Integration of WSN with IoT Applications: A Vision, Architecture, and Future Challenges

Karan Bajaj, Bhisham Sharma, and Raman Singh

1 Introduction

The Internet of Things (IoT) is the connectivity of the physical devices and objects that are used in daily life, which are connected over the Internet network. It is connected to the different types of objects which communicate with each other through various sensors, actuators, and processors. The goal of IoT is to attain high degree of intelligence with least human intervention [1]. The IoT brings the automation and intelligence in all sectors of life, making it comfortable; here devices are made self capable to take smart decision by themselves. In the IoT, a large number of heterogeneous devices are connected over the network. Today the IoT covers a large domain and every aspect of the society from industry, healthcare, and transport to the agriculture and home environment provides the services.

A smart city covers all the domains of the society that use information and communications technologies (ICTs) [2]. It also covers all the different applications and makes the city services and monitoring more aware, interactive, and efficient [2]. wireless sensor network (WSN) is the backbone of IoT, without which the concept of a smart city cannot be realized. Sensors and actuators are the devices, which interact with the physical world and impose the changes. Under the heterogeneous environment, a large number of devices are connected together using sensors and

K. Bajaj · B. Sharma (✉)
Chitkara University School of Engineering and Technology,
Chitkara University, Himachal Pradesh, India
e-mail: karan.bajaj@chitkarauniversity.edu.in; bhisham.sharma@chitkarauniversity.edu.in

R. Singh
Department of Computer Science & Engineering, Thapar Institute of Engineering and Technology, Patiala, Punjab, India
e-mail: raman.singh@thapar.edu

S. Rani et al. (eds.), *Integration of WSN and IoT for Smart Cities*,
EAI/Springer Innovations in Communication and Computing,
https://doi.org/10.1007/978-3-030-38516-3_5

generate large amount of data. This data is stored and analyzed to derive the information and support decision-making [1].

A smart city consists of a large number of heterogeneous devices, including smart as well as simple objects. A large amount of data is gathered due to a large number of sensors connected to the objects. IoT network in the case of a smart city must be scalable as there can be requirement of adding new devices and deleting old devices, anytime and anywhere. Due to wide application areas and difference of technology among the devices, incorporating WSN becomes challenging [3]. From the perspective of the smart city, the main facing challenges of IoT are interoperability, context awareness, scalability, and management of large volumes of data, security, privacy and integrity, dynamic adaptation, reliability, and latency.

The smart city covers all the aspects of society by having large number of applications. Figure 1 represents the key aspects of society that make the smart city. It shows healthcare, industries, transport, agriculture, and home automation; all are the essential part of the smart city. The smart city is equipped with several equipment and technologies which make the life of people smarter through several applications; there are several aspects of the smart city such as smart technology, infrastructure, and governance. IoT is bringing transformation in education sector and security requirements of smart cities [4].

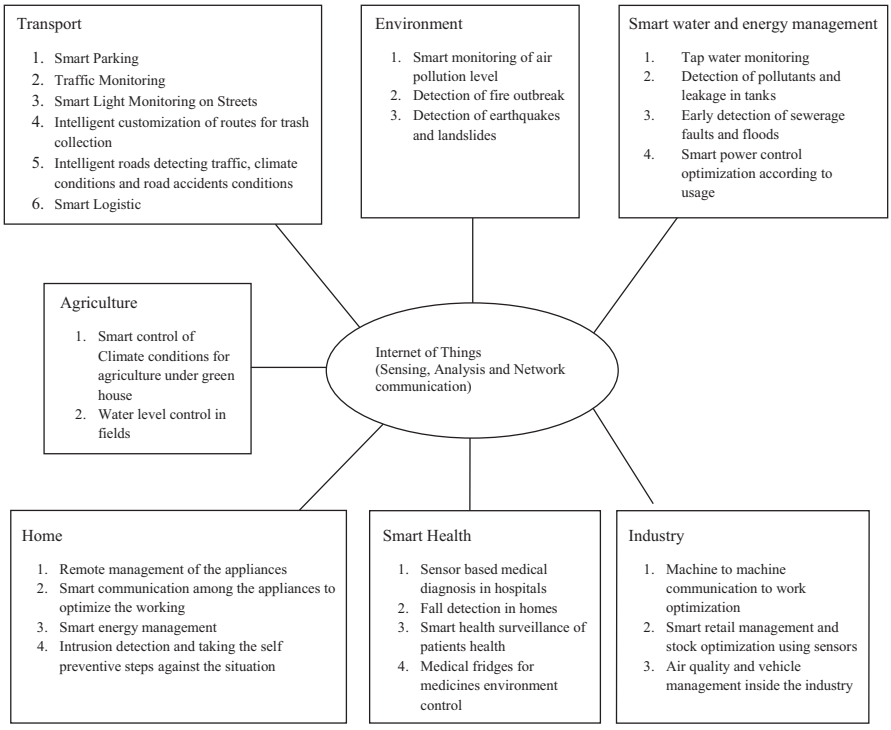

Fig. 1 Key aspects of smart city

2 Architectural Need of the Smart City

Architecture supports the services and their working and is required to solve the key issues that are faced by IoT applications. It provides the level of abstraction over physical devices and services and supports the heterogeneity and interoperability among devices, which is one of the key properties of IoT. A large number of devices and objects are connected under IoT having different functionalities, capabilities, characteristics, and Internet protocols which also raise the concern of security issues in IoT. In smart city IoT structure, a large number of independent systems or applications work together. These devices have different kinds of sensors, and both the hardware and software heterogeneity exist among the devices; therefore, we need the architecture which is flexible to support both hardware and software diversity among these objects.

In smart city IoT architecture, information is shared not only among the different applications of the society but also to the interested parties like government and management sectors, etc. The smart city should be capable to scale any number of devices with different technology anytime; therefore, cross-application services are the requirement of smart city. The author in [5] suggests that some domains in smart city need real-time immediate response for well-organized resource planning, to help in the effective use of resource utilization. There is the need of standardization among the architectures to solve the common issues that arise due to the management of a huge amount of data, communication issues related to a large number of protocols, real-time processing of data, data security, privacy and expansion in existing application due to changes in technology, and increasing usage also termed as scalability [6]. Security among the IoT applications, especially in the case of smart city where there is a large amount of intercommunication among the different applications, becomes one of the major challenges due to diversity among the devices and dynamic nature in terms of network and scalability. In IoT applications, the existing solutions do not fully satisfy the need of security. Some solutions demand high energy requirements and become costly solutions [7].

Figure 2 shows a generalized open architecture proposed to support the different applications. It also shows that different sectors will contain the sensors and will be connected to a common gateway as these sectors will share the information to support each other. The kind of processing requirement of the architecture to support the issues in IoT such as the processing of data will be done at edges; it means device level itself, to support critical applications like healthcare and also some data that cannot be handled at edge level, will be processed at middleware, also called as fog computing.

With the study of issues in architectures and understanding the need of the architecture in smart city, the conclusion is drawn that the smart city needs open flexible architecture which supports the scalability, which means a large number of devices can be added in the system anytime. Also, scalability and heterogeneity among the devices should be taken care of. A general architecture is proposed which is

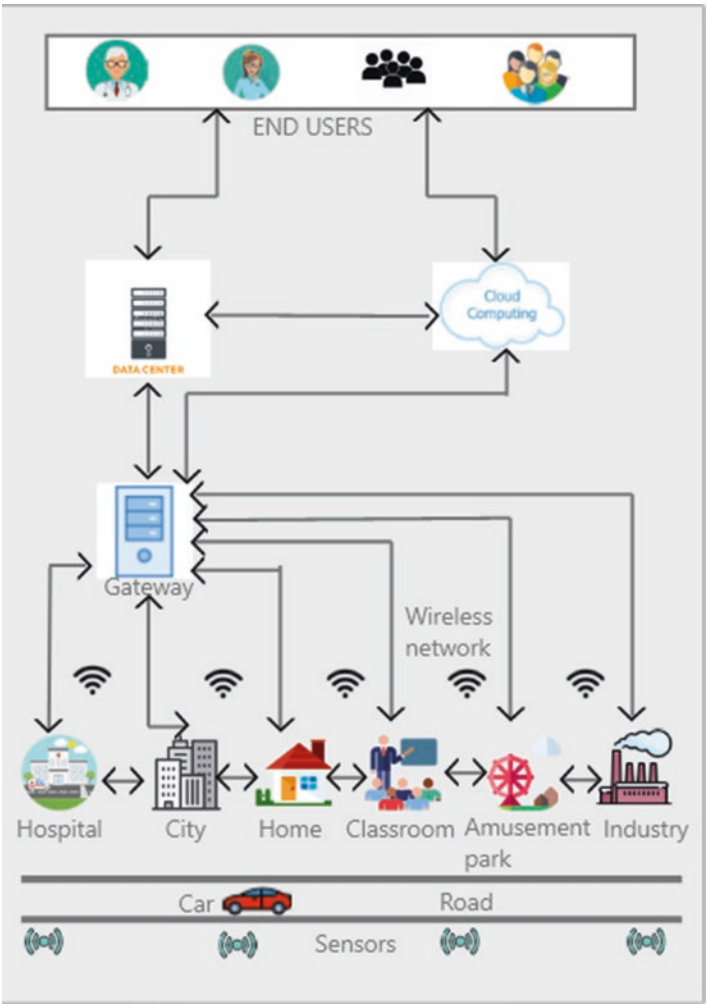

Fig. 2 IoT-based generalized architecture of smart city

edge-based open architecture so that real-time data processing can be done and latency issue can be handled.

Smart City Platform

The smart city uses the emerging technologies such as WSN and big data analytics as a large amount of data is produced by sensors to reduce the resource utilization and bring intelligence in applications. Effective data storage is also required because data grows at a very rapid rate and similarly high computational and processing requirement need is handled by edge devices [8].

For building the smart city, we need a network of smart things using sensors connectivity among them. They collect a huge amount of data using smart gateways where all devices send their data. Some initial amount of data can be processed by task off-loading to the nearby devices or using the concept of femto cloud or fog structure at the middleware level [9]. Whereas the tasks that need a high-computation cloud structure are used for processing and analytics and data lake for storing data, the value of which is yet to be defined and cleaned, and structured data is sent to the data warehouse. Data analytics and machine learning algorithms are implemented at the middleware level and cloud level for processing and analytics task, and finally commands are sent to the actuators to control the applications used by the end users [10].

IoT Application Requirements

To implement the IoT solutions, there is a need to create the applications, but application implementation requires some basic requirements that are:

1. Scalability is one of the main requirements of IoT. The platform should be capable of adding any number of devices anytime without having any effect on the application.
2. IoT applications should be secure and trustworthy. These are the essential components as information flows in wide forms over the sensor network.
3. IoT applications require self-adaptable, optimizable, and configurable system according to the changing need of the environment.
4. IoT applications should be able to understand the situation and emotion according to the context and personalize the services and are capable of decision-makings.
5. Critical applications in IoT are required to be dynamic and should respond in real time without any latency. For example: critical applications like healthcare and inter vehicle communications have dangerous impact in case of latency.
6. IoT applications collect a large amount of personal and private data which may contain the personal data and activity log of people. There is a requirement of privacy compliant law for data protection.

3 IoT-Integrated Applications and Role of WSN in Smart City

Smart cities are touching and transforming all the areas of modern society, like e-health, e-transport, energy, environment, and education. For example: data from weather department can be extremely helpful for environment, flood, and agriculture monitoring. Similarly monitoring the health of elder people and patients in the live environment can be highly useful. Some of the application fields where IoT is bringing a great advantage are:

3.1 IoT in Healthcare

IoT is transforming the healthcare and is one of the most important and critical applications among the society. Using wireless sensor networks to enhance the capability of healthcare structure and real-time monitoring and processing is one of the most challenging goals. Reducing the cost and improving the care of the patients and at the same time dealing with the shortage of staff are the primary concerns [11]. Problems related to complex data in terms of its variety, pace, and latency also need to be taken care of [12]. Healthcare needs multilayer architecture having edge-level computing at device level, fog computing, and cloud computing for computation-intensive tasks.

Mobile Computing in Healthcare Applications
Mobile can give the facility of edge computing to monitor the health of patients from the distant locations and can be done by using central cloud at local level. The authors in [13] proposed a window-based rate control algorithm (w-RCA) and medical quality of service (m-QoS) to provide better service and quality in the mobile edge computing based healthcare [13]. Patients will be wearing the sensor devices for continuous monitoring linked to the mobile applications for real-time processing.

The cloud platform implementation helps the patients' 24/7 monitoring by using smartphone app. Patients can track their health while traveling or relaxing at home anytime and anywhere. Farahani B. et al. [12] say P2P video/audio capabilities can be provided to patients for identification of diseases as well as their treatments and refills of medicine whenever required.

IoT in Medication
The IoT in medication of patients can be of great help especially in the case of elderly patients. In home caring service, a self-alarm system is proposed by the authors in [14] to take the medicine. Also the state of medicine bottle is tracked by the sensors using weight sensors to give warning in case of medicine overdose. In [15] authors purposed the use of RFID (radio frequency identification) technology labels and tags on patient's medicines connected over the Internet of Things with the patient's personal medical files. This will also help in better connectivity between the doctor and patient. Using this architecture, physician can remotely monitor the patient state, and warning can be generated to physician or nurse in case of some changes in patient state. Here the authors have used machine learning algorithms and probabilistic learning structure to enhance the accuracy using classification.

As studied in [16], the authors have proposed a smart necklace to determine the intake of medication by patients. It checks and observes the skin movement of the neck part during the intake of medicine. Bayesian network is used in the study to accurately identify the swallowing of medication capsules, normal speaking, and chewing of vitamins [16]. In combination, medicine bottles are also made smart with wearable audio sensors, and classifications are used to get the accuracy in assessment of medication adherence.

IoT in Ambient Assisted Living

The Ambient Assisted Living (AAL) [17] is particularly targeting the quality of life for older people who are dependent and are at home. It not only includes the medication and continuous health monitoring but also checks the indoor air quality (iAQ) and comfort. The devices and objects in the home will be connected to each other to help the elderly and disabled persons in their day-to-day routine activities [18]. It will also take care of the growth of diseases by live check on the vital signs of the persons.

Challenges in IoT Healthcare

IoT in healthcare brings lots of new hopes to patients and elderly people, but the seamless connection among locations, patients, and hospitals is not easy to achieve. The main challenges in the way of IoT integration in healthcare are:

1. Management of a large amount of data in the healthcare system. The large numbers of medical sensors are attached to the patients and around them. The dynamic nature of the body with continuous state changing becomes more challenging. So collecting and analyzing data with accuracy becomes challenging.
2. Different formats among the data is also an issue as some data is collected by the images using cameras, some data is captured in the form of variations and vibrations, some in the form of body temperature, etc. Accumulating all these different data and analyzing on common platform become an issue.
3. IoT applications particularly in the case of healthcare are time bounded, and emergency services cannot tolerate latency and require real-time monitoring and analysis. But the tasks that require high computations cannot be handled at the edge level, so an open research challenge is present in the domain.

IoT healthcare has lot of advantages and scope, but still there are lot of challenges which need to be addressed like device-network human interfaces, security, and privacy. A large variety and volume of data and lack of standard architecture are also an issue, including this network architecture, which should be scalable; latency rate should be lower with high bandwidth.

3.2 IoT in Industries

The IoT is bringing revolution in industries by improving the machine-to-machine and machine-to-human communication and bringing intelligence in value chain of system and making it a smart value chain. Industries are embedding intelligence and network communication among the process belts to improve their own systems and products. Checking the events, warning of failures, and suggestions to improve and upgrade the existing hardware, refineries, and offices according to IoT applications to enhance the efficiency of the existing system are the advantages of bringing the IoT. The main purposes of bringing the IoT in industries to offer their customers new sets of premium services are:

- Using machine learning (ML) and natural language processing (NLP) to bring smart handling of equipment and their pre-maintenance.
- Making pricing dynamic and analyzing the data based on the usage and providing it to the manufacturing value chain help companies increase efficiency and reduce the processing costs.
- In retail sector, giving retailers and customers personalized experience [19].

The IoT is among one of the future technologies gaining large popularity for all kinds of industrial domains. In this, there is a global network where machines and devices work in conjunction with each other. The author in [20] says that the full power of IoT in industries can be achieved by complete connectivity of devices in industries. For all kinds of processing, monitoring and management of data cloud-based business model can be used. IoT is not only touching but also becoming part of every aspect of industries from logistics, retail management, and customer support to supply chains.

IoT Value Chain

In a broader view, it is not restricted to one organization; rather it allows the data to be shared publicly in multiple organizations. This data is the information that can help the other actors to perform better in terms of design, decision-making, and controlling other devices to optimize the services. IoT value chain has different components like, for taking inputs, there are different sources of IoT value chain, devices/sensors, open data, and corporate databases. Then, initial development of information and components is done under production and manufacture, while processing of information is done using data analytics to create knowledge. Packaging is also a component of this chain, wherein a product is made ready for distribution; and finally distribution and marketing. In this information products are used for improving internal decision-making and for resale to other economic actors.

Today corporate sector wants to provide direct and customized service to the consumer, and this is becoming possible with the merging of machine-to-machine (M2M) value chain with IoT services. Data has not remained specific company based now; it is collected over various sensors and radio frequency identification (RFID). Today we need information-driven value chain in industries. Industries not only want to sell their products but also want to know the potential of the business. Before starting up, analysis reports are generated to know the current and future aspect of business, what can be its growth rate, how future demand will rise or decline, or what kind of scalability will be required in the business [21]. For example, today your GPS device can learn that, after a long journey, you prefer a cup of coffee, and after journey your smartphone shows you immediately the nearest best cafe areas, or coffee business makers can learn that in this region lot of customers after traveling from train prefer a coffee, so let's start cafeteria in a nearby location; earlier no smart learning or searching was there, and people use to walk and search by asking the people nearby.

Similarly, clothing retailers can learn your preference and choices from your buying and trial habits which he could use to give customized service to customer

as well as it can help him to stock only the preferred choices of customers in the store.

Challenges in IoT Industry

Here the IoT deals with some common challenges that the healthcare system deals with, like scalability is a big challenge in IoT implementation in industries, it means growth in terms of capability, system, and network. Infrastructure and processes in industries grow at a rapid rate; the IoT structure should be capable to accommodate that growth. As industries are of different domains, for example, manufacture sector is different from retail and logistic sector; similarly, information technology sector is different from the production. There is a gap of technological standardization as a lot of hardware is involved in the technology or platform. Due to the lack of standards, companies that make the IoT-based products use the random architectures that they feel comfortable and easy in implementation [21].

As different hardware and platforms are involved, interoperability becomes a challenge. This hardware makes use of different software to swap over and utilize information, and a broader software infrastructure will be needed on the network and on background servers in order to deal with the smart objects and offer services to support them.

Fault tolerance is a big issue in IoT devices, as they are dynamic and mobile in nature. They change their state and behavior rapidly. Structuring an Internet of Things and an ability to automatically adapt to changed conditions is required [21].

3.3 Internet of Things in Agriculture

Recently agriculture farming has gone through technological transformations. In the last decades, it has become more technology-driven and industrialized, bringing a large number of benefits to the farmers. The ever-increasing demand of food in terms of both quality and quantity has made agriculture more as industry where now farmers have gain complete control from production to selling of crops. Revolution of technology in agriculture is possible due to the Internet of Things (IoT); it is a highly promising family of technologies which offer solutions to the several existing problems in agriculture. Researchers and scientific groups are continuously working on IoT applications integrated with wireless sensor network (WSN) to help the agriculture sector to deliver better services and enhanced IoT products.

Using automated machinery to control and optimize water use, energy management and use of chemicals for pest control and use of fertilizers, precision agriculture [22] aims to boost and develop agricultural processes to make sure maximum output and require quick, dependable, scattered measurements in order to give growers a more detailed overview of the in progress state in their cultivation area. Agriculture applications will also keep track on weather and environment information, gather the data from various heterogeneous systems, evaluate the knowledge and organize them in the form of smart algorithms to provide a better insight into

the in progress processes, do the interpretation of the present conditions, and make predictions based on heterogeneous inputs, and based on the collected information, warning signal will be produced. The different fields of agriculture where the IoT is bringing changes are:

1. Greenhouses observe the climate conditions using sensors and control them to maximize the production and maintain the quality.
2. Control the various parameters of humidity and temperature levels to form the compost to prevent fungus and other microbial contaminants.
3. Tracking the animals and identifying their grazing locations using sensors and study of the air quality in farms and detection of harmful gases from excrements.
4. Continuous monitoring of crops for reducing spoilage and crop waste [23].

Implemented Solutions Available in IoT Agriculture

The Kaa IoT platform provides sensor-based remote monitoring of crops and equipment including livestock management with climate monitoring and forecasting. Provided services include livestock tracking, stats on livestock production, and smart logistics and warehousing [24].

Farm Logs is a sensor-based software application for technology-enabled farms. It helps to manage day-to-day operations on the field and create agronomic plans that calculate field-level profit/loss based on your input expenses and rates. It also helps in documentation for reporting and analysis and tracks your marketing position and makes more profitable crop sales [25].

The Phytech gives the ability to direct plant sensing, connects you directly to the plants, sensors are connected to the plants micro-variations of stem diameter that are scientifically proven stress indicators. The data is transmitted in real time to the Phytech cloud for further analytics, providing certainty in decision-making, optimizing production, and reducing risk. Patented algorithms are continuously performing data analysis and do predictive analysis to provide meaningful alerts and recommendations. Machine learning algorithms provide irrigation scheduling recommendations to maintain the plant status in the optimal zone with minimal resources [26].

The Semios platform with monitoring of conditions also checks the disease condition and plant health in real time. It's a powerful tool in yield improvement that helps growers assess and respond to insect, disease, and plant health conditions. It provides sensor-based integrated pest control, whether monitoring with forecasting, disease model conditions and risk evaluation, and monitoring moisture and soil conditions using big data analysis and data prediction [27].

Challenges of IoT in Agriculture

In agriculture, for the successful implementation of IoT, there is a deployment of the large number of IoT devices because of the large area; this can arise the interference problem with the local spectrum such as ZigBee, Wi-Fi, Sigfox, and LoRa [28]. There is one more challenge of exposition of devices to the harsh environmental conditions like physical damage and degradation.

The IoT in agriculture will need a large number of IoT devices, while the lack of standardization in existing gateways and protocols leads to heterogeneity and scalability issue [28].

3.4 IoT-Integrated Smart Home/Building

A smart home and building using devices and objects connected over the Internet for remote monitoring of daily used appliances of home such as lightning, water utilization, monitoring and optimizing electrical equipment. Using smart homes and buildings concept, not only day-to-day devices like smart doors, lights are controlled but also security of home and building are monitored. IP-based cameras, alarms, motion sensors, firefighting equipment, and connected door locks give more home security. To provide such kind of automations in home and buildings, IoT-connected wireless sensors are bringing the revolution.

The IoT in conjunction with sensors provides a large number of services and applications such as smart metering to optimize the energy usage and sending the consumption data to the energy provider to reduce the waste further; in a similar manner, smart metering for water consumption can be done, which can provide great aid to societies and cities by looking into the matter of depleting water resources. In the same way, all home resources work together by sharing the information among each other processing, optimizing the tasks, and taking decision accordingly form the smart environment. Sensors optimize the home utilities based on human activity, for example temperature sensor, humidity sensor to auto control the air conditioning. For elder people alone at home it can support their medication and raise alarm in case of emergency situations, giving support to the elder people and patients [29].

Smart home works by automation of home and its appliances and minimizes the user input for controlling home appliances. One of the most common hardware platforms that is used to create a smart home application is Arduino using sensor and actuators, and for networking, Zigbee technology is mostly used. Cloud structure is an important part for big data analytics and data prediction [30]. In literature, Son et al. [31] introduced a system based on resource awareness; they mentioned mobile device access remotely to home using Web Services Description Language (WSDL) and Simple Object Success Protocol (SOAP). Energy management is also an important application in smart home and buildings in this context; Han et al. [32] suggested a new smart home energy management system (SHEMS) based on IEEE802.15.4 and ZigBee, a multi-sensing application for reducing the total energy cost. Wu et al. [33] studied the home nature of a smart home in serving its users; they mentioned a framework of intercommunication among the services and users, using the framework, and they developed two pervasive applications of “Media Follow Me (MFM)” and “Ubiquitous Skype.” To predict the user activity, a sequence prediction algorithm is proposed by

Alam et al. [34] using enhanced episode discovery. It monitors the user behavior in sequence of activities. Based on human activity patterns, Chen et al. [35] used a multi-sensor approach which consists of activity recognition from context ontology modelling and situation formation process, for real-time continuous activity recognition.

Challenges of IoT in Home and Building Structure
Heterogeneity among the IoT objects becomes one of the challenges of smart home and building; the IoT should be capable of integrating these devices seamlessly. In the case of a smart city, proposing the general architecture of IoT is hard due to a large number and different types of devices, protocols, and services [36].

Seamless connection among the devices means easy to connect anytime and anywhere in the IoT system, termed as interoperability. It's a prime concern in smart home devices and network system comes from a different vendor, so joining them to achieve interoperability becomes a challenge.

In IoT smart homes and buildings to achieve self maintenance and management becomes one of the major concern, devices should be capable of self-monitoring to optimize their health and notify the user [37].

3.5 Intelligent Transport System

The IoT is playing a big role in smart transportation giving solutions to many existing problems and providing Intelligent Transportation System. There are large numbers of issues that exist among the transport application like traffic congestion, management, minimize the environment impact due to pollution to give the benefits of transportation to commercial users and the public in general. Intercommunication applications among vehicles can be provided to help citizens save time for smarter city. Intelligent Transport System (ITS) works to improve the traffic management by reducing traffic issue, giving the prior information about real-time traffic, local convenience, seat availability, etc., which helps commuters as well as enhances their safety and comfort.

Application Areas of Intelligent Transport System
In smart city, all domains of the society will be digital to make the life of the citizens easy. The transport system for children going to school and people to office and college should be safe. In case of elderly people, the need of smart transport even rises. Old-age drivers and pedestrians have more accidental rate; a large number of application areas exist in Intelligent Transportation Systems (ITS) to enhance the user, and citizen facility in smart city like blind people can be helped by self-guidance applications and can save a lot of time of the users.

For the implementation of IoT to make smart transport, a large number of sensors are embedded in vehicles by the automotive manufacturers to enhance the road safety and better management of traffic. Government departments for road and con-

struction can use the smart ITS to enhance the road infrastructure by implementing sensors, devices, and cameras that will monitor the environment and traffic in live conditions.

The authors in [38] mentioned that ITS is providing great help in improving the road safety, reducing the traffic congestion by using a number of sensors and actuators like tire-pressure monitoring and rear-view visibility; through this, many more sensors are now embedded in vehicles to enhance and monitor the performance. Number of sensors is continuously increasing in vehicles to make the vehicles as the smarter vehicles.

In [39] the authors have mentioned that the IoT and WSN are supporting a large number of applications like logistics support, emergency services, and several other applications. Not only are the vehicles with sensors but number of sensors are also used on the roads to enhance the road safety and conditions.

Challenges of IoT in Smart Transport System

In intelligent transport system, a large number of vehicles are connected using IoT in geographically dispersed area using cloud computing centers; a huge amount of data is generated and transferred. Big data processing and analytics are performed. Due to the large amount of data created and processed, the issue of latency arises which is risky in case of medical emergency.

Fog computing brings the solution to the above problem by real-time big data analysis which gives the feature of processing data at the middleware level and the edge of nodes, but the smart transport systems have a dynamic nature, so implementing such solution becomes challenging; also, the huge amount of big data collected over the transport system is heterogeneous in nature [40].

3.6 Efficient Energy Management Using IoT

Smart utilization and management of the energy are the biggest concern of the modern society. Using IoT to make the city smart require large number of IoT-enabled applications. IoT devices are increasing in number and features, the need of power to manage these devices also grow. It is the essential need of the smart city to efficiently utilize the energy. The energy utilization information of smart homes, buildings including school's offices, amusement parks and roads street lights etc. are collected and analyzed for the optimization as also send to the grid system for proper resource utilization.

The authors in [41] mentioned that consumption of energy can be minimized by effective management of home appliances, education, and healthcare system. To manage the energy consumption of home, commercial, and industries, big data is collected from them and utilized by using various processing algorithms and making analysis. Energy management system (EMS) and data acquisition system on chip (SoC) are presented in the paper to gather the consumption data of energy from the devices. Data is sent to the centralized server where it can be processed and

analyzed. In [42] the authors propose an on-demand supply model. Here consumer is also informed about their consumption nature so that user can make decision on their consumption to reduce the cost and consumption itself.

DC-powered home concept is given in [43] as a distributed system for residential area, but due to the lack of any standardization in protocols, intelligent DC-powered home currently cannot be considered to replace the traditional system of AC supply. In [44] multiple in-home display systems (IHDs) and automatic meter reading systems (AMR) are discussed to provide energy management information. Here, the smart home system, by analyzing the proper condition of the resources, chooses by itself the display interface such as television, smartphone, etc. A home energy management system (HEMS) architecture is proposed in [45]. Here, smart meter data is used for monitoring real-time information on home energy consumption and giving online remote control to devices status. This model is only proposed for small area using the HTTP protocol, but for large residential areas, Message Queuing Telemetry Transport (MQTT) protocol is required. In [46], a model is proposed where all the nodes and devices connected in smart home plan their operations based on the weather conditions. In this system, data is sent to the Web server using Extensible Markup Language (XML) and XML files, but bandwidth issues are faced due to large size of files.

Smart grid concept is discussed in [47] for effective monitoring, smart control, and reliable and efficient power delivery. Using IoT, a smart grid is formed by having wireless sensor networks as it is the main component. The smart grid provides the smart monitoring, which is the main goal of it. Smart plugs, gateways, and meters connected to the appliances using network create a communication channel between the provider and consumer to provide a better energy production and consumption. The smart grid keeps the track of both energy generation and consumption.

Challenges in Efficient Energy Management

Various kinds of attacks can be done on smart home and buildings like impersonation/identity spoofing that aims to consume someone's energy on its behalf. Eavesdropping is another attack on IoT-based smart grid as it uses the public communication infrastructure to gain the energy consumption information of the user and households. In data tampering, attackers gain the access of modifying the exchanged data, can change the rate pricing of energy. Attackers can gain the authorization and control access and can remotely monitor and configure energy utilization information by changing the readings of smart meters and sensors. Including this private information of the users can be monitored by analyzing the usage information [48].

In general, the energy resources are volatile in nature, and smart grid should be capable of managing the volatile behavior; also, energy systems have to follow governmental laws and regulations, and this includes energy delivery that needs to be optimized according to the business needs and potential legal constraints [49].

3.7 Smart Water Management

Smart water management means various processes to manage the water resources and its consumption, in optimized way, so that there will be least wastage. We know that water depletion is a big challenge among the society; in [50] the author looks into these issues including equipment maintenance. The water management system works in conjunction with the water resources, society, and environmental systems. The water management system is fragile and continuously changing and evolving due to the different sectors from industries to agriculture, and household has a different requirement.

The utilization of water is the biggest consumer in the field of agriculture [51], while the main causes of the water wastage are leakages in distribution and irrigation. Moreover, problems like under-irrigation and over-irrigation need to be managed. The IoT in agriculture needs the integration of large number devices, objects having heterogeneous, and advanced sensors. They will work in conjunction with the software application that will implement cloud computing and big data analytics.

In [52] distribution of large number of sensors and actuators near to the water grid, water distribution resources are proposed for real-time monitoring and controlling for efficient management. Water meter and pumps are monitored and controlled in real time. A smart water quality monitoring system was proposed in [53], and an interface was designed for data storage and data processing. The different sensors used for quality monitoring are temperature sensor, turbidity sensor, pH sensor, and water flow sensor. The system is connected with the Arduino hardware for measurement and analysis. This proposed system was designed for maintaining the quality of environmental water resources reservoirs.

Jing [53] designed a model based on software using language VC++6.0 to remotely manage the water supply based on wireless sensors based on GPRS and microcontroller. Purohit and Gokhale [54] used Intel microcontroller to design a real-time water quality measurement system based on water quality measuring sensors. Beri [55] designed a device that measures in real-time various parameters of water such as pH, temperature and turbidity. In [56] the author proposed an android-based mobile application where the user can check the water level in tank using sensors, and this information will be sent to the cloud. This model can help the residential societies to minimize the water wastage level.

Several major advancements have been attempted to automate meter reading such as smart motor controlling, and automated meter reading (AMR) systems are the features of the proposed system. This model will also do troubleshooting by:

Identifying the leaks and breaks and optimizing performance through optimizing pressure, flow, and usage.

Challenges of IoT in Water Management

In water management scenarios, one of the biggest concerns is the risk of physical attacks over the devices; most of the devices are accessible, making capturing easy. Cloning of the devices can be done, by installing any malware or firmware.

Water is a vital resource for life, and management of water is facing big challenges like interoperability and lack of standardization in monitoring protocols and equipment.

Cyber security of the implemented devices in the IoT is also a big concern as devices and objects are vulnerable during networking and intercommunication [51, 57].

3.8 Environment Monitoring Using IoT

The optimization of home resources according to the usage is termed as home automation, similarly if the environment can be made to self-optimizing according to the needs of the human termed as smart environment [58]. A smart environment means making things around us easy, for example, moving heavy objects for the elderly. IoT-based smart environment focuses to facilitate our lives and to investigate its effect on human life; it gains the knowledge from inhabitants and adapts according to its inhabitants. The integration of IoT with the environment will consist of several applications to monitor and analyze the environment. These applications will enable to monitor the environment and its various parameters from the remote sites, smart home, building, transport, health, etc.; all in composition become the part of smart environment [59].

In [60] the author proposed microcontroller-based garbage bins or dustbins having IR wireless system; this system will show the current status of garbage on mobile Web browser and when the dustbins are overloaded. Air pollution is one of the biggest threats to the environment, and the main causes of the air pollution are industrialization and emission of harmful gases through vehicles; thus, a real-time monitoring is required to detect the pollutants [61]. This paper presents IoT-based solution to the air pollution problem called Polluino. This is an Arduino-based system that monitors the air pollution, and a cloud-based platform is also developed to maintain the data coming from several external sensors. The following parameters are measured to determine the quality of air carbon monoxide, carbon dioxide, nitrogen dioxide, methane, hydrogen sulfide, ozone, ammonia, particulate matter, benzene, ethanol, toluene, and propane.

In [62] this paper presents the air quality monitoring system with context awareness, which means personalizing the services based on situation and context of person or place. In a context-aware system, monitoring alone is not enough; there should be a notification system regarding citizens; there is a need to give alerts in real time; and the information provided to users should be adapted accordingly to the activity in which the user is going to be involved, and notifications should be sent accordingly. In this paper, a smart context-aware system has been proposed and implemented. This system can obtain relevant context from the user, provide real-time air quality information, and notify citizens accordingly. With such a system, we can prevent unexpected health issues related to poor air quality conditions, as

well as be able to suggest more suitable places or activities to users according to their context and current air quality. Therefore, the system provides one step forward in the scope of smart cities, improving life quality for citizens, in general, and for risk groups, in particular.

In [63] an early warning firefighting system is proposed based on the Internet of Things; it detects the early sign of fire by using the various sensors like temperature, humidity, flame, and gas. While warning message is generated based on the threshold value set in the sensors accordingly, the system generates the notification email and text message to the user's phone and switches off the main power system.

Wireless sensor networks (WSN) are providing an aid in measuring the environmental parameters in real time including environmental disaster, and live monitoring. In [64] a Raspberry Pi-based IoT system enabled with video cameras is proposed for landslide detection. The data collected by the video streaming are sent to the computer vision algorithm and generate notifications through android application.

Topographical images are used to perform the surface modelling and detect the recent activity of landslides known as Light Detection and Ranging (LIDAR) [65]. In [66] satellite images make use of image thresholding by genetic programming to detect landslide activity in a region. Bag-of-Visual-Word (BoVW) and Probabilistic Latent Semantic Analysis (pLSA) [67] methods are used for landslide detection using the image sensing classification method based on k-NN classifier to detect landslide and non-landslide region.

The authors in [68] proposed a complete solution to monitor the landslides; this architecture is composed of micrometeorological node to collect temperature, relative humidity, wind vane, wind speed, and rainfall and a ground node which measures the soil moisture at different depth.

Animals are under observation for the early detection of natural calamities [69]. This article presents that various animal can detect early the approaching disaster; therefore, the applications that use sensors and computer vision to collect data on animal behavior need to be developed. The behavior of animals is studied as an indicator of natural disasters using data processing and analysis.

In [70] the authors proposed an earthquake early warning using IoT integrated with WSN. The sensors are placed in the surface of the earth. The system is based on compression P wave and transverse S wave which radiates during the earthquake; P wave travels faster and trips the sensors, and early alert signals are generated giving humans and automated electronic system a warning to take precautionary actions with S waves. The Zigbee transmitters are used to send the alert signals, while warnings are sent to the smart phones.

Challenges of IoT in Environmental Study

Deployment of IoT to create the smart environment needs a successful meeting of certain parameters like compatibility of different products being connected. A large amount of data is generated, and attention should be given to storage, access, and processing of such big data generated by devices forming an IoT environment.

It is difficult to monitor every landslide-prone area because of the costly instrumentation and maintenance; also, the delay in sensitive information is critical to the environment [65].

Recognition of animal activities is not accurate all the time, since there can be several other parameters that can change the behavior of animals like climatic conditions, magnetic storms, seasonal factors, noise, etc. [69].

4 Comparative Analysis and Discussions

After the study of various issues and challenges in IoT, a conclusion is drawn, and it has been found that, irrespective of application areas, there are some common key issues that exist, including incorporation of WSN in the IoT, which are summed up in Table 1.

After the detailed study of the various applications and understanding the challenges in them, a detailed discussion about the IoT in healthcare and agriculture is made in Table 2, as both the applications are essential in the realization of the smart city concept. In Table 2, implementation aspects of the applications along with the main sensors used by them with their feature and contribution details are discussed.

Table 3 discusses the smart home/building; its requirement for sensing has been divided into three categories of units. With this, the features of home and building that it support are discussed.

Table 1 Challenges of IoT in WSN

Challenges	Descriptions
Inherently distributed	As IoT applications deals with video of different kind and type of systems design, a common approach for development and designing is challenging
Data management	In IoT applications, the large number of heterogeneous devices with a huge number of sensors is connected; they generate a large volume of data having different formats and are generated at different speeds. There is a need of regular application maintenance system due to risk failure of sensors or introduction of an invalid data by a malicious user
Human-centric applications	Psychological and behavioral data of humans are required to be studied, which vary from human to human; therefore, it becomes more complex to design human-centric application
Interdependent applications	Several problems in IoT applications arise due to interdependency among one or more applications; in real life, there is sharing of the resources among the applications. Services of different applications can also conflict with each other. Detecting and resolving such issues are critical and challenges in the IoT system

Table 2 Feature details of the sensors in applications

Applications	Sensor	Features	Contribution
IoT in healthcare	Accelerometer [71]	The ADXL362 from Analog Devices, 3-axis MEMS accelerometer with ultralow power utilization, which consumes less than 2 μA when the output datarate is 100 Hz and only 270 nA	The ADXL362 is an accelerometer which is used for recognizing the fall; it wakes the MCU controller up and an emergency notification generated to smartphone
	Temperature sensor [71]	It has a high accuracy range of 0.1 °C from 37 °C to 39 °C, high-resolution (16-bit) and low-power utilization (600 μA at 2.7 V to 3.3 V)	It can provide an over temperature alarm and communicate with the MCU
	Pulse sensor [71]	The pulse sensor works on low power and contains low-power light photo sensor (APDS-9008) and amplifier (MCP6001) with the typical supply current of 42 μA and 100 μA, respectively	Pulse sensor can measure the heartbeat of the radial artery at the wrist
	Chest-worn ECG monitor [72]	Three electrodes, two of them elliptical (6.5 cm and 3.5 cm), for ECG were stitched on the two sides of the torso on the belt and a circular electrode for the ground (Ø2.5 cm) next to the navel	Long-term ECG recording, distant expertto identify cardiovascular problems earlier
IoT in agriculture	Temperature sensor [73]	The LM 35 sensor is vastly used because its output voltage is linear with the Celsius scaling of temperature. The range isfrom −55 degrees to +150 degrees	Used as an indicator of water level inside a tank and water resources
	Moisture sensor [73]	There is the principle of open and short circuit. The output is high or low reflected by the LED	Sensor used to sense the moisture level of soil
	PIR sensor [73]	PIR sensors detect the infrared radiation generated or reflected from an object	This sensor detects the progress of people, animals, and other things
	Humidity sensor [74]	The HDC1010 digital humidity sensor is used to measure the moisture and humidity level in the environment	The HDC1010 is stronger against dirt, dust, and other ecological impurities

Table 3 Sensor unit type of smart home and building

	Sensing unit type	Power supply	Features
IoT-integrated smart home/building [58]	Hot water system monitoring	Electrical outlets	Real-time monitoring of warm water and solar heating system
	Household electrical appliance monitoring and controlling	Electrical outlets	Monitoring and controlling of normal domestic appliances such as battery charging units, room heaters, washing machines, refrigerators
	Measuring environment temperature	Battery	Sensors are capable of measuring the room temperature accordingly and enable to regulate the usage of the appliances

5 Conclusions

In this paper, a detailed study of IoT applications is done with the major issues and challenges in their implementation. After the study, a conclusion has been drawn that there are some common issues among all the applications related with the integration of WSN with the Internet of Things (IoT). Later in the chapter, implementation details of the key sensors used in the applications with its features are discussed. A requirement of edge-based open and flexible architecture that can support the heterogeneity and scalability issue is also proposed. This paper will aid the researchers to understand the representation of the physical world of devices and objects connected over the network using wireless sensors.

References

1. Seth, P., Sarangi, S.R.: Internet of things: architectures, protocols, and applications. J. Electr. Comput. Eng. **2017**, (2017)
2. Jin, J., Gubbi, J., Marusic, S., Palaniswami, M.: An information framework for creating a smart city through internet of things. IEEE Internet Things J. **1**(2), 112–121 (2014)
3. Giri, A., Dutta, S., Neogy, S., Dahal, K., Pervez, Z.: Internet of things (IoT): a survey on architecture, enabling technologies, applications and challenges. In: Proceedings of the 1st International Conference on Internet of Things and Machine Learning, p. 7. ACM (2017)
4. Talari, S., Shafie-Khah, M., Siano, P., Loia, V., Tommasetti, A., Catalão, J.: A review of smart cities based on the internet of things concept. Energies. **10**(4), 421 (2017)
5. Bawany, N.Z., Shamsi, J.A.: Smart city architecture: vision and challenges. Int. J. Adv. Comput. Sci. Appl. **6**(11), 246–255 (2015)
6. Al-Qaseemi, S.A., Almulhim, H.A., Almulhim, M.F., Chaudhry, S.R.: IoT architecture challenges and issues: lack of standardization. In: Future Technologies Conference (FTC), pp. 731–738. IEEE (2016)
7. Li, Y., Björck, F., Xue, H.: Iot architecture enabling dynamic security policies. In: Proceedings of the 4th International Conference on Information and Network Security, pp. 50–54. ACM (2016)

8. Hashem, I.A.T., Chang, V., Anuar, N.B., Adewole, K., Yaqoob, I., Gani, A., et al.: The role of big data in smart city. Int. J. Inf. Manag. **36**(5), 748–758 (2016)
9. Aazam, M., Zeadally, S., Harras, K.A.: Offloading in fog computing for IoT: review, enabling technologies, and research opportunities. Futur. Gener. Comput. Syst. **87**, 278–289 (2018)
10. How To Build a Holistic Smart City Architecture.: Retrieved from https://www.iotforall.com/holistic-smart-city-architecture/ (2019)
11. Catarinucci, L., De Donno, D., Mainetti, L., Palano, L., Patrono, L., Stefanizzi, M.L., Tarricone, L.: An IoT-aware architecture for smart healthcare systems. IEEE Internet Things J. **2**(6), 515–526 (2015)
12. Farahani, B., Firouzi, F., Chang, V., Badaroglu, M., Constant, N., Mankodiya, K.: Towards fog-driven IoT eHealth: promises and challenges of IoT in medicine and healthcare. Futur. Gener. Comput. Syst. **78**, 659–676 (2018)
13. Sodhro, A.H., Luo, Z., Sangaiah, A.K., Baik, S.W.: Mobile edge computing based QoS optimization in medical healthcare applications. Int. J. Inf. Manag. **45**, 308–318 (2019)
14. Sohn, S.Y., Bae, M., Lee, D.K.R., Kim, H.: Alarm system for elder patients medication with IoT-enabled pill bottle. In: 2015 International Conference on Information and Communication Technology Convergence (ICTC), pp. 59–61. IEEE (2015)
15. Laranjo, I., Macedo, J., Santos, A.: Internet of things for medication control: service implementation and testing. Procedia Technol. **5**, 777–786 (2012)
16. Kalantarian, H., Motamed, B., Alshurafa, N., Sarrafzadeh, M.: A wearable sensor system for medication adherence prediction. Artif. Intell. Med. **69**, 43–52 (2016)
17. Marques, G., Pitarma, R.: An indoor monitoring system for ambient assisted living based on internet of things architecture. Int. J. Environ. Res. Public Health. **13**(11), 1152 (2016)
18. Rghioui, A., Sendra, S., Lloret, J., Oumnad, A.: Internet of things for measuring human activities in ambient assisted living and e-health. Netw. Protoc. Algorithms. **8**(3), 15–28 (2016)
19. P. Raj and A. C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases. Boca Raton, FL, USA: CRC Press (2017)
20. Lee, I., Lee, K.: The Internet of Things (IoT): applications, investments, and challenges for enterprises. Bus. Horiz. **58**(4), 431–440 (2015)
21. J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Avesand, and D. Boyle, From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence. Amsterdam, The Netherlands: Elsevier (2014)
22. Tzounis, A., Katsoulas, N., Bartzanas, T., Kittas, C.: Internet of Things in agriculture, recent advances and future challenges. Biosyst. Eng. **164**, 31–48 (2017)
23. Patel, K.K., Patel, S.M.: Internet of things-IOT: definition, characteristics, architecture, enabling technologies, application & future challenges. International journal of engineering science and. Computing. **6**(5), (2016)
24. Solutions for Smart Farming (Agriculture IoT).: Retrieved from https://www.kaaproject.org/smart-farming (2019)
25. Powerful software for running a modern farm.: Retrieved from https://farmlogs.com (2019)
26. The Phytech Platform.: Retrieved from https://www.phytech.com/ (2019)
27. Semios We Help Growers Worry Less.: Retrieved from https://semios.com/ (2019)
28. Elijah, O., Rahman, T.A., Orikumhi, I., Leow, C.Y., Hindia, M.N.: An overview of Internet of things (IoT) and data analytics in agriculture: benefits and challenges. IEEE Internet Things J. **5**(5), 3758–3773 (2018)
29. Sundmaeker, H., Guillemin, P., Friess, P., Woelfflé, S.: Vision and challenges for realising the Internet of things. Clust. Eur. Res. Proj. Internet Things Eur. Commiss. **3**(3), 34–36 (2010)
30. Soliman, M., Abiodun, T., Hamouda, T., Zhou, J., Lung, C.H.: 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, pp. 317–320. IEEE (2013, December)
31. Son, J.-Y., et al.: Resource-aware smart home management system by constructing resource relation graph. IEEE Trans. Consum. Electron. **57**, 1112–1119 (2011)
32. Han, D.-M., Lim, J.-H.: Design and implementation of smart home energy management systems based on zigbee. IEEE Tran. Consum. Electron. **56**, 1417–1425 (2010)

33. Wu, C.-L., Fu, L.-C.: Design and realization of a framework for human–system interaction in smart homes. IEEE Trans. Syst. Man Cybern. **42**, 15–31 (2012)
34. Alam, M.R., et al.: SPEED: an inhabitant activity prediction algorithm for smart homes. IEEE Trans. on Systems, Man and Cybernetics. **42**, 985–990 (2012)
35. Chen, L., Nugent, C.D., Wang, H.: A knowledge-driven approach to activity recognition in smart homes. IEEE Trans. Knowl. Data Eng. 961–974 (2012)
36. Zanella, A., Bui, N., Castellani, A., Vangelista, L., Zorzi, M.: Internet of things for smart cities. IEEE Internet Things J. **1**(1), 22–32 (2014)
37. Pradeep, S., Kousalya, T., Suresh, K.A., Edwin, J.: Iot and its connectivity challenges in smart home. Int. Res. J. Eng. Technol. **3**, 1040–1043 (2016)
38. Guerrero-Ibáñez, J., Zeadally, S., Contreras-Castillo, J.: Sensor technologies for intelligent transportation systems. Sensors. **18**(4), 1212 (2018)
39. Abdelhamid, S., Hassanein, H.S., Takahara, G.: Vehicle as a mobile sensor. Procedia Comput. Sci. **34**, 286–295 (2014)
40. Darwish, T.S., Bakar, K.A.: Fog based intelligent transportation big data analytics in the internet of vehicles environment: motivations, architecture, challenges, and critical issues. IEEE Access. **6**, 15679–15701 (2018)
41. Ejaz, W., Naeem, M., Shahid, A., Anpalagan, A., Jo, M.: Efficient energy management for the internet of things in smart cities. IEEE Commun. Mag. **55**(1), 84–91 (2017)
42. Al-Ali, A.R., Zualkernan, I.A., Rashid, M., Gupta, R., Alikarar, M.: A smart home energy management system using IoT and big data analytics approach. IEEE Trans. Consum. Electron. **63**(4), 426–434 (2017)
43. Rodriguez-Diaz, E., Vasquez, J.C., Guerrero, J.M.: Intelligent DC homes in future sustainable energy systems: when efficiency and intelligence work together. IEEE Consum. Electron. Magaz. **5**(1), 74–80 (2016)
44. Kim, D.S., Son, S.Y., Lee, J.: Developments of the in-home display systems for residential energy monitoring. IEEE Trans. Consum. Electron. **59**(3), 492–498 (2013)
45. Son, Y.S., Pulkkinen, T., Moon, K.D., Kim, C.: Home energy management system based on power line communication. IEEE Trans. Consum. Electron. **56**(3), 1380–1386 (2010)
46. Kushiro, N., Suzuki, S., Nakata, M., Takahara, H., Inoue, M.: Integrated residential gateway controller for home energy management system. in IEEE Trans. Consum. Electron. **49**(3), 629–636 (2003)
47. Ozger, M., Cetinkaya, O., Akan, O.B.: Energy harvesting cognitive radio networking for iot-enabled smart grid. Mob. Netw. Appl. **23**(4), 956–966 (2018)
48. Bekara, C.: Security issues and challenges for the IoT-based smart grid. Procedia Comput. Sci. **34**, 532–537 (2014)
49. Marjani, M., Nasaruddin, F., Gani, A., Karim, A., Hashem, I.A.T., Siddiqa, A., Yaqoob, I.: Big IoT data analytics: architecture, opportunities, and open research challenges. IEEE Access. **5**, 5247–5261 (2017)
50. Robles, T., Alcarria, R., de Andrés, D.M., de la Cruz, M.N., Calero, R., Iglesias, S., López, M.: An IoT based reference architecture for smart water management processes. JoWUA. **6**(1), 4–23 (2015)
51. Kamienski, C., Soininen, J.P., Taumberger, M., Fernandes, S., Toscano, A., Cinotti, T.S., et al.: SWAMP: an IoT-based smart water management platform for precision irrigation in agriculture. In: 2018 Global Internet of Things Summit (GIoTS), pp. 1–6. IEEE (2018)
52. Ntuli, N., Abu-Mahfouz, A.: A simple security architecture for smart water management system. Procedia Comput. Sci. **83**, 1164–1169 (2016)
53. Nikhil, R., Rajender, R., Dushyantha, G.R., Jagadevi, N.: Smart water quality monitoring system using IoT environment. Int. J. Innov. Eng. Technol. **10**(4), (2018). Jing, M.: The design of wireless remote monitoring system of water supply based on GPRS. In: Computer Science and Society (ISCCS), 2011 International Symposium on, Kota Kinabalu, pp. 29–31 (2011)
54. Purohit, A., Gokhale, U.: Real time water quality measurement system based on GSM. IOSR J. Electron. Commun. Eng. **9**(3), 63–67 (2014)
55. Beri, N.N.: Wireless sensor network based system design for chemical parameter monitoring in water. Int. J Electron. Commun. Soft Comput. Sci. Eng. **3**(6),

56. Wadekar, S., Vakare, V., Prajapati, R., Yadav, S., Yadav, V.: Smart water management using IOT. In: 2016 5th International Conference on Wireless Networks and Embedded Systems (WECON), pp. 1–4. IEEE (2016)
57. Koo, D., Piratla, K., Matthews, C.J.: Towards sustainable water supply: schematic development of big data collection using internet of things (IoT). Procedia Eng. **118**, 489–497 (2015)
58. Kelly, S.D.T., Suryadevara, N.K., Mukhopadhyay, S.C.: Towards the implementation of IoT for environmental condition monitoring in homes. IEEE Sensors J. **13**(10), 3846–3853 (2013)
59. Ahmed, E., Yaqoob, I., Gani, A., Imran, M., Guizani, M.: Internet-of-things-based smart environments: state of the art, taxonomy, and open research challenges. IEEE Wirel. Commun. **23**(5), 10–16 (2016)
60. Navghane, S.S., Killedar, M.S., Rohokale, V.M.: IoT based smart garbage and waste collection bin. Int. J. Adv. Res. Electron. Commun. Eng. **5**(5), 1576–1578 (2016)
61. Fioccola, G.B., Sommese, R., Tufano, I., Canonico, R., Ventre, G.: Polluino: an efficient cloud-based management of IoT devices for air quality monitoring. In: 2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a Better Tomorrow (RTSI), pp. 1–6. IEEE (2016)
62. Garcia-de-Prado, A., Ortiz, G., Boubeta-Puig, J., Corral-Plaza, D.: Air4People: a smart air quality monitoring and context-aware notification system. J. Univ. Comput. Sci. **24**(7), 846–863 (2018)
63. Eltom, R.H., Hamood, E.A., Mohammed, A.A., Osman, A.A.: Early warning firefighting system using internet of things. In: 2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), pp. 1–7. IEEE (2018)
64. Aggarwal, S., Mishra, P.K., Sumakar, K.V.S., Chaturvedi, P.: Landslide monitoring system implementing IOT using video camera. In: 2018 3rd International Conference for Convergence in Technology (I2CT), pp. 1–4. IEEE (2018)
65. McKean, J., Roering, J.: Objective landslide detection and surface morphology mapping using high-resolution airborne laser altimetry. Geomorphology. **57**(3–4), 331–351 (2004)
66. Rosin P.L., Hervas J.: Image Thresholding for Landslide Detection by Genetic Programming (unpublished)
67. Gong, C., Lei, G., Tianyun, Z., Junwei, H.: Automatic landslide detection from remote-sensing imagery using a scene classification method based on BoVW and pLSA. Int. J. Remote Sens. **34**(1), 45–59 (2013)
68. El Moulat, M., Debauche, O., Mahmoudi, S., Brahim, L.A., Manneback, P., Lebeau, F.: Monitoring system using internet of things for potential landslides. Procedia Comput. Sci. **134**, 26–34 (2018)
69. Pirmagomedov, R., Blinnikov, M., Amelyanovich, A., Glushakov, R., Loskutov, S., Koucheryavy, A., et al.: IoT based earthquake prediction technology. In: Internet of Things, Smart Spaces, and Next Generation Networks and Systems, pp. 535–546. Springer, Cham (2018)
70. Alphonsa, A., Ravi, G.: Earthquake early warning system by IOT using Wireless sensor networks. In: 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), pp. 1201–1205. IEEE (2016)
71. Wu, T., Wu, F., Redouté, J.M., Yuce, M.R.: An autonomous wireless body area network implementation towards IoT connected healthcare applications. IEEE Access. **5**, 11413–11422 (2017)
72. Mankodiya, K., Hassan, Y.A., Vogt, S., Gehring, H., Hofmann, U.G.: Wearable ECG module for long-term recordings using a smartphone processor. In: Proceedings of the 5th International Workshop on Ubiquitous Health and Wellness, vol. 2629. Copenhagen, Denmark (2010)
73. Suma, N., Samson, S.R., Saranya, S., Shanmugapriya, G., Subhashri, R.: IOT based smart agriculture monitoring system. Int. J. Recent Innov. Trends Comput. Commun. **5**(2), 177–181 (2017)
74. Prathibha, S.R., Hongal, A., Jyothi, M.P.: IOT based monitoring system in smart agriculture. In: 2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT), pp. 81–84. IEEE (2017)

Karan Bajaj received his Bachelor of Engineering in Computer Science in 2009 and Master of Engineering in Computer Science in 2013 and is currently pursuing PhD. He is currently Assistant Professor in the Department of Computer Science and Engineering in Chitkara University His main research interests include machine learning, wireless network, and IoT.

Bhisham Sharma received a PhD in Computer Science and Engineering from the PEC University of Technology (formerly Punjab Engineering College), Chandigarh, India. He is currently Associate Professor in the Department of Computer Science and Engineering, Chitkara University, India. His research interests include mobile computing, wireless communication, wireless sensor networks, wireless mesh networks, network security, and Internet of Things. He has published more than 30 papers in international and national journal/conferences.

Raman Singh is working as Assistant Professor with the Computer Science and Engineering Department, Thapar Institute of Engineering and Technology Patiala (India). He has completed PhD (CSE) from the University Institute of Engineering and Technology, Panjab University, Chandigarh, on February 2016. He has completed Master of Engineering (IT) from UIET, Panjab University, Chandigarh, in May 2010. He has published 14 research papers in international journals and conferences. He has won Best Publication of the year 2016 award from UIET Panjab University. He is currently executing three funded research projects. He has served the Information Technology industry for 2 years as a technology solution consultant. He is a Microsoft Certified Technology Specialist (MCTS) and Microsoft Technet Certified Technology Expert. His area of interest includes intrusion detection, network security, and machine learning.