is also utilized for causing prepared messages to the consumer presumably it is running or any article identification to alert the consumer that the device will come back to the updated state.

3.1 Ultrasonic Detector

An associate degree ultrasonic sensor is an associate degree device that measures the space of a target object by emitting ultrasonic soundwaves associate degreed that convert the mirrored sound into an electrical signal. Ultrasonic waves travel quicker than the speed of loud sound (i.e., the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound victimization electricity crystals) and also the receiver (which encounters the sound once it is cosmopolitan to and from the target).

Ultrasonic sensors are often used for several applications, together with the precise detection of objects and contactless observance of fill levels. Ultrasonic detectors add abundant identical means as measuring devices and measuring system. They produce high return sound waves and assess the reverberation that is received by the sensor.

3.2 Rain Detector

A rain sensor is a reasonable shift device that is employed to observe precipitation. It works sort of as a switch and also the working rule of this detector is, whenever there is rain, the switch is usually off.

Essentially, the board includes nickel-coated cables, and it works on the resistance principle. This detector module permits wetness to be determined through analog output pins and it offers a digital output when the wetness threshold is exceeded.

3.3 GSM

Worldwide framework versatile correspondences was created as a computerized framework utilizing time division multiple access procedure for correspondence reasons. A GSM digitizes and reduces the data, and then sends it down through a channel with two distinct surges of client information, each in its own specific time allotment. The computerized framework features the capability to transmit 64 kbps to 120 Mbps of information. The system is capable of instructing the user via Short Message/Messaging Service (SMS) from a selected signal to vary the condition of the house appliance as per the user's desires and necessities. The second facet is that of a security alert that is achieved in an exceedingly means that on the detection of intrusion, the system permits automatic generation of an SMS, therefore alerting the user of a security risk.

Figure 1 addresses the framework usage and activity. We have utilized the Raspberry Pi board for interfacing all ultrasonic and rain sensors. The Open CV technique is used for the reconnaissance camera. The triangulation technique is used for camera position. Furthermore, the GSM module is likewise associated with the Raspberry Pi for sending ready messages to the client, as it is sufficiently skilled to inform the client through SMS. The subsequent viewpoint is that of security ready, which is accomplished in a manner that on the identification of an interruption, the framework permits programmed age of SMS along these lines cautioning the client against a security hazard.

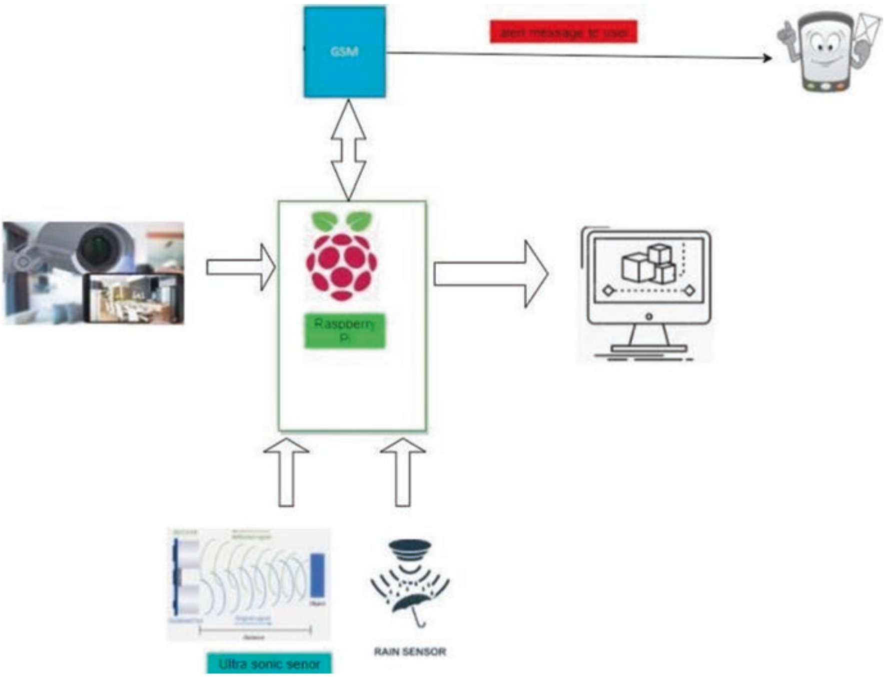


Fig. 1 Smart environment system overview arrangement

4 Triangulation Method for Camera Arrangement

From Fig. 2 jolts address left camera with associate degree angle (A) and right camera with purpose (B) and discovering the purpose within the area addresses an object and expects that two cameras lie on a comparative plane. noticelwe discover} the purpose from object to camera associate degree and that we find the purpose from object to camera B. Here, we use a beautiful range connected issue calculation known as triangulation to work out {the purposelthe purpose} that in the area is simply an issue and creating a right point triangle by drawing a line (d) from the issue to the plane and also the total partition between the two cameras is 'l'. In mathematics, we tend to perceive that diversion is akin to the converse over the connecting. Thus, to find out the length (l) we intend to create as $l = d/\tan(A) + d/\tan(B)$. The essential issue we intend to find the chance to possess by then could be a purpose from camera and a degree from camera B. $\tan = 0/a$, $\tan(39) = 320/x$, $d = 320/\tan(39)$, $d = 395$.

Figure 3 represents coverage of a camera with pixels 640p we are able to utilize any scope of pixels. So, the camera is all the way down to the sting and our camera

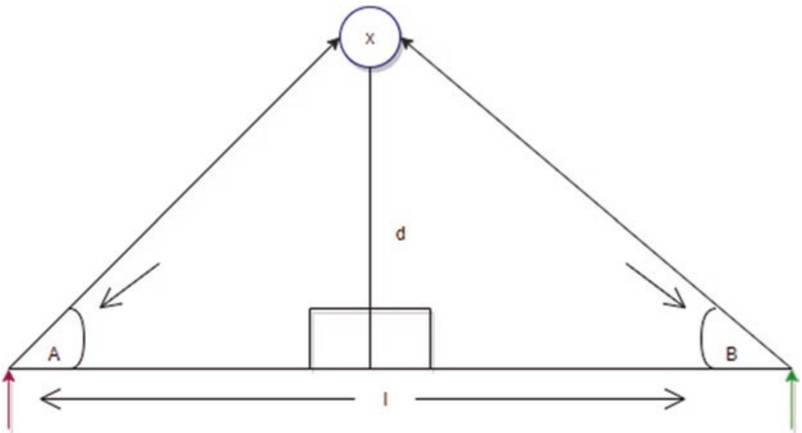
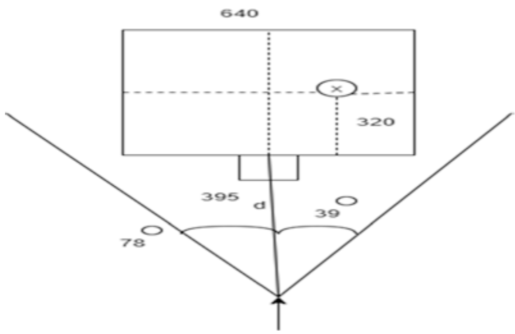


Fig. 2 Setting the camera position by triangulation

Fig. 3 Frame of the camera



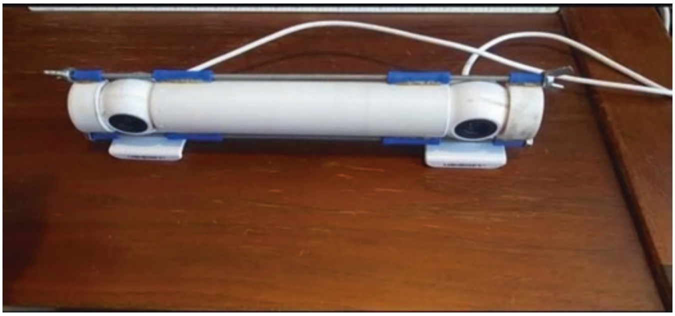


Fig. 4 Camera setup

contains a field of vision that the camera vision produces with sure purpose from those points we have a tendency to area unit finding the separation consistent with the equation.

We need to orchestrate the two cameras as per Fig. 4, additionally checking the cameras wherever the square measure examination to every alternative or not and what is more we want to urge three hatchets indisputably. By running the code, it shows the detachment of the zeroed-in-on article on the screen.

5 Results

The code runs adequately and showed the gap of the zeroed-in-on article and gave security to the widget to anticipate the updated condition of the widget. This is the screen capture of the yield in Fig. 5 regarding video that had sent an alarm message to the shopper through the GSM module. We see a warning once it acknowledges the movement of a piece of writing or a private. Here, we see that the notice was sent to the tip shopper as type of video. It begins by giving the admonition no matter what the purpose of the article is. Therefore we get the clear thought relating to the item. It likewise provides the life to observe what is happening.

From Fig. 6 it is a clear yield for motion detection. We are able to see the excellence from two footage. Also, we have a tendency to have recognized the motion in Fig. 5 and it is shown with the help of the observation camera. Like these we have a tendency to effectively finish the venture by utilizing the triangulation strategy. During this technique we have a tendency to analyze the two occasions for reference on the off-chance that there is no modification in each of the examples, when they clear their information and once more begin filtering. If they recognize something whereas at a similar time different each of the cases, then they consequently build the screen efforts and send the warning to the tip consumer. Within the higher than given image, we are able to see that the associated item is passed before the camera; therefore, it analyzes if there is any modification by utilizing the last case that was employed for reference. At that time, it quickly sends the alert message to the consumer.

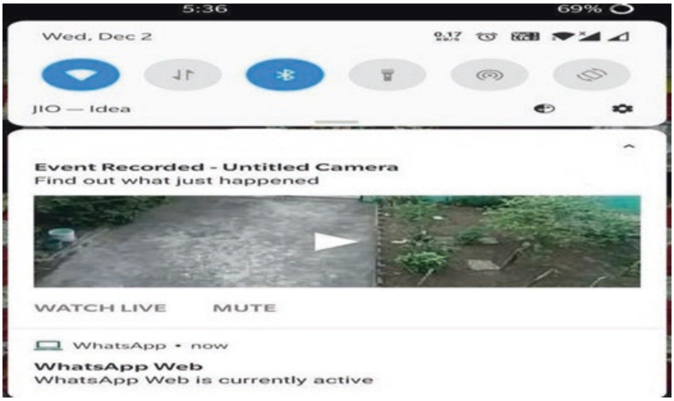


Fig. 5 Notification from the camera

Fig. 6 Motion detection with the experimental setup

6 Conclusion

The venture was completed effectively, and the ideal codes were executed. The momentary point includes a detailed investigation of the video preparation dependent on triangulation for computer vision. Also, we have effectively added security by adding other two modules for the reconnaissance. An effort was made to assemble the most information about it from individuals who have accomplished exemplary work in the field. This was trialed by use of a similar utilizing standard informational collection. We additionally intend to investigate more methods of computer vision in the not so distant future. Our long-term objective is to have the option to actualize a method where the obscured pictures could be de-obscured with a degree of adequate precision. We have wanted to investigate different existing approaches for de-obscuring strategies where an obscured picture is honed and smoothened to make it more comprehensible for human use.

References

1. G. Immadi, M. Venkata Narayana, Y. Suraj, N.M.V.L. Nara Simha Rao, P.S.V.S. Naveen Chowdary, M. Emmanuel Raju, Estimation of effect of troposphere rain on radio link in tropical environment. ARPN J. Eng. Appl. Sci. **12**(17), 4960–4966 (2017)
2. C. Mohan Kumar, M. Kameswara Rao, Critical review attacks and countermeasures in internet of things enabled environments. Int. J. Eng. Technol. (UAE) **7**(2), 163 (2018)
3. J. Madhusudanan, S. Geetha, V. Prasanna Venkatesan, U. Vignesh, P. Iyappan, Hybrid aspect of context-aware middleware for pervasive smart environment: A review. Mob. Inf. Syst. **2018**, 1–16 (2018). Article ID 6546501
4. C. Goswami, R. Shahane, Transport Control Protocol (TCP) enhancement over wireless environment: Issues and challenges, in *Proceedings of the International Conference on Inventive Computing and Informatics, ICICI 2017*, (Institute of Electrical and Electronics Engineers, Piscataway, 2018), pp. 742–749
5. D.V.A.N. Ravi Kumar, S. Koteswara Rao, K. Padma Raju, Design of a robust estimator for submarine tracking in complex environments. Lect. Notes Electr. Eng. Electr. Eng. **471**, 273–282 (2018)
6. V. Neelima, P. Naveen Kumar, N.V. Padma Priya, K. Sripath Roy, K. Sripriya, S.K. Matin Kausar, Implementation of home environmental conditions monitoring system by multiplexing technique on NodeMCU. J. Adv. Res. Dyn. Control Syst. **10**(2), 569–578 (2018)
7. K. Krishnaveni, K. Venkata Ratnam, G. Prathyusha, P. Gopi Krishna, Development of real time environment monitoring system using with MSP430. Int. J. Eng. Technol. (UAE) **7**(2), 72–76 (2018)
8. T. Penchala Naidu, J.G.R.S.N. Sri Varma, K.L.N.P.V.P. Sumanth Kumar, N.V. Prasad, H. Saketh, Surveillance of environment using node MCU based on IoT. Int. J. Recent Technol. Eng. **8**(1), 785–788 (2019)
9. S.S. Harsha, H. Simhadri, K. Raghu, K.V. Prasad, Distinctly trained multi-source CNN for multi- camera-based vehicle tracking system. Int. J. Recent Technol. Eng. **8**(2), 624–634 (2019)
10. M. Kavitha, D. Pavani, Y. Lahari, M. Prasanna, Safe navigation system framework for visually impaired users using a micro-digital camera. J. Adv. Res. Dyn. Control Syst. **11**(7), 631–637 (2019)
11. R. Kamble Rita, P. Rajarajeswari, A review of various camouflage moving object detection techniques. J. Eng. Appl. Sci. **12**(Special issue 12), 9514–9519 (2017)
12. A.V.N. Reddy, C. Phanikrishna, Contour tracking-based knowledge extraction and object recognition using deep learning neural networks, in *Proceedings on 2016 2nd International Conference on Next Generation Computing Technologies, NGCT 2016*, (IEEE, Piscataway, 2017), pp. 352–354
13. R.P. Das, G. Roja, A. Sampath Dakshina Murthy, S. Koteswarao Rao, Global positioning system object tracking by applying fuzzy logic nonlinear techniques. J. Adv. Res. Dyn. Control Syst. **9**, 725–735 (2017)
14. R. Kamble, R. Rajeshwari, Moving object detection in static background using tensor flow. J. Adv. Res. Dyn. Control Syst. **10**(6), 501–506 (2018)
15. R. Bandi, J. Amudhavel, Object recognition using Keras with backend tensor flow. Int. J. Eng. Technol. (UAE) **7**(0), 229–233 (2018)
16. C.A. Ghuge, S.D. Ruikar, V.C. Prakash, Query-specific distance and hybrid tracking model for video object retrieval. J. Intell. Syst. **27**(2), 195–212 (2018)
17. I.V.R. Rao, S. Anusha, A.B. Mohammad, D. Satish Kumar, Object tracking and object behavior recognition system in high dense crowd videos for video supervision: A review. J. Adv. Res. Dyn. Control Syst. **10**(2 Special Issue), 377–380 (2018)
18. J.B. Kulkarni, M.S.R. Chetty, Depth analysis of single view image objects based on object detection and focus measure. Int. J. Adv. Trends Comput. Sci. Eng. **8**(5), 2608–2612 (2019)
19. G. Krishnaveni, B. Lalitha Bhavani, N.V.S.K. Vijaya Lakshmi, An enhanced approach for object detection using wavelet based neural network. J. Phys. Conf. Ser. **1228**(1), 1742–6596 (2019)

20. M. Narayana, H. Nenavath, S. Chavan, L. Koteswara Rao, Intelligent visual object tracking with particle filter based on Modified Grey Wolf Optimizer. Optik **193**, 1–21 (2019). Article ID 162913
21. A.E. Alami, S. Das, B.T.P. Madhav, S.D. Bennani, Design, optimization and realization of high gain RFID array antenna 4 Ã—1 for detection system of objects in motion. J. Instrum. **14**(5), 5002–5018 (2019)
22. S. Harika, S. Nagarjuna, T.V. Naveen, G. Sanjay Harshanth, K.C.S. Kavya, S.K. Kotamraju, Analysis of rain fade mitigation using site diversity technique in southern tropical region of India. Int. J. Eng. Technol. (UAE) **7**(1.1), 622–626 (2018)
23. B.J. Philip, K.S. Kumar, K.C. Sri Kavya, C. Susmitha, C.N. Rao, S. Vasu, A. Madhulika, Comparison of different rain attenuation prediction models at Visakhapatnam and Hyderabad regions. J. Adv. Res. Dyn. Control Syst. **9**(4), 220–229 (2017)
24. G. Immadi, M. Venkata Narayana, S.K. Kotamraju, T.S.S.P. Sarvani, T. Manasa, C.H. Vamsi Yaswanth, J. Akshaya Kalyan, Computation of attenuation due to rain for Ku band frequencies using DSD for the tropical region. J. Theor. Appl. Inf. Technol. **95**(10), 2197–2205 (2017)
25. V.A. Kotkar, V. Sucharita, A comparative analysis of machine learning based anomaly detection techniques in video surveillance. J. Eng. Appl. Sci. **12**(Special issue 12), 9376–9381 (2017)
26. C.M. Sheela Rani, K. Dheeraj, P. Sai Vineeth Reddy, K. Satyasai, Image segmentation for pattern recognition in surveillance. Int. J. Eng. Adv. Technol. **7**(3), 45–49 (2018)

Design of a Corn Seed Sowing Machine for Uniform Distribution of Corn Seeds Using Optimum Seed Distribution Algorithm

A. Bhujangarao, K. Vidyasagar, B. Surya Prasad Rao, and G. Suryaprakash

1 Introduction

Existing seed sowing machines are developed with mechanical structures by considering all mechanical characteristics. The mechanical structures are not susceptible to frictional opposing forces. The initial dead band of the components introduces lags and leads. This forces to increase the time constant of the system. This will influence on behavior of the system, which results decrease in sensitivity and reliability. Physical operation and supervision of the machine are tedious.

These limitations motivated to develop a sensor-based semi-autonomous seed sowing machine for uniform distribution of seeds at pre-programmed distinctive locations. The operation is supervised by the controllers both at the field and at remote level, which will improve the functional efficiency of the system. The sensor sampling time (seed drop detection) is estimated by considering the initial dead band, which is due to mechanical frictional opposing forces (Fig. 1).

A semi-autonomous corn seed sowing machine is shown in Fig. 2 for distribution of corn seeds at pre-programmed distinctive locations. A methodology has been proposed for uniform distribution of corn seeds over the entire crop, so the production rate is increased and the corn seed distribution rate is meticulous. ATmega328 microcontroller is elected as a control unit to drive the machine. The function of the controller is shown in Fig. 1. The seed bin level (seed position in the seed bin) measuring transmitters will transfer the input signals to the local controller. If the logic is high, then control unit will drive the sliding disc for every 360° rotation of the geared wheel and valve 2 is open to drop the corn seeds into corn seed groves with no deviation. The corn seed bin empty status is automatically detected by the level

A. Bhujangarao · K. Vidyasagar (✉) · B. Surya Prasad Rao · G. Suryaprakash
VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, India
e-mail: vidyasagar_k@vnrvjiet.in; surya@kitscart.com

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_18

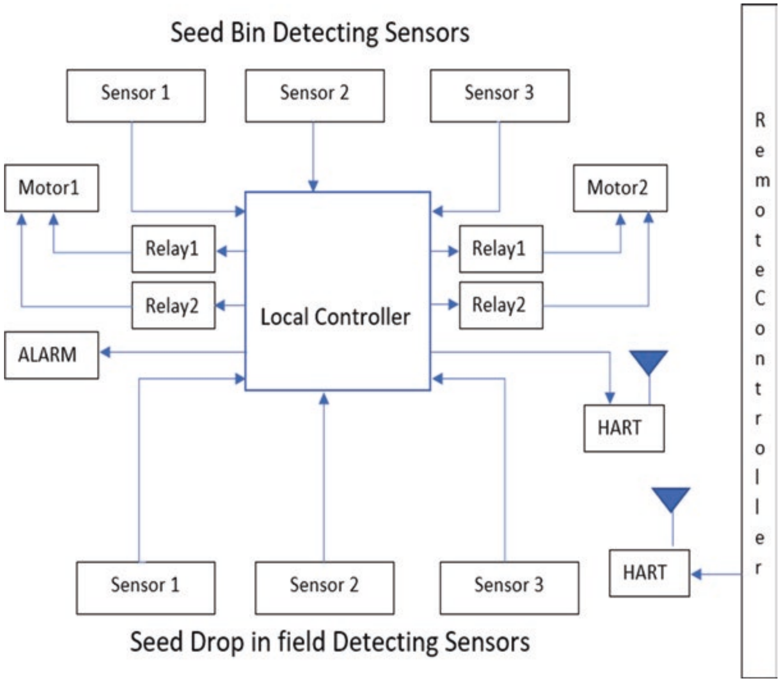


Fig. 1 Block Diagram of seed sowing machine

transmitters and the signal is transferred to the local controller. The refill of the corn seed bin is made by opening valve 1 by the controller and the seeds will refill from the stand by bin. Triple modular redundancy (TMR) is used at each sensing stage of the device. Diversified technology has been adopted with three distinctive transmitters in order to obtain the redundancy and improve the functional efficiency. The mean value of the sensors is considered to improve the accuracy of the input signal. The mean of the three field input signals is considered for estimating the true redundant input field signals. Field devices' fault presentation of the signal is able to troubleshoot at two stages of the circuit, that is, at the field sensing stage and at the central control stage. The fault analysis is continuously supervised by the remote controller in order to improve the operational efficiency of the developed corn seed sowing machine. LA/25 fault alarm is enabled if the controller identifies any fault. Magnetic flow meter is used to detect one revolution of the geared wheel, which will produce one pulse. The generated pulse will be read by the controller to drive valve 2 open. Flow transmitters (FT1, FT2, and FT3) are considered in a loop to monitor the seed dropping position. For meticulous distribution of corn seeds, optimal corn seed distribution algorithm has been proposed.

Spring loaded metal disc is placed in the corn seed bin. Metal disc is positioned on top of the seed bin. Once the seed bin is filled with corn seeds, the position of the metal disk will move downward along with emptying the corn seeds. The spring is

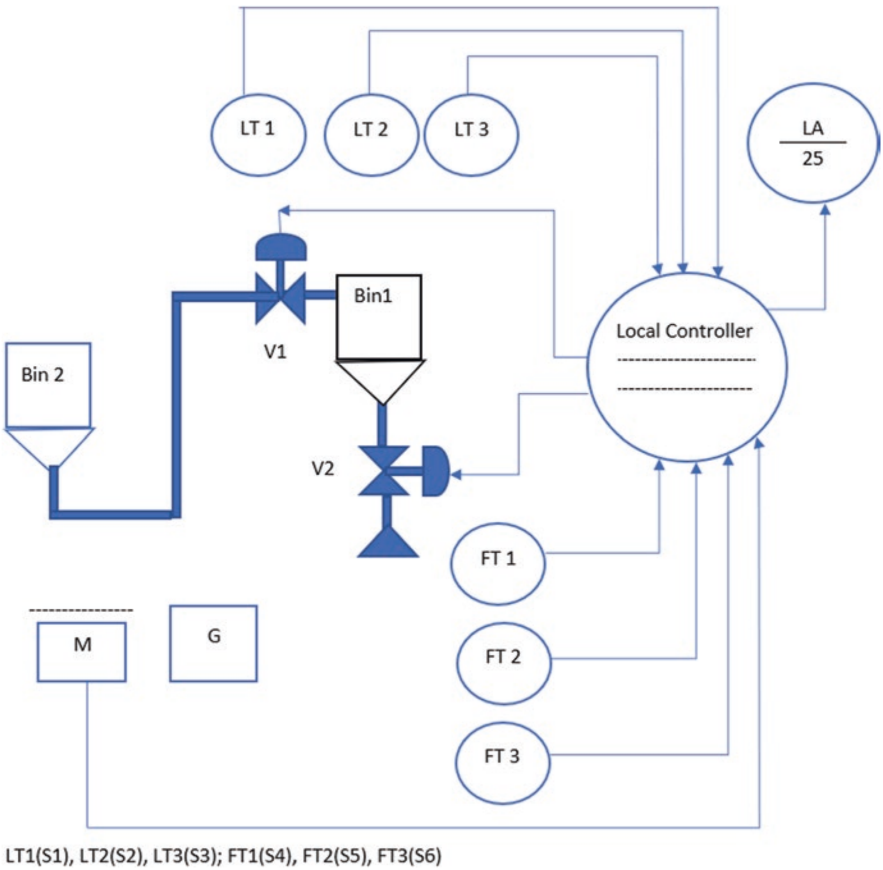


Fig. 2 Instrumentation piping diagram of seed sowing machine. LT, level transmitter; FT, flow transmitter (seed detection); M, magnetic flow transmitter; G, gear

used to improve the linearity of the disc movement, so that the sensor output signal is meticulous. The spring stiffness constant is estimated based on the corn seed load and the height of the corn seed bin. Since the spring is compressed for empty status of the bin, the magnitude of the force will cause to decrease in height (depth) of the corn seed bin, where "*K*" is the stiffness constant of the spring. The full status of the bin is represented with 22.04 lbs load. The maximum depth of the corn seed bin is 24 inches. Then, the stiffness constant is estimated as 0.918 lb/m at full load condition using Eq. 1.

$$K = \frac{F}{x} \tag{1}$$

Here,

"*K*" is the spring constant.
"*X*" is a change of length from its equilibrium.
"*F*" is the force in the direction of its equilibrium.

An analog ultrasonic sensor RPS-412A is used with an accuracy of 0.0005 to sense the corn seed bin status. The air temperature is compensated 50 times per second. The factors that influence on the speed of sound like relative humidity, and variations in barometric pressure are compensated.

1.1 Sensor 1 Ultrasonic Sensor

This sensor, that is, RPS-412A will draw an output of 20 mA, if the metal disc in the corn seed bin is at 4 inches from the upper surface of the bin. This distance is used to estimate the full status of the corn seed bin. Sensor output produced 4 mA when the disc plate is at a distance of 16 inches from the upper surface of the seed bin. This distance is considered as empty (low) status of the bin. For improving accuracy, the center line of the sensor is used to position the metal disc perpendicular to it. The bright red LED indication is the optimum placement of the sensor to acquire the signal with no deviations. The dimension of seed bin is 24 × 24 × 24 inches (length × width × height). The height of the seed bin is organized into five levels:

Level 1 = 16 inches
Level 2 = 12 inches
Level 3 = 8 inches
Level 4 = 4 inches

Level 4, that is, 4 inches from the top surface of the bin, is considered as bin full and the seeds in seed bin are at 16 inches height from the top surface of the bin, which is considered as bin empty. The signal received at output of the sensor is between 4 and 20 mA. The output of 20 mA is received when the metal disc plate is at 16 inches.

1.2 Sensor 2 Infrared Sensor

GP2Y0A02YK0F is used as sensor "2" to estimate the seed level in seed bin. This sensor has adopted the triangulation method. So, the environmental conditions like reflectivity of the measuring object and ambient temperature influences are nullified. Position sensitivity detector, infrared rays (IR) emitting diode, and signal conditioning circuit are integrated with this device. The sensor is used to measure the maximum distance of the objects at 59.0 inches. The emitted infrared rays by the IR diode stick the object and reflect toward the photodiode. Based on the received magnitude of infrared ray, the resistance will change and the change of resistance is measured as an output voltage. Maximum output voltage detected is 2.75 V at 16-inch distance of the metal disc. The output voltage will vary with respect to the distance between the metal disc in the seed bin and the sensing coil.

1.3 Sensor 3 LIDAR Sensor

The sensor 3 (LIDAR) uses near infrared rays to measure the precise distance (depth) of the corn seed bin. After striking the metal disc, the time interval between near infrared ray transmission and receiving is estimated to determine the position of the metal disk in the corn seed bin. The sensor produces pulse width modulation (PWM) output signal with duty cycle of 10 ms and using the low pass filter, this PWM signal is converted into 0–5 V range.

In order to improve the sensitivity and compensate the ambient light levels, a receiver routine is executed. A reference signal is sent from transmitter to receiver. This signal causes to set the time delay for zero distance measurement. The distance (corn seed status) of the disc plate in the corn seed bin is estimated. This acquisition process repeats and integrates all the acquisition values until the signal peak value reaches to maximum. Signal threshold value is estimated using the noise floor. If the magnitude of the peak signal is above the threshold value, then the estimated signal is a true value, which is to be transmitted to the controller using I2C interface protocol.

For clear object detection, retro reflective sensor “Qs18”(sensor “4”) is used. The emitter of the sensor directs the light beam continuously in a narrow axis. So, the possibility of false detection can be enveloped. If a corn seed is dropped from the corn seed bin, the emitted light signal will attenuate a noticeable percentage and the attenuated signal is redirected to the receiver. Qs18 is able to detect the dropping seed at a distance of 130 inches maximum. The sensor is kept at a distance of 12 inches from the seed dropping hole.

A laser-based sensor “Q4x” (sensor “5”) is elected to detect the small corn seed objects precisely. The variations in laser light intensity are detected with dual mode sensing capability, that is, the sensor detects the corn seed drop when it receives light signal strength. When the corn seed enters into the sensing range, the beam intensity will alter with the corn seed drop position.

Sound wave based sensor “M25u” (sensor “6”) is an ultrasonic sensor. The emitted sound wave returns echo after detecting corn seed dropped from the bin, that is, the corn seed blocks the signal between emitter and receiver. The sensor is able to sense the object at a maximum distance of 19.7 inches. The sensor is positioned at a distance of 12 inches from the seed dropping hole.

2 Relevant Work

Roshan V. Marode et al. [1] discussed the seed bin design mechanisms and furrow assembling process. D. Ramesh and Girish Kumar [2] developed multi-purpose seeding equipment and animal drawn seed cum fertilizer drill is designed. Prof. Pranil V. Sawalakhe et al. [3] proposed a methodology for corn seed sowing methods and placement of fertilizer comparing the proposed method with traditional methods, the proposed method reduces the total cost and minimizes the efforts required. K.A. Sunitha et al. [4] described a mechanism of agricultural robot. A camera is used to track the path. The saw blades are used at the rare side works in association with geared wheels. The rare part of the robot is driven by locomotion. Tekalign Tujo G et al. [5] proposed a methodology to predict and classify the corn seeds using neural network-based machine learning algorithm certain determinant factors are identified to classify the corn seeds for ranking. Vlasov and A. S. Fadeev [6] proposed a methodology for purification improvement and to classify corn seeds of a grain crop. The corn seed features are estimated with machine learning algorithm. With proposed deep learning, the ability to classify the corn seeds is improved. Payal Srivatsava, Neda, and Kriti [7] implemented a model of robotic former. The methodology includes land plowing, corn seed sowing, and fertilizer spraying. Arduino uno is used as a controller to drive the robotic former. B. Mohan, et al. [8] designed a sowing machine for soya bean pigeon pea, Bengal gram, and ground nut corn seeds.

A.V P. Premalatha and Sharath Singh [9] developed a methodology to curtail the wastage of corn seeds, productivity improvement, and minimize the time for corn seed sowing. Solar power source is used to drive the robot. Parshapally Johnson, Nenavath Shivakumar, Shaik Umairahmed [10] developed an automated corn seed sowing machine using cam and follower mechanism. The pulley will drive the cam attached to front axle. A hopper is used to store the corn seeds. The follower drives the diaphragm for a single corn seed, which is let into the pit for complete rotation of the cam.

Antonio Tassio Santa Ormond, et al. [11] developed a pneumatic mechanism powered by two corn seed metering devices operating at different speeds. The mean of two corn seed meters is estimated by regression plots. Kiran K. Jadhav, et al. [12] discussed double fuel installation on frame. R. Kathiravan, P. Balashanmugam [13] developed an approach to drop a corn seed in specified depth and significant gap between two corn seeds.

3 Design Considerations

Triple redundancy is considered at two stages of the machine to improve the functional efficiency of the corn seed sowing machine. Sensing seed bin full/empty status is labeled as stage1. Sensing seed drop from the seed bin into soil is labeled as stage 2.

At stage 1, three sensing devices are used for estimating the seed level in the seed bin, which are functioning with independent technologies. Sensor 1 is functioning using ultrasonic signals, sensor 2 is functioning with infrared signals, and sensor 3 is functioning with near infrared rays. So, the common cause fault may not occur from all the field transmitters simultaneously And redundancy is achieved with this approach.

At stage 2, another set of three sensing devices is used for meticulous detection of seed drop into soil. Sensor "4" is functioning with light beam, sensor "5" is functioning with laser beam, and sensor "6" is functioning with sound wave. These three sensors function with diversified technology. So, common cause failures will certainly not produce faulty signals from three sensors simultaneously. The TMR is also considered at this stage.

The corn seed size and shape are not the same. At ear, the shape is like a small round kernel. At the middle, the seeds are flats. But, at the end the ear is large round shape. So, to drop the seeds from the seed bin, the large round shape kernel size of 0.214 mm is considered. So, the seed discharge aperture like hole diameter is considered as 0.428 inches.

The uniform distribution of corn seeds across the cultivating field is further improved. The sensors relays and motors interfaced with Atmega 328, and the communication between two controllers is using HART protocol AD 5700 as shown in Fig. 3.

An intelligent sensing technology has been proposed to diagnose input faults. Each sensor is equipped with AD 7124, 24 bit ADC to convert analog signals into digital signals. Low power isolation is also considered before the signal transfer to the Atmega 328 micro controller. HART AD 5700 modem is used to communicate the field signals to the remote controllers. The communication between the micro controller and the HART modem is asynchronous. Universal asynchronous receiver transmitter is imparted for communication between HART and Atmega 328 micro controller. The analog current signals (output of transmitters) are converted into discrete signals using AD 5421 digital to analog converter.

The entire process is supervised remotely by incorporating process management database system. The operator interface will log the data and analyze the data for improving the efficiency of corn seed distribution process. The corn seed distribution machine is able to control remotely using HART protocol. The possible fault conditions are supervised by the local and remote controllers, that is, field device faults, and communication faults between the field device and the controller and between local and remote controllers. With the proposed methodology, operation functionality of the corn seed sowing machine and the production rate is further improved and the cost per unit production is significantly minimized.

The setpoint (SP) to the controller is 16 inches, which corresponds to 20 mA (5 V). The measured variable (MV), that is, bin status is always compared with the setpoint to produce an error signal (CO). Proportional + integral controller is used to regulate the seed bin status at 16 inches. If the measured variable (bin status) is deviated from the desired value, that is, setpoint, the seeds will be refilled from the bin "2," that is, restore bin. The controller output is estimated using Eq. 2.

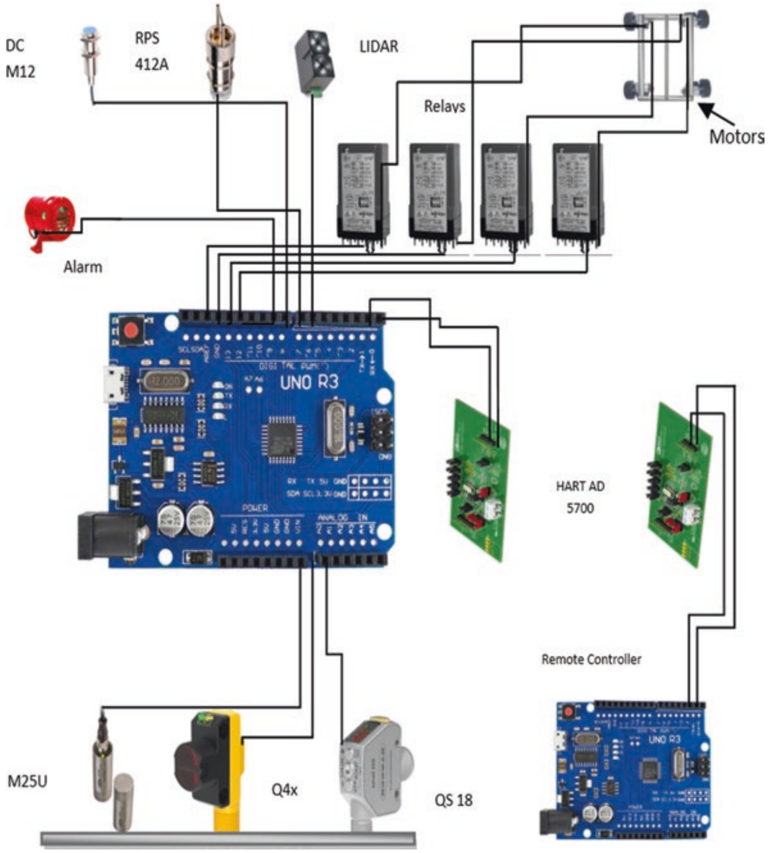


Fig. 3 Architecture of the proposed system

$$\mathrm{CO} = K_{\mathrm{P}}\left(e_{\mathrm{i}}\right) + K_{\mathrm{P}} \times K_{\mathrm{I}} \int_{t}^{0} e_{\mathrm{i}} dt + \mathrm{bias} \quad (2)$$

Here,

K_P = Proportional gain

K_I = Integral gain

e_i = error input (SP−MV)

bias = baseline value of the controller output

When the error is zero, the controller output should not be zero, and it will be maintained at baseline value. The baseline value is depending on the proportional gain value. The proportional gain of 50% is considered as a baseline value.

The essential parameters are considered to design the corn seed sowing machine. Torque on the wheel (T) is determined by multiplying the coefficient of rolling wheel resistance (K), total weight of the corn seed sowing machine (W), and radius of the wheel (R).

$$T = K \times W \times R \tag{3}$$

The coefficient of rolling wheel resistance (K) is considered to allow the developed model to move on uneven surfaces. The effect of rolling resistance leads to unexpected runouts than expected due to the mechanical deformation of the rolling wheel and due to surface deformations of the soil field. Owing to these deformations, an asymmetrical contact stress is developed between the wheel and the field soil.

Here,

"r" is the cylinder radius.
"O" is the geometric center of uniform cylinder.
"F_{AX}" is the horizontal resultant reaction force at point "A."
"F_{AY}" is the vertical resultant reaction force at point "A."

The static contact forces replace the contact stress that is developed between the wheel and the soil field. The direction of wheel movement is opposed by the frictional force (F_r) and shift distance (S_d) as shown in Fig. 4. The variation of rolling resistance impact on angular velocity minimizes the speed of the corn seed sowing machine. F_{AY} is the resultant reaction force acting vertically on the wheel.

"g" is earth's gravitational force.

The field surface deformation is represented with "D." The rolling resistance of the wheel is minimized by considering distance "d." The rolling resistance is greatly influenced by the resultant longitudinal (F_{AY}) and axial forces (F_{AX}). The soil field

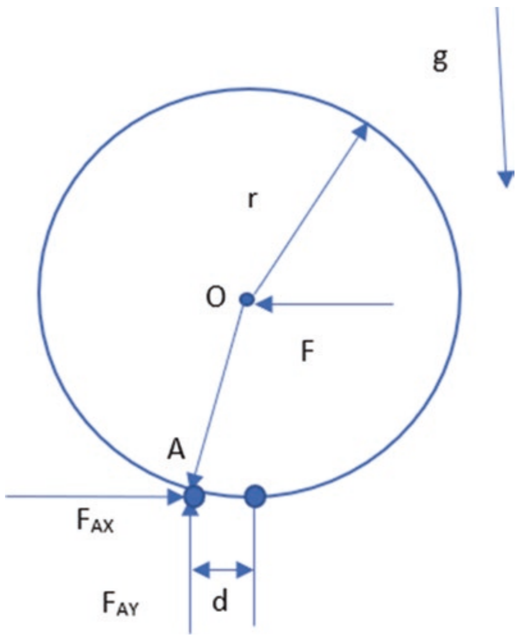


Fig. 4 Rolling frictional forces at constant speed

surface deformation is influencing the wheel direction deformation. Thus, the coefficient of rolling wheel resistance (K) is considered to estimate the total torque developed.

The coefficient of rolling wheel friction (F) is estimated with the ratio of frictional forces between the wheel and the surface (F_{ws}) and the pressing force (F_d).

$$\begin{aligned}&\text{The coefficient of rolling wheel friction } (F)\\&= (\text{Total load on the wheel / Actual radius of the wheel})\\&\quad\times\text{coefficient of rolling wheel resistance}\end{aligned}$$

$$F = (W / R) \times K \tag{4}$$

$$\text{Radius } (R) = 2 \text{ inches}$$

$$\begin{aligned}&\text{Load on the wheel } (w)\\&= \text{weight of the seed sowing machine}\\&+\text{weight of the seed load in Bin1}\\&+\text{Weight of the seed refil bin}\\&= 12 + 20 + 20 = 52 \text{ kg} = 114.64 \text{ lbs}\end{aligned}$$

$$\begin{aligned}&\text{Coefficient of rolling wheel resistance}\\&= 0.047 \text{ inches (since the material is polyurethene)}\end{aligned}$$

$$\text{The coefficient of rolling wheel friction } (F) = W / 2 * F = 2.679 \text{ lbs} \tag{5}$$

In fact, the corn seed sowing machine consists of four wheels. So, the total force required to move the corn seed sowing machine is 4 × 2.679 = 10.716 lbs.

In order to avoid wheel spinning, more static frictional forces are considered than the force from the torque, because the static friction will turn into sliding friction. And further spinning of the wheel is curtailed by deliberating the wheel roll forward movement. The torque force is considered with minimum static frictional force, in order to drive the wheels of the corn seed sowing machine in the forward direction.

The torque developed on the wheel is as follows:

$$T = 0.047 \times 114.64 \times 2 = 10.776$$

Total torque developed on the sowing machine is calculated as follows:

$$= 10.776 \times 4 = 43.10 \text{ lb} \quad \text{in}$$

Both left side and the right side wheel torques are balanced in order to move the sowing machine in a straightline with no deviations, so that the corn seeds can be dropped in appropriate locations. For angular motion of the motor driving shaft under no load condition, the angular velocity of the motor is considered as 150 rpm. The rotational power is estimated as follows:

$$\text{Power} = \text{Torque} \times \text{rotational distance per unit time}$$

$$\text{The rotational power of the Motor} = \text{Torque } (T) \times \text{Angular velocity } (w) \quad (6)$$

$$\text{Angular velocity}(w) = \frac{2\Pi}{60} \times 150 = 15.7\text{rad/s} \quad (7)$$

$$\text{Required power}(P) = \text{Torque load} \times \text{Angular velocity } (w) \times \text{conversion factor} \quad (8)$$

$$\mathbf{P} = 43.10 \times 150 \times 0.1047 = \mathbf{676.958}$$

The required mechanical rotational power (P) = 676.958

The power transmitting component, that is, the chain drive to transmit mechanical power between two parallel shafts using sprockets is considered for corn seed sowing machine.

The run in and run off points of a socket are considered to harvest the link joint motion. This is estimated as follows:

$$2 \propto = \frac{360}{\text{number of teeth}} \quad (9)$$

In order to achieve the link joint motion (2α) to 10°, 36 tooth sprockets are considered. So, the chain resistance is enhanced to 100%.

The tractive force is calculated as actual weight load (G) × gravitational force (g) × coefficient of rolling friction (μ).

$$F_{\text{T}} = G \times g \times m \quad (10)$$

From steel guides with moderate lubrication, the coefficient of rolling friction "μ" is considered as 0.12.

Estimated weight load is 52 kg = 114.64 lbs.

Tractive force = 114.64 × 9.81× 0.12 = 134.95.

The tractive force is considered as high, that is, 134.95 N/m^2, since the machine is operating on uneven surfaces so the chain speed should become slow. For optimizing the operational safety and to improve the fatigue of the machine multiple chains reasonably, big pitch value of 15.875 mm is adopted. The shaft design is considered by considering the stress developed at any location of the shaft, which is smaller than the material yield stress.

The bending stress is estimated as follows:

$$\sigma_b = \frac{32M}{\prod d^3 \left(1 - K^4\right)} \tag{11}$$

Here,

"M" is the bending moment at the point.
"d" is the shaft outer diameter = 1.25 inch.
K is the ratio of shaft inner and outer diameter = 0.25 inches.
$\sigma_{b\,=}$ 828 K-P/in^2.

When a force is applied on the shaft, the shaft of the corn seed sowing machine tends to deflect (bend). The deflection is depending on the length of the shaft and the direction of the force applied on the shaft (Fig. 5).

The maximum bending moment is estimated using the following equation:

$$\begin{aligned} M &= \mathrm{WL}/4 \\ M &= 114.64 \times 2/4 = 57.32 \end{aligned} \tag{12}$$

Here,

w is the load applied.
L is the length of the beam.

The force applied on the corn seed sowing machine at the center is balanced equally both at left and right orientations. In order to keep the centripetal force in a circle, the force applied is perpendicular to the velocity. Considering the conservation of angular momentum, the corn seed sowing machine wheel velocity is four times the angular velocity (w). The radius (R) of the wheel is considered as 4 inches, and this reduces the rotational inertia (I) by a factor of "4." In order to avoid the spinning of the wheel, the torque (T) is applied perpendicular to the angular velocity (w), so that the corn seed sowing machine wheel moves in a circle rather spinning, since the wheel is a cylinder shape. The moment of inertia is estimated by considering the product of mass and the square of perpendicular distance.

$$I = MR^2/2 \tag{13}$$

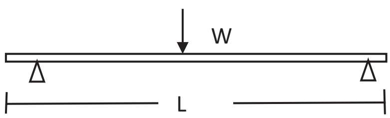


Fig. 5 The Shaft of the Seed sowing machine design

Here,

M is the mass = 114.64 lbs.
R is the radius of the wheel = 4 inches.
I = 917.12.

The gear connected to the servo motor shaft will be driven by PWM signal. The rotation of the teethed wheel is depending on varying the width of pulse. The gear is in rest position with 1 ms pulse width. For 180° rotation of the teethed wheel, it requires 2 ms. Subsequently, for one complete rotation (360°) of the wheel, the required pulse width is 4 ms with a period of 20 ms. Based on the experimental result, 0.25 s is taken for 60° rotation of the wheel connected to servo motor. For complete rotation, that is, 360° rotation, it requires "1" s. The machine is designed to drop a seed from the bin for every 1 s.

Corn Seed Scheduling Algorithm 1
Equal corn seed distribution methodology is used to improve the production rate:
Step1: Number of corn seeds = m, Number of holes = n
Then $m \leq n$
$P_i \in \{1. \ldots n\}$ and $i \in \{1 \ldots m\}$
$P_i < P_j$ and $i < j$
$\min_{J \in \{1 \ldots m\}} \{P_{i+1} - P_i\}$ Maximize minimal distance between holes
$i \neq j$
$\max_{J \in \{1 \ldots m\}} \{P_{i+1} - P_i\}$ Minimizes the maximum distance between corn seeds
$i \neq j$

Step2: $[x_2 - x_1, \quad x_n - x_{n-1}]$ gap between two holes is equated

Step3: $\frac{(n-1)}{(m-1)} = K(n-1) = Q\#m-1\#$ optimal gap adjustment between holes

Every vector has 'Q' values of 'K + 1' and
$n - q - 1$ values of K
Step 4: Repeat step1.

Algorithm 2
Algorithm 2 is used for improving the function of the seed sowing machine (Fig. 6).

4 Results and Discussion

The results of sensor 1, sensor 2, and sensor 3 are extracted to estimate the empty status of the seed bin. The empty status is represented with 16 inches. The depth from upper surface of the seed bin to bottom position of the seed bin is 16 inches. The actual depth of the bin is 24 inches. The upper 4 inches are considered as a null

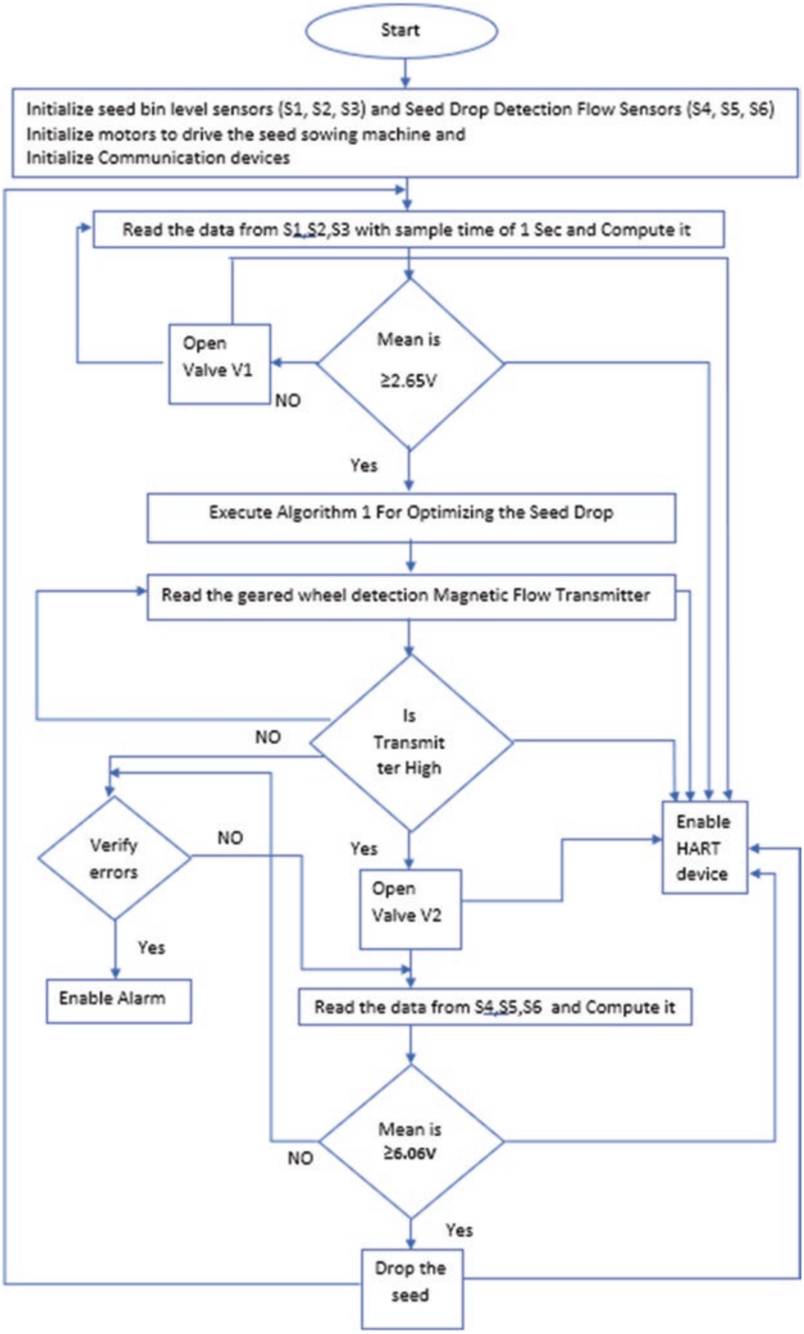


Fig. 6 Operational flow chart of the Seed sowing machine

value at sensing stage and from 20 inches to 24 inches, the sensor will consider as zero. The sensors are positioned on top of the bin surface. The sensor "1," sensor "2," and sensor "3" produced 4 mA (0 V), 1.5 V, and 2 mA (0 V), respectively. The mean of these three readings is the estimated value for bin empty status. The mA signal is converted into mv and then amplified into a voltage signal of 0 V to 5 V. The mean value for bin empty is 0.5 V. Similarly, the full status of the seed bin is estimated with the three sensors. Sensor 1, sensor 2, and sensor 3 produced 5 V, 2.45 V, and 0.5 V, respectively. The mean value of the seed bin full status is 2.65 V. The controller will drive the alarm for 10 s since the bin status is detected as 0.5 V.

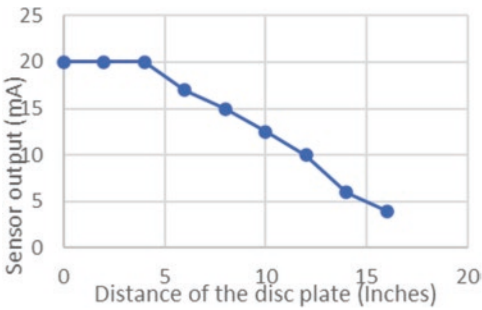
Sensor 4 is positioned at a distance of 12 inches from the seed drop position. The sensor produced 15.384 continuously when no seed is detected. When a seed drop is detected, 9.2 mA is drawn from the sensor 4. The sensor "5," that is, Q4X draws an out signal with 20 mA when it is detected the dropping seed. The sensor "5" produces 4 mA in the absence of seed.

The sensor "6" produces an output voltage of 60.91 mA when it detects the dropping seed. It produced 4 mA in the absence of the seed granule. The mean of the sensor "4," sensor "5," sensor "6" is considered to detect the seed dropping state into the soil. The mean value 30.03 mA (6.06 V) is considered as logic high, that is, the seed is dropped. If the output voltage is 4 mA (0 V), then the controller records the fault condition.

The response of seed bin detection sensors S1, S2, and S3 is tested with varying bin levels. Figure 7 shows the response of sensor 1 with varying bin levels. The output signal of the sensor remains constant from zero inches to 4 inches. This is due to initial dead band of the sensor. The sensor output signal response is proportional with varying bin levels. Minimum output signal, that is, 4 mA is detected with a bin level of 16 inches.

Figure 8 shows the response of sensor 2 with varying bin levels. The peak output signal value of 2.7 V is detected at 6-inch bin level. With increasing bin level, the response of the sensor out signal is exponentially decayed. Figure 9 represents the response of sensor 3 with varying bin levels. The output signal follows the input signal. With increasing bin level, the sensor output signal is increasing correspondingly.

Fig. 7 Sensor 1 output signal Vs Distance of the metal disc



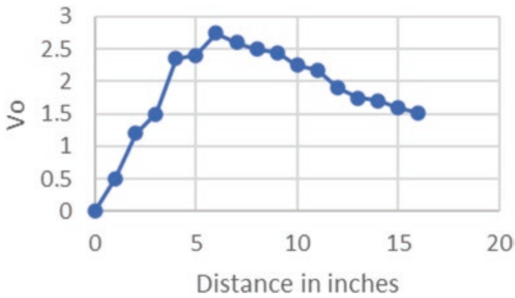


Fig. 8 Sensor 2 output signal Vs Distance of the metal disc

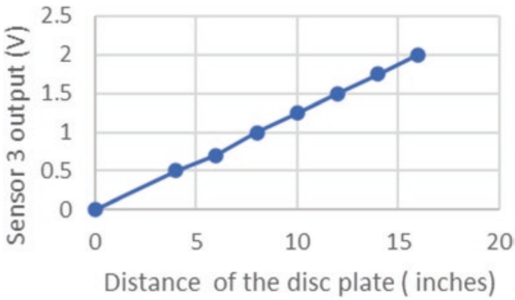


Fig. 9 Sensor 3 output signal Vs Distance of the metal disc

5 Conclusion

The corn seed sowing machine is designed to operate with 26.455 lbs load to enhance the functional efficiency. The TMR applied to sensor technology will further enhance the performance of the machine. The diversified technology is used for the sensor technology for corn seed bin empty status detection and corn seed distribution detection at distinctive stages of the machine. The velocity of corn seed sowing machine is minimized by deliberating the rolling resistance. The motion stability is also significantly improved by considering the rolling resistance of the wheel, that is, 0.047 inches. A set of four relays is used to drive the rear wheels of the machine. The front wheels are driven by the driving rare wheels, which will further improve the motion stability of the machine. Since the static frictional force turns into sliding friction, the forward movement of the wheel without any slipping is considered. So, the corn seed distribution, that is, drop into soil groves, is further improved meticulously. For further improving the motion stability of the machine, the chain speed is deliberated with significantly high tractive force, that is, 31.2 N/m^2. The machine wheels' velocity is considered four times the angular velocity, that is, 62.8 rad/s, which will further improve the stability of the machine and curtail the chances of slippage on uneven surfaces in fields. Pre-programmed one complete rotation of the geared wheel will drop the corn seeds into the soil grove by sliding the disc in axial direction. This function is supervised by the remote controller. Every scan of the controller checks for the possible faults that arise during corn seed distribution process. The sensor faulty status and the communication failure status at distinct levels of the system will be troubleshot by the supervisory (remote) controller for every scan of the process. This will further improve the accuracy of the machine meticulously. The alarm system will certainly add the functional efficiency of the machine. The designed corn seed sowing machine will certainly become a handy device for the corn seed cultivators in order to improve the production rate of the needed food to the society.

Further, this work is advanced with Internet of Things (IOT). So, the remote supervision by the operator or former will improve the functionality of the corn seed sowing machine.

References

1. R.V. Marode, G.P. Tayade, S.K. Agrawal, Design and implementation of multi corn seed sowing machine. Int. J. Mech. Eng. Robot. Res. **2**(4), 422–429 (2013)
2. D. Ramesh, H.P. Girish Kumar, Agricultural corn seed sowing equipment: A review. Int. J. Sci. Eng. Technol. Res. **3**(7), 1987–1992 (2014)
3. Pranil et al., Solar powered corn seed sowing machine. Glob. J. Adv. Res. **2**(4), 712–717 (2015)
4. K.A. Sunitha et al., Agricultural robot designed for corn seeding mechanism. IOP Conf. Ser.: Mater. Sci. Eng. **197**, 7–9 (2016)
5. G. Tekalign Tujo et al., A predictive model to predict corn seed classes using machine learning. Int. J. Eng. Res. Technol. **6**(8), 334–344 (2017)
6. A.V. Vlasov, A.S. Fadeev, A machine learning approach for grain crop's corn seed classification in purifying separation. Int. Conf. Inf. Technol. Bus. Ind., Ser. **803**, 1–6 (2017)
7. P. Srivatsava, K. Neda, Robotic former. Int. J. Eng. Dev. Res. **5**(2), 827–830 (2017)
8. B. Mohan, M.V. Ramesh, T. Srinivasa Rao, Electrical based corn seed sowing machine. J. Emerg. Technol. Innov. Res. **5**(11), 649–655 (2018)
9. P. Premalatha, S. Singh, Design and development of automatic corn seed sowing machine. Asian J. Electr. Sci. **8**(1), 51–54 (2019)
10. P. Johnson, N. Shivakumar, S. Umairahmed, Corn seed sowing machine using CAM and follower mechanism. Int. J. Sci. Res. **8**(3), 1787–1790 (2019)
11. A.T.S. Ormond et al., Maize sowing speeds and corn seed-metering mechanisms. J. Agric. Sci. **10**(9), 468–476 (2018)
12. K.K. Jadhav et al., Design and fabrication of manually operated corn seed sowing machine. Int. Res. J. Eng. Technol. **6**(4), 3006–3011 (2019)
13. R. Kathiravan, P. Balashanmugam, Design and fabrication of manually operated corn seed sowing machine. Int. Res. J. Eng. Technol. **6**(6), 3767–3774 (2019)

IoT-Based Wastebin-Monitoring and -Tracking System Using GSM and GPS

Khode Mounika, E. N. V. Purna Chandar Rao, and Sudha

1 Introduction

The collection and the disposal of waste are carried out by cities for their residential communities. In the budget plan for waste management, nearly 85% of the cost comes from collection and transportation. This amount is excessive because the current setup lacks a sophisticated tracking system. The tasks of accumulating and transferring waste are overseen by city maintenance workers. Sometimes, not removing waste from an area can lead to its spilling over and thus littering the bordering area. To prevent this, a system that features a series of real-time monitored wastebins is required. This study recommends using an online monitoring device for wastebins via a cloud server, to save fuel time by avoiding the need to check these wastebins in person every day. Finally, this system uses GPS to locate the correct area for loading the wastebins and to help drivers navigate the route.

This chapter aims to remove or decrease a waste disposal problem. The Internet of Things (IoT) is a modern communication system that uses microcontrollers and transceivers to connect people as essential parts of the Internet. The IoT-based wastebin-tracking system is a modern device that helps to keep cities clean. This device monitors wastebins and keeps track of the level of accumulated waste by using ultrasonic sensing units located on the containers. The device connects to a Wi-Fi modem to send out this information and to trigger a buzzer. The tool is powered through a 12 V transformer. A liquid crystal display (LCD) screen shows the status of waste that has accumulated in containers (Fig. 1).

K. Mounika (✉) · E. N. V. Purna Chandar Rao · Sudha
Department of ECE, CMR College of Engineering & Technology,
Hyderabad, Telangana, India
e-mail: hodece@cmrcet.org; dsudha@cmrcet.org

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_19

Fig. 1 Proposed operation model

1.1 Objectives

Urban areas and their populations continue to grow, and more of them over the coming couple of years are emerging as smart cities. Yet smart cities are insufficient without smart waste control systems. To encourage the adoption of such systems, the federal government of India needs to launch a marketing campaign. In the current system, in most cities, municipal personnel do not visit wastebins every day to check for accumulated waste, which results in infections. This chapter aims to establish a reliable series of wastebins using an IoT-based system and to educate policymakers on why their waste maintenance systems should use ultrasonic sensors.

2 Related Work

The increase in the population of India likewise increases the amount of waste produced in the country. India has carried out ecological modifications on its inadequate waste collection, transportation, and disposal [1]. But it still requires a large workforce. With the assistance of integrated devices interfacing with the Internet of Things (IoT), the proposed waste management tracking system would lower the number of people in the workforce. The Internet of Things includes the devices that are connected via a wireless network [2]. In this system, the numerous wastebins of a city of facility can be monitored. Ultrasonic sensors identify the level and weight of the waste inside the wastebins and include a specific ID to facilitate determining which wastebin is full. The layout uses a Wi-Fi module (ESP8266) that sends data to a web server using bootstrapping [4]. The data is sent out with a timestamp through an RTC issue, which additionally provides the location of the wastebin by using a global system for mobile communications (GSM) element. The services for waste management encounter several problems. The recommended solution is using a GSM element and a sensing unit, which directly relay data on the level of waste in the wastebin to the registered user. IoT devices are used for communicating, processing, saving, and retrieving data [5]. The proposed device helps to solve the problem of monitoring levels of waste by using IoT. This system includes an Arduino Uno controller, wastebins equipped with ultrasonic sensors, a monitoring panel at the administrative center, and GSM and GPS modules [6]. The waste may be discarded in the government-assigned bins or be handed over to corporations. Afterward, the waste needs to reach its final destination, where monitoring ceases. Our proposed model will track waste throughout this journey [7–9].

3 Existing System

India is the most populous country in the world. This large population produces a lot of waste from its houses and markets. Sometimes, waste decays, generating unhygienic gases that pollute the surroundings. Mumbai, for example, is a smart city that generates a massive amount of waste: 11,000 tons of waste every day [10, 11]. To deal with this waste, wastebins have been placed in various locations throughout the city; however, they often overflow and go unattended. The city does not keep records concerning the overflowing of its wastebins [12, 13].

Smart cities need smart devices that monitor wastebins and provide status updates in real time. At present, the municipal corporations in India do not have access to real-time information on the statuses of their wastebins. The proposed model uses a system based primarily on IoT that can update commercial enterprises of the level of waste in and the toxicity of their wastebins [14]. An Internet connection is hooked up to a display screen to show the wastebins that are being monitored. A GSM module sends messages to a smartphone, and additional information associated with the wastebin's condition is uploaded to a website. On this website, users can likewise send instructions associated with wastebins or waste control [15]. In the proposed system, an Arduino Uno, a microcontroller, is used as an interface for the GSM/GPS sensors. Ultrasonic sensors and gas sensors measure waste levels and toxicity levels, respectively [16].

One of the IoT-based waste-monitoring and waste management systems is being tested in India: one in every smart city. Ahmedabad is called the GIFT City (Gujarat International Finance Tec-City). A smart solid waste management system is using Swiss technology, where the waste is disposed of with minimum human interference. The waste will be recycled to create organic manure and generate power, which can be consumed in the GIFT City itself. The solid waste is collected from the bins and sent to the gathering center by using vacuum-suction pipes about 2 km away from the buildings. The speed and the direction of the waste are monitored and controlled by a completely computerized console. “An experiment of this project was held at GIFT City and was successful, and further improvements are done”, said administrator of GIFT City Ramakant Jha. He also said that “The organic waste is going to be incinerated using plasma technology”. This incinerator has a capacity of 50 tons per day, which is able to gradually increase to 400 tons per day as the population increases, and the thermal energy generated by this incinerator can be used by the city. The IoT sensors employed in waste-monitoring and waste management systems save time and reduce fuel consumption.

4 The Proposed System

India is a developing financial machine that needs to manage its waste. In India, 64 million tons of municipal waste are produced every day, which ranks it as the fifth highest in the world. Currently, every day in numerous areas, waste accumulates, and roads are loaded with clutter. These surprising points create several problems, such as dangerous contamination. They also necessitate a control machine to alleviate this problem by tracking the waste in cities. The data from such tracking is sent out as a record to an IoT-based cloud-connected device for real-time monitoring.

In this chapter, a smart wastebin is built with an Uno microcontroller that uses the Raspberry Pi platform that interfaces with an ultrasonic sensor, a weight sensor, a rainfall sensor and a smoke sensor. Here, the weight sensor monitors the load of the wastebin. The weight sensor is positioned on the bottom of the wastebin to determine the weight of the wastebins. The ultrasonic sensor is located on the top of the wastebin so that the surrounding environment can be monitored. The rainfall sensor monitors the weather and whether rain or in any other precipitation is falling. In the even that rain falls on the bin, the wastebin door immediately closes; otherwise, the wastebin door remains open. This tool is powered by an electric servomotor. The smoke sensor monitors the bin and surroundings for smoke from various sources. Raspberry Pi tracks when the wastebin is being loaded and continues to track the accumulation; a restriction on its height may be also set. When the waste reaches the limit of the bin, the ultrasonic sensor will prompt the GSM module to alert the on-site professional until the waste inside the wastebin has been removed. If necessary, this professional can use the GPS module to send a message that marks the site to a separate manager. The data from the device can also be uploaded to the IoT server.

5 Materials and Methods

Ultrasonic sensors monitor the waste being stuffed into the wastebins. Raspberry Pi is configured to make sure that after the waste level has reached a particular threshold, a worker is dispatched to empty the bin (Fig. 2). The waste statuses of wastebins are monitored in real time via the cloud server.

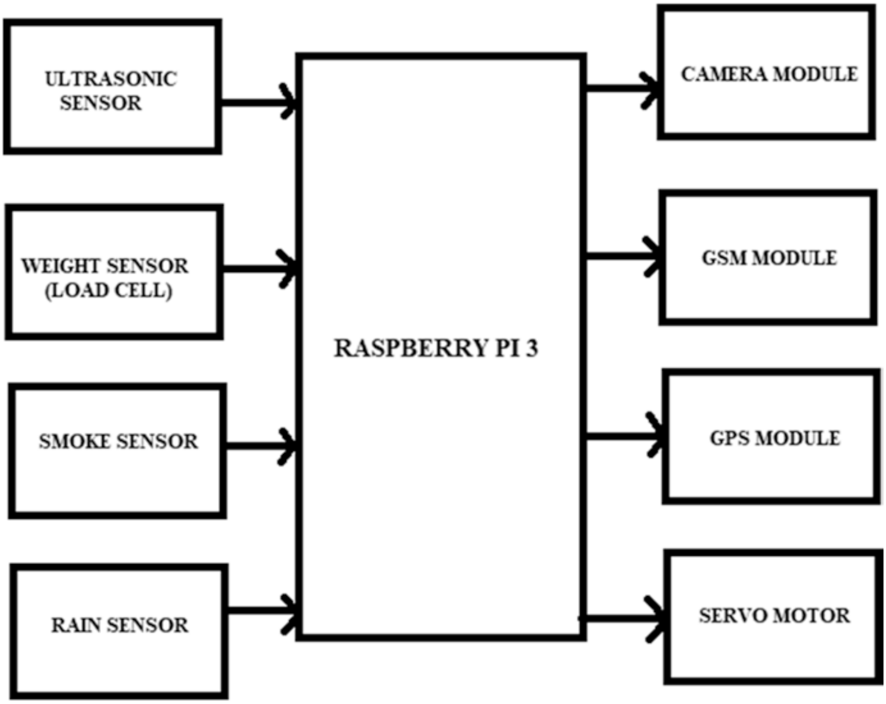


Fig. 2 Proposed block diagram

5.1 Ultrasonic Sensor

An ultrasonic sensor uses sonic waves to measure its distance from its target. A sonic wave is dispatched, and the length of time after which the wave returns determines the level of waste in the bin. The ultrasonic sensor in this study is an HC-SR04 unit with a noncontact range of 2–400 cm.

5.2 Weight Sensor (Load Cell)

The weight sensor is a bar that measures hundreds of cellular sources (frequently referred to as a stress scale) and can translate 5 kg of stress (force) into an electrically powered signal. Each cellular load changes the electrical resistance, which varies in unison with the stress on the bar. With this stress scale, the weight (mass) of items, the overall weight of the bin as that changes over time, and the pressure or load on the bin can be monitored. Each bar is composed of an aluminum alloy and can sustain 5 kg of stress (force). Each bar has four strain gauges that are usually connected in Wheatstone bridge formation.

5.3 Rain Sensor

A rain sensor consists of two modules: a rain board that detects the rain and a control module that compares the analog value and converts it to a digital value. A rain sensor may be used on a vehicle to modify the behavior of windshield wipers. In farming, they automate in-house devices.

5.4 Smoke Sensor

A smoke sensor is a safety device used in industry and homes to alert people to an emergency. An alarm control board is part of this device. A home smoke detector normally triggers an audible or visual alarm in the event of smoke. The Analog Smoke/LPG/CO Gas Sensing Unit (MQ2) module uses an MQ2 as the sensory element and has a protection resistor and a bendy resistor onboard.

A smoke detector senses smoke, typically as an indicator of fire. Commercial smoke detectors trigger an alarm from a control panel. Household smoke detectors, also called smoke alarms, generally trigger audible or visual alarms from the detectors themselves, and in concert if multiple devices are interlinked. Smoke detectors are usually housed in plastic enclosures, typically shaped as disks about 150 mm (6 in) in diameter and 25 mm (1 in) thick, but the shapes and sizes vary. Smoke may be detected either optically (photoelectric) or physically (ionization). Detectors may use one or both sensing methods. Sensitive alarms may be customized to detect and deter smoking in banned areas. Smoke detectors in large commercial or industrial buildings are usually connected to a central fire panel. Domestic smoke detectors range from individual battery-powered units to many interlinked units with battery backups so that detection can continue and alarms can be triggered when household power has gone out. The risk of dying during a residential fire is cut in half in houses with working smoke detectors. However, some homes do not have any smoke alarms, and some others homes do not have any working batteries in their smoke alarms.

5.5 Servomotor

A servomotor is a type of motor that can turn with incredible precision. Typically, this shape of motor incorporates a managing circuit that gives feedback on the present status of the electric motor shaft. This response allows the servo to electrically power vehicles to revolve with incredible precision. A servomotor is composed of a smooth electrically powered motor that operates through a servo tool.

5.6 GPS Module

The global positioning system (GPS) gives the specific position for almost anywhere in the world at any time. The GPS module can accept data from GPS satellites and then discern the modules geographical location. The GPS is a worldwide direction satellite system composed of a minimum of 24 satellites, yet already 30 satellites have been set up by the United States.

5.7 GSM Module

The GSM module works on a frequency of 850/900/1800/1900 MHz and might be used not only to access the Internet but also for spoken languages (provided that the voice is connected to a microphone on one end and a speaker on the other) and for SMSs. Externally, it is a large package (2.3876 cm × 2.3876 cm × 0.3048 cm (0.94 inches × 0.94 inches × 0.12 inches)) with L-shaped contacts on four sides so that they can be soldered both on the side and on the underside. Internally, the module is managed by an AMR926EJ-S processor, which controls phone communication, digital communication (through an integrated Transmission Control Protocol (TCP)/IP stack) and analog communication (through an UART and a TTL serial interface). The processor uses a SIM card (3 or 1, 8 V) that must be attached to the outer wall of the module. Additionally, the GSM900 device integrates an analog interface, an A/D converter, an RTC, an SPI bus, an I^2C and a Pulse Width Modulation (PWM) module. The radio section is GSM phase 2/2+ compatible and is class 4 (2 W) at 850/900 MHz. The TTL serial interface can not only communicate all the data already received by the SMS and people who are available during the TCP/IP sessions in GPRS (the data rate is set by the GPRS class 10: max. 85.6 kbps) but also receive the circuit commands (in this case, coming from the Peripheral Interface Controller (PIC) governing the remote control, which is either the AT standard or the AT-enhanced Subscriber Identity Module (SIM) type).

5.8 Camera Module

- The Omnivision 5647 CMOS Sensor comes in a very focused package.
- It is capable of taking 5 MP (2592 × 1944 pixels) images and recording in three modes: 1080 p at 30 fps, 720 p at 60 fps and 640 × 480 p at either 60 or 90 fps.
- Its connection uses a 15-pin ribbon cable linked via the camera serial interface (CSI) connector (just behind the ethernet port on the model B). CSI connectors are to be used especially with cameras.
- It has a very small form and is light weight: at just 25 mm * 20 mm * 9 mm and 3 g.
- Many adjustment settings are available: exposure, white balance, image effects, metering modes and much more.
- It comes at a price of just over GBP 16.

5.9 Raspberry Pi

Raspberry Pi 4 can be used to communicate with an external embedded system. It has 40 pins, 28 of which are General-Purpose Input/Output (GPIO) pins and the rest power pins. GPIO pins are used for more than just simple input/output (I/O). They may provide connectivity via Universal Asynchronous Receiver/Transmitter (UART), Serial Peripheral Interface (SPI) or Inter-Integrated Circuit (I2C). Raspberry Pi 4 comes with all of today's communication systems. For wireless data transfers, it contains internal Wi-Fi and Bluetooth connectivity. It can be utilized internally without causing any disruptions. Because of the Wi-Fi support, Raspberry Pi can transfer within the same network. In the event that Wi-Fi is unavailable and the network must interact via conventional means, the device also includes local area network (LAN) support.

Raspberry Pi started as a series of small single-board computers (SBCs) developed within the UK by the Raspberry Pi Foundation in association with Broadcom. The Raspberry Pi project originally leaned toward the promotion of teaching basic engineering in schools and developing countries. The first model became more popular than anticipated, selling outside its target marketplace for uses like robotics. It is widely employed in many areas, such as for weather monitoring, thanks to its low cost, modularity and open design. It is typically employed by computer and electronic hobbyists thanks to its adoption of HDMI and USB devices.

5.10 IoT

The Internet of Things (IoT) is a network of physical objects—"things"—embedded with sensors, software and other technologies to connect and exchange data with other devices and systems over the Internet.

Some popular IoT applications include the following:

- Smart manufacturing
- Preventive and predictive maintenance for connected assets
- Smart power grids
- Smart cities
- Coordinated logistics
- Smart digital supply chains

5.11 Ubidots

Ubidots is an Internet of Things platform that allows innovators and businesses to create prototypes, and it brings IoT applications into production. Data can be sent to the cloud from any Internet-connected device by using the Ubidots platform. Next, using visual tools, actions and alerts can be defined and amended on the basis of real-time data. Ubidots provides a Representational State Transfer Application

Programming Interface (REST API) that allows data from the following sources to be read and written: variables, values, events, and insights. The API accepts both HTTP and HTTPS requests and requires an API key.

Ubidots is a data analytics and visualization firm focused on the Internet of Things (IoT). It converts sensor data into useful information for corporate decision-making, machine-to-machine interactions, educational research, and resource economization. Ubidots is a simple and inexpensive way to incorporate the power of the Internet of Things into a business or a research project. Ubidots' technology and engineering stack were built to provide users with a secure, white-glove experience. Device-friendly APIs (accessible through HTTP/MQTT/TCP/UDP protocols) make sending and retrieving data in real time to and from a cloud service both simple and secure.

For IoT data storage, computing and retrieval, Ubidots' time-series backend services are performance optimized. Its application enablement platform includes interactive real-time data visualization (widgets) and an IoT app builder that allows developers to customize the platform to their own HTML/JS code. Ubidots was created to help users take control of their data from device to visualization.

6 Working Methodology

The ultrasonic sensor and weight sensor are secure to the wastebin. These sensors identify and monitor the waste level and the weight of the wastebin. When the waste level and weight exceed specific thresholds, the sensors send signals to Raspberry Pi. After that, they collect GSM and GPS details and send a message containing the location of the bin to the community agency in charge of the wastebin's maintenance. The rain sensor is affixed to the lid at the top of the wastebin. If rain drops on the wastebin, its servomotor immediately closes the lid. The smoke sensor is used to detect smoke close to and inside the wastebin. If the level of waste reaches a certain threshold, pictures will be sent to the agency in charge of removal. Lastly, all the sensors' records can be uploaded to the cloud server (Fig. 3).

Algorithm

Step 1: Turn on the energy supply.
Step 2: Review the various sensors (ultrasonic, weight, smoke and rainfall sensors).
Step 3: If the ultrasonic sensor on a wastebin detects that the waste has reached its threshold, the sensor will send the location and a photo of the wastebin to the agency in charge of its maintenance.
Step 4: If the weight sensors detects that the weight threshold has been reached, it will send an alert over the IoT server.
Step 5: If any sort of smoke is detected by the smoke sensor, it will send an alert with the location of the wastebin.
Action 6: If rain drops on the wastebin, the rain sensor will instruct the electrically powered servomotor to close the bin's lid.
Step 7: Stop the system.

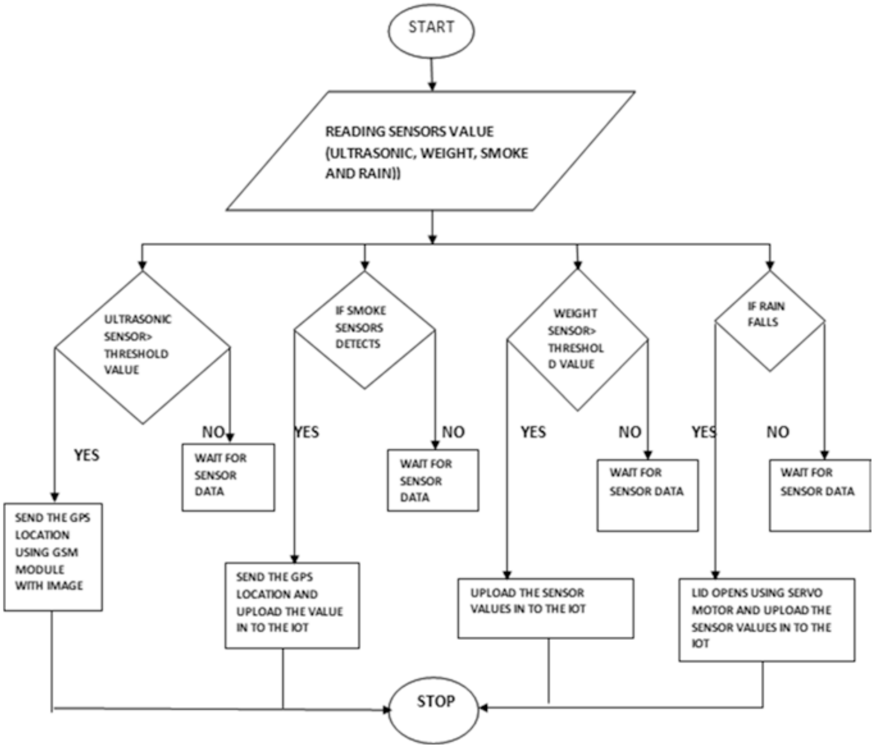


Fig. 3 Flowchart of the proposed system

The hardware kit of our working model was slowly delivered to the bin over time (Fig. 4). Figure 5 shows the location of the wastebin as indicated on a screen. Figure 6 contains the information dispatched from the sensor over the IoT server. Here, blue represents the sensor's on status, whereas red represents the sensor's off status. Figure 7 shows a picture of a filled wastebin taken by a digital camera. Figure 8 displays a message, containing the wastebin's location, that appears on a mobile device.

7 Conclusion

In this chapter, a protected device including a Wi-Fi modem, IoT, GSM, and an ultrasonic sensor was proposed for the detection and removal of waste from wastebins. This took provides detailed information on the time, location, and level of waste in each connected wastebin.

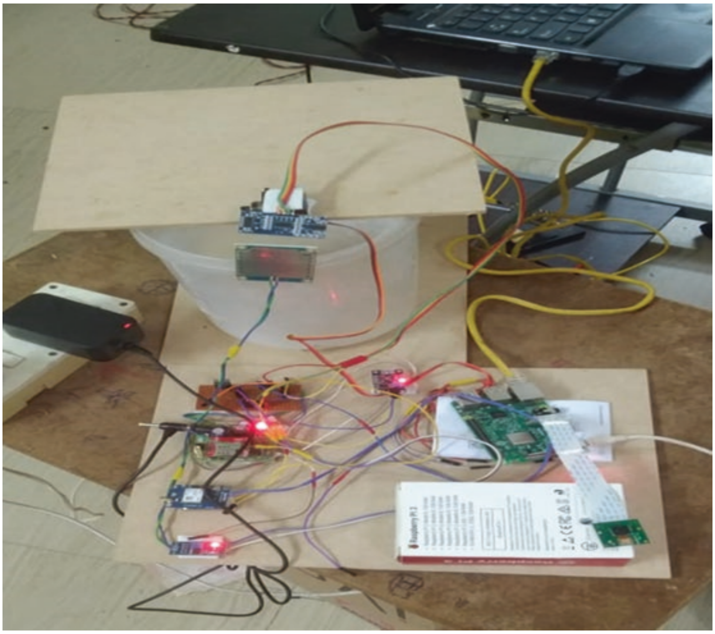


Fig. 4 Hardware kit of working model

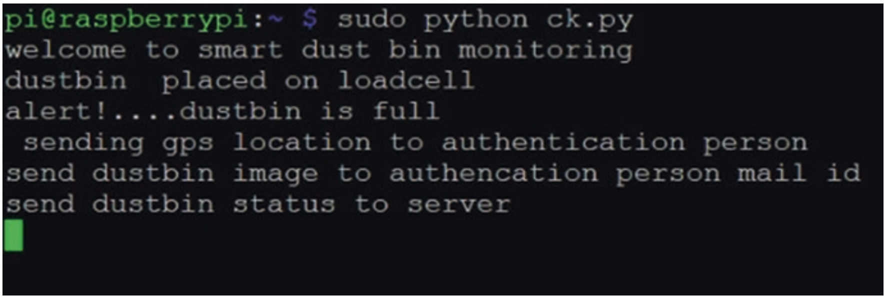


Fig. 5 Wastebin location as indicated on a screen

We analyzed these details for the implementation of IoT. The proposed model can save and money in that it prevents needing works to check these details in person. It can mechanically display the waste level and send data to a relevant agency so that it can monitor this level. These advantages can improve waste collection via machine monitoring and lead to greener surroundings.

Fig. 6 Wastebin location sent over an IoT server

Fig. 7 Image of a filled wastebin taken by a digital camera

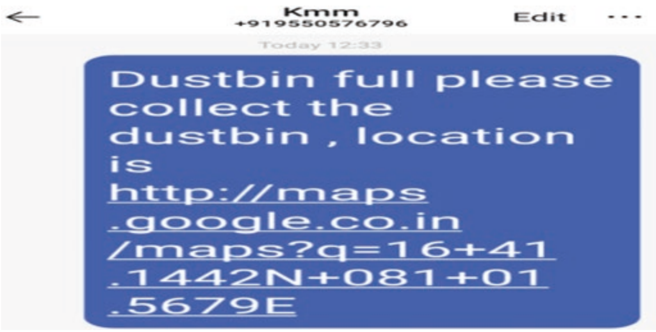


Fig. 8 Output message on mobile device containing the wastebin location

References

1. M.S. Chaudhari, B. Patil, V. Raut, Iot based waste collection management system for smart cities: An overview, in *2019 3rd International Conference on Computing Methodologies and Communication (ICCMC)*, (IEEE, Piscataway, 2019), pp. 802–805
2. S.S. Navghane, M.S. Killedar, V.M. Rohokale, IoT based smart garbage and waste collection bin. Int. J. Adv. Res. Electr. Commun. Eng. (IJARECE) **5**(5), 1576–1578 (2016)
3. A. Bajaj, S. Reddy, Garbage monitoring system using IoT. Int. J. Pure Appl. Math. **114**(12), 155–161 (2017)
4. H. Kasliwal Manasi, B. Suryawanshi Smithkumar, A novel approach to garbage management using internet of things for smart cities. Int. J. Curr. Trends Eng. Res. **2**(5), 348–353 (2016)
5. N.M. Yusof, M.F. Zulkifli, M. Yusof, A.A. Azman, Smart waste bin with real-time monitoring system. Int. J. Eng. Technol. **7**(2.29), 725–729 (2018)
6. P.V. Amrutha, B.N. Chaithra, D.R. Kavyashree, P.S. Kumar, M.S. Chethan, IoT-based waste management using smart dustbin, in *Recent Advances in Technology and Engineering 6th National Conference by TJIT*, (2017)
7. G. Shobana, R. Sureshkumar, Automated garbage collection using GPS and GSM. Int. J. Pure Appl. Math. **118**(20), 751–755 (2018)
8. V. Vijeya Kaveri, V. Meenakshi, B. Bharathi, J. Albert Mayan, Smart garbage monitoring system using IoT, in *International Conference on Computational and Bio Engineering*, (Springer, Cham, 2019), pp. 421–428
9. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
10. S. Mirchandani, S. Wadhwa, P. Wadhwa, R. Joseph, IoT enabled dustbins, in *2017 International conference on big data, IoT and data science (BID)*, (IEEE, Piscataway, 2017), pp. 73–76
11. A. Anitha, Garbage monitoring system using IoT. IOP Conf. Ser.: Mater. Sci. Eng. **263**(4), 042027 (2017). IOP Publishing
12. V.K. Gunjan, S. Kumar, M.D. Ansari, Y. Vijayalata, Prediction of agriculture yields using machine learning algorithms, in *Proceedings of the 2nd International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications*, (Springer, Singapore, 2022), pp. 17–26
13. T. Anagnostopoulos, A. Zaslavsky, K. Kolomvatsos, A. Medvedev, P. Amirian, J. Morley, S. Hadjieftymiades, Challenges and opportunities of waste management in IoT-enabled smart cities: A survey. IEEE Trans. Sustain. Comput. **2**(3), 275–289 (2017)

14. K. Nirde, P.S. Mulay, U.M. Chaskar, IoT based solid waste management system for smart city, in *2017 International Conference on Intelligent Computing and Control Systems (ICICCS)*, (IEEE, Piscataway, 2017), pp. 666–669
15. N.S. Kumar, B. Vuayalakshmi, R.J. Prarthana, A. Shankar, IoT based smart garbage alert system using Arduino UNO, in *2016 IEEE Region 10 Conference (TENCON)*, (IEEE, Piscataway, 2016), pp. 1028–1034
16. A. Borozdukhin, O. Dolinina, V. Pechenkin, Approach to the garbage collection in the "Smart Clean City" project, in *2016 4th IEEE International Colloquium on Information Science and Technology (CiSt)*, (IEEE, Piscataway, 2016), pp. 918–922
17. G.S. Narayana, M.D. Ansari, V.K. Gunjan, Instantaneous approach for evaluating the initial centers in the agricultural databases using K-means clustering algorithm. J. Mob. Multimed. **18**(1), 43–60 (2022)

Implementation of Secure Health Care Application Using IoT

Hema Sai Sree Gullapalli, Deepika Lakshmi Gunnam, Gopi Krishna Popuri, Kiran Kumar Anumandla, and Shaik Razia

1 Introduction

In the present scenario, all devices are interlinked to the internet for monitoring remotely. There are many applications of Internet of Things (IoT), which are lacking security for data while sending it from the devices to the cloud or the end users. Not only that but also, from the end user to the devices to control it be vice-versa. To avoid this glitch, a solution is proposed and applied in one of the applications of IoT, that is, healthcare application. So, here, it mainly focuses on encryption and decryption of data in cryptography algorithms. The word cryptography refers to converting plain data to unintelligence data, and it not only protects the data but also provides authentication. It has three sorts we have picked: symmetric key, a calculation that offers only one key for both encryption and decoding and public key which is an additional asymmetric key, a calculation that utilizes two keys that are public key and private key [1–4]. AES, DES, and Blowfish are some of the symmetric key algorithms. Outcomes get some new experiences on the subject of how well these lightweight codes are fit to get the IoTs. The casing work is utilized to benchmark the usage of lightweight codes [5]. We have chosen Blowfish because as of now no attack is detected and simple to operate compared to other algorithms. Another reason for choosing this is it is a replacement for IDEA and DES. It is freely available and easily understandable for everyone who has basic knowledge of asymmetric

H. S. S. Gullapalli · D. L. Gunnam · G. K. Popuri (✉) · K. K. Anumandla
Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India
e-mail: gopikrishna.popuri@kluniversity.in

S. Razia
Department of Computer Science Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_20

key algorithms such as RSA and ECC. The purpose of picking ECC is it gives equivalent security more modest key size. It speaks to cubic structure. It utilizes both public key and private key for scrambling and decoding [6]. The lightweight cryptography is an encryption method; it is easier and runs very fast than conventional cryptography [3]. The purpose of picking ECC is it gives equivalent security more modest key size. It speaks to cubic structure. It utilizes both public key and private key for scrambling and decoding. IoT hardware was also vulnerable to more attacks like scan chain attacks [7–9] and reverse engineering techniques. To prevent the secret keys, a secured random number generator was proposed [10] to prevent reverse engineering attacks. The main motto of this chapter is to verify which utilizes low memory and less time for computing resources to give security solutions that can do by devices. Main drawbacks observed are the loss of data when it is transferred from the devices to the cloud and the end user/remote user. The time complexity is the other one.

This chapter is discussed as follows: Sect. 2 has related work, Sect. 3 illustrates problem statement, Sect. 4 contains experimental setup and its working process of Blowfish and ECC, Sect. 5 demonstrates results and discussions, and in Sect. 6, we conclude this chapter.

2 Related Work

Dhanda S and Singh B [1] have dissected the correspondence necessities of IoT and identified fitting remote advances that can meet those prerequisites. A few open issues stay to dot dressed which we have examined. It is an innovative worldview, which empowers Internet network to a wide range of items and individuals. Such articles, additionally called IoT gadgets, can be sensors, actuators, implanted frameworks, savvy gadgets, and cell phones. In this new worldview, everything and everybody with a typical interest can be associated, and therefore, it is called as IoT. The arrangement of IoT applications is quickening with the assistance of remote advances. In this work, we have introduced the most encouraging and practical remote arrangements reasonable for IoT applications. This work will be useful in managing fashioners and analysts on the remote innovation decisions accessible for gigantic IoT arrangements. A force saving instruments, correspondence security, and greater organization contextual investigations will be embraced as a feature of our future works. Shamala and Zayaraz [2] have analyzed the current lightweight calculations and its examination challenges in cloud climate that are centered on future exploration are talked about. As of late utilized encryption and decoding calculations, in any case, called figures that are not pertinent for all the applications because of its intricacy. The plan prerequisites and various components, issues, and patterns in its IoT security enunciated and gave an esteemed strong thought in planning a lightweight square code. This encourages lesser assets for utilization contrasted with heavyweight arrangements. It has no compelled prerequisites for any lightweight calculation to fit in; nonetheless, the key size, block size, code measures, and clock cycles are given higher significance. Objectives of making a less calculation configuration to bargain different components are low asset necessities, execution, and cryptographic strength of the calculation. Mohr and Hayajneh [3] investigated openings for execution improvement in future code plans. Further, the ideal energy is accomplished when the amount of computation changes is less. Ideal throughput is cultivated by executions with tremendous square sizes and gigantic number of completed changes. With phenomenal development in the web of things, the measure of information traded between these gadgets is developing at an uncommon scale. The majority of the gadgets are low-asset gadgets taking care of touchy information. Encryption strategies are improper for low-asset gadgets. The goal of this examination is to investigate freedoms to improve execution and enhance energy utilization for figure plans focused for low-asset gadgets. In this chapter, we introduced an inside and out conversation of low weight block figures for low asset. In low-asset gadgets, energy is perhaps the most difficult asset. The focal point of our work was to improve light weight figure plan execution and oversee energy to draw out battery life in even extreme utilization or force assaults. Okello et al. [4] gave lightweight cryptography as an answer for security in the IoT, introducing the various orders of calculations and a case for every characterization. A couple of lightweight calculations were investigated for execution, while introducing the primary cryptanalysis methods against them. We likewise introduced extraordinary examination openings and some outstanding gatherings and organizations to watch and continue in this norm. The primary commitment of this chapter is a healthy introduction on the viewpoint of information security for the IoT with examination for certain calculations utilizing an exceptionally later and affirmed benchmarking instrument and calling attention to compelling specialists in this field. This chapter can be extended to break down different parts of security like IoT network security and actual gadget security [11–14].

3 Problem Statement

Cryptographic procedure is one of the safe information transmission for securing the data as it not only protects but also provides authentication but majority algorithms are time taken to complete. In both conventional and lightweight cryptographies, the lightweight cryptography is simple and faster compared to other ones. We have chosen two types as symmetric where only one key is enough, and in asymmetric, we need public key and private key to encrypt and decrypt. So, we have chosen one from each that is Blowfish from symmetric and ECC from asymmetric. For choosing health parameter in IoT, although there are many applications and in them, most of them have solutions but when comes to health parameter in this paper, we not only want to secure the patient details but also prove which is best from our observation. From healthcare field, we have taken heart beat details of patients in a dataset using python language. Considering the current time, it takes to encrypt and to decrypt, plain text size, cipher text size, and it is ratio these are the parameters we do comparison and conclude by saying which is best to follow.

4 Experimental Setup

In reallife healthcare application which consists numerous parameters, we have chosen patients heart details and their health status in a csv file. In addition to that, we have done coding in python using Google co laboratory and then added dataset heart.csv, and later on encrypted and decrypted the details to show which is good enough to secure the details of patients from hackers.

4.1 Working

In lightweight cryptography calculations, the symmetric (Blowfish) and asymmetric (ECC) include significant job and keeping in mind that making sure about the information documents or text. In clinical field, making sure about each patient's record is fundamental concern, credited to numerous fake cases happening in the wellbeing area. The information of each individual should be engraved and sent into end-client with no issues. Chief in the clinical administrations industry, where thoughts are routinely based on saving someone's life and as it should be, yet secures induction to interfaces and PC structures that store private data like clinical records is in like manner a fundamental factor to consider. Data security is a contrasting movement between controlling permission with information while allowing free and basic induction to the people who need that information. Still, couple of issues are locked in by the specialist in the prosperity region. Patient's data should be kept securely in clinical provider laborers with the objective that specialists can give proper medications. To ensure secure limit and access the chiefs, we propose a novel lightweight encryption using swarm improvement computation. The proposed coronary heart disease dataset methodology Blowfish encryption and ECC figuring, which gives the lightweight features. Overall, the lightweight encryption computations are affected by the key space (Fig. 1).

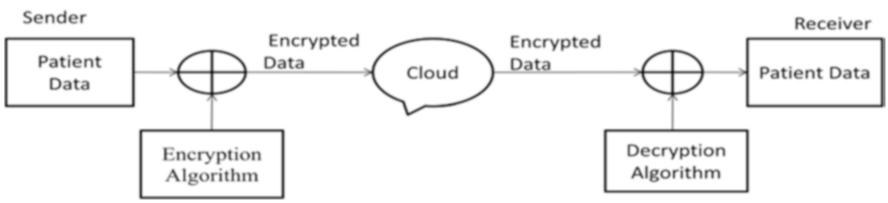


Fig. 1 Block Diagram

4.1.1 Blowfish

Blowfish is an encryption method planned by Bruce Schneider in 1993 as an option in contrast to DES encryption technique. It is fundamentally quicker than DES and furnishes a decent encryption rate with no compelling cryptanalysis method found to date. It is one of the principal, secure square codes not expose to any licenses and subsequently unreservedly accessible for anybody to utilize. Block size is 64-bits, key size is 32-pieces to 448-bits variable size, number of sub keys is 18 [P-array], number of rounds is 16, and number of substitution boxes is 4 [each having 512 sections of 32-bits each] (Fig. 2).

In this chapter, a banking system is done by utilizing Blowfish algorithm. People can do an easy access with their banking accounts through web by means of PCs and smartphone utilizing different organizations or some information association. Yet, security of money exchange is a major issue. This system will give a protected web base application where just approve people can get to all data utilizing an assigned secret key [7].

4.1.2 Elliptic Curve Cryptography

Elliptical curve cryptography is a public key encryption strategy dependent on elliptic bend hypothesis that can be utilized to make quicker, more modest, and more productive cryptographic keys. It creates keys through the properties of the elliptic bend condition rather than the customary strategy for age as the result of extremely huge indivisible numbers. It depends on properties of a specific kind of condition

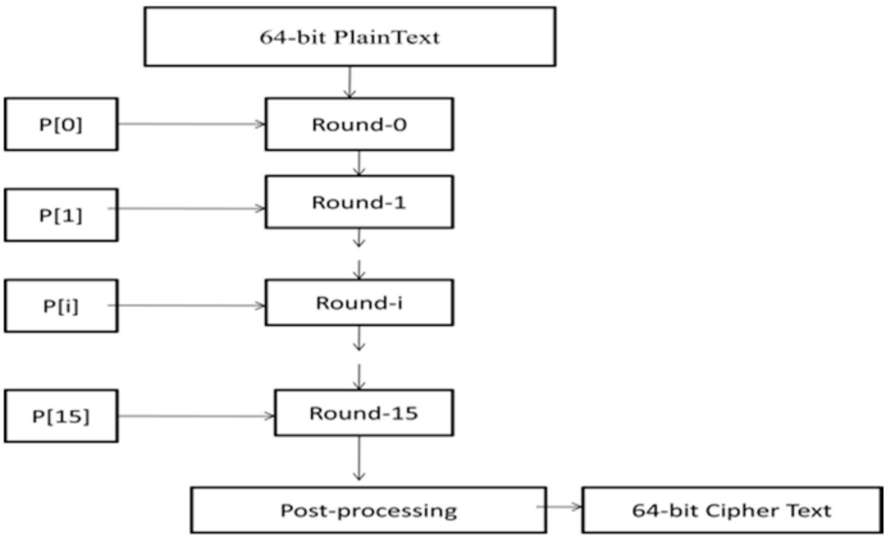


Fig. 2 Block Diagram of Blowfish

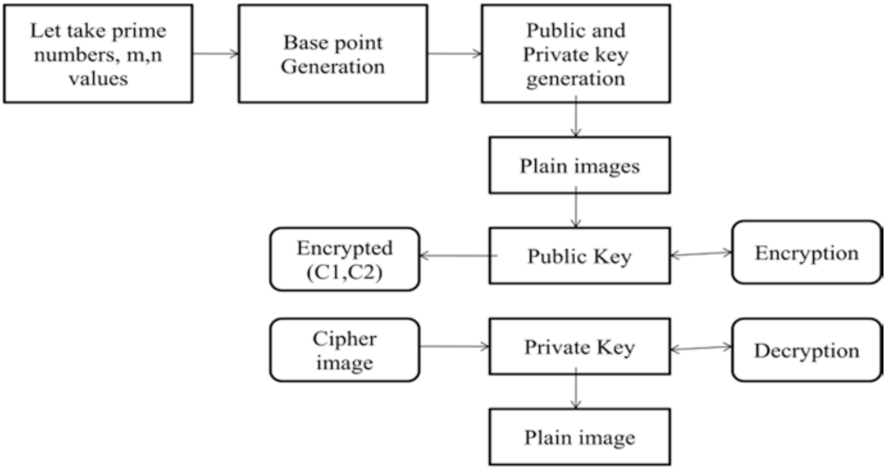


Fig. 3 Block diagram of ECC

made from the numerical gathering got from focus where the line converges the tomahawks. It offers an extraordinary potential as an innovation that could be executed worldwide and across all devices (Fig. 3).

In this chapter, encryption and decryption perform with mid-point of chart. Objective is to create a very strong key worth having least length of pieces, which will be helpful in lightweight cryptography. Utilizing elliptic curve cryptography with mathematical algebraic diagram finds a secret key. ECC is a strong algorithm that creates a pair of public and private and furthermore produces secret key, an incentive with the above pair of key. Secret key boundaries are not in network, so it will safeguard against man-in-center assault. This calculation might be appropriate for smart card, sensors, and remote organization security [8–11].

5 Results and Discussions

We have executed Blowfish and ECC algorithms separately by considering the same dataset that contains details such as age, sex, cholesterol, chest pain, blood pressure, heart beat, ECG and THAL (thallium heart scan), and fasting blood sugar. The whole experiment ran on python compiler and we calculated its execution time and code size, which is almost 3 kB and 4 kB corresponding to ECC and Blowfish, respectively. We have taken a csv file which is of size 42 kB and uploaded it while running python code in Google co lab. As our main aim is to secure the data, we encrypt and decrypt each line from csv file and at last, calculate the execution time of each algorithm. Not only securing but we also want to compare both the algorithms and show which is more accurate and takes less time and memory. Furthermore, our proposed approach has both algorithm time and size parameters

Table 1 Performance Analysis

Algorithm	Plain text size(kB)	Cipher text size (kB)	Encryption time (s)	Decryption time (s)	Total Execution Time (s)	Ratio of plain to cipher text
Blowfish	42	50	2.00022	0.01562	2.01584	0.8400
ECC	42	90	14.9951	11.5958	26.5909	0.4666

and at last, a comparison for those two which is highly secured, and which has chance of less attacks and also takes less time. We have performed encryption and decryption for various files irrespective of their sizes and concluded which is best when comes for securing the data (Table 1).

6 Conclusion

In this study, we talked about exhaustively a progression of lightweight security answers for IoT. We overviewed research work on asymmetric cryptographic calculations and symmetric cryptographic calculations for IoT. We likewise reviewed exceptionally late examination work on Blowfish and ECC for IoT. As per our comparison, Blowfish is the best option because it takes only 2 seconds approximately, whereas ECC takes 26 seconds, which is quite more. Not only that but also in memory, the same happens when it comes to the ratio of cipher text to plain text; Blowfish ratio is 0.84 and ECC is 0.466. So, by this work, Blowfish is the better option because irrespective of our comparison, there are no attacks detected on this algorithm. Thus, further, we will also compare the parameters such as speed and power consumption for the algorithms and provide more accurately.

References

1. S. Dhanda, B. Singh, P. Jindal, Wireless technologies in IoT: Research challenges, in *Engineering Vibration, Communication and Information Processing. Lecture Notes in Electrical Engineering*, ed. by K. Ray, S. Saran, S. Rawat, vol. 478, (Springer, Singapore, 2019)
2. L. Mary Shamala, D.G. Zayaraz, et al., Lightweight cryptography algorithms for internet of things enabled networks: An overview. J. Phys.: Conf. Ser. **1717**, 012072 (2020). https://doi.org/10.1088/1742-6596/1717/1/012072. IOP Publishing
3. B.J. Mohd, T. Hayajneh, Lightweight block ciphers for IoT: Energy optimization and survivability techniques. IEEE Access **6**, 35966–35978 (2018)
4. W.J. Okello, Q. Liu, F.A. Siddiqui, C. Zhang, A survey of the current state of lightweight cryptography for the internet of things, in *IEEE International Conference on Computer, Information and Telecommunication Systems (CITS)*, (IEEE, Piscataway, 2017), pp. 292–296
5. D. Dinu, Y. Le Corre, D. Khovratovich, L. Perrin, J. Großschädl, A. Biryukov, Triathlon of lightweight block ciphers for the internet of things. J. Cryptogr. Eng. **9**(3), 283–302 (2019)
6. K.C. McKay, L. Bassham, M.S. Turan, N. Mouha, *Report on Lightweight Cryptography (NiSTIR8114)* (National Institute of Standards and Technology (NIST), 2017)

7. A. Borah, L.P. Saikia, Information security using blowfish algorithm in E-banking. Int. J. Comput. Sci. Mob. Comput. **6**(3), 50–57 (2017)
8. S. Banerjee, A. Patel, ECC Based encryption algorithm for lightweight cryptography, in *18th International Conference on Intelligent Systems Design and Applications, India*, vol. 1, (Springer, Cham, 2018), pp. 600–609
9. S. Kalanadhabhatta, K.K. Anumandla, S. Khursheed, A. Acharyya, Secure scan design with a novel methodology of scan camouflaging, in *Proceedings of European Conference on Circuit Theory and Design (ECCTD)*, (Sofia, Bulgaria, 2020a), pp. 1–4
10. S. Kalanadhabhatta, D. Kumar, K.K. Anumandla, S.A. Reddy, A. Acharya, PUF-based secure chaotic random number generator design methodology. IEEE Trans. Very Large Scale Integr. (VLSI) Syst. **28**(7), 1740–1744 (2020b)
11. P. Gautam, M.D. Ansari, S.K. Sharma, Enhanced security for electronic health care information using obfuscation and RSA algorithm in cloud computing. Int. J. Inf. Secur. Priv. (IJISP) **13**(1), 59–69 (2019)
12. A. Ksibi, H. Mhamdi, M. Ayadi, L. Almuqren, M.S. Alqahtani, M.D. Ansari, A. Sharma, S. Hedi, Secure and fast emergency road healthcare service based on blockchain technology for smart cities. Sustainability **15**(7), 5748 (2023)
13. Z.A. Jaaz, M.D. Ansari, P.S. JosephNg, H.M. Gheni, Optimization technique based on cluster head selection algorithm for 5G-enabled IoMT smart healthcare framework for industry. Paladyn, J. Behav. Robot. **13**(1), 99–109 (2022)
14. M.D. Ansari, V.K. Gunjan, E. Rashid, On security and data integrity framework for cloud computing using tamper-proofing, in *ICCCE 2020: Proceedings of the 3rd International Conference on Communications and Cyber Physical Engineering*, (Springer, Singapore, 2021), pp. 1419–1427

Air- and Sound-Quality Monitoring with Alert System Using Node MCU

Ch. Bhupati, J. Rajasekhar, T. Mohan Kumar, Ch. Nagendra, and A. Bhanu Chand

1 Introduction

The principal target of a noise- and atmosphere-quality-measuring system is to reduce sound and atmosphere pollution. This task has been made easier thanks to the adaptability and ease of Internet of Things (IoT). With the increase in industry and vehicles, the environment, including air and noise quality, has suffered. Dangerous impurities have leaked into the atmosphere. In this chapter, we make and check estimations of atmosphere and noise contamination for our investigation. The data for these estimations are taken from numerous zones. We then examine the evidence to determine the levels of atmospheric impurity and noise impurity.

2 Literature Survey

Air contamination in metropolitan zones adversely affects people and the climate. Environmental crises in India are rapidly developing, and atmospheric pollution is primarily brought about by vehicles. Furthermore, such air-quality problems can cause carious respiratory conditions. The quality of the atmosphere is substandard in major urban communities because CO_2 and various other dangerous gases are emitted from vehicles and industry.

One study has shown that air contamination–detecting devices can be used by people or equipped on adaptable vehicles [1]. In two studies [2, 3], the authors used an

C. Bhupati (✉) · J. Rajasekhar · T. Mohan Kumar · C. Nagendra · A. Bhanu Chand
Department of Electronics and Computer Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India
e-mail: bhupati@kluniversity.in

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_21

ecological detecting approach to reduce air contamination levels for residents. Presentation Sense is a versatile detecting system that is utilized to carry out regular tasks.

In another study [4], the authors presented a cloud-based shell that gathers information to continuously monitor atmospheric quality. The information gathered from observation zones are used for related geographical areas. This framework utilizes a versatile system for checking purposes. In another study, by Al Ahasan et al. [5], the authors used natural detecting approaches to raise people's awareness of contamination.

"Atmosphere impurity is a test that compromises fundamental human government assistance, harms characteristic and actual capital, and compels monetary development" [6]. This chapter aims to determine the costs and losses and communicate them to policymakers so that more assets will be allocated to improving atmospheric quality. By cleaning up urban areas [7], we can reduce harmful emissions, minimize environmental changes, and saves lives. The report on atmospheric contamination calls on governments to act. According to Dr. Chris Murray, "Of all the diverse danger factors for unexpected losses, this is one zone, the air we inhale, and over the people have little control. Policymakers in wellbeing and climate offices, just as pioneers in different ventures, are confronting developing requests – and desires – to address this issue." Finally, the observation and control of air contamination are turning into vital needs in metropolitan territories because of such contamination's considerable impact on humans and their environments.

The main objective of this chapter is to design and present a framework for monitoring contamination and to predict future contamination by incorporating contamination estimations and meteorological boundaries. First, a contamination model utilizing spatial introduction is assembled [8]. By computing barometric boundaries, the model can also determine the level of soil contamination from atmosphere contamination. By studying contamination data, the framework can predict future contamination levels and set limits [9].

The entire framework is featured on an easy-to-use website, and its system produces framework reactions. The framework is based on information for a metropolis in Macedonia. The mathematical target of the framework information was not reached, but the results were acceptable and auspicious. The framework informed the design of an Internet of Things (IoT) detecting device, and the information from it will help meet the mathematical goal above [10, 11]. A cloud-based system has been developed to monitor the atmosphere results in ThingSpeak [12]. Monitoring the air-quality system produces data to help prediction future developments [13], and some air-quality-monitoring systems are designed with fault tolerance at different levels [14, 15].

3 Existing Model

The commercial meters available include the Fluke CO meter for carbon monoxide, a CO_2 meter for carbon dioxide, and a Forbix Semicon liquefied petroleum gas (LPG) overflow sensor for alerts for LPG overflow. The analysts in this field have proposed different frameworks for observing atmospheric quality, which depend on a wireless sensor network, a global system for mobile communications, and a geographic information system. The various devices are restricted to being used as indicated. For example, Zigbee devices are intended for clients who have Bluetooth-enabled Zigbee transcollectors.

A geographic information system–based shell was used to measure several areas for air contamination. The readings for a specific area can be found in a short amount of time. The global positioning system (GPS) module is attached to a framework to precisely mark the contamination sources in a zone. The recorded information is occasionally uploaded to a personal computer through the General Parcel Radio Service. Afterward, the information shows up on the website for the client to view. Thus, an enormous number of individuals can benefit.

4 Theoretical Analysis

4.1 Wireless Sensor Network

Wireless sensor networks are associated with sensor hubs, which remotely gather information. Wireless sensor networks have restricted calculation capabilities and limited memory. Wireless sensor networks are utilized to screen for low-recurrence information in remote areas. The wireless sensor network format can detect gases and other impurities in a particular area. Carbon dioxide, carbon monoxide, and methane gases [5] are considered as pollutants in the atmosphere.

By adding more devices, an organization can prevent needing to revise or make complex changes. Additionally, wireless sensor networks can be customized for developing circumstances. They are connected to all the devices through Wi-Fi and monitor their conditions. If one device is damaged, a working device can alert the output device, and it can monitor the data from the damaged device and send those data to the cloud.

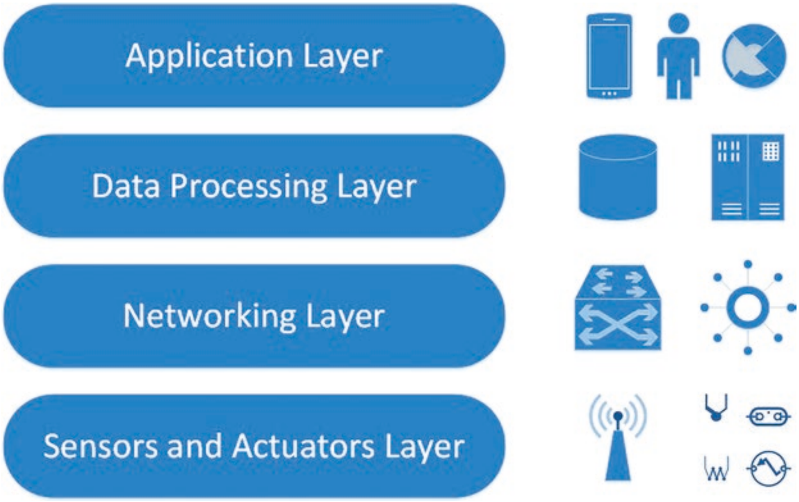


Fig. 1 Layered architecture of system for smart air- and sound-quality monitoring

4.2 Internet of Things

The Internet of Things (IoT) includes a set of Internet-connected, mechanical, and computerized devices that are enhanced with the ability to transfer data without requiring direct person-to-person communication. The IoT has progressed as a result of the convergence of wireless technology, small electromechanical shells, microservices, and the Internet. This combination allows device-derived data to be checked and studied for future improvements (Fig. 1).

4.3 Node Microcontroller Unit

Node microcontroller unit uses a free source of software in that the free-source shelling board plans are easily accessible by users. A microcontroller unit is also known as a small regulator unit. Node microcontroller units have autoflow features. They are being developed around the world.

The browse mode for the Lua project uses a type of scripting language. The software for the Lua project is based on Espresso. It is one of many other open-source projects, such as Lua JavaScript object notation and the Serial Peripheral Interface Flash File System (SPIFFS). Because of the asset limitations, users need to pick out the modules that are applicable to their purposes and customize their own software to their requirements. Approval for a 32-digit ESP32 device has been carried out.

5 Experimental Investigations

5.1 Air-Quality Parameters

Carbon dioxide (CO_2) is a dry and nonburnable gas. It is classified as a suffocating gas because it reduces the accessibility of inhaled O_2 for the body's tissues. CO_2 is a basic component of life on the planet in that during photosynthesis, sunlight is converted into usable energy as sugar. Emissions of carbon dioxide have exploded predominantly because of massive oil production. This increase in CO_2 emissions makes plants develop quickly. The fast development of bothersome plants has prompted the increased utilization of synthetic compounds to dispose of them.

Sulfur dioxide (SO_2) is a toxic gas that is distinguishable by its particular scent and taste. Like carbon dioxide, it is for the most part emitted during oil production and mechanical processes. In heavy concentrations, it causes breathing problems, especially for people with asthma. It is also contributes to acid rain.

Nitrogen dioxide (NO_2) is a highly toxic gas, distinguishable by its odd scent. It is also emitted as one of the consequences of oil production. Generally, when nitrogen monoxide is emitted into the air, it is converted to nitrogen dioxide. In high concentrations, nitrogen dioxide may cause respiratory issues. Like sulfur dioxide, it contributes to acid rain.

Tobacco is smoked by around 1.3 billion people in the world, most of whom are from preindustrial nations. Almost eight million individuals die every year because of inhaling tobacco smoke, which poses serious dangers to people of all ages.

Liquefied petroleum gas (LPG) comes from a fluid that promptly dissipates into an unscented gas. It is treated with an odorant so that any spillage can be easily recognized. It is classified as a burnable gas and a cancer-causing agent. It is toxic if its butadiene content is over 0.1%. LPG may leak as a gas or spill as a fluid. In the event that it spills as a fluid, it will promptly dissipate into a gas and will in the end form an enormous and noticeable haze of gas because it is heavier than air. As a liquid, it travels a significant distance along the ground and gathers in channels or storm cellars. When this liquid dissipates into gaseous form, it can be detonated by a spark.

Temperature and moisture measurements are significant for the security of individuals and influence our fundamental abilities. The overall impact can be checked by comparing current climatic conditions and any changes between those and records of climatic conditions taken at various other times. Humidity is a type of gas that traps warm air closer to land. As this moisture level increases, so too does the temperature, to dangerous levels (Table 1, Fig. 2).

Table 1 Air-quality condition, based on levels of pollutants

Condition	Carbon Monoxide (ppm)	Carbon Dioxide (ppm)
High quality	≤10	≤1000
Medium quality	$10 < *\alpha \leq 25$	n/a
Poor quality	>25	>1000

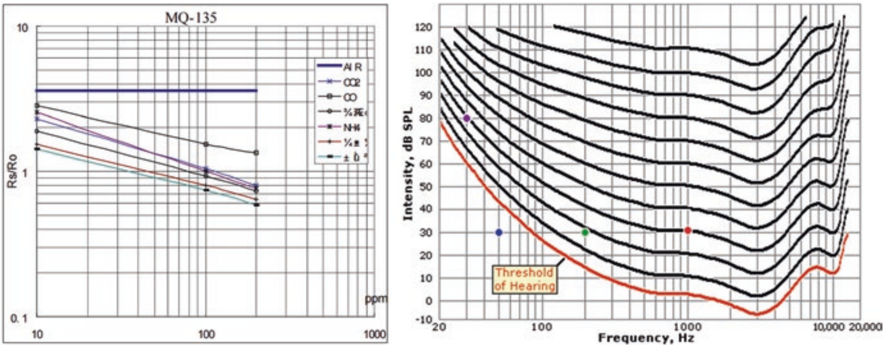


Fig. 2 (**a**) Sensitivity curve of MQ-135 sensor and (**b**) sensitivity curve of LM393 sound sensor

6 Experimental Results

6.1 Block diagram (Fig. 3)

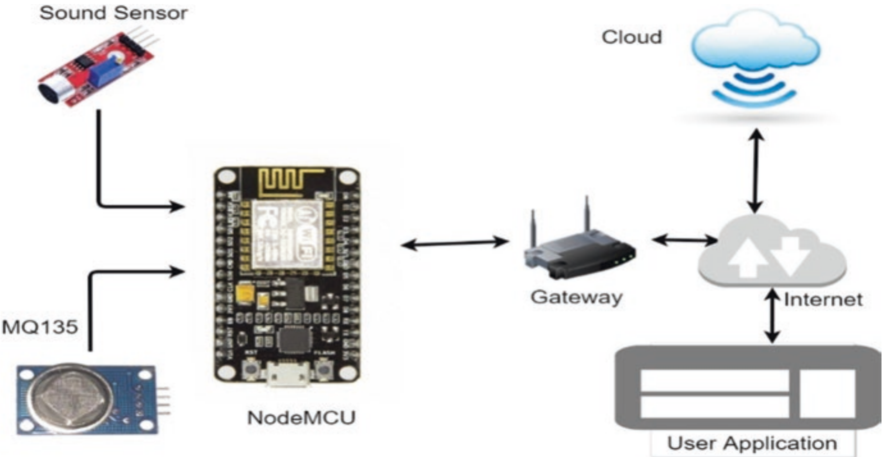


Fig. 3 Block diagram of system for monitoring air and noise quality

6.2 Algorithm

Step 1: Start the sensor to read and gather the values.
Step 2: The values are sent to the node microcontroller unit for processing to determine the threshold.
Step 3: Check the Air-Quality Index and Sound-Quality Index classified above.
Step 4: Determine which is less than or equal to the threshold according to what the Air-Quality Index and Sound-Quality Index have classified as normal.
Step 5: If the value is larger than the minimum value, then the quality is classified as poor.
Step 6: If the quality is poor, then an alarm will alert the user.
Step 7: The gathered information is made available on the attached liquid-crystal display (LCD) screen.
Step 8: The above sensor details are uploaded in an appropriate format.

6.3 Flowchart (Fig. 4)

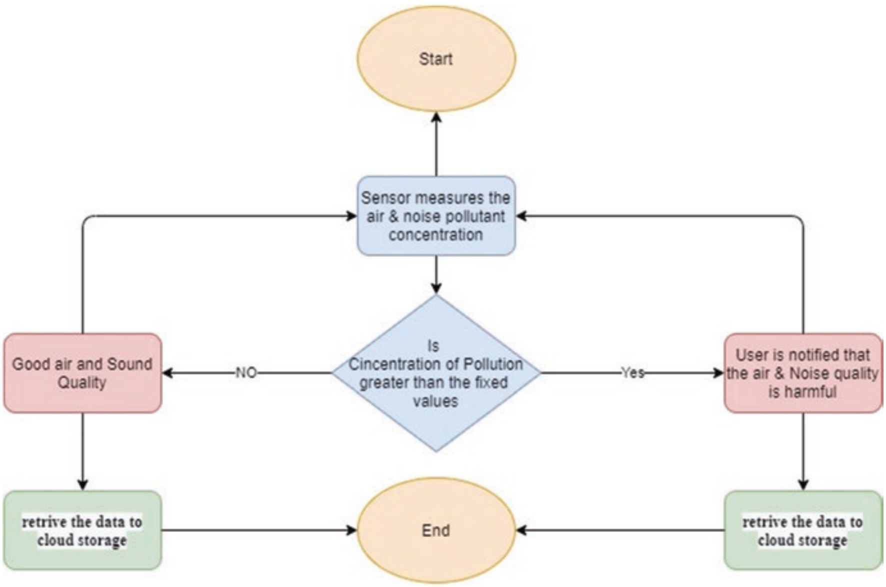
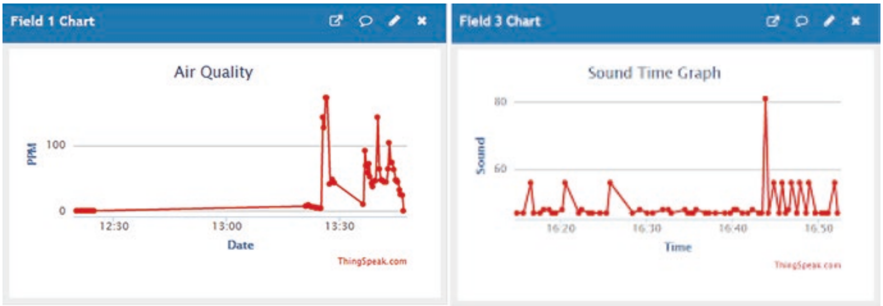
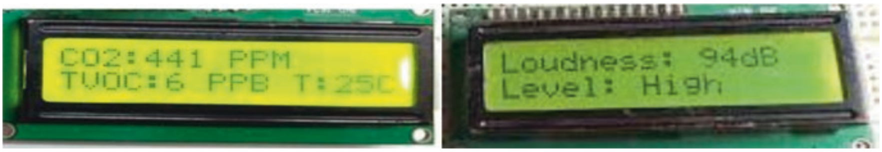


Fig. 4 Flowchart of system for measuring air and noise quality



Figs. 5 and 6 Screenshot of user interface graph on the ThingSpeak platform



Figs. 7 and 8 User display interface in 1 6 * 2 LCD

6.4 Results

We set up a ThingSpeak cloud platform to demonstrate its monitoring of noise and air quality, aiming to detect toxins in the atmosphere. If the concentration of carbon dioxide in the atmosphere is larger than the maximum limit value (i.e., 1000 parts per million) and the sound-quality value is larger than the maximum value (i.e., 90 decibels), then the alarm will trigger an alert to the user and display the values on the LCD screen, showing the information from the ThingSpeak cloud by using a Wi-Fi module—as shown in Figs. 5 and 6, and 7 and 8.

7 Study Statistics

Device statistics and experimental results have shown that atmospheric changes have been observed and recorded in several regions of Andhra Pradesh, according to the Air-Quality Index readings from several municipalities. In this process, we set up devices in various regions with different climatic conditions. Fig. 9a, shows the air condition, thanks to Air-Quality Index values, of the forest area in Tirupati. Fig. 9b shows the air condition, thanks to Air-Quality Index values, of the coastal area and metropolitan city in Visakhapatnam. Figure 9c shows the air condition of the river area, and Fig. 9d shows the air condition of the capital cities of Rajamahendravaram and Amaravathi. Those results were observed and recorded at specific times on the same day.

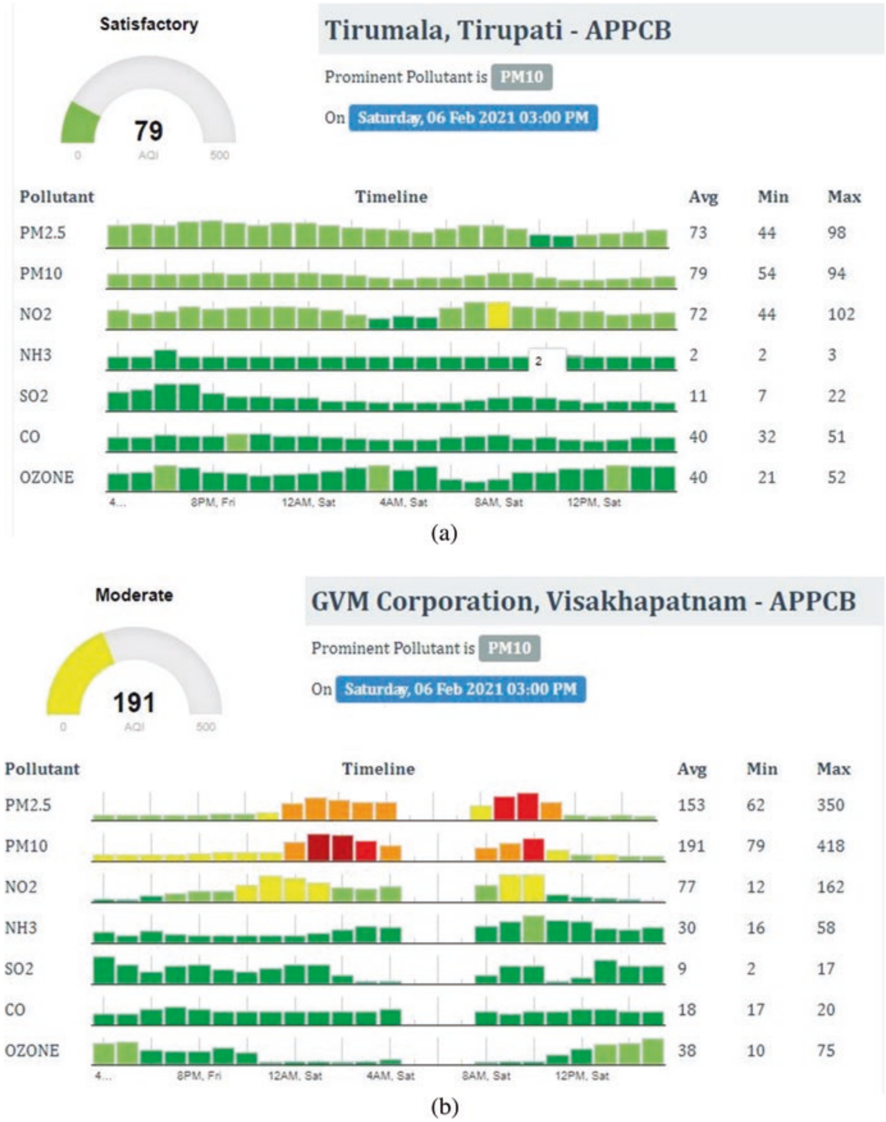
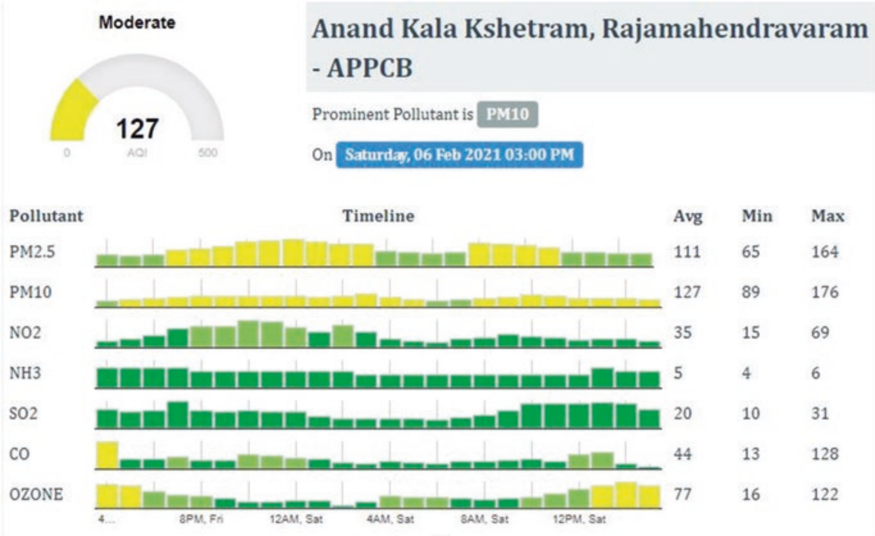
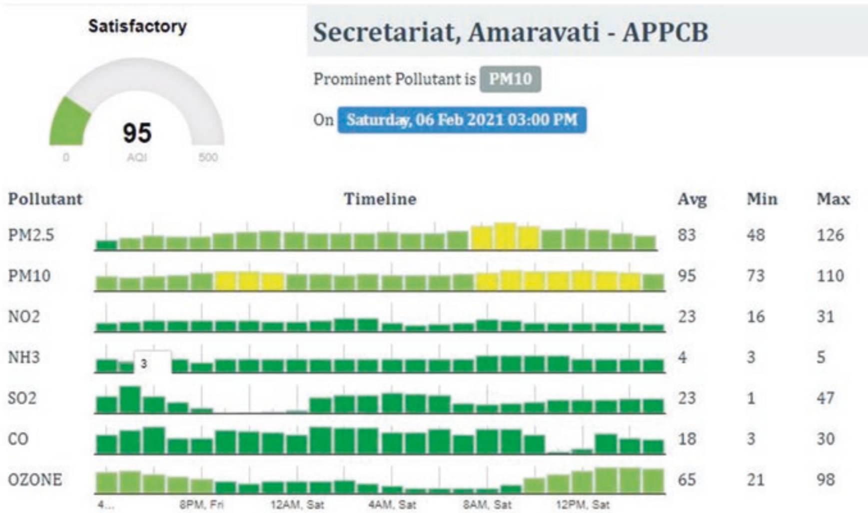


Fig. 9 Air-Quality Index values: (**a**) in Tirupati city, (**b**) in Visakhapatnam city, (**c**) in Rajamahendravaram city, (**d**) in Amaravati city



(c)



(d)

Fig. 9 (continued)

8 Conclusion

Devices in the environment were set up to monitor air quality in the atmosphere. Sensor devices in the environment measure atmospheric conditions and report that data to other connected devices. These data can be assessed, and the results of these assessment can be shared through Wi-Fi.

The technique introduced in this chapter monitors the environment in a new way and included several variables. The air-quality- and noise-quality-monitoring system uses the Internet of Things to check the limits of both and report the sensor data to the cloud (ThingSpeak, Google Spread Sheets).

The sensor data will help in future assessments and can be shared among stakeholders. This small device can be used in any metropolitan zone for pollution monitoring, and its data can be used to predict and compare levels of pollution in the environment.

References

1. H. Zhi-Gang, C. Cai-Hui, The application of Zigbee based wireless sensor network and GIS in the air pollution monitoring, in *2009 International Conference on Environmental Science and Information Application Technology*, vol. 2, (IEEE, Piscataway, 2009), pp. 546–549
2. P. Pal, R. Gupta, S. Tiwari, A. Sharma, IoT based air pollution monitoring system using Arduino. Int. Res. J. Eng. Technol. (IRJET) **4**(10), 1137–1140 (2017)
3. G. Parmar, S. Lakhani, M.K. Chattopadhyay, An IoT based low cost air pollution monitoring system, in *2017 International Conference on Recent Innovations in Signal Processing and Embedded Systems (RISE)*, (IEEE, Piscataway, 2017), pp. 524–528
4. H.N. Shah, Z. Khan, A.A. Merchant, M. Moghal, A. Shaikh, P. Rane, IOT based air pollution monitoring system. Int. J. Sci. Eng. Res. **9**(2), 62–66 (2018)
5. M.A. Al Ahasan, S. Roy, A.H.M. Saim, R. Akter, M.Z. Hossain, Arduino-Based real time air quality and pollution monitoring system. Int. J. Innov. Res. Comput. Sci. Technol. **6**(4), 81–86 (2018)
6. S. Maurya, S. Sharma, P. Yadav, Internet of things based air pollution penetrating system using GSM and GPRS, in *2018 International Conference on Advanced Computation and Telecommunication (ICACAT)*, (IEEE, Piscataway, 2018), pp. 1–5
7. A.K. Saha, S. Sircar, P. Chatterjee, S. Dutta, A. Mitra, A. Chatterjee, S.P. Chattopadhyay, H.N. Saha, A raspberry Pi controlled cloud based air and sound pollution monitoring system with temperature and humidity sensing, in *2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)*, (IEEE, Piscataway, 2018), pp. 607–611
8. V. Sajjan, P. Sharma, Analysis of IoT architecture for low cost air pollution monitoring systems, in *2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA)*, (IEEE, Piscataway, 2020), pp. 63–69
9. S. Dhingra, R.B. Madda, A.H. Gandomi, R. Patan, M. Daneshmand, Internet of Things mobile–air pollution monitoring system (IoT-Mobair). IEEE Internet Things J. **6**(3), 5577–5584 (2019)
10. M. Korunoski, B.R. Stojkoska, K. Trivodaliev, Internet of things solution for intelligent air pollution prediction and visualization, in *IEEE EUROCON 2019-18th International Conference on Smart Technologies*, (IEEE, Piscataway, 2019), pp. 1–6
11. R.K. Kodali, S. Pathuri, S.C. Rajnarayanan, Smart indoor air pollution monitoring station, in *2020 International Conference on Computer Communication and Informatics (ICCCI)*, (IEEE, Piscataway, 2020), pp. 1–5
12. J.R.K. Dabbakuti, C. Bhupati, Ionospheric monitoring system based on the Internet of Things with ThingSpeak. Astrophys. Space Sci. **364**(8), 1–7 (2019)
13. A.K. Kumar, A. Sri Lakshmi, P.J.N. Rao, Moving average method based air pollution monitoring system using IoT platform. J. Phys. Conf. Ser. **1706**(1) (2020). https://doi.org/10.1088/1742-6596/1706/1/012078

14. J.K.R. Sastry, Bhupathi, Enhancing fault tolerance of IoT networks within device layer. Int. J. Eng. Technol. Eng. Res. **8**(2), 491–509 (2020). https://doi.org/10.30534/ijeter/2020/37822020
15. Bhupathi, J.K.R. Sastry, A framework for effecting fault tolerance within IoT network. J. Adv. Res. Dyn. Control Syst. **10**(2), 424–432 (2018)

IoT-Enabled Patient Assisting Device Using Ubidots Webserver

Chella Santhosh, P. Kanakaraja, M. Ravi Kumar, C. H. Sai Sravani, V. Ramjee, and Y. Asish

1 Introduction

Internet of Things (IoT) has made its mark in the clinical sectors as well as industrial purposes with the initiation of basic sensors and contraptions. IoMT (Internet of Medical Things) is an assortment of clinical gadgets related with clinical thought IT frameworks for various applications. The development of IoMT has especially affected medical care for the matured and handicapped individuals, however not simply restricted to them. In the quick moving world, even standard people need uphold with their day-by-day exercises. One such significant action is to assist them with taking their meds consistently without missing any portion. The by-and-by accessible gadgets for medicine adherence have a few disadvantages and are confined to fundamental usefulness like filling just a solitary need of an update framework [1]. The multifaceted nature and cost related with more detailed frameworks prompted the advancement of another versatile gadget in this chapter named as "MEDIBOX" – a clever drug administering gadget. It is intended to help the older individuals who frequently neglect to take their prescriptions or take some unacceptable pills or dose. It likewise causes individuals who used to travel much of the time and should take ordinary prescription. Subsequently, the proposed system of medical box with the feature of IOT, which is used in many applications of healthcare industry.

C. Santhosh · P. Kanakaraja (✉) · M. R. Kumar · C. H. S. Sravani · V. Ramjee · Y. Asish
Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A.P, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_22

2 Literature Survey

The IoT is an interconnection of various devices and sensors over an internet, where the data of these are collected. Without the use of human-to-human or human-to-computer communication, will send and communicate data over the relationship. Vainglorious as it would sound, the IoT has quite recently become part of our consistent life and no vulnerability and it will settle there for good [2]. Considering this, let us right now have a compact research on the device behind the IoT world that makes it go around. PC innovation has been with us since the focal point of the twentieth century. Notwithstanding, the development behind the IoT had quite recently been in the making for a long time before the PCs opened up to everybody on the planet. The investigation of telemetry (Greek tele = far off, and metron = measure), the most reliable harbinger to the IoT, has been used to check and assemble environment data or track regular life over wire phone lines, radio waves, and satellite correspondences as of now since the second half of the nineteenth century. Despite the whole of its specific requirements, it laid ground to machine-to-machine correspondence (M2M), which, growing consistently alongside the degrees of progress in accessibility courses of action, delivered the chance of the IoT as we likely are mindful of it today.

3 Proposed Methodology

The IoT is comprehensively seen by many researchers as maybe the most present-day developments with the intention to definitely security and address critical impacts inside the overall population [3]. The IoMT gives an area where the patient's fundamental breaking point subtleties get bestowed through an entryway onto a cloud-based stage where it is dealt with, amassed, and investigated. Helped living is another methodology, which guarantees to address the requirements of older individuals.

Distinctively, this medicine box has made the industry and the world smarter during the last 30 years. Utilizing half breed programmed update, the system reminds the patient to take the medication in accordance with a specific plan that is determined by customer intake. Medication update and clinical consideration is an application where patients can set a preferred time or remainder for their portion timings without the need to remember their prescription portion timings every time. With the help of DS3231, RTC chip is used to set date, time, and medication portrayal. A message will be delivered in the form of an email as picked by the patients [4].

In this chapter, the game plan not simply alarms the eager about the admission of cure but it similarly builds up a sensible environment to keep up the adequacy of the medicine.

4 Methodology

Various types of devices used in this chapter are explained below.

4.1 ESP32

The structure of ESP32 is depicted in Fig. 1. It is a development of the straightforwardness low-power system on a chip microcontroller with joined Wi-Fi and dual mode Bluetooth.

4.2 DHT11 Sensor

DHT11 is a temperature and humidity sensor module. The operating voltage is between 3.5 V to 5.5 V. Operating current is 0.3 mA. It measures a temperature range of 0C to 50C. It is a general saturation sensor [5] as shown in Fig. 2.

4.3 RTC DS3231

RTC implies real time clock. RTC modules are basically TIME and DATE recalling systems, which have a battery which makes the module run [6]. So, we can know exact TIME and the DATE from this module at whatever point we need. Its working voltage is 2.3 V to 5.5 V as shown in Fig. 3.

4.4 20 × 4 LCD Display

A liquid valuable stone exhibit (LCD) is a level board show, electronic visual presentation, or video show that utilizes the light changing properties of fluid gems [7]. 20 × 4 infers that 20 characters can be appeared in all of the 4 segments of the 20 × 4 LCD, thus a total of 80 characters can be appeared at any instance of time as shown in Fig. 4.

Fig. 1 Structure of ESP32 Module

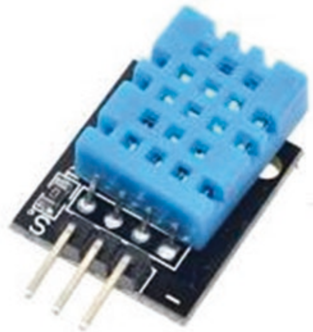


Fig. 2 Structure of DHT11 Sensor

Fig. 3 Structure of RTC DS3231

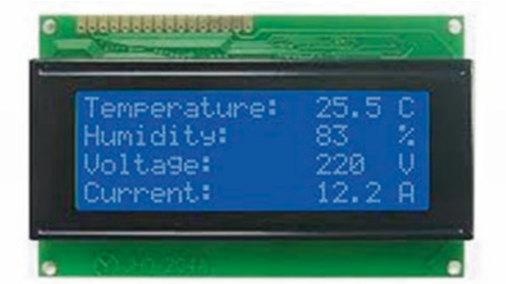


Fig. 4 Structure of LCD Display

4.5 I2C Module

It changes sequential information over to resemble information. The PCF8574 I2C chip integrated within the I2C module transforms I2C serial data into parallel data for the LCD display [8]. The I2C module's construction, as depicted in Fig. 5.

4.6 LM35 Sensor

The output voltage of the LM35 series precision integrated-circuit temperature sensors is linearly proportional to the temperature in degrees Celsius. In comparison to linear temperature sensors calibrated in Kelvin, the LM35 device has an advantage

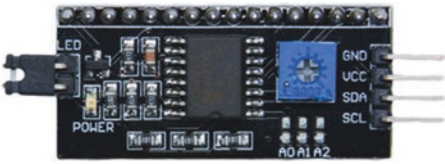


Fig. 5 I2C Module

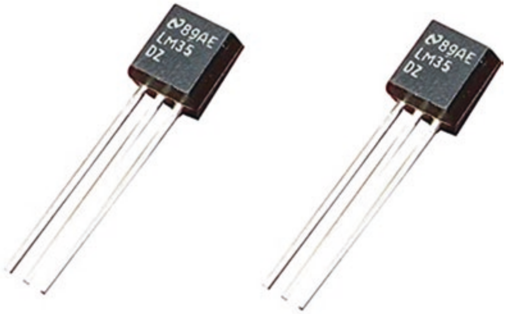


Fig. 6 Structure of LM35

because it does not require the user to deduct a significant constant voltage from the output in order to gain convenient Centigrade scaling. The LM35 device can deliver typical accuracies of 14°C at room temperature and 34°C over the entire temperature range of 55°C to 150°C without the need for any external calibration or trimming. Trimming and calibration at the wafer level ensure lower costs. Interfacing to readout or control circuitry is notably simple with the LM35 device's low output impedance, linear output, and exact intrinsic calibration [9]. The structure of the LM35 is seen in Fig. 6.

4.7 Buzzer

Ringer is utilized as a sign in a little yet convincing area to add sound highlights to our framework. Working voltage is 4–8 V DC. Sound type is continuous beep. The physical characteristics of the piezo buzzer are depicted in Fig. 7, along with a piezoelectric ringer, speaker, active passive buzzer, and module.

4.8 Circuit Diagram

As shown in Fig. 8 is the schematic diagram of proposed implementation.

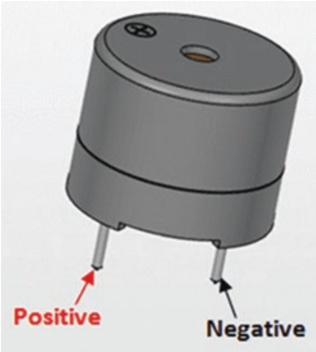


Fig. 7 Structure and pin description of Buzzer

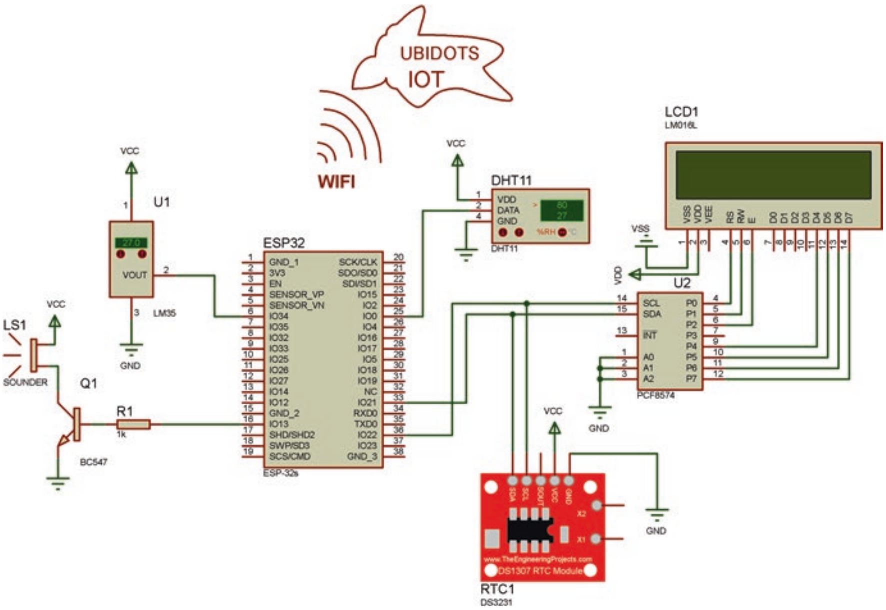


Fig. 8 Circuit Diagram of the Full Setup

5 Flow Chart

In this first phase, we need to initialize the sensors to measure physical parameters such as DHT11, DS3231, and LM35 sensor. After assembling all the circuit connections as per the circuit diagram and after receiving the required power supply, the title of the project is displayed on the 20 × 4 LCD Display. After initializing IoT Ubidots web server, this receives the sensor information from the sensors. Here, sensor acquisition takes place. And the informational records are going to be updated every time. Depending on parameters, a buzzer indication is shown in Fig. 9 as it represents the program flow and conditional statements.

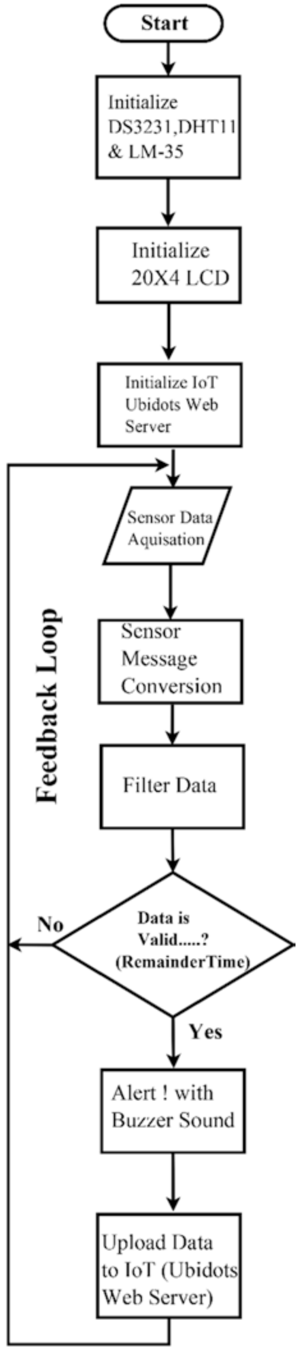


Fig. 9 The proposed implementation Algorithm

6 Block Diagram

Figure 10 shows the basic steps involved in the block diagram consisting of multiple sensors like DHT11, LM35, and DS3231, which are used to monitor the room temperature and humidity. This data is given to micro controller and then displayed on LCD.

7 Results and Discussions

As shown in Fig. 11, it displays all parameter values on the 20 × 4 LCD display and simultaneously monitors these values in the IoT Cloud Platform.

As shown Fig. 12, it describes the creation of physical parameters in Ubidots IoT platform.

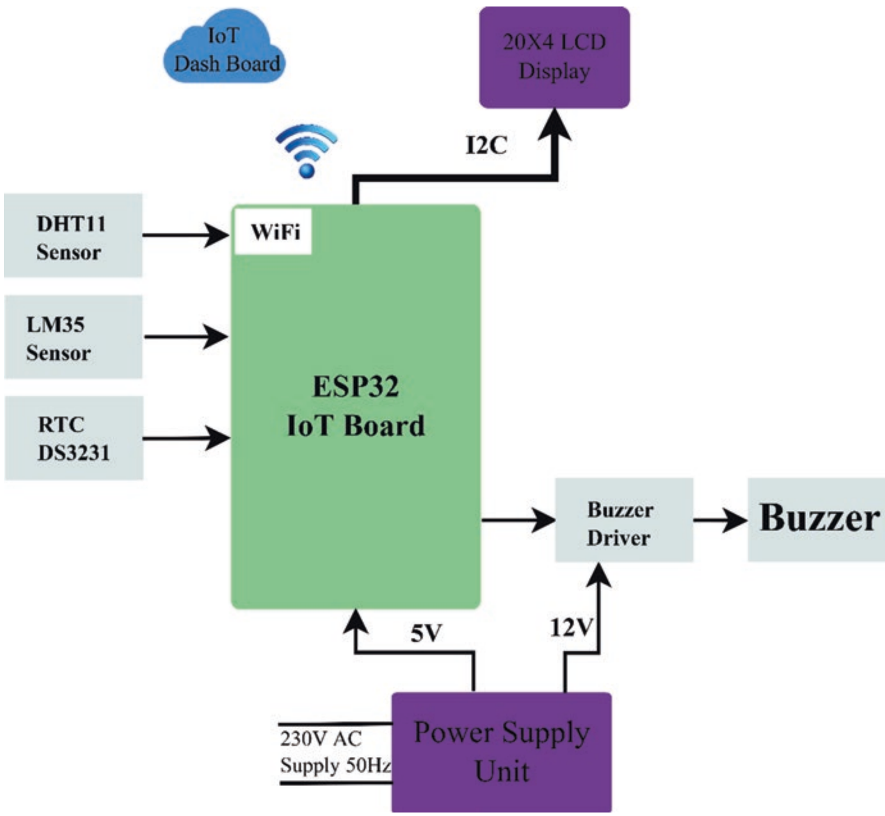


Fig. 10 Proposed Block Diagram

Fig. 11 Displaying the project title on the LCD Display

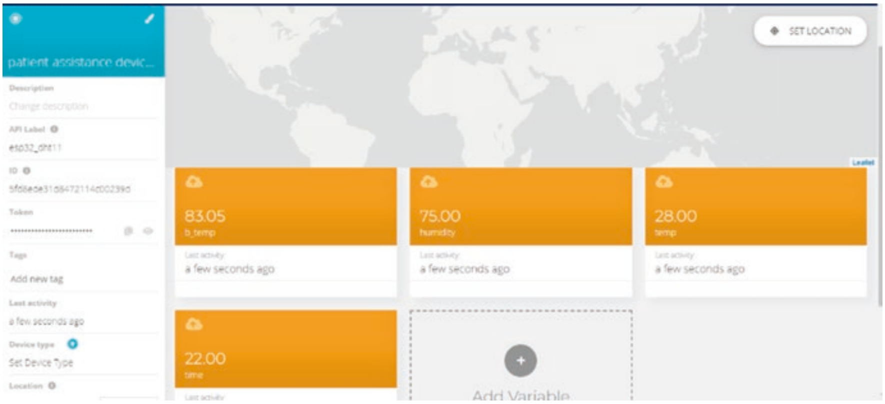


Fig. 12 Monitoring all the results such as temperature, humidity, and time values on Ubidots dashboard

As shown in Fig. 13, it describes about the overall connections of the real time implementation.

As shown in Fig. 14, we are displaying the output values on 20 × 4 LCD display.

Figure 15 illustrates, overall outcomes will be tracked in Ubidot's GUI platform for easier comprehension and the data will be store as CSV file format for feature analytics.

8 Conclusion

In the current situation, individuals are occupied with their reliable plans and cannot recollect their drug timings, which places them in an infuriating condition. Another device, the Medical Box, which aims to completely assist a patient in a clear and important way, was orchestrated for the suggested implementation module. It alerts the patient to burn-through the cures and gives a reasonable gathering condition to the medications. Cutoff of medications use subtleties can help the master for future recommendations, for example, the adequacy of remedies on the patient with the

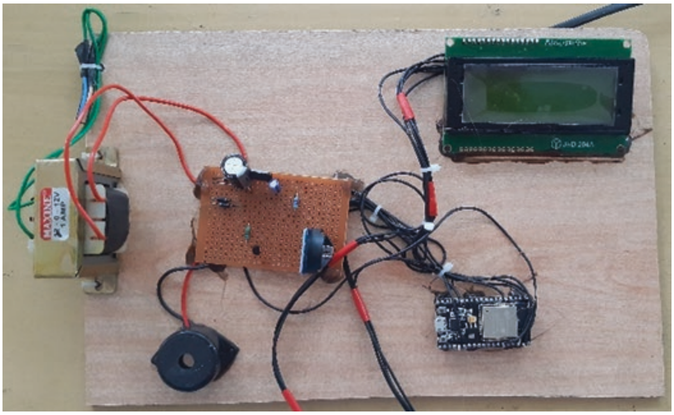


Fig. 13 Overall connection view of the entire system

Fig. 14 Displaying the overall output on the LCD display

Fig. 15 Overall result: the temperature, humidity, and the time over that area is shown in the Ubidots screen

bonafide foundation of drug use assisting him with endorsing in like manner to the patient. The prescription subtleties are likewise dealt with in a secured cloud near to its collecting subtleties. One test confronted with the plan of the compartment was the cooling module.

9 Future Scope

As a future climb to the medical box, flourishing checking sensors devices can comparatively be added to the framework. Measuring the breaking point in addition to considering the blueprint of various components inside the case to meet the needs of diverse clients in a room temperature, conditions related to the design delivers the protection in a more intelligent manner. Additionally, to incorporate Artificial Intelligence (AI) algorithms that use an existing database to identify diseases based on their symptoms.

References

1. M.T. Brown, J.K. Bussell, Medication adherence: WHO cares? Mayo Clin. Proc. **86**(4), 304314 (2011). https://doi.org/10.4065/mcp.2010.0575
2. J.A. Cramer, R.H. Mattson, M.L. Prevey, R.D. Scheyer, V.L. Ouellette, How often is medication taken as prescribed? A novel assessment technique. Erratum in JAMA **262**(11), 1472 (1989 Sep 15)
3. Machine Ying-Wen Bai and Ting-Hsuan Kuo, Medication adherence by using a hybrid automatic reminder, in *IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, USA*, (2016)
4. D. Sathish Kumar, P. Gajendran, R. Satheesh Kumar, B. Lalitha, IoT based smart irrigation system, in *Innovations in Information and Communication Technology Series*, (2020)
5. J.X. Low, K.W. Choo, IoT-enabled heart monitoring device with signal De-noising and segmentation using discrete wavelet transform, in *2018 15th International Conference on Control, Automation, Robotics and Vision (ICARCV), Singapore*, (2018), pp. 119–124. https://doi.org/10.1109/ICARCV.2018.8581315
6. M. Saravanan, A.M. Marks, MEDIBOX-IOT enabled patient assisting device. IEEE Int. Conf. (2018)
7. S. Pirbhulal, N. Pombo, V. Felizardo, N. Garcia, A.H. Sodhro, S.C. Mukhopadhyay, Towards machine learning enabled security framework for IoT-based healthcare, in *2019 13th International Conference on Sensing Technology (ICST), Sydney, NSW, Australia*, (2019), pp. 1–6. https://doi.org/10.1109/ICST46873.2019.9047745
8. S. Gill, J. Hearn, G. Powell, E. Scheme, Design of a multi-sensor IoT-enabled assistive device for discrete and deployable gait monitoring, in *IEEE Healthcare Innovations and Point of Care Technologies (HI-POCT), Bethesda, MD*, vol. 2017, (2017), pp. 216–220. https://doi.org/10.1109/HIC.2017.8227623
9. U. Jaimini, PhD forum: Multimodal IoT and EMR based smart health application for asthma management in children, in *2017 IEEE International Conference on Smart Computing (SMARTCOMP), Hong Kong*, (2017), pp. 1–2. https://doi.org/10.1109/SMARTCOMP.2017.7947025

Smart Home-Based Smoke Detection with Image Surveillance System

K. Kiran Kumar, P. S. G. Aruna Sri, G. Vijay Kumar, and G. Murali

1 Introduction

Smoke detection system is able to utilize for the initial intimation of upcoming fire events. When smoke is intense, it is not clear and no visible knowledge of the original frame is available. Even though the smoke is present, a slight radiant view of the environment is still obtainable which provides enough information to detect smoke. The risk of dying in a home fire is decreased with working smoke alarms.

The United States Fire Protection Association reports indicate approximately 0.53% deaths in infrastructure with working smoke system compared to 1.18 deaths without. Internet of Things is an appointment of interrelated processing gadgets, mechanical and computerized machines, or individuals that are given one-of-a-kind identifiers and therefore the capacity to maneuver information over a network that allows us to make more intelligent choices [1]. If we are able to observe smoke in AN early amount, we tend to might stop hearth. In our proposed smoke detection system it uses an MQ135 sensor to detects the smoke or gas leakage and then by using esp32 camera module it will capture a real-time image and then notify the house owner's by using a Telegram Bot through a mobile phone by sending the alerts, followed by the captured real-time images [2].

K. Kiran Kumar (✉) · G. Vijay Kumar · G. Murali
Department of CSE, KLEF Vaddeswaram, Vaddeswaram, Andhra Pradesh, India
e-mail: kiran5434@kluniversity.in

P. S. G. Aruna Sri
Department of ECM, KLEF Vaddeswaram, Vaddeswaram, Andhra Pradesh, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_23

2 Literature Survey

Sowah et al. [3] used fuzzy logic to build and implement a fire detection system for vehicles. For fire detection, they used temperature, flame, and smoke sensors. The technology can also put out a fire in 20 seconds, and they employed the air-conditioning system to do it.

Sudhir G. Nikhade outlines a wireless sensor network system that was created utilising open source hardware platforms such as the Raspberry Pi and Zigbee in [4].

Chen et al. [5] and Gaikwad et al. [6] proposes a fire detection system based on video processing. To detect a likely fire outbreak, they analyzed smoke color and spread characteristics. However, processing the photos takes time and requires advanced resources. Because clothes are highly flammable, a fire in a garment factory should be spotted as soon as feasible.

Fuzi et al. [7] created a ZigBee wireless fire alarm detecting system. The Arduino Uno Microcontroller, temperature sensor, buzzer alarm, and operational software comprise the system. The device relied solely on a temperature sensor to detect fire, and the receiver could receive signals from up to 10 m away.

Islam et al. [8] created and implemented a system that uses camera image processing to identify fire outbreaks. Although this is an innovative technique, it is not as effective or accurate as a sensor-based system for detecting fire [9].

Samudera and Sugiharto [10] Demonstrated a concept for detecting forest fires utilizing a wireless sensor network. Apart from sensor nodes, they employed software called mobile agent. Data is collected from the sensor nodes and returned to the sink by software mobile agents. They didn't put the system in place.

3 Methodology

In this project, smoke detection is carried out by Mq135 sensor. This sensor is used to detect the smoke or LPG gas and also helps to find out the quality of air, that is, percentage of CO_2, nitrogen, etc in air can be measured.

Our project is designed to detect smoke and alert the people by giving an alarm and a message to the corresponding user. This project is made out by integrating Mq135 sensor with Esp32 camera module and a buzzer attached to it. By the above combination Whenever a smoke is detected near the system, It analyzes and makes sound to alert the user, It also sends a picture with the help of ESP32 camera module. So the user can see the picture in his mobile and can recognize the impact of situation going out near the system. The notification alert and image are sent through the telegram messaging app. The location information of the system is also sent through to the user through the same app.

For the project integration Mq135 sensor is connected to the esp32 camera module with the breadboard as intermediate. Buzzer is also connected to this system. Mq135 sensor senses the smoke or LPG or gas and sends a signal to the buzzer and esp32 module [11]. Buzzer starts to buzz, simultaneously esp32 module takes a snap/picture of the situation infront of it. The photo which is taken by esp32 module is processed and gray scaled and converted into Low kb jpg Image format, so that it can be sent to owner/authorized person with in less time because of very low image size.

Mq135 sensor consists of four pins. Those are (a) Vcc, (b) digital out (do), (c) analog output (Ao), (d) ground (Gnd).

The connection with esp32 is as follows:

The power supply to the mq135 sensor is given through the esp32 camera module by connecting it with the 3 V pin on the esp32 board. Mq135 ground pin is connected with the esp32 board ground pin. By the connection of these pins the power flow is maintained normally. For our project we have chosen the result in an analog way from Mq135 sensor, So analog output in Mq135 sensors connected with the gpio13 on esp32 board [12].

Whenever a smoke detected by the sensor, mq135 sensor sends the signal to esp32 module through gpio13 on esp32 board. It is data pin so the esp32 can analyze that smoke is detected.

Buzzer consists of two pins. One is positive pin (6 V) and negative pin (ground), these pins are interconnected with smoke sensor and esp 32 camera module.

Esp32 camera module is programmed with the help of FTDI module for the system to work [13, 14]. Esp32 module interconnects with telegram bot. The telegram bot is created by ourself and programmed to the esp32 camera module, So, whenever smoke is detected, Notification alert, location information, and picture are sent to the telegram bot. The user gets notified through this way.

The communication between telegram bot and esp32 modules is as follows:

Communication with Bot: create a bot in telegram using basic telegram api which gives a better exposure towards the functioning we also find many shortcuts in which they are not very much fast.

Connecting our channel to the Telegram account:

While connecting the channel to esp boards, we must get an api key and chat id from the telegram. Sending an http request to telegram: The data is transferred through the internet so we must use a-protocol to transfer data over Internet. We can also request smoke status by using "/start "command in telegram bot. We can use different commands like /photo, /Flash, /smoke_status.Major plus point is that owner knows the causes the smoke (Figs. 1 and 2).

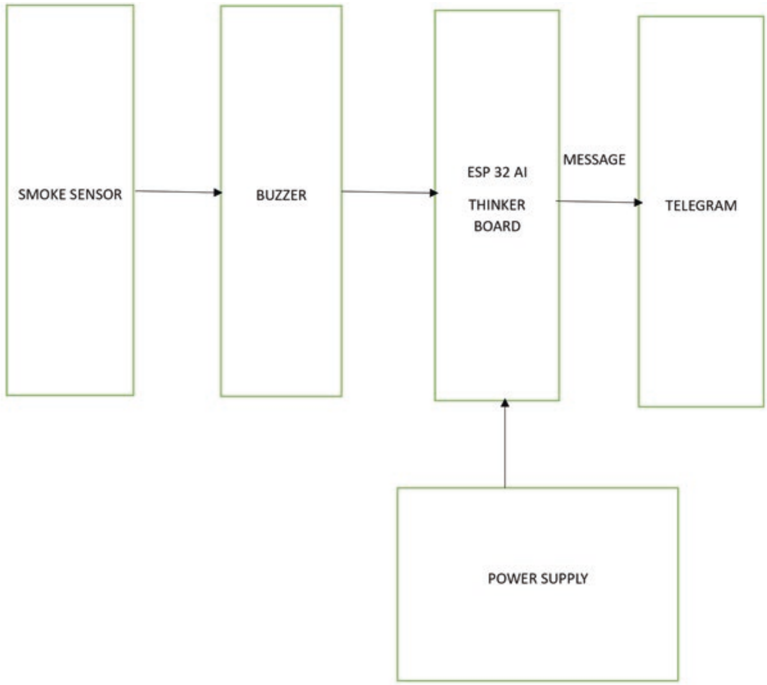


Fig. 1 Schematic Diagram of the System

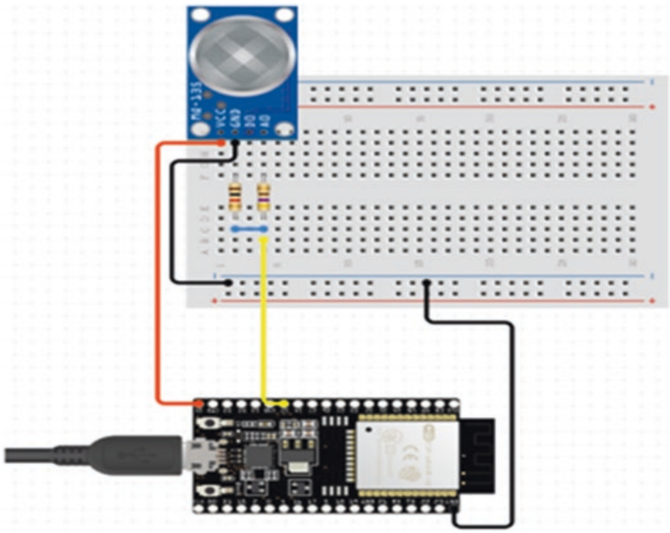


Fig. 2 Circuit diagram

4 Materials and Components

ESP32 AI Thinker Camera Module: The ESP32-CAM is a little size, low power utilization camera module dependent on ESP32. It accompanies an OV2640 camera and gives installed TF card slot.

The ESP32-CAM can be broadly utilized in insightful IoT applications, for example, remote video checking, Wi-Fi picture transfer, QR Identification, etc.

MQ-135 Sensor: Smoke sensor is used to detect smoke, LPG gas. We can also check air quality and percentage of co_2 and nitrogen etc.

Buzzer: A buzzer is a device used to alert the user/owner to notify of something like fire and smoke alert, motion/movement alert.

FTDI programmer module: This module is used to write code for esp 32 cam. FTDI is a programming module. We use this to program a code to the system [15].

5 Result

The Functionality of the system can work in any location. The output gives a view of the smoke and atmosphere near the system. The location info and low image size increase project accuracy with less response time (Figs. 3 and 4).

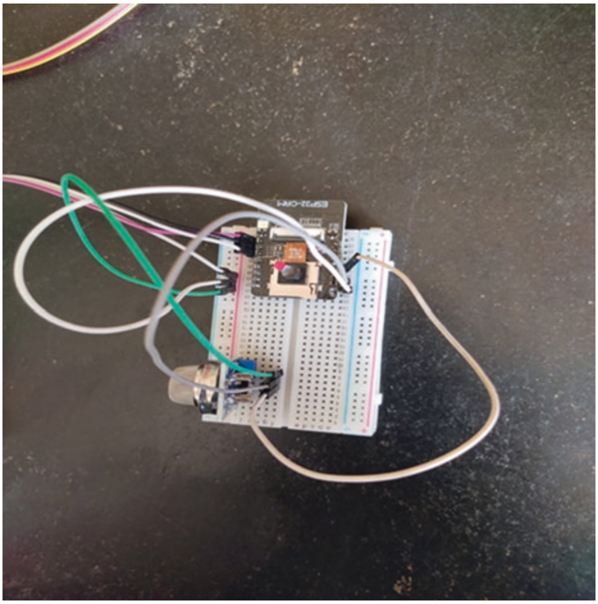


Fig. 3 Project model

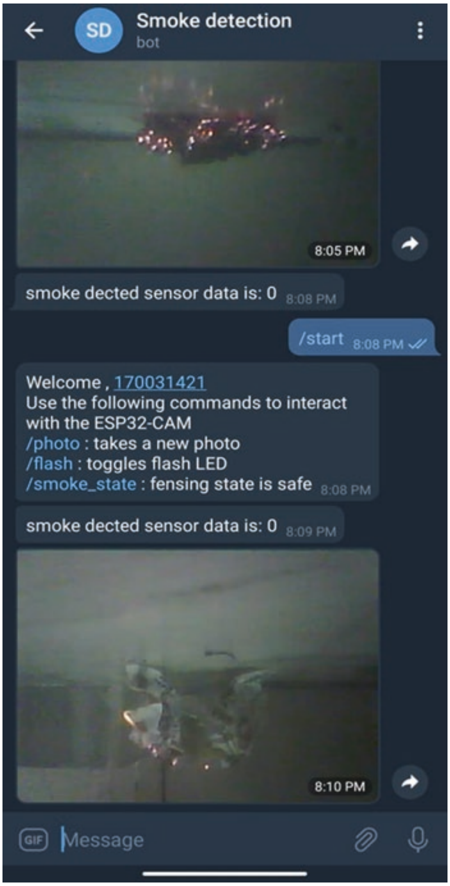


Fig. 4 Telegram output

6 Conclusion

Gas leaks and cylinder blasts are two of the most common societal problems in our neighborhood. Our smart device can detect the gas in seconds and send an alert to the owner and protection groups immediately, with two types of interfaces (Adafruit and Telegram) and low maintenance and manufacturing costs. However, if many sensors are added to the same module, the data rate of Adafruit is reduced, so if many sensors are added to the same module, the data rate of Adafruit is reduced. This strategy has been demonstrated in the lab to function and produce satisfactory results. It assists in alerting the user and stores/sends smoke photos. We can include the concept of deep learning into it, but it will not be 100% accurate.

References

1. D.F. Murad, B.S. Abbas, A. Trisetyarso, W. Suparta, C.H. Kang, Development of smart public transportation system in Jakarta city based on integrated IoT platform, in *2018 International. Conference on Information and Communications Technology (ICOIACT)*, (IEEE, Piscataway, 2018), pp. 872–878
2. V.Y. Lukman Hakima, Deteksi kebocoran gas LPG menggunaka Detektor Arduino dengan Algoritma Fuzzy Logic Mandani. Rekayasa Sist. dan Teknol. Inf. **1**(2), 114–121 (2017)
3. R. Sowah et al., Design and implementation of a fire detection and control system for automobiles using fuzzy logic, in *Proceedings of Industry Applications Society Annual Meeting*, (IEEE, Piscataway, 2016)
4. L. Yu, N. Wang, X. Meng, Real-time forest fire detection with wireless sensor networks, in *Proceedings of International Conference on Wireless Communications, Networking and Mobile Computing*, vol. 2, (IEEE, Piscataway, 2005)
5. T.-H. Chen et al., The smoke detection for early fire- alarming system base on video processing, in *Proceedings of International Conference on Intelligent Information Hiding and Multimedia*, (Pasadena, California, 2006)
6. K.M. Gaikwad et al., Fire monitoring and control system. Proc. Int. Res. J. Eng. Technol. (IRJET) May-2016, (2016), 3(5), PP:1800–1802
7. M.F.M. Fuzi et al., HOME FADS: A dedicated fire alert detection system using ZigBee wireless network, in *Proceedings of Control and System Graduate Research Colloquium (ICSGRC)*, (IEEE, Piscataway, 2014)
8. T. Islam, H.A. Rahman, M.A. Syrus, Fire detection system with indoor localization using ZigBee based wireless sensor network, in *Proceedings of International Conference on Informatics, Electronics & Vision (ICIEV)*, (IEEE, Piscataway, 2015)
9. R.C. Luo, K.L. Su, Autonomous fire-detection system using adaptive sensory fusion for intelligent security robot. IEEE/ASME Trans. Mechatron. **12**(3), 274–281 (2007)
10. D. Samudera, A. Sugiharto, Sistem Peringatan dan Penanganan Kebocoran Gas Flammable Dan Kebakaran Berbasis Internet of Things (Iot). J. TeknoSAINS Seri Tek. Elektro **1**(1), 1–13 (2018)
11. K.L. Su, Automatic fire detection system using adaptive fusion algorithm for fire fighting robot, in *2006 IEEE International Conference on Systems, Man and Cybernetics*, vol. 2, (IEEE, Piscataway, 2006), pp. 966–971
12. S.L. Rose-Pehrsson, S.J. Hart, T.T. Street, F.W. Williams, M.H. Hammond, D.T. Gottuk, M.T. Wright, J.T. Wong, Early warning fire detection system using a probabilistic neural network. Fire. Technol **39**(2), 147–171 (2003)
13. C.P. Sari, Aktif Pencegahan Kebakaran Di Hotel Graha Agung Semarang Tahun 2015 (2016)
14. F. Valdes-Perez, R. Pallas-Areny, Introduction to microcontrollers, in *Microcontrollers*, (CRC Press, Boca Raton, 2010), pp. 1–14
15. T.D.I. Bei, Rancang Bangun Sistem Proteksi Kebakaran pada Mini Smart Kitchen berbasisi Arduino. J. Kaji. Tek. Elektro **2014**(April), 2014 (2014)., E – ISSN

IoT-Based Smart Irrigation System

P. S. G. Aruna Sri, K. Kiran Kumar, B. B. V. S. V. Prasad, and G. Vijay Kumar

1 Introduction

In numerous nations, most of the economy relies upon horticulture, and there is an extraordinary need to modernize the traditional farming practices for the better efficiency. Due to inefficient water utilization, the groundwater is depleting day by day, absence of downpours and shortage of land water additionally brings about decrement in volume of water on earth. In our everyday life likewise, water is fundamental need. Horticulture is one of fields where water is needed in huge amount. Water is an essential component of our daily lives. Water wastage is viewed as a significant issue. Each time abundance of water is provided for the fields. An enormous horticulture field is presented with various piece of regions. Internet of Things is an appointment of interrelated processing gadgets, mechanical and computerized machines or individuals that are given one-of-a-kind identifiers and therefore the capacity to maneuver information over a network which allows us to make more intelligent choices [1].

IoT is used for getting accurate and innovative result in the smart irrigation. It is likely to assess the solid substance of keen water system like detecting water levels in repository, providing water at whatever point required lastly investigation the measure of water consumption through everyday analysis. The MQTT convention is used for end-to-end communication in this proposed system [2].

P. S. G. Aruna Sri (✉) · B. B. V. S. V. Prasad
Department of ECM, KLEF Vaddeswaram, Vaddeswaram, Andhra Pradesh, India
e-mail: arunasri_2012@kluniversity.in

K. Kiran Kumar · G. Vijay Kumar
Department of CSE, KLEF Vaddeswaram, Vaddeswaram, Andhra Pradesh, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_24

2 Literature Survey

Y. Manoj Kumar Reddy, S. Muthunpandian et al. [3] developed and implemented an automated system for crop field monitoring in real time. The method maintains the same level of water in the crop field as the amount of electricity used in the agricultural field. The created system can help the irrigation system. By taking into account the time of water constraints, Joaquin Gutierrez et al. [4] showed an automated irrigation system that more effectively minimizes water resources. They show how water is used sparingly and how a solar power system is used to reduce energy consumption. This was made with the help of a smartphone that evaluated sensor data via the internet. The focus of Mohanraj, AshokKumar et al. [5] is on data monitoring in the farming cycle. GSM-enabled ATMEL microcontroller-based sensors for monitoring wind turbine temperature and water PH levels are included in the system. After then, an Arduino-based IoT system is used, although a Raspberry Pi system is better ideal for monitoring a large number of Raspberry Pi systems. A raspberry pi watering system was demonstrated by Michael G. Williams [6]. Home automation, entertainment, and security systems based on the Raspberry Pi. It's more interesting to develop Raspberry systems for pressing scenarios [7].

3 System Overview

Our proposed prototype screens the external factors in the environment like soil moisture, environment temperature, humidity and then based on these factors our prototype automatically supplies water. This prototype gather's information from all the sensors interfaced to the NodeMCU [8]. To achieve this, we have to fix the range for the soil moisture in which we need to toggle the motor. During this process, the range of moisture depends on the s oil type it can vary based on soil type.

The moisture content of the soil is measured by the interfaced soil moisture sensor continuously based on the given range if it reduces the specified range or exists within the specified range relay toggles the motor status to ON otherwise it remains OFF. The continuously monitored values from the sensors are also being transmitted continuously to Blynk A PI using MQTT protocol [9].

4 Proposed Methodology

The soil moisture sensor, temperature, and humidity sensors are connected to the ESP8266 NodeMCU Microcontroller, and the sensors transfer data from their respective locations to the ESP8266 NodeMCU. The controller can analyze the analog data and then send it to end users via MQTT broker, such as a web application or a mobile phone [10]. The soil moisture sensor, temperature, and humidity sensors all send data to the microcontroller. The water pump was bound using a relay. The end user receives temperature and humidity information. The moisture sensor measures the amount of water in the soil, and when the amount of water in the soil declines, the water pump kicks in. End users may receive notifications such as "Water shortage in the soil ON water pump," "Water efficiency in the soil OFF water pump," and so on. MQTT (Message Queue Telemetry Transfer) is a network data transmission technology. It's also a publish/subscribe system designed for untrustworthy networks. Water scarcity is becoming more prevalent all across the world. Water usage must be done appropriately, especially when it comes to irrigation. Water waste can be reduced by combining smart watering strategies.

Sensors are attached to a server called a broker in the MQTT structure, and information is transmitted from the broker to all subscribing clients [11].

5 Hardware Components

5.1 NodeMCU Microcontroller

A NodeMCU is a microcontroller, which consists of inbuilt Wi-Fi module. NodeMCU is an amazingly practical, power the executives, requires insignificant outside hardware, ground-breaking enough regarding putting away capacity and on-board handling. We can interface various sensors to the NodeMCU at their respective GPIO pins with less delay. It is equipped with self-calibrated RF on the chip, allowing it to function in any environment.

Features of NodeMCU:

- NodeMCU consists of 802.11 b/g/n WLAN.
- It consumes less power. It is power efficient.
- NodeMCU is embedded with an inbuilt 10 bit A2D converter
- It is supported with TCP/IP network protocols.
- NodeMCU consists of a power management unit as well as regulators.
- NodeMCU works with WLAN which supports 2.4GHz spectrum.
- NodeMCU supports a linking function to interface with Android and IOS
- NodeMCU supports UART, remote control, etc.
- It is having a safety interval of 0.4 s.
- NodeMCU Deep sleep power is less than 10uA.
- NodeMCU is having a power down leakage current that is less than 5uA.
- NodeMCU is supported from −ve 40C to +ve 125C (Fig. 1)

Fig. 1 NodeMCU

5.2 Soil Moisture Sensor

The soil moisture sensor is used to determine the amount of water in the soil. Whenever there is a water shortage within soil the module yield is high otherwise, the yield is poor [11]. This sensor alerts the client to water their plants and also monitors the soil moisture content. Agriculture, ground water systems, and plant gardening have all made extensive use of it. Capacitance is used to determine the dielectric permittivity of the surrounding medium. The volumetric water content sensor generates a voltage that is conducive to dielectric permittivity. The level surface of the sensor does have a 2 cm region of impact, but the exceptional edges have almost no affectability. The volumetric water content sensor is used to determine long-term moisture deficit due to dissipation and plant absorption, assess ideal soil dampness substance for various plant types, and track soil dampness substance to balance water system (Fig. 2).

5.3 Humidity and Temperature Sensor

The DHT11 is a simple computerized sensor that measures temperature and humidity. Any miniature regulator can be effectively interfaced with this sensor. A capacitive humidity sensing component and another special component for temperature detection make up the DHT11 sensor. A dampness-holding layer acts as a dielectric between the two terminals of the humidity-detecting capacitor. As the humidity level changes, the capacitance value changes as well. DHT11 has a spectrum of 0–50° with a precision of 2°. This sensor's humidity range is 20–80%, with a 5% accuracy. The examining pace of this sensor is 1 Hz. For example, it gives one perusing for consistently. The most outrageous current used while assessing is 2.5 mA (Fig. 3).

Fig. 2 Soil Moisture sensor

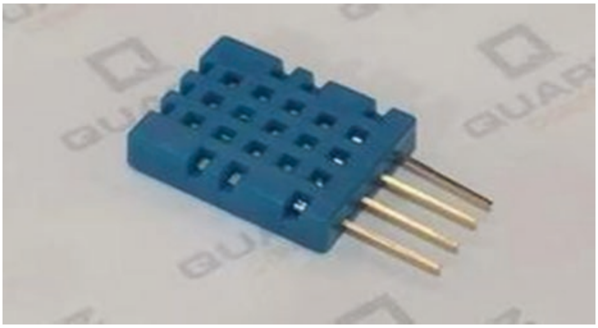


Fig. 3 DHT 11

5.4 Relay

A relay is a switch that is triggered by electricity. The turn can have a wide number of contacts with multiple contact systems, such as make contacts, split contacts, and blends. As energy flows through the loop, it generates an enticing field that enacts the armature, and the creation of the portable touch either reflects the moment of reality or an interaction with a set contact. If the contacts plan was closed when the exchange was disabled, the progression then opens the contacts and removes the affiliation, and vice versa if the contacts plan was available. Reed transfers are very reliable tools, but they can be ineffective when used incorrectly. Understanding their decisions will assist a competent Engineer

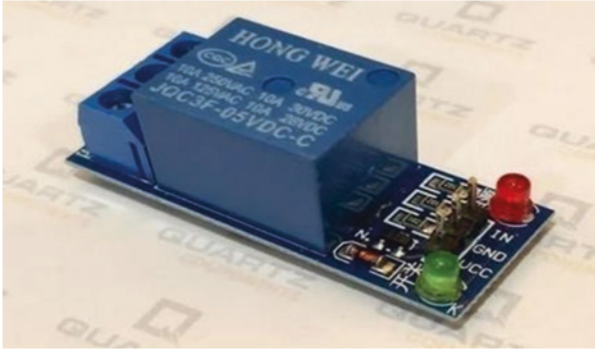


Fig. 4 Relay

Fig. 5 Water pump

in avoiding any of these predicted problems. The attractive field created by the current coursing through the working curl, which is wound with copper wire, operates the reed turn (Fig. 4).

5.5 *Water Pump*

It can be characterized as a device which utilizes mechanical as well as pressure-based standards in a channeling system in order to generate more power for potential use. They've been around in some way or another since the beginning of growth. Currently, these pumps are used in a number of housing, agricultural, urban, and industrial applications. The working guideline of a water pumps mostly relies on the positive removal standard just as dynamic energy to push the water (Fig. 5).

6 Flowchart (Fig. 6)

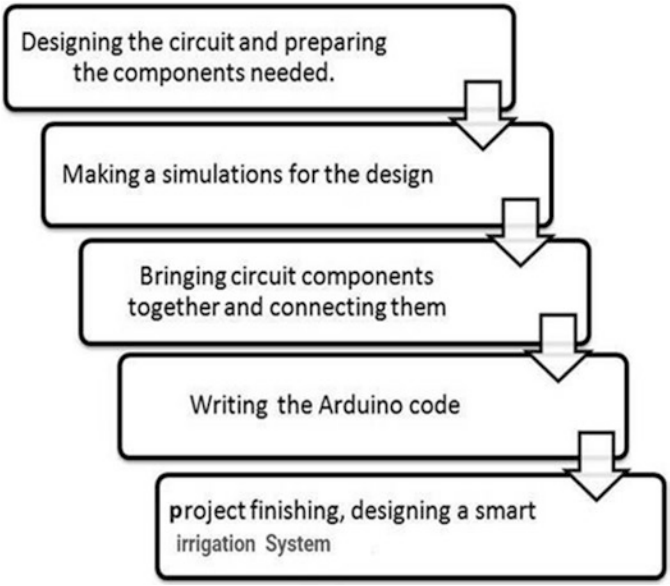


Fig. 6 Flowchart

7 Working

The inadequacy of water in the field is detected by volumetric water content measuring sensor. At whatever point, there is a need of water in the specific area, and the motor state switches to ON (1) shows up on the yield pin of the sensor of that specific field. All the sensors are interfaced to the NodeMCU at their certain GPIO pins. The high signal from the sensor is entertained by the microcontroller at specific pin. By detecting the GPIO pin on which signal shows up, the microcontroller imparts the signal to relay to toggle the DC motor connected. Now water starts flowing into the required field. Presently water begins streaming into the necessary field. After finish of watering, the sensor imparts low signal (logic 0) to microcontroller. When microcontroller receives this signal, it turns OFF the device. At whatever point there is signal at any pin the microcontroller repeats the above cycle. This cycle continues and we can achieve smart irrigation in the field (Fig. 7).

The Soil Moisture Sensor, which is connected to a microcontroller, obtains values from the soil on which it is mounted. The VWC sensor uses analog values, which are translated to digital using the ESP8266 NodeMCU's inbuilt ADC. The DHT11 sensor has four pins as well. The first pin is wired to the 3.3 V supply, the second pin to D2, and the last pin to land.

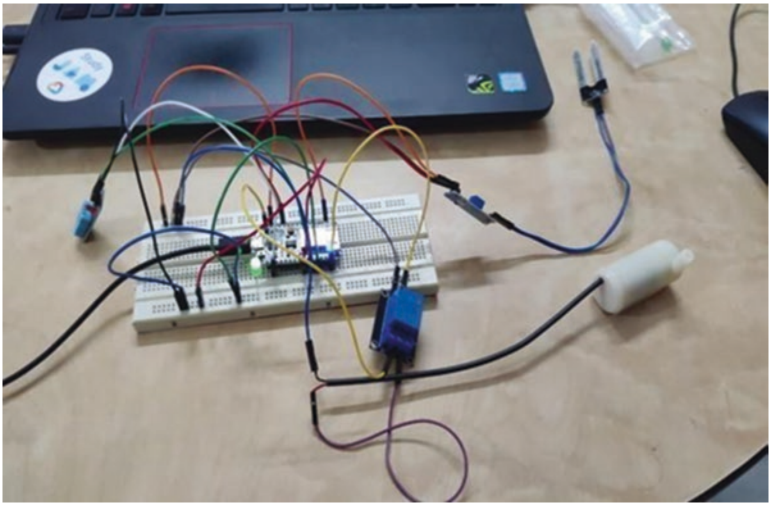


Fig. 7 Interfaced Components

There are three pins on the relay. The −ve pin of the relay is connected to the GND pin of the Node MCU, the +ve pin to the 3.3V pin of the MCU, and the input pin is connected to the D6 pin of the NodeMCU.

Similarly, the water pump has two pins. One pin is connected to out1 value of relay and another pin is connected to GND of NodeMCU.

All the sensors are interfaced with the Microcontroller. Now the sensed data from the sensors are transmitted to the API with the help of Wi-Fi module existing in the NodeMCU. Then microcontroller transmits the data to server by using Message Queue Telemetry Transport Protocol.

Blynk permits you to rapidly fabricate interfaces for controlling and observing your equipment ventures from your iOS and Android device. It can control equipment distantly, it can show sensor information, and it can store information, visualize it, and do numerous other things. The received data from the interfaced sensors are transmitted to Blynk API with the help of microcontroller.

8 Result Analysis

The data collected by sensors is saved in the cloud and may be accessed by the farmer via his smartphone or computer. The correct values that actually occur from the system are viewed by the farmer, and irrigation runs automatically at his crop fields without his interference. Every time the sensors were checked, the microcontroller processed and linked vast amounts of data to the threshold levels. The calibration of the sensors system is critical in this situation. The system shows the

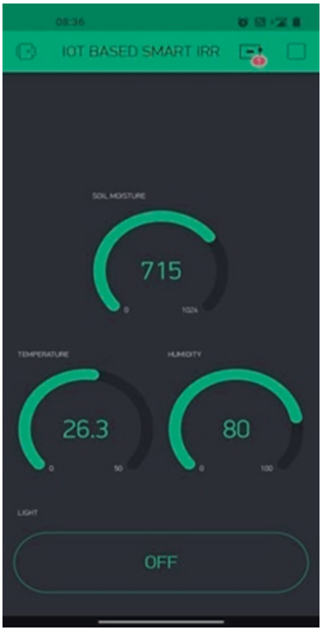


Fig. 8 Blynk API

temperature and soil moisture conditions, as well as the motor's condition, based on the two sensors. The state of the system can be checked from afar, and the system's complexity is low, thus firmware troubleshooting is simple. The outcomes of the suggested method are shown in the figures below. The soil moisture value, Humidity and Temperature Sensor values, and manual LED toggle are all seen in the diagram (Fig. 8).

9 Conclusion

The creation of a device to test soil moisture levels, as well as the ability to investigate existing systems, were all part of this endeavor. By properly positioning the sensor over the soil level, this invention saves water for irrigation. According to this study, plants may flourish in low moisture environments with moderate temperatures. Because it analyses numerous parameters, this method is useful for working in the field. This cycle not only records temperature and humidity estimates, but it also operates the motor accordingly. Examining the climate condition engine will maintain water supply automatically, allowing for the maintenance of vegetation without human involvement.

References

1. D.K. Sreekantha, A. Kavya, Agricultural crop monitoring using IOT – A study, in *2017 11th International Conference on Intelligent Systems and Control (ISCO)*, (IEEE, Piscataway, 2017), pp. 134–139
2. V. Naga, R. Guntur, Micro controller based automatic plant irrigation system. Int. J. Adv. Res. Technol. **2**(4) (2013), pp. 194–198
3. Y. Manoj Kumar Reddy, IOT based crop-field monitoring and irrigation automation. International Journal of Advanced Research Trends in Engineering and Technology (IJARTET) **4**(19) (2017), pp. 450–456
4. J. Gutiérrez, J.F. Villa-Medina, A.N. Garibay, M.Á. Porta-Gándara, Automated irrigation system using a wireless sensor network and GPRS module. IEEE Trans. Instrum. Meas. **17** (2017), pp. 164–176
5. I. Mohanraj, K. Ashokumar, J. Naren, Field monitoring and automation using IOT in agriculture domain. Int. J. Comput. Sci. Netw. Secur. **15**(6) (2015), pp. 931–939
6. M.G. Williams, A Risk Assessment on Raspberry PI using NIST Standards, Version 1.0 (2012)
7. J. Gutiérrez, J.F. Villa-Medina, A. Nieto-Garibay, M.Á. Porta-Gándara, Automated irrigation system using a wireless sensor network and GPRS module. IEEE Trans. Instrum. Meas., **63**, pp. 0018–9456 (2013)
8. A.N. Harun, M.R.M. Kassim, I. Mat, S.S. Ramli, Precision irrigation using wireless sensor network, in *2015 International Conference on Smart Sensors and Application (ICSSA)*, (IEEE, Piscataway, 2015), pp. 71–75
9. P. Rajalakshmi, S. Devi Mahalakshmi, IOT based crop-field monitoring and irrigation automation, in *2016 10th International Conference on Intelligent Systems and Control (ISCO)*, (IEEE, Piscataway, 2016), pp. 1–6
10. R.K. Kodali, A. Sahu, An IoT based soil moisture monitoring on the Losant platform, in *2nd International Conference on Contemporary Computing and Informatics (IC3I)*, (IEEE, Piscataway, 2016), pp. 764–768
11. R.K. Kodali, V. Jain, S. Karagwal, IoT based smart greenhouse, in *2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*, (2016), pp. 1–6

Agricultural Monitoring and Control of a System Using Smart IoT Devices

Y. Padma, M. Sailaja, Shaik Razia, and Mohammed Ali Hussain

1 Introduction

Most people in world depend on agriculture to live. It also increases a country's gross domestic product (GDP). Growth in the agricultural sector is essential for developing countries' economies. Unfortunately, most farmers are still using traditional agricultural practices, which has resulted in stagnant crop development. IoT based application in terms of automation in agriculture gives better yield and crop growth when compared with human based agriculture. IoT applications can replace human intervention in agriculture. IoT-enabled farming equipment in agriculture further improve crop output. A recent study has shown how to use sensor networks to father information and upload it to cloud servers and protocol networks to share it with other people and devices [1, 2].

Data are gathered from parametric sources and used for irrigation system monitoring. Our proposal introduces the real-time monitoring of data collected from

Y. Padma
Department of Information Technology, P.V.P. Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India

M. Sailaja
Department of CSE, P.V.P. Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India

S. Razia
Department of CSE, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India

M. A. Hussain (✉)
Department of ECM, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India
e-mail: dralihussain@kluniversity.in

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_25

fields, which help us regulate and operate them more efficiently. Our primary goal is to install smart irrigation and field-monitoring devices. Various forms of parametric data can be obtained by using sensors, which include smart irrigation data. IoT-enabled components on smart phones and other wireless devices process those data in real time by remaining connected to the Internet via Wi-Fi and Raspberry Pi interfaces.

2 Background

In our work, we utilize a monitoring system to regulate and collect data from various sensors to smart devices utilizing a Wi-Fi module to stay up to date on soil quality data and water levels [1]. The Bluetooth block focuses on greenhouse field parameters and controls key factors involved in regulation. We focus on creating a smart farming method that uses metrics such as soil moisture, temperature, and humidity—acquired via DHT11—and that remotely uploads data on those metrics to a server [3]. The proposed model would regularly record temperature and humidity data by using an Arduino microcontroller at various time intervals through ESP8266 and a Wi-Fi block [4]. The major goal of this study is to send collected data on various conditions to a user via a mobile app connected to a Wi-Fi relay and a Uno R3 so that water management can be carried out in the moment [5–15].

3 Proposed Model of a System (Fig. 1)

The proposed model consists of four primary components: Raspberry Pi, a moisture sensor, a relay, and an IFTT app.

The system block model is shown below.

Raspberry Pi is a series of small single-board computers that are used to perform small computing operations on a network. This component is the major element

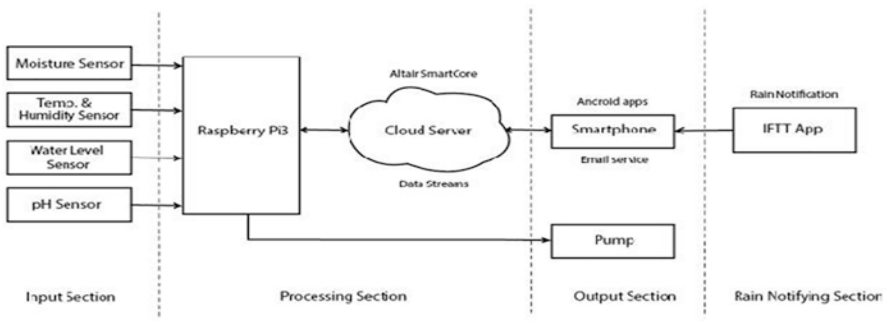


Fig. 1 Proposed model

used in IoT. It provides an entry point in operation with the Internet to perform various automatic operations over Wi-Fi.

The humidity sensor is used to immediately transfer digital data over a network. This component performs analog-to-digital conversion (ADC) operations and measures the humidity in the atmosphere around the field. The data captured from the sensor in real time are transmitted to the Internet and stored on a server.

The moisture sensor is used to measure the moisture level and water content in soil. It uses the basic property of electric resistance to gather data on soil. It also compares the data captured from soil to environmental factors such as type, temperature, and electric conductivity of soil.

The mobile application provides up-to-date information from various sensors to the user and server to analyze the data and record them in a database. The app sends a notification to the user in the form of an alarm.

The IFTT app is connected to a controller and physical device that uses the Internet. The device receives various commands from other applications that control its components. IFTT is based on the notification that the pump is on or off on the day notified. The IFTT app, which is connected to the Internet, creates a link between devices to show various conditions. The IFTT app is available on smartphones connected to the Internet.

4 Methodology of Study

Our proposed model collects data from various stages of inputs by using sensors, which are processed by Raspberry Pi because of the constraints on the work. Initially, the sensor has to access the data on soil moisture. Next, the sensor monitors the water management system, which controls the moisture level of soil. It automatically uploads these data onto the Altair SmartCore server, notifies to the user, and activates the pump. In this way, the user gathers all the relevant information on humidity, temperature, and water in the field by using sensors (Fig. 2).

In the second phase, the level and flow of water are measured by using a sensor. Depending on the moisture level and level of the water in soil, the pump has to be turned off or on. The condition of the soil is reported to the user in a notification bar with additional data on humidity and temperature.

Data Analysis

We built an IoT-based, moisture- and temperature-monitoring, automated irrigation system utilizing field data sensor that transmit data via a microcontroller. Using Raspberry Pi, a serial device communicates with the moisture sensor and temperature sensor. Raspberry Pi is equipped with a learning technique, namely a K-Nearest Neighbors (KNN) classifier, that factors in soil temperature and moisture values. KNN categorizes the nearest training data set objects according to space feature values. This is functionally local. The classifier method detects earlier data supplied as needed. By analyzing the field for irrigation, the various conditions of the

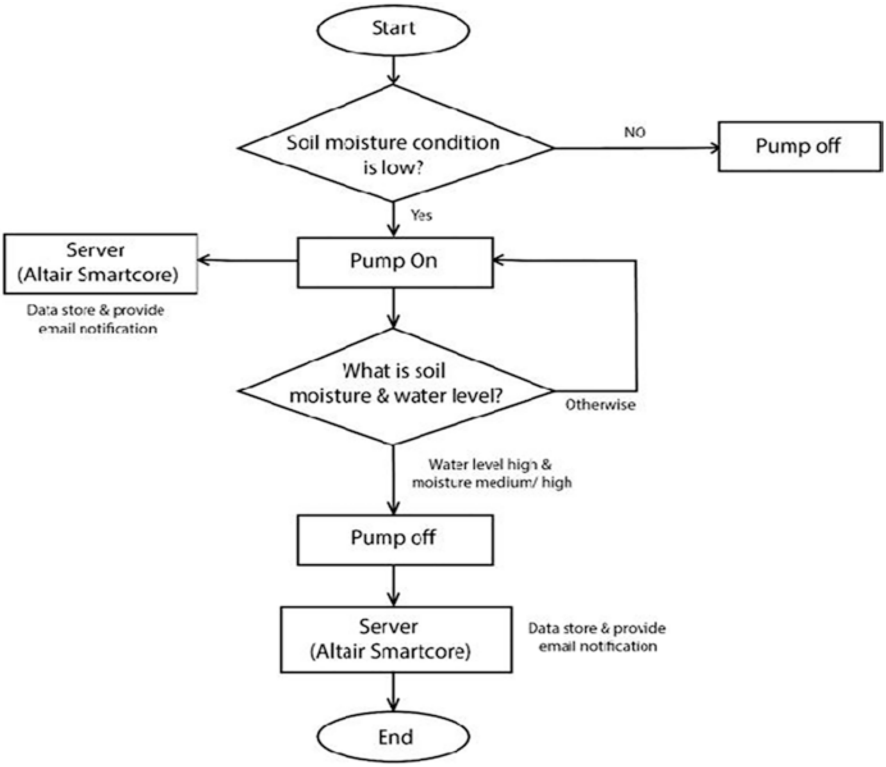


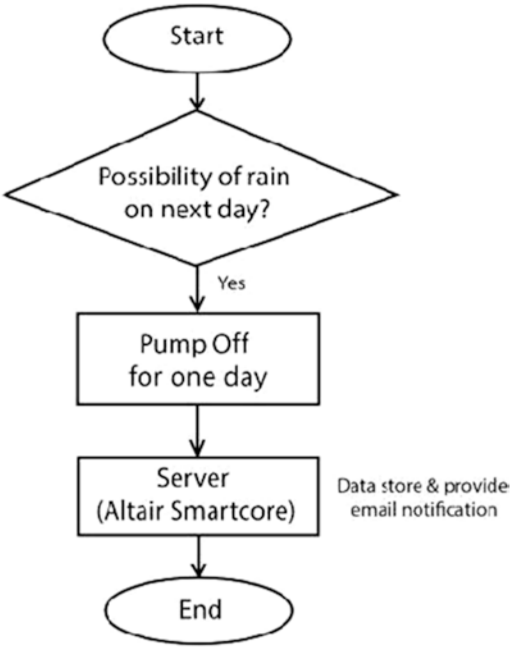
Fig. 2 Workflow of the proposed model

soil—i.e., wet, slightly wet, dry, or slightly dry—are compared against the training data set. The model monitors soil status in real time, obtaining data from the actuator, and may activate the water pump that supplies the fields. Finally, analyzed field data and the time necessary to irrigate the fields are updated to a server, informing the user of the soil condition and how much water to irrigate. All of these data are available on the farmer's/user's smartphone app. A temperature-versus-moisture data sheet containing a Comma-Seperated Values (CSV) file relevant to the training data set is also saved on server (Fig. 3).

On rainy days, there is no need to display the water level in the fields. If the moisture level is low, the IFTT application will offer data updates on the current day and day after. If heavy and regular rain occurs, this application will inform the server and user via the Internet. A rain alert notifies the user via the IFTT app. Depending on the type of notification, the pump will be on/off for the notified day. The IFTT app, connected to the Internet, constructs a condition-dependent chain connection utilizing applets (Fig. 4).

To access the app, the user must first set up and log in to a Gmail account. Then, using Gmail, the user must set up a user account for IFTT. After logging in, the user can turn on and off the rain-related forecast notifications. If the user wants to find

Fig. 3 Flow of verifying the rain condition



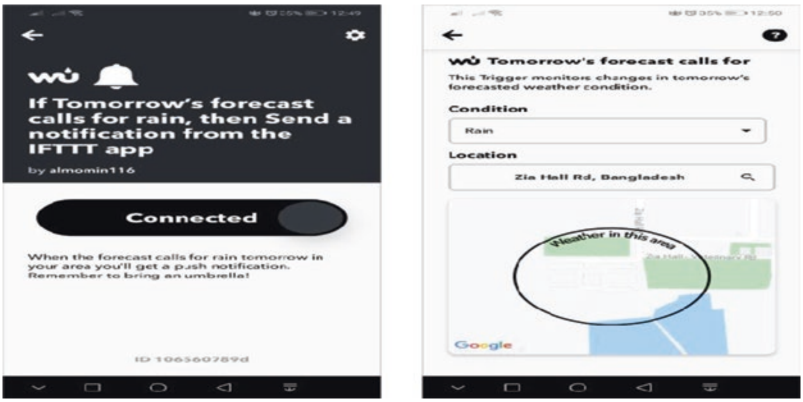


Fig. 4 Setup and connection location of IFTT app

out tomorrow's rain forecast, they may set the date. After setting the date, the IFTT app notify the user of the rain forecast. To ensure the correct forecast, the user must select the field area location. Communication between the server, app, and user must be established via IoT in such a way that only the user may start receiving notifications via the app. The app notifications feature rain-related data such as overcast, partly cloudy, and rainy. It offers status information such as high, low, and medium. It also features ultraviolet (UV) index values. When a user receives a rain notification, they will not need to utilize this app on the pump.

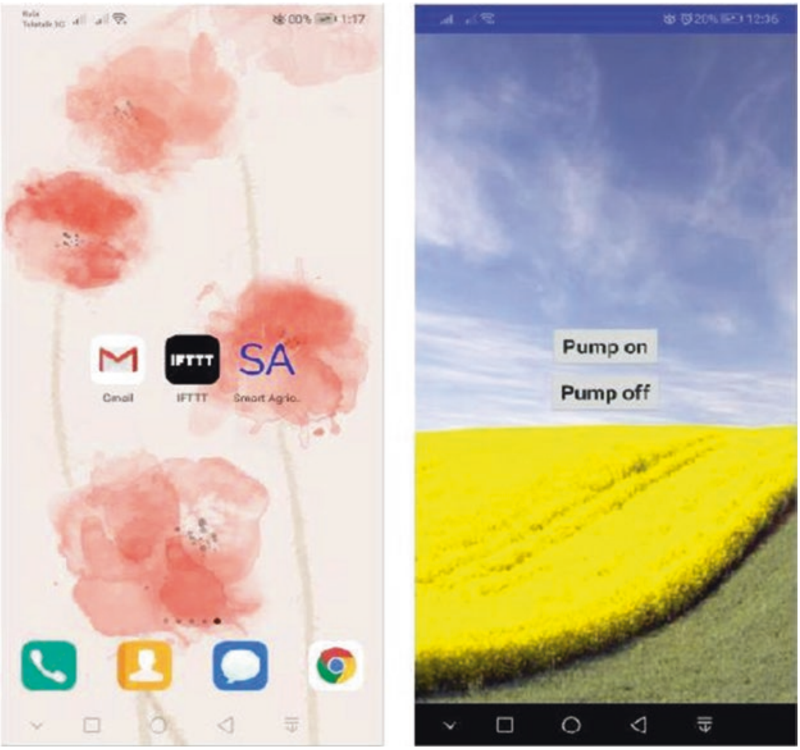


Fig. 5 IoT app for agriculture, for turning the pump on or off

This information is continuously saved on a SmartCore server. The server also alerts the user via email whether the pump is on or off and includes the current soil humidity and temperature values (Fig. 5).

The soil pH value indicates acidity or alkalinity. A numerical scale is used to measure pH levels. This scale ranges from 0.00–14.00, where its minimum value, 0.00, is the most acidic and its maximum value, 14.00, is the most alkaline. The middle value, 7.00, is neutral, meaning that this value is neither alkaline nor acidic. The soil pH value affects the basic factors for plant growth:

1. The availability of nutrients
2. The structure of soil
3. The number of bacteria available in soil
4. The toxicity of soil
5. Nutrient leaching

Various nitrogen-free bacterial products, including fertilizers and some organic substances, may influence soil pH. Beneficial bacteria operate best in a 5.5–7.00 pH range. Aluminum in the soil can dramatically affect plant development by reducing the pH value to 5.0. The optimal pH range for most plants in clay soil is 5.0–7.0. Where alkalinity or acidity is severe in soil, the pH value affects plant production and growth. The pH level does not affect fertilizer itself, but it does affect fertilizer nutrients.

A pH sensor evaluates the soil conditions while confirming the pH value on a 5.5–7.0 scale. If the soil pH value is higher, pH-related information is uploaded to and saved on an Altair SmartCore server. At the same time, the user of this server is notified of the current pH value of the soil. If the pH sensor value drastically changes, such as it exceeds a value higher than 7.0, indicating alkalinity, this pH value will be uploaded to and saved on the server. At the same time, the user is notified via an email also containing data on other various conditions of the soil, including the sulfur content, peat sphagnum content, sulfate aluminum content, sulfate iron content, fertilizer acidity, and amount of compost and mulch.

5 Discussion with Results

Input Training Data Sets (Table 1)

Analysis (EDA) of Training Data

Python was used to visualize the relationships between the data. A pairs plot allows us to see both the distribution of single variables and the relationships between the two variables.

Table 1 Input Training Data Set

	A	B	C	D	E
1	28	75	76.34	300	no
2	28	63	76.34	330	no
3	27	77	76.44	290	no
4	27	78	76.54	300	no
5	27	78	75.95	330	no
6	27	78	75.12	333	no
7	30	72	43.37	250	yes
8	29	72	36.17	222	yes
9	27	79	27.27	200	yes
10	27	80	39.1	100	no
11	27	89	39.1	90	no

Temperature	Humidity (Y)	Soil Moisture	Water level	KNN distance	Target Value
28	75	76.34	300	261.873	No
28	63	76.34	330	**233.018**	No
27	77	76.34	290	271.599	No
27	78	75.12	333	261.985	No
30	72	43.37	250	305.048	Yes
29	72	36.17	222	332.19	Yes
27	79	27.27	200	353.642	Yes
27	80	39.1	100	454.191	No
27	89	39.1	90	464.422	No

Field A: Temperature in percentage (%)
Field B: Humidity in percentage (%)
Field C: Soil moisture in percentage (%)
Field D: Water level in centimeters (cm)
Field E: Target value

Figure 6 contains scatter plots comparing each pair of columns against the target value column (i.e. yes/no). The columns are temperature, humidity, soil moisture, and water level. The target values ‘no’ are marked as blue plots, and the target values ‘yes’ are marked as orange plots (Figs. 7 and 8).

Calculations for the new instance [21.00, 69.00, 9.38, 553], where k = 3.

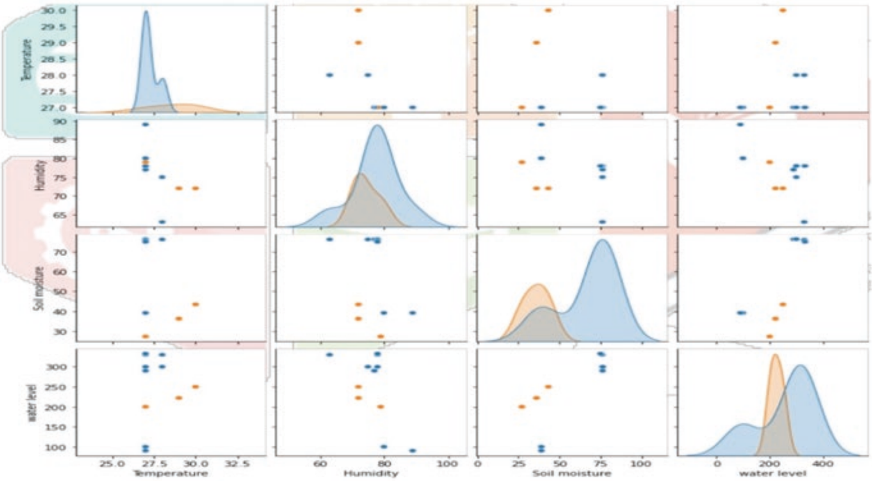


Fig. 6 Feature mapping graph

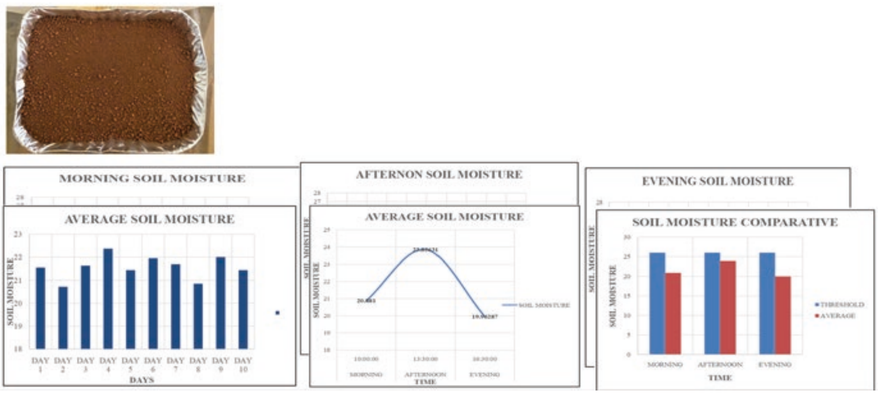


Fig. 7 The temperature and moisture levels in three stages for soil −1 grade

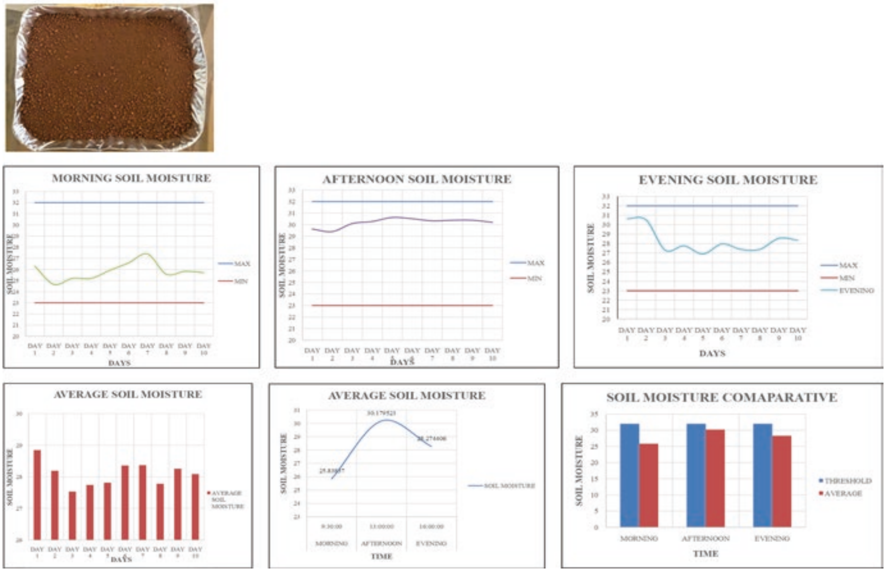


Fig. 8 The temperature and moisture levels in three stages for soil −2 grade

The Soil Was Tested at Various Temperatures to Identify the Moisture Level (Tables 2 and 3)

Snapshot of Short Messaging Service (SMS) Text Sent to User

- Scenario 1: Soil moisture is LOW, but water level is empty; hence MOTOR will remain OFF.

Scenario 2: Soil Moisture is LOW; hence MOTOR is ON.
Scenario 3: Soil Moisture is HIGH; hence MOTOR is OFF (Fig. 9).

Depending on which SMS was sent to the user, which itself depends on the water level detected, they will be notified of whether to turn the motor on or off.

(a) The pump flips on or off depending on the detected condition:

When the water level is low, the pump motor turns on automatically. In certain scenarios, while the pump is in operation, data can be sent to the user accord to their preferences.

(b) The pump is flipped on or off by the user:

Water flow is measured within a specific period of time, and this measurement determines whether the pump is on or off. The pump's on/off condition is based on the condition detected by the moisture sensor. The user is notified of this condition in a notification bar that details the humidity and temperature values. Also, the notification can be sent when the user is far away, depending on the user's notification bar settings, which can display more details than just the water level.

Table 2 Measured values of soil moisture levels

Value	Soil moisture level
Maximum	26%
Minimum	17%
Morning average	20.881%
Afternoon average	23.856%
Evening average	19.962%

Table 3 Measured values of soil moisture levels

Value	Soil moisture level
Maximum	32%
Minimum	23%
Morning average	25.83%
Afternoon average	30.179%
Evening average	28.274%

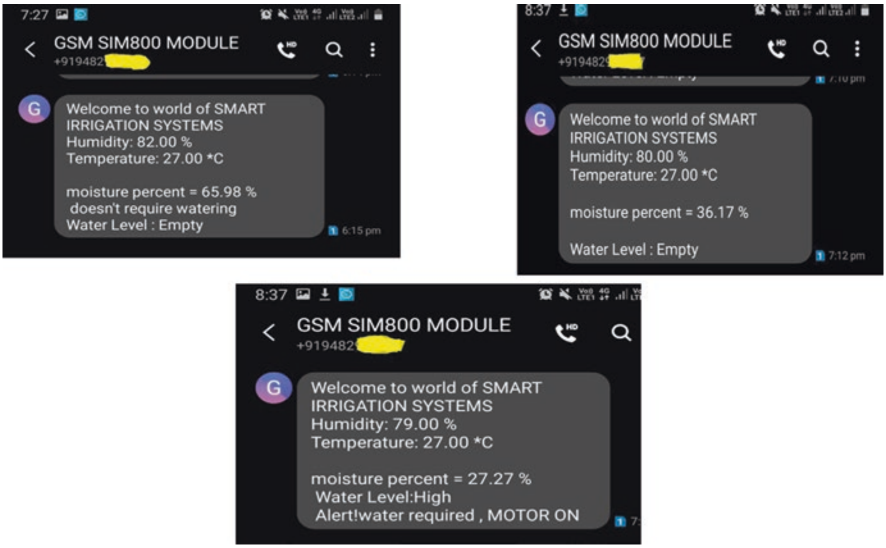


Fig. 9 A notification send to the user's smartphone

(c) The soil acidity increases:

If the soil acidity increases, the user's email address will be notified of this change, and the details of that email will include the current pH values of their soils.

(d) The soil alkalinity increases:

When a pH sensor detects a pH value higher than 7.0, the soil is alkaline. The detected pH value is at this point uploaded to and saved on an Altair SmartCore server. At the same time, the information is automatically sent to the user's email address, along with details on the correct chemical composition of the soil,

Fig. 10 Agriculture monitoring system and smart irrigation system

including the sulfur content, peat sphagnum content, iron sulfate content, fertilizer acidity, and amount of mulch.

The pH Database

The database bridges the gap between the sensor and the user, saving time. The database is managed and stored on a native cloud platform. This platform contains the digital information from the sensor and other IoT components. The Altair SmartCore improves the reliability of and speed in accessing the platform and its data. The stored data are analyzed and converted into readable reports that they can be used when making decisions. The reports also date the information (Fig. 10).

6 Future Scope and Conclusion

The proposed model offers flexible setup options when configuring various components, reduces costs, and can be customized in how it monitors the conditions of agricultural production. The flexibility of this setup improves its ability to detect and solve more problems. This model can effectively control and monitor large areas of farmland.

Future studies should increase the model's throughput by adding more sensors to record more inputs at the same time so that the various elements necessary for crops are accurately supplied in fertilizer instead of extracting them from the ground. This model can be also implemented in other industries to monitor tanks and tank leaks.

References

1. S. Mehta, N. Saraff, S.S. Sanjay, S. Pandey, Automated agricultural monitoring and controlling system UsingHC05 BT module. Int. Res. J. Eng. Technol. (IRJET) **05**(05) (2018)
2. S. Nath, J.K. Nath, K.C. Sarma, IoT based system for continuous measurement and monitoring of temperature, soil moisture and relative humidity. Int. J. Electr. Eng. Technol. (IJEET) **9**(3) (2018)
3. D.P. Patil, A.H. Singh, S.R. Jadhav, S.R. Thombare, IoT based agriculture and transportation surveillance. Glob. Res. Dev. J. Eng. **3**(6) (2018)
4. B. Singla, S. Mishra, A. Singh, S. Yadav, Astudy on smart irrigation system using IoT. International Journal of Advance Research, Ideas and Innovations in Technology **5**(2) (2019)
5. M. Mehedi Islam, M. Al-Momin, A.B.M. Tauhid, M. Kamal Hossain, S. Sarker, International Journal of Recent Technology and Engineering (IJRTE) **8**(6) ISSN: 2277–3878 (2020)
6. R. Shaik, N.K. Gudapati, N.K. Balijepalli, H.R. Medida, A survey on applications of internet of things. Int. J. Civil Eng. Technol. **8**(12), 558–571 (2017)
7. M. Bansal, Face recognition implementation on RaspberryPi using OpenCV and python. Int. J. Comput. Eng. Technol. **10**(3), 141–144 (2019)
8. J. Bhagya Maybel, A. Umamakeswari, Hardware implementation of secure image transmission in raspberry PI, international journal of mechanical. Eng. Technol. **9**(2), 670–678 (2018)
9. T.S. Roy, S. Ghosh, R. Datta, A. Santra, IoT based home automation using raspberry PI. Int. J. Comput. Eng. Technol. **10**(3), 70–74 (2019)
10. D. Sunehra, Raspberry Pi based pollution and climate monitoring system using Internet of Things. Int. J. Adv. Res. Eng. Technol. **10**(2), 44–54 (2019)
11. H. Liu, Z. Meng, S. Cui, A wireless sensor network prototype for environmental monitoring in greenhouses, in *Proceedings of the International Conference on Wireless Communications, Networking and Mobile Computing, 2007*, (WiCom 2007, 2007), pp. 2344–2347
12. R. Hussain, J.L. Sahgal, Anshulgangwar, M.D. Riyaj, Control of irrigation automatically by using wireless sensor network. Int. J. Soft Comput. Eng. (IJSCE) **3**(1) ISSN:2231-2307 (2013)
13. A. Rajpal, S. Jain, N. Khare, A.K. Shukla, Microcontroller-based automatic irrigation system with moisture sensors, in *Proceedings of the International Conference on Science and Engineering*, (ICSE, 2011)
14. A. Vijayakrishna, G. Gopichand, M.D. Ansari, G. Suryanarayana, IOT based smart agriculture using LIFI, in *In 2022 5th International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT)*, (IEEE, 2022, November), pp. 1–7
15. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)

An IoT Framework to Support Rural Population with Diabetic Related Issues via Optimization Algorithms

Vinit Kumar Gunjan, Fahimuddin Shaik, and Rashmi Pathak

1 Introduction

As human life is more important than everything, much effort was made today to identify an illness and its disorders. In biomedical imaging technologies, edge computing is becoming more prominent option for overcoming those restrictions and introducing new IoT analytics devices and facilitating connectivity, database transfer, and local database query-enabled devices. The special issue seeks to explore more advanced approaches of data handling to ensure that physicians obtain data in real time with an ever-growing number of analytics and IoT devices put into the healthcare networks.

Diabetic mellitus is a metabolic disorder that is characterized by the pancreas 'failure to control the production of blood glucose. This problem leads to blood glucose out of normal reach [1]. Cardiovascular disease causes 80 percent of deaths, which are most due to CAD (coronary artery disease), among diabetic patients. Nevertheless, diabetic patients are increasingly recognized to have an extra cardiac insult called diabetic cardiomyopathy [2].

The underlying problem in most CVD diabetic patients is atherosclerosis, which reduces blood vessels that support the heart, due to heart failure. Atherosclerosis

V. K. Gunjan (✉)
CSE, CMR Institute of Technology, Hyderabad, India

F. Shaik
ECE, Annamacharya Institute of Technology & Sciences,
Rajampet, Kadapa (Dt), Andhra Pradesh, India

R. Pathak
Accenture, Hyderabad, India

National Institute of Technology, Silchar, Silchar, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_26

(also known as ASVD) is a condition in which artery wall thickens as a consequence of an increase in fatty materials such as cholesterol. The increased incidence and prevalence of diabetes heart failure has been verified by epidemiological and clinical trials [3]. Diabetic myonecrosis is a rare diabetes complication caused by the infringed tissue in the thigh, usually. Just about 100 cases were published [7]. The incidence of specific complications rises as diabetes continues, so this unusual condition can be seen in patients with long-term diabetes.

The ultimate purpose of a large number of image processing technologies is to collect important features of the image data from which the scene can be represented, viewed, or understood by humans or provide "better" information to other automated image processing technology [4]. The biological eye is one of the main means of human exploration of the environment and carries out complex tasks with great ease, such as study, perception, identification, and description of patterns [5]. To optimize the results obtained by Image processing models, Nature inspired Optimization algorithms are added as a grain of salt. However, in several areas of application [6] natural computation has proved useful, with significant contributions for optimization, pattern recognition, form detection, and machine learning. There are drawbacks of clinical evaluation and analysis of visual photographs that are currently available in the deemed question through different testing methods. The study of the medical image should be carried out in a new way by algorithm adjustment based on the application of both data recognition and optimization approaches. The end bundle of this work should be useful to identify and forecast the problems caused by D.M.

2 Review of Literature

In literature, most of the earlier works presented on extraction of vessels from coronary angiograms are based on gray level values. Provided that the gray backdrop level is actually higher than that of the vessel [9–11], enhance the vessels and post processing using morphology filters for extraction purpose. Filters such as top-hat can eliminate the part of noise and whenever the size of noise is near to a value of vessel this filter becomes incapable. In order to enhance the image a Gaussian filter is used in two-dimensional matched filter methodology as in [12, 13]. In order to find the fine details, [8] the importance of removing the vessels is clearly mentioned. While the arteries are removed as seen in [8], there is a need for an examination of the inner portion of the blood vessels to help an average individual recognize the disorder's abnormality and severity. The main preference is the cross-section of images of blood vessels (also known as capillary basement membranes) obtained by the Electron micrographic imagery modality as specified in [3]. Recently, the amalgamated Web definition for m-health stuff (m-IoT) was released. It is well known that diabetes is a big chronic problem worldwide with an immense economic and social impact and explores the potential benefits of using m-IoT in non-invasive glucose sensing and future m-IoT dependent diabetes care infrastructure [17]. Myonecrosis has also been identified as the infarction of the skeletal muscle, as the skeletal muscle has a large blood supply collateral [15]. The clinical symptoms of diabetic myonecrosis are non-specific, and diagnosis and treatment are therefore often delayed.

In non-invasive diagnostic procedures for muscular parts of body the Image processing plays a significant role for further processing. The fundamental and foremost preferred medical imaging diagnostic is ultrasonography. This procedure demonstrates well-marinated, hypo echoic, intramuscular lesion [16]. The reason for ultrasonography to be chosen is that it has innate advantages such as availability, non-invasive procedures and optimal diagnosis by segregating other muscular tissue problems.

While simplex-rays, ultrasounds and CT are scientifically capable of visualizing the position and distribution of the lesion, the image characteristics obtained here are not accurate. Although MRI is more superior tox-rays and CT, MRI studies often include skeletal myonecrosis [14]; in literature, there are no extensive research using image processing methods. The definition of the Internet of Things (IoT) plays an important role in the treatment of diabetes. IoT uses sensors to help control diabetes by controlling blood pressure, glucose levels, calorie intake, and physical activity. This study suggests an Innovative Health Care Service Model that offers meaningful guidance to individuals in the management of diabetes [18–21].

3 Need and Significance of the Proposal

As it is evident from the survey that Diabetes combined with other ailments becomes a lethal combination, the link should be removed if not at least reduced to the possible extent. The clinical interpretations of images acquired from diagnostic methods existing today have inadequacy in terms of analysis and not reachable to poor and rural people. The literature analysis of the implementation of diabetic-related image processing techniques is mostly restricted to diabetic retinopathy, and most findings are not properly understood by a common person. This is why there has been a lot of scope for researchers from imagery technology to explore approaches for diabetic cardiomyopathy and diabetic myonecrosis photos. On the other hand, Nature inspired Optimization algorithms are the algorithms, which adopts processes in succession in the nature. The usage of such Optimization algorithms along with image processing algorithms can provide optimum solution for the problem. Further proposed IoT process has to be indexed to act as image data collector, transmitter, and receiver such that the poor and rural people in remote areas receive the benefits to overcome the problems. Thus a framework with image processing and IoT Optimization techniques is a prospective in aiding for earlier detection, education, and treatment of people in remote areas.

4 Methodology

Phase-I: Analysis of Diabetic Related Issues Using Optimization Algorithms

(i) *Medical visual database collection:*

Acquiring the photographs from rural areas in line with the online public repositories and also from diabetic research institutes that offer accurate copyright owners a quotation.

(ii) *Design and Implementation of proposed algorithm:*

(a) Designing of Multiple level Image thresholding model involving Electromagnetism—Like Optimization (EMO) Algorithm.

(b) The *fundamental image processing* methods here are Otsu's Global Thresholding and Kapur thresholding algorithms. The thresholding technique Otsu suggests emphasizing the variations between classes, while the second strategy, proposed by Kapur et al., uses the activation of entropy in order to measure class homogeneity in pictures.

(c) Electromagnetic—Like Optimization (EMO), an Optimization Algorithm inspired by Nature is also considered a stochastically evolutionary computation method based on theory of the electromagnetic field. Every solution is known to be a charged particle. EMO transfers each particle according to its charge in a crowd attraction or repulsion field using the Law of Coulomb and the theory of overlapping. The EMO algorithm's mechanism for attraction and repulsion coincides with replication, transversal, and mutation in the basic genetic algorithm.

(d) The modifications proposed in this algorithm are based on the two above said thresholding algorithms where the basic functionalities of EMO are added and EMO calculation has four stages:

- Initialization
- Local search.
- Calculation of the total force vector
- Movement

(e) The development of algorithm initiates from the step of how an input image is considered for segmentation and post segmentation respective thresholds are obtained by EMO algorithm and with their parameters and graphs.

(f) The design and implementation are carried out in two processes: pre-processing and post-processing as clearly shown in Fig. 1 as a block diagram.

Implementation Throughout this research, input pictures taken from various rural areas and sources have to be simulated on an Intel Core i5 PC at 2.5 GHZ with a total physical memory of 4 GB (Matrix Laboratory), a high degree of Technical Computer Language (R2010a version and above), and more than 100 toolboxes available, but only a few such as picture acquisition, image

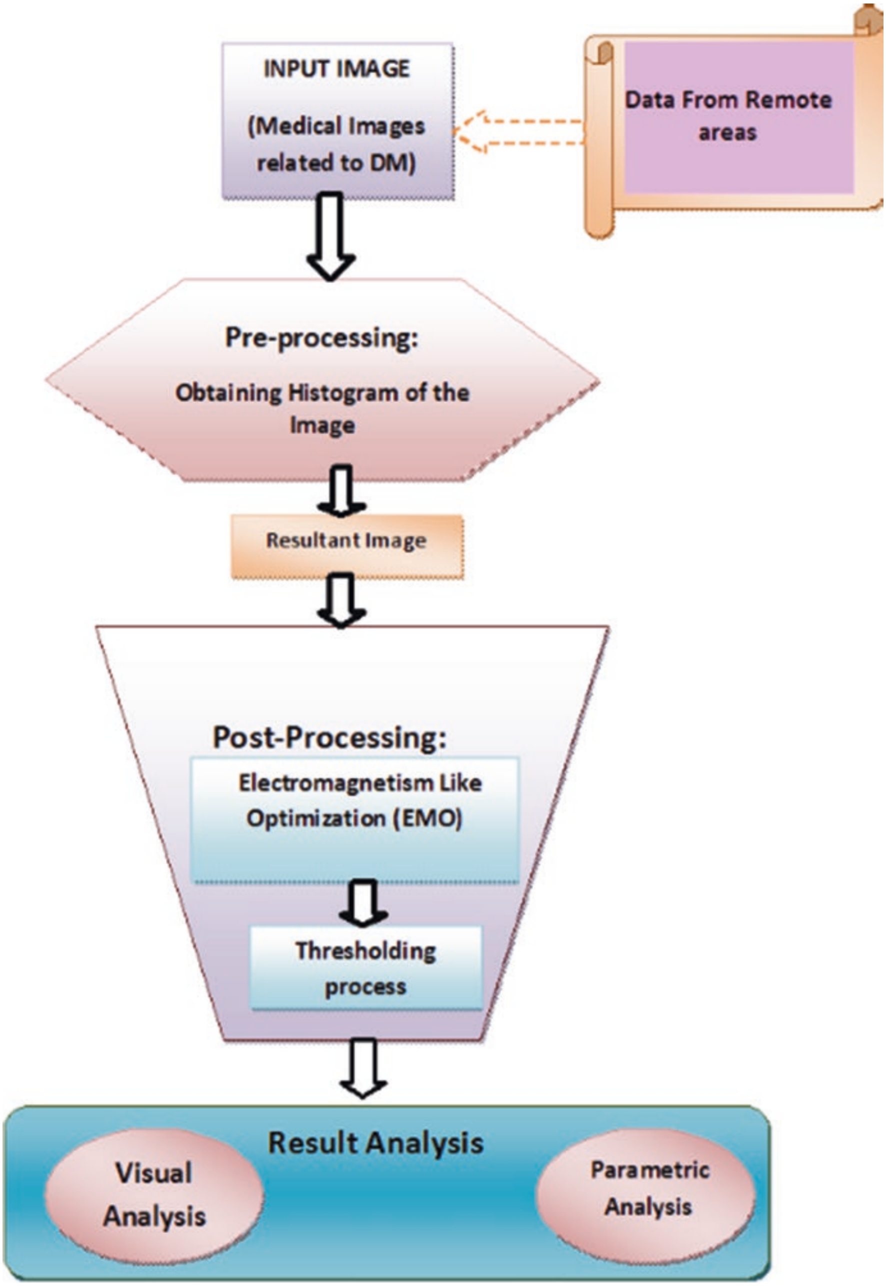


Fig. 1 Image Processing module

processing, fixed point, and new memory were simulated. Matlab is a MathWorks Inc. proprietary software that allows matrix manipulation [17]. Another state-of-the-art MIPAV method (Medical Image Recognition, Interpretation, and Visualization) is used to derive the value attributes from the images. Such characteristics are useful in specifically describing the anomalies. The key attribute that allows MIPAV use is the applicability of MIPAV even with 3D images and quantification. MIPAV is a Java program that can be run on any Java computer. This is the result of the Information Technology Center, the national health institutes, and Bethesda [18].

Phase-II: Design and Implementation of IoT Framework

These instruments are portable safety resources that allow the operation of sensitive bodies outside hospitals, the study group said. For example, portable medical devices such as heart rate, blood glucose, and blood oxygen levels can be used to monitor. This software can also be used to track the physical activity, exercise, and sleep patterns of an adult. Wearable medical devices make it possible for hospitals to limit access to people with minor health issues or patient follow-ups. The report shows that doctors also track patients remotely to enhance care efficiency using wearable medical devices. Electronic health records (EHRs) are a significant source of health observer data that restrict the quality of structured data. Recorded symptom reports and endurance are useful but can provide only a lot of insight into public health. Analytical tools and IoT are innovations for deeper and stronger ties, but an organization's health IT network has to be able to accommodate the amount of data trackers and other related medical equipment. The alternative to the data collection needed to draw more accurate conclusions based on a patient's personal lifestyle and behavior is wearable medical devices. Patients can even use their own portable devices for the collection of data by healthcare facilities, including smart watches and fitness bands. This requires IoT from the initial stage as an interface between the instruments used to track the movement of the human. In addition, appropriate filters are used to pre-process the necessary portion of the data for further classification. The proposed IoT Framework is shown in Fig. 2.

An ANFIS abstraction and ant colony optimization architecture to simplify efficient IoT network routing. This section discusses ANFIS and ACO definitions and how they relate to the work proposed. Devices and applications were initially used to classify disabled persons and user information is moved onto the cloud network during the contact process. The figure shows a basic definition of the ANFIS model which comprises five stages of architecture. The first and second layers are used to track the sensor information on the basis of the threshold value specified in the system model and the class. Eventually, the stored data is transmitted via the cloud network to the rural unit.

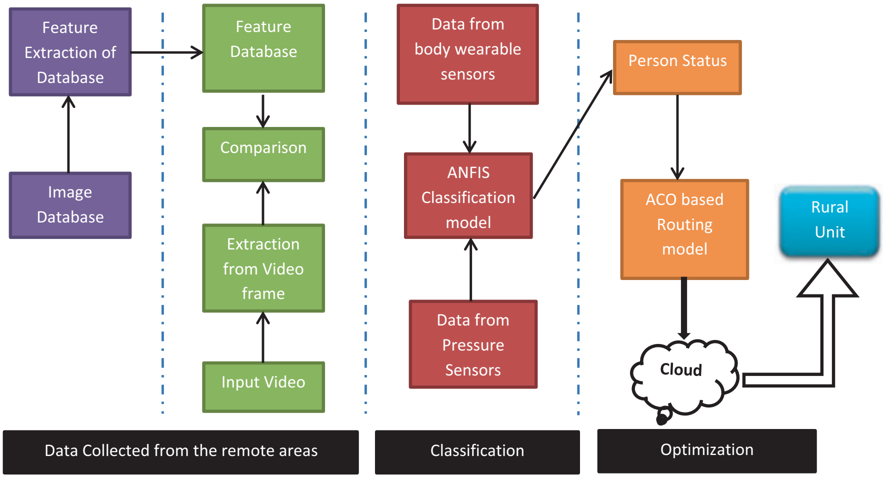


Fig. 2 IoT framework

5 Conclusion

This medical image analysis was performed in a novel manner by altering the algorithm, which was based on both image processing and IoT technologies. Predictive models and IoT are innovations for better and faster links, but an organization's health IT network must be able to accommodate the number of data trackers and other relevant medical equipment. According to the study, Diabetes mixed with other conditions is a dangerous combo; therefore, the link should be eradicated or reduced to the greatest extent possible. Clinical interpretations of images obtained from diagnostic technologies now in use are insufficient in terms of analysis and are inaccessible to the poor and rural populations. As a result, this study was conducted to aid in the earlier discovery, education, and treatment of persons in distant places.

References

1. A. Sharifi, A. Vosolipour, M. Aliyari Sh, M. Teshnehlab, Hierarchical Takagi-Sugeno type fuzzy system for diabetes mellitus forecasting, in *Proceedings of 7th International Conference on Machine Learning and Cybernetics, Kunming*, vol. 3, (12–15 July 2008), pp. 1265–1270
2. S.M. Ahmed, B. Kovela, V.K. Gunjan, IoT based automatic plant watering system through soil moisture sensing—a technique to support farmers' cultivation in rural India, in *Advances in Cybernetics, Cognition, and Machine Learning for Communication Technologies*, (Springer, Singapore, 2020), pp. 259–268
3. O. Asghar, A. Al-Sunni, S. Withers, Diabetic cardiomyopathy, in *Clinical Science*, (The Manchester Heart Centre, UK, 2009)

4. V.K. Gunjan, S. Kumar, M.D. Ansari, Y. Vijayalata, Prediction of agriculture yields using machine learning algorithms, in *Proceedings of the 2nd International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications*, (Springer, Singapore, 2022), pp. 17–26
5. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
6. J. Liu, K.C. Tsui, Toward nature-inspired computing. Commun. ACM **49**(10), 59–64 (2006)
7. L.G. Mancillas-Adame, J.G. González-González, J.O. Jáquez-Quintana, et al., Diabetic myonecrosis in a patient with hepatic cirrhosis: a case report and review of the literature. J. Med. Case Rep. **3**, 1–5 (2009)
8. W. Kang, K. Wang, W. Chen, Y. Li, Segmentation of coronary arteries based on transition region extraction, in *2nd International Asia Conference on Informatics in Control, Automation and Robotics*, (2010)
9. S. Eiho, Y. Qian, Detection of coronary artery tree using morphological operator, in *Computers in Cardiology*, (IEEE, Lund, 1997), pp. 525–528
10. Z.W. Tang, H. Zhang, G.S. Hu, Morphological multiscale vessel enhancement for coronary angiograms. J. Tsinghua Univ. Sci. Tech. **46**(3), 418–420 (2006)
11. Y.H. Yu, Study of coronary artery segmentation from coronary digital angiography. Shandong J. Biomed. Eng. **21**, 5–10 (2002)
12. Z. Xu, Y.D. Yu, H.B. Xie, X.D. Chen, J.X. Huang, Heat vessels extraction from angiogram. Chin. J. Biomed. Eng. **22**(1), 6–11 (2003)
13. G. Chen, H. Yi, Z.H. Ni, Automatic vessel boundary extraction and stenosis quantification method based on Laplacian-of- Gaussian algorithm using DSA images. Chin. J. Sci. Instrum. **27**(12), 1641–1646 (2006)
14. N.J. Khoury, G.Y. El-Khoury, M.H. Kathol, MRI diagnosis of diabetic muscle infarction: Report of two cases. Skelet. Radiol. **26**, 122–127 (1997)
15. S.S. Bhat, V. Selvam, G.A. Ansari, M.D. Ansari, M.H. Rahman, Prevalence and early prediction of diabetes using machine learning in North Kashmir: A case study of district Bandipora. Comput. Intell. Neurosci. **2022**, 1 (2022)
16. A. Nagdev, M. Murphy, C. Sisson, Bedside ultrasound for the detection of diabetic Myonecrosis. Am. J. Emerg. Med. **26**, 969.e3–969.e4 (2005)
17. R.S.H. Istepanian, S. Hu, N.Y. Philip, A. Sungoor, The potential of Internet of m-health Things "m-IoT" for non-invasive glucose level sensing, in *Engineering in Medicine and Biology Society (EMBC), Annual International Conference of the IEEE*, (2011)
18. V. Mishra, M.K.P. Naik, Use of wireless devices and IoT in management of diabetes, in *National Conference on Emerging Trends in Science, Technology and Management*, (November 2017)
19. MATLAB version 7.9.0.529 (R2009b), Mathworks Inc., August 2009
20. Matthew McAuliffe, MIPAV (medical image processing, analysis, and visualization), February 2012
21. S.S. Bhat, V. Selvam, G.A. Ansari, M.D. Ansari, Analysis of diabetes mellitus using machine learning techniques, in *2022 5th International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT)*, (IEEE, November 2022), pp. 1–5

IoT-Based Heart Disease Prediction System

Vemula Manvitha, Syed Musthak Ahmed, P. Ramchandar Rao, and Vinit Kumar Gunjan

1 Introduction

As per the statistical survey, it is observed that around 2 million of the Indian population suffer from heart attack every year. The rate of death is one person for every 0.5 second. The World Health Organization predicted that this rate might go up by 23.3% by the year 2030 around the globe.

Heart disease or cardiovascular disease is caused due to narrowing down of blood vessels or due to blockage of blood vessels (Fig. 1), leading to heart attack or heart stroke.

Many of the heart diseases can be prevented by following good health practices and changing the lifestyle. The symptoms of these diseases vary in gender. Chest pain is a likely symptom in men while women have a sense of discomfort in the breast followed by short breathing, nausea, and fatigue.

Cardiologists report the following symptoms during cardiac problems: chest pain, chest discomfort (angina), shortness of breath, numbness, weakness in legs, coldness in legs or arms, neck pain, and jaw pain.

V. Manvitha (✉)
SR Engineering College, Warangal, Telangana, India

S. M. Ahmed · P. R. Rao
Department of ECE, SR University, Warangal, Telangana, India

V. K. Gunjan
CMR Institute of Technology, Hyderabad, Telangana, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_27

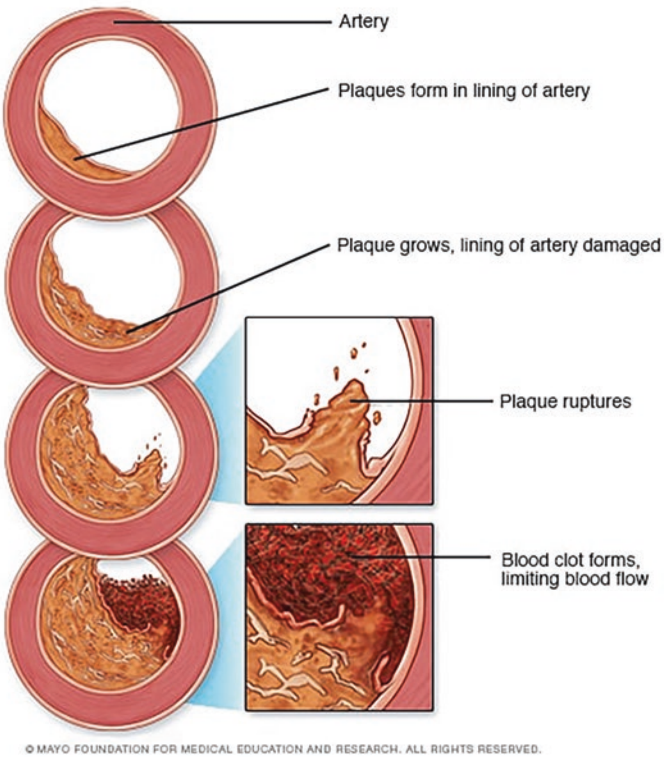


Fig. 1 Causes of cardiovascular disease

2 Literature Review

Recently, a remote innovation has expanded rapidly in different areas and fields of medicine, consumer, agriculture, engineering, and social living [1–11]. Biomedical is one such ongoing fields that provide a better medical assistance and service. Healthcare will be a biggest sector to monitor patients' health using Internet of Things (IoT). It is expected that the IoT market will be above 117 billion by 2020. Medical researchers are attempting in the field of advancement and exploration since numerous a very long time to improve wellbeing administrations and joy in living souls. Their commitment in clinical territory is vital to us and cannot be ignored. The present auto constructions have the root thoughts coming from the previous rudiments. Likewise, early recognition of constant infections can be simple with this technology [12, 13]. The internal heat level, pulse, circulatory strain, and breath rate are prime boundaries to analyze the infection. This task gives temperature and pulse esteems utilizing IoT. An IoT framework for medical care is regularly made out of loads of detecting contraptions identified with a web worker;

it presents real time observation of a putting or clients [14–17]. IoT replaces the old and traditional procedures of manual heart rate monitoring to remote heart rate monitoring. It supports medical attention to the patient in the absence of guardian connecting the doctor remotely. With login credentials, the doctors can monitor the patient via Android app using his smart phone [18–22].

3 Existing Methods

Nowadays, we see people suffering with large number of heart diseases and this leads to the risk of heart attack. In existing systems, an Arduino UNO is employed along with sensors, which help one to detect the heart rate of a person. The high and low heart rate beat limit can be set. Once it is calibrated, then the sensor interface starts monitoring and calculates the heartbeat.

If the person's heart rate exceeds the threshold level, it alerts the controller, which then records and displays the heartbeat and sends recorded information to a doctor or to the concerned person. Besides, the system also alerts for lower heartbeats. Such a system block is shown in Fig. 2. By this way, we will be able to save people from heart problems on time.

4 Objectives

This product is developed with the aim and objective to

(a) See that care is taken to family/person suffering from heart problems.
(b) See caring is done from a place away from home.
(c) Make use of technology and serve society at large.
(d) Develop low-cost Indigenous products.
(e) Sets aside the hassle of travelling for healthcare centers.

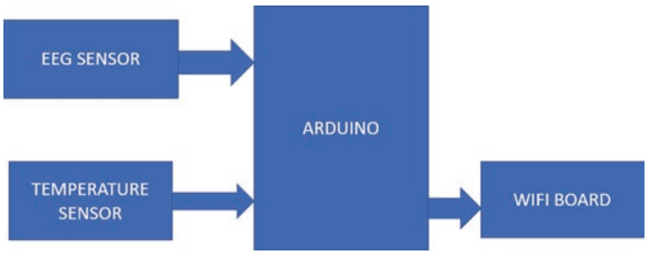


Fig. 2 Basic model of existing system

5 Proposed System

In the present work the critical elements such as temperature, EEG, and heartbeat values are examined using MSP430. Because the signals level is low (acquire), an enhancer circuit is used to acquire the signals and transfer them to the MSP430 through speaker circuit and signal conditioning unit (SCU). Individual sensors are used to estimate the patients' internal heartbeat levels, EEG, and pulses, which are displayed on a PC screen using MSP430 and a cloud data set structure, that supports to be viewed and examined by medical experts from any corner of the Globe via the internet. Using MSP430, the framework for patient checking can monitor the patient's health conditions like EEG, heartbeat, temperature, and pulse levels. Following the connection of the web to the MSP430, will be linked to the cloud database framework, which functions as a worker. The worker will then naturally communicate information to the beneficiary system. As a result, the specialist can keep an eye on the patient's health at all times. Any unanticipated increase or decrease in these critical health elements values can be detected at the soonest and thus essential preventive and mitigation steps can be executed by the specialist at right time without losing the life of a patient. Figure 3 shows the proposed system block diagram.

6 Experimental Setup, Results and Discussion

The experimental setup of the developed system is shown in Fig. 4a. The contributions through supported techniques had made suitable for a practical way of life. The main advantage of this is to have a sort of smart home robotization gadget which helps people distinctively in directing and saving an eye on home framework. The implementation of IoT with the gadget helps in identifying the development at

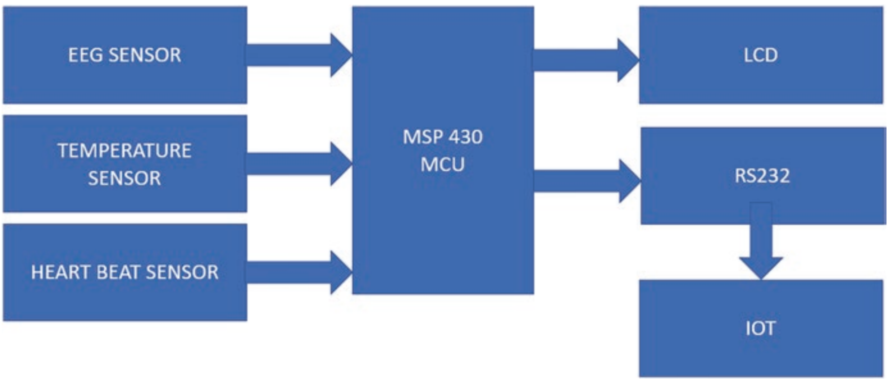
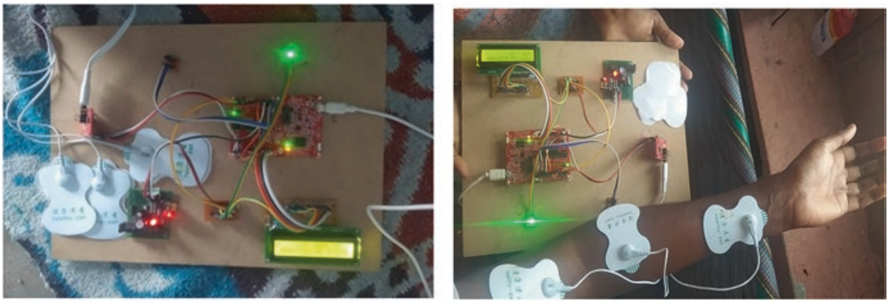


Fig. 3 Proposed system block diagram



(a) (b)

Fig. 4 (**a**) Practical implemented hardware system (**b**) Testing the hardware system

home with deceased and also support security and arrangement of medical services. The testing of the module is shown in Fig. 4b. The sensors are fixed at appropriate location to monitor. The signal received to the mobile can be transmitted to the doctor on emergency thereby taking care of patient at home.

Usually, the patient's temperature, heartbeat, and pulse rate were measured and examined by doctors manually with medical equipment and instruments. These measurements and examinations will consume a huge work, time, and cost. To overcome this a IoT-based network was installed at the patient and to the PC which will continuously monitor the patient's health condition.

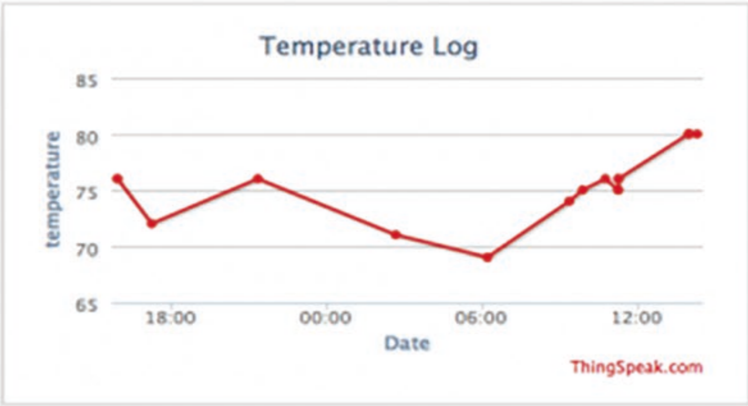
The main components of this network include LCD, ECG, EEG, Buzzer, Wi-Fi Module, MSP430 controller, temperature sensor, and power supply. The connection between these components is as follows: ECG sensor, temperature sensor, and heartbeat sensors were connected to MSP430, and this MSP430 was connected to LCD and buzzer through internet. These ECG, EEG and temperature sensors will regularly record the patient's heartbeat, temperature and pulse and transfers to MSP430 from there the data will be sent through internet from website to LCD and displays (see Fig. 4). All the standards measurements or values related to the body temperature, heartbeat and pulse rates were fixed in a range in the website and MSP430, if there are any fluctuations in these values recorded by sensors from patient will alert the medical experts by ringing the buzzer automatically and the data will be also shown in the display. Figure 5 depicts the Graphical representation of recorded parameters while the sensors are connected to the patient.

Discussion

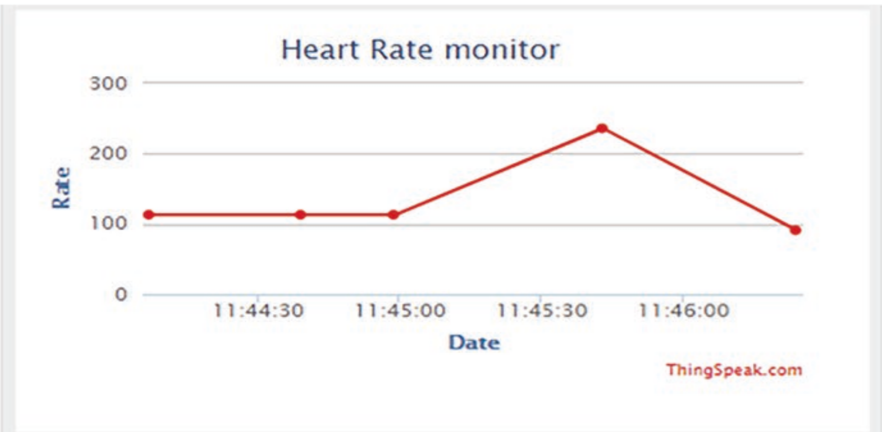
The developed system with sensors

1. Monitor the heartrate of the patient.
2. Records temperature, ECG from sensors.
3. Connects smart phone to the practitioner with login credentials through IoT.
4. Display readings on LCD display as well.
5. Reading was detected at intermittent times.

(a)



(b)



(c)

Fig. 5 Recording of patient parameters (**a**) ECG (**b**) Temperature (**c**) Heartbeat

7 Conclusion

In this challenge, an IoT framework is presented to check people's health and fitness problems as well as notify them to keep healthy monitoring. The suggested device incorporates a wearable IoT node with a cell phone software program, via which the IoT sensor node collects the persons health standards, collectively with temperature state and blood oxygen saturation, and the cellular smart phone connected to the network to transmit out the statistics to the net server. This proposed work supports high frequency distance-tracking which runs for interior as well as outside environments to alert individuals to maintain the physical standards and fitness. Applying IoT components on body specifications makes it viable to check people's wellness situations and to alert people in real time. The developed system is extremely useful in emergency situations wherein medical attention to the patient is needed in the absence of guardian connecting the doctor remotely.

References

1. M.A. Iqbal, K. Devarajan, S.M. Ahmed, A literature survey on identification of asthma using WPT and ANN. Int. J. Sci. Technol. Res. (IJSTR) **9**(02), 1311–1314 (2020)
2. M.A. Iqbal, K. Devarajan, S.M. Ahmed, A brief survey of asthma classification using classifiers. Int. J. Adv. Sci. Technol. **28**(15), 717–740 (2019)
3. F. Shaik, A.K. Sharma, S.M. Ahmed, Hybrid model for analysis of abnormalities in diabetic cardiomyopathy and diabetic retinopathy related images. Springerplus **5**(1), 1–17 (2016)
4. F. Shaik, A.K. Sharma, S.M. Ahmed, A novel approach for detection and analysis of abnormalities in MRI images related to diabetic myonecrosis. Int. J. Mod. Electron. Commun. Eng. (IJMECE) **4**(1), 1–5 (2016)
5. F. Shaik, A.K. Sharma, S.M. Ahmed, A novel approach for detection of anomalies in images related to diabetic Myonecrosis. Int. J. Innov. Res. Electr. Electron. Instrum. Control Eng. ISSN (Online) 2321–2004, ISSN (Print) 2321–5526 **3**(12), 181–184 (2015)
6. F. Shaik, A. Kumar, S.S.M. Ahmed, Review of image processing methods on diabetic related images. Int. J. Eng. Tech. **1**(4), 99–108 (2015)
7. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
8. P. Ramchandar Rao, S. Srinivas, E. Ramesh, A report on designing of wireless sensor networks for IoT applications. Int. J. Eng. Adv. Technol. **8**(6), 2005–2009 (2019)
9. J.T. Kumar, P.R. Rao, M.S. Reddy, IOT based email enabled smart home automation system. Int. J. Recent Technol. Eng. (IJRTE) **8**(1C2), 90–99 (2019)
10. S.M. Ahmed, B. Kovela, V.K. Gunjan, IoT based automatic plant watering system through soil moisture sensing-A technique to support farmers' cultivation in rural India, in *Advances in Cybernetics, Cognition, and Machine Learning for Communication Technologies*, (Springer, Singapore, 2020), pp. 259–268
11. V.K. Gunjan, S. Kumar, M.D. Ansari, Y. Vijayalata, Prediction of agriculture yields using machine learning algorithms, in *Proceedings of the 2nd International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications*, (Springer, Singapore, 2022), pp. 17–26
12. S.J. Jung, W.Y. Chung, Adaptable and versatile patient's wellbeing observing framework in 6LoWPAN. Sens. Lett. **9**(2), 778–785 (2011)

13. W.Y. Chung, C. Yau, K.S. Shin, R. Myllylä, A phone-based wellbeing checking framework with self-analysis processor utilizing remote sensor network innovation, in *Proc. 29th Annual. Int. Conf. Eng. Prescription. Biol. Soc.*, (Lyon, France, 2007)
14. G. Lawton, Machine-to-machine innovation prepares for development. Computer **37**(9), 12–15 (2004)
15. C. Kim, A. Soong, M. Tseng, X. Zhixian, Worldwide remote machine to machine normalization. IEEE Internet Comput. **15**(2), 64–69 (2011)
16. A. Abdullah, A. Ismael, A. Rashid, A. Abou-ElNour, M. Tarique, Real time wireless health monitoring application using mobile devices. Int. J. Comput. Netw. Commun. (IJCNC) **7**(3), 13–30 (2015)
17. F.F. Firdaus, H.A. Nugroho, I. Soesanti, Deep neural network with hyperparameter tuning for detection of heart disease, in *Wireless and Mobile (APWiMob) 2021 IEEE Asia Pacific Conference*, (2021), pp. 59–65
18. P. Singh, Internet of Things based health monitoring system: opportunities and challenges. Int. J. Adv. Res. Comput. Sci. **9**(1), 224–228 (2018)
19. K. Xian, Internet of Things online monitoring system based on cloud computing. Int. J. Online Eng. **13**(9), 123–131 (2017)
20. M.U. Farooq, M. Waseem, S. Mazhar, A. Khairi, T. Kamal, A review on Internet of Things (IoT). Int. J. Comput. Appl. **113**(1), 1–7 (2015)
21. J. Gomez, B. Oviedo, E. Zhuma, Patient monitoring system based on Internet of Things. Proc. Comput. Sci. **83**, 90–99 (2016)
22. G.A. Ansari, S.S. Bhat, M.D. Ansari, S. Ahmad, J. Nazeer, A.E.M. Eljialy, Performance evaluation of Machine Learning Techniques (MLT) for heart disease prediction. Comput. Math. Methods Med. **2023**, 1–10 (2023)

Smart Agriculture Monitoring System Using IoT

Erra Thirupathi, Chakradhar Adupa, P. Ramchandar Rao, Vinith Kumar Gunjan, and Syed Musthak Ahmed

1 Introduction

Agriculture is the main occupation of rural people in our country. More than 50% of the rural population depends on agriculture for their survival. As per Central Statistics Office (CSO), our countries' cross value addition (GSA) is around 8%, which is an adequate figure. According to the current market survey, nearly 85% of the water resource are utilized for agriculture. Thus, water has to be saved, conserved and preserved, and better utilized besides improving the agriculture yield. Thermal imaging to monitor fields and check water status and irrigation scheduling are being developed earlier. The Internet of Things (IoT) has emerged and deployed in various sectors such as health, manufacturing, communications, and agriculture. The motive is to improve efficiency and performance across all markets.

The primary need of agriculture mainly depends on monsoon and the kind of soil for the particular crop. Second, the water supply to the crop and amount of water to the crop are essential. The majority of time is squandered by farmers and many other aspects for crop monitoring, timely availability of electricity, and many other

E. Thirupathi
SR Engineering College, Warangal, Telangana, India

C. Adupa (✉)
SR Engineering College, Warangal, Telangana, India

Department of ECE, SR Engineering College, Warangal, Telangana, India
e-mail: chakradhar.a@sru.edu.in

P. R. Rao · S. M. Ahmed
Department of ECE, SR Engineering College, Warangal, Telangana, India

V. K. Gunjan
CMR Institute of Technology, Hyderabad, Telangana, India

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7_28

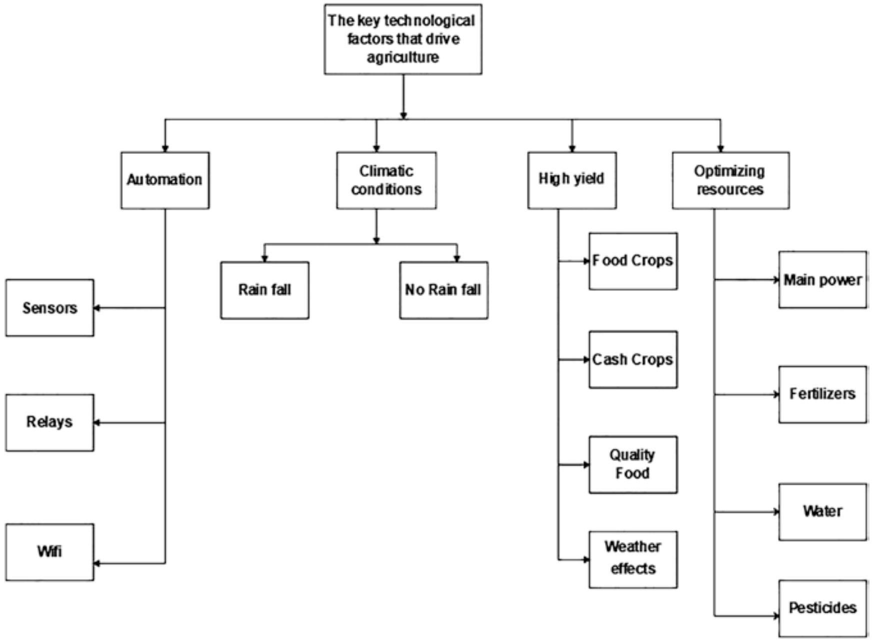


Fig. 1 The key technical factors that drive agriculture

problems. To overcome this, automation of agriculture becomes important. The key factors for good yield of agriculture depend on water, climate, soil nutrients, and proper monitoring. Climate is a natural phenomenon, which is not in the hands of the farmer. However, proper nutrition such as pesticides, fertilizers, herbicides, and chemicals may be added in proportion depending upon the nature of the crop. Availability of labor is also one of the setbacks in today's agriculture system.

The implementation of IoT in agriculture sector has led to the concept, namely "smart agriculture"—a method to improve agriculture yield with less resources and labor. This technology is helping the farmers in all stages of crop from sowing to harvesting. Thus, IoT in agriculture finds high potential and research challenges in future. The main challenges that drive this technology are shown in Fig. 1.

2 Literature Review

Smart farming is a new concept of managing the crop cultivation by making use of modern tools and technologies to enhance the quality of farming and agriculture harvesting [1–6]. Smart agriculture system addresses issues such as population growth, labor need, and climate changes. Starting from planting of the crop, watering it, and to the stage of harvesting the IoT-based smart agriculture system are being implemented using several sensors that control the crop yield. Sensors such as light sensor, humidity sensor, temperature sensor, and soil moisture sensor can support the process of automatic irrigation. This smart system also incorporates cameras, monitors, and other devices along with sensors to control every element involved in farming.

The advent of IoT brought several changes in various fields and one such being the agriculture [7, 8]. The system involved the monitoring of the environmental conditions such as light, rain, soil content, humidity, temperature, and then watering the crop. The systems also include water level indicator to look into the water content and that is needed for a particular crop and then water it. The whole system is automatically controlled to make the complete agriculture process smarter. Thus, smart agriculture using IoT has shown a way to the farmers to solve their problems and at the same time, monitor the agriculture system [8–13].

In reference [14], the authors have presented on technology assistance to agriculture related applications. In their work, they incorporated wireless sensor network to address problem like field water pumping and providing nutrients to the crop to make a better yield. Automation by observing field parameters like temperature, humidity, and rainfall are monitored using suitable sensors to control the pumping of water to the garden. They made use of microprocessor along with GSM module to demonstrate their experiment.

3 Existing System

The basic requirement of any irrigation system is to monitor temperature, humidity, moisture, and water level. To monitor, suitable sensors, relays, and control system with necessary hardware are essential. Smart agriculture makes use of temperature sensor to record the temperature requirements, the humidity sensor to observe the moisture and humidity contents, and automatic pump control circuitry to maintain the level of the water.

In the existing system, Arduino Uno is used as an interface module for controlling the smart agriculture process. The various sensors interfaced include temperature sensor, moisture and humidity detection sensors, and rain detection sensor with WiFi communication. WiFi communication is achieved using ESP 8266. These sensors control the switching ON and OFF of the motor to water the fields. Such a system implementation is shown in Fig. 2.

4 Proposed System

To make the agriculture system smarter with Wi-Fi and Cloud, the implemented circuit is shown in Fig. 3.

The system consists of an Arduino Uno board with WiFi interface, along with several other sensors for temperature, humidity, and rainfall monitoring. The DHT11 temperature sensor is incorporated for temperature measurement. A 16 × 2

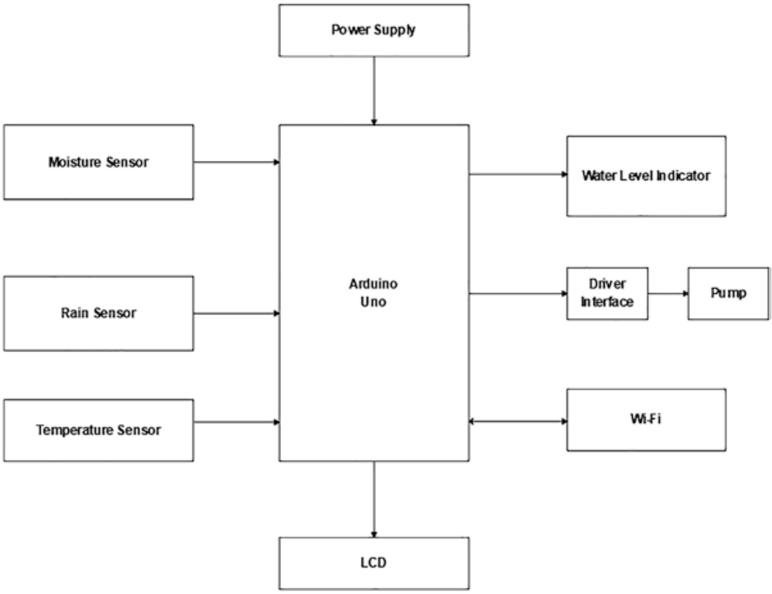


Fig. 2 Block diagram of basic system

LCD display is connected to Arduino for displaying water level and water pump status. ESP8266 connected to arduino board is used for wireless communication.

The developed module with associated sensors perform the following functions:

1. Temperature sensor for recording temperature
2. Humidity and moisture sensor to find the soil fertility
3. Water level sensor to sense the water level content and to switch ON and OFF the motor for maintaining the level of water to the plant.

The complete setup with WiFi supports the formers to ease their work and monitor the crop.

5 Hardware Requirements

The components required in the implementation are shown in Fig. 4a–f. They are water level sensor to maintain the required water level, humidity and moisture sensor to check the moisture content in the soil, a relay unit to control the ON/OFF of the pump, an LCD module to display the water level and the pump status, and an Arduino UnoModule.

The implementation makes use of the following hardware—water level sensor, humidity sensor, moisture sensor relay module, Arduino UnoModule, and 16 × 2 LCD display. The water level sensor (Fig. 4a) is interfaced to the water pump via a

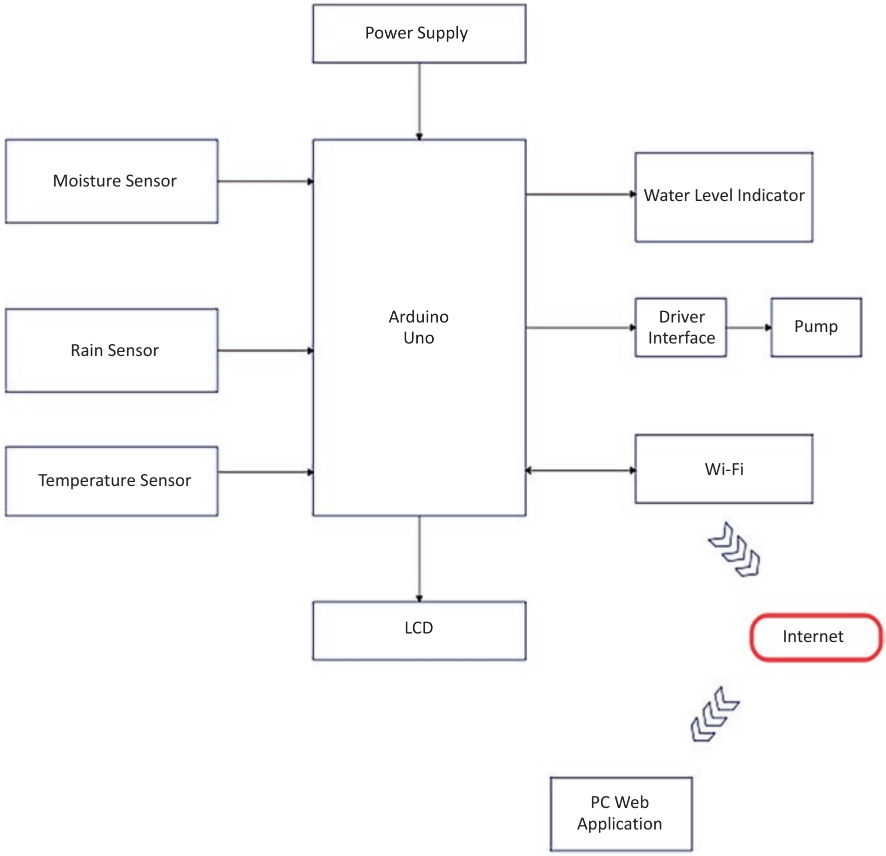


Fig. 3 Smart Agriculture with WiFi and Internet

relay. Depending on the water requirements to the crop, the motor is switched ON and OFF via relay depending upon the signal from the sensor. If the level of the water is low, the sensor signals so that the relay is closed switching the motor ON. In the event, if the required level of water is reached, the relay connects the motor to the power supply, switching the motor ON.

Humidity and moisture sensors are incorporated to check the humidity content and moisture content of the soil. Figure 4b, c shows an interface in the module for this purpose. The DTH11 is used to sense the humidity. The operating range of the sensor is 3–5 V with an accuracy of 1, humidity—5% and 2, and temperature—±2 °C.

Figure 4d shows a relay incorporated in developing the system. Figure 4e shows the Arduino Uno board, the heart of the system. It consists of CPU, Flash RAM, and I/O Built within it.

A 16 × 2 LCD Display is used in the developed module to display the level of the water in the tank, as shown in Fig. 4f.

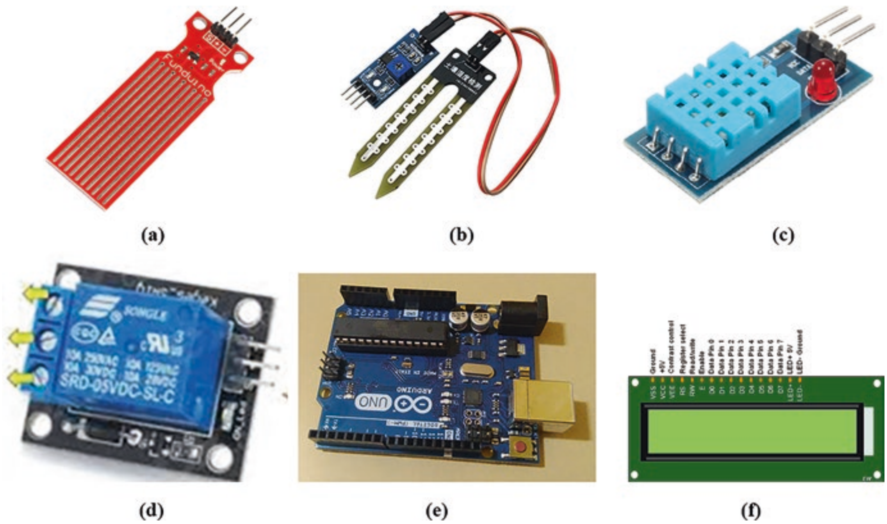


Fig. 4 Hardware components (**a**) Water level sensor (**b**) Moisture sensor (**c**) Humidity sensor (**d**) Relay Module (**e**) Arduino UnoModule (**f**) 16 × 2 LCD display

6 Flow Chart Implementation

The complete working of the smart system implemented is explained by a flow graph as shown in Fig. 5. Intially, the various monitoring parameters are intialized into the system.

From the flow graph, we infer that depending upon the parameters and the water level contents, the system controls the water requirements to the crop.

7 Results

Figure 6a presents the proposed model setup for smart agriculture monitoring system with real time monitoring of soil properties such as humidity, moisture, and temperature, using various control operations of the field using web application. The IoT is incorporated into the system to increase the yield of the crop by studying the various environmental parameters to the farmers remotely. The developed system can be implemented in any agriculture field crops and soil contents. The developed system is a low cost, simple in design, and implementation. The whole purpose of the project is to support formers for better irrigation and yield. This system reduces the need of labor, human intervention, and wastage of water. Once the level

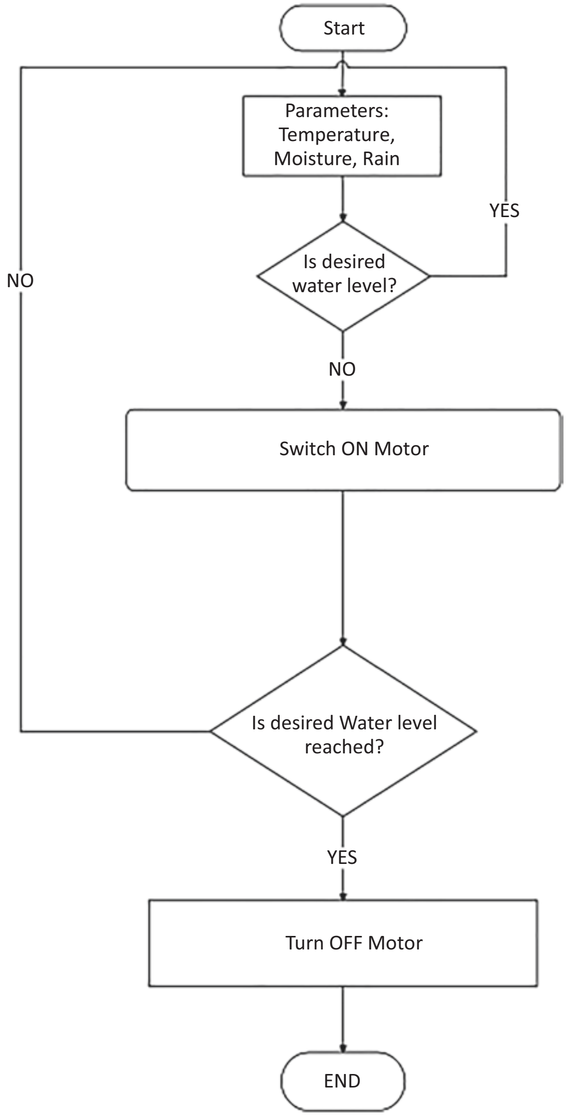


Fig. 5 Flow chart showing the working of Proposed system

of the water required for the crop is fixed, the sensor monitors the level of water requirements by controlling the water requirement. Whenever the level of the water goes below the desired level, the motor automatically switches ON and the water is supplied, and once the desired level is reached, the system automatically switches OFF by maintaining the desired water level. Figure 6b shows a vegetable plant with sensors for testability.

Watering the plants is also controlled depending upon the temperature and the humidity levels. So, as long as the desired level is maintained, the system remains OFF. Any deviation from the desired requirement switches OFF the motor. The monitoring of various parameters recorded on a particular day with varying parameters of temperature, humidity, rainfall, and water level content is tabulated in Table 1. The readings recorded are a prototype testing carried out on a plant as shown in Fig. 6b. However, this can be incorporated into the agriculture field for better yield and monitoring without any human intervention.

The graphical representation of soil parameters variations recorded on a particular day as shown in Table 1 and is graphically represented in Fig. 7.

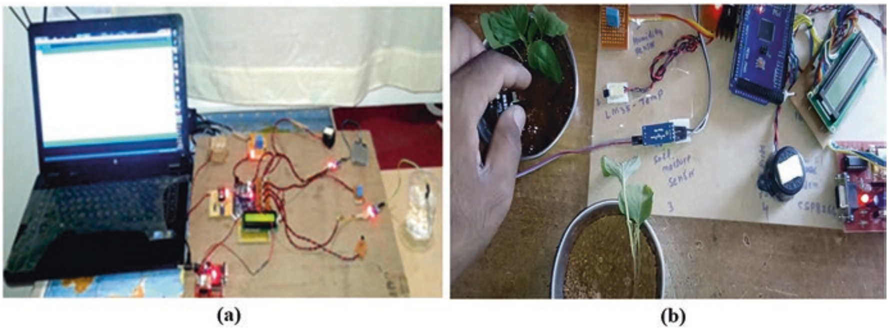


Fig. 6 (**a**) Smart agriculture monitoring system setup (**b**) Prototype testing

Table 1 Parameter Recording on a particular day

Date	Temperature	Humidity	Water level	Rainfall
20-01-21	36	59	53	2
20-01-21	36	60	53	2
20-01-21	37	53	50	2
20-01-21	35	60	30	2
20-01-21	36	59	62	1
20-01-21	35	53	38	2
20-01-21	37	58	43	0
20-01-21	37	59	69	2
20-01-21	37	53	52	0
20-01-21	36	53	51	0
20-01-21	36	54	23	0
20-01-21	37	54	48	1
20-01-21	35	56	25	2
20-01-21	36	53	58	2
20-01-21	35	60	36	1
20-01-21	36	59	35	2

(continued)

Table 1 (continued)

Date	Temperature	Humidity	Water level	Rainfall
20-01-21	37	53	51	0
20-01-21	35	59	58	1
20-01-21	36	59	51	1
20-01-21	37	52	71	2
20-01-21	35	59	23	1
20-01-21	37	57	48	2
20-01-21	36	58	55	2
20-01-21	35	59	35	2
20-01-21	37	58	62	0
20-01-21	35	52	69	2
20-01-21	37	60	41	0
20-01-21	35	55	60	2
20-01-21	37	58	26	2
20-01-21	36	59	60	2
20-01-21	35	53	28	1
20-01-21	36	52	57	1
20-01-21	36	58	42	1
20-01-21	36	53	31	0

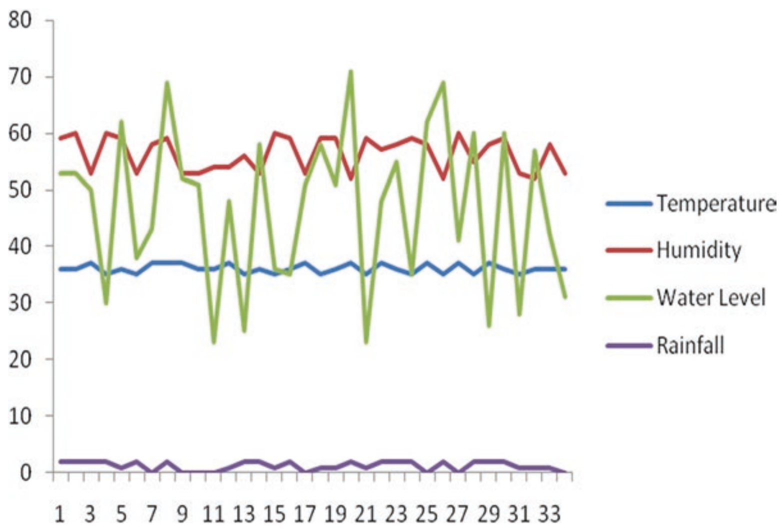


Fig. 7 Graph depicting the variations of the soil parameters

8 Conclusions

Smart agriculture system is an emerging concept wherein the IoT sensors are able to provide information of the agriculture field conditions. Remote monitoring of crop saves cost, time, and effort on the farmers. The proposed project is the implementation of this evolving technology to make smart agriculture using automation by monitoring the moisture content and temperature of the field. Monitoring environmental factors is the major factor to improve the yield of the efficient crops. With the implementation of the present system, the irrigation becomes practically easy and accurate. In the present system, the temperature moisture and rain sensors play an important role in obtaining the output. This smart agriculture monitoring system is prototype tested successfully. The action is performed depending upon the humidity of the soil. If the soil is dry, a signal is sent to Arduino, which automatically switches ON the motor and runs a pump for watering the plants. If the necessary humidity is available, the motor remains OFF, thereby automatically switching OFF. The module developed is economically efficient and affordable and can be extended for large-scale cultivation and support farmers.

References

1. C.H. Sandeep, K.S. Naresh, K.P. Pramod, Security challenges and issues of the IoT system. Indian J. Public Health Res. Dev. (IJPHRD) **9**(11), 748–753 (2018)
2. F.H. Tani, S. Barrington, Zinc and copper uptake by plants under two transpiration rates. Part I. Wheat (*Triticum aestivum* L.). Environ. Pollut. **138**, 538–547 (2005)
3. J. Gutiérrez, J.F. Villa-Medina, A. Nieto-Garibay, M.Á. Porta-Gándara, Automated irrigation system using a wireless sensor network and GPRS module. IEEE Trans. Instrum. Meas. **63**(1), 166–176 (2014)
4. S.S. Patil, A.V. Malvijay, Review for ARM based agriculture field monitoring system. Int. J. Sci. Res. Publ. **4**(2), 1–4 (2014)
5. S.K. Nagothu, Weather based smart watering system using soil sensor and GSM, in *2016 World Conference on Futuristic Trends in Research and Innovation for Social Welfare (Startup Conclave)*, (2016)
6. W.A. Jury, H.J. Vaux, The emerging global water crisis: managing scarcity and conflict between water users. Adv. Agron. **95**, 1–76 (2007)
7. L. Ting, M. Khan, A. Sharma, M.D. Ansari, A secure framework for IoT-based smart climate agriculture system: toward blockchain and edge computing. J. Intell. Syst. **31**(1), 221–236 (2022)
8. V.K. Gunjan, S. Kumar, M.D. Ansari, Y. Vijayalata, Prediction of agriculture yields using machine learning algorithms, in *Proceedings of the 2nd International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications*, (Springer, Singapore, 2022), pp. 17–26
9. S.M. Ahmed, T.S. Chandu, U. Rohit, G. Naveen, S. Naveen, IoT based garbage disposer for educating rural India, in *International Conference on data Sciences, Machine Learning and Applications (DSMLA 2019)*, (2019, 29–30 March)
10. G.S. Narayana, M.D. Ansari, V.K. Gunjan, Instantaneous approach for evaluating the initial centers in the agricultural databases using K-means clustering algorithm. J. Mob. Multimed, **10**, 43–60 (2022)

11. S.M. Ahmed, B. Kovela, V.K. Gunjan, IoT based automatic watering system through soil moisture sensing—a technique to support farmers' cultivation in rural India, in *International Conference on Cybernetics, Cognition and machine Learning Applications (ICCCMLA 2019)*, (Springer, 2019, 16–17 March)
12. S.M. Ahmed, B. Kovela, V.K. Gunjan, Springer Book Chapter 28: IoT based automatic plant watering system through soil moisture sensing–a technique to support farmers' cultivation in rural India, in *Published in Lecture Notes in Electrical Engineering, LNEE Springer Book Series*, vol. 643, (2020), pp. 259–268
13. A. Tendolkar, S. Ramya, CareBro (Personal Farm Assistant): An IoT based Smart Agriculture with Edge Computing, in *2020 Third International Conference on Multimedia Processing, Communication & Information Technology (MPCIT)*, (2020), pp. 97–102
14. K. Guravaiah, S.S. Raju, e-agriculture: irrigation system based on weather forecasting, in *15th IEEE International Conference on Industrial and Information Systems (ICIIS)*, (2020, Nov), pp. 617–622

Index

V. K. Gunjan et al. (eds.), *Modern Approaches in IoT and Machine Learning for Cyber Security*, Internet of Things, https://doi.org/10.1007/978-3-031-09955-7