Chapter 38
A Concise Study on IoT-Based Health Care

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Abstract Internet of Things (IoT) simply refers to taking and connecting all the surrounding smart devices (things) to the Internet. It is one of the most hopeful future technologies with a wide range of applications. The implementation of the IoT in the healthcare sector plays a significant role in handling various chronic diseases, and also in the prevention and control of diseases. IoT devices provide remote health monitoring, emergency notification, and human well-being systems. These health tracking devices extend from monitoring health parameters to advanced wearable devices that upgrade the quality of human life. Smart health care can be accomplished at all stages, starting from observing pediatric patients to tracing of chronic conditions in the aged. Different technologies and constituents are used in the Internet of Things for providing better health. This paper gives a glance at various applications of IoT that serves in the healthcare systems for providing a better quality of life.

38.1 Introduction

Internet of Things (IoT) refers to a concept that connects all devices to the Internet that also allows their communication with each other over the same. It extends the power of the Internet beyond computers and smartphones to an entire range of other things, processes, and environs. IoT is a colossal network of connected devices that gather and share data about their usage and the environments in which they are employed. Kevin Ashton is known as the Father of Internet of Things. He is a founder director of MIT's Auto-ID Center which is an alumni to Procter and Gamble. IoT has undergone a transformation from interrelated embedded computing devices to that of smart sensor devices. IoT networks use a wide variety of sensors and actuators to make the system smart and intelligent. IoT gives users the ability to organize their

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daily life and integrate real-world entities such as smart gadgets that provides both physical and virtual communications. IoT has an extensive range of applications in areas, such as health care, water management, cities, waste management, traffic control, parking activities, agriculture, surveillance and security, and industry sector. Low storage and restricted processing capacity are some of the issues faced by IoT when applied to the smart city environs.

Fog computing is one of the most hopeful technologies that reinforce IoT applications. IoT systems that are based on fog computing consists of three layers, namely device layer, fog layer, and cloud layer. It acts as an intermediate between IoT devices and the cloud computing framework forming a cloud–fog–thing network. Cloud computing is the delivery of different services including resources, tools, and applications like data storage, servers, databases, networking, and software through the Internet. IoT–cloud technologies require a conceptual infrastructure that provides patient-centric, and high-quality smart health care economically.

IoT applications are suffering from some major challenges: (i) Fail in reliability, data integrity, data provenance, and security for IoT applications through the Internet secures the communication channels, (ii) Lack of support of the broadcast nature of wireless media for IoT communications, (iii) Efficient handling of a large amount of data generated by IoT devices, (iv) How to assure sensor data, and (v) How to issue both local and global communication efficiently among numerous heterogeneous devices. However, IoT is in its initial stage in the healthcare sector which requires a thorough awareness of current research that could provide useful guidance for various researchers. This paper provides a brief description of the trends in IoT-based healthcare research and the available systems for this purpose.

38.2 Smart Health Care

Traditional health care fails in many cases due to a terrible increase in population. Here, comes smart health care as a solution for it. Smart health care refers to the technology that helps in upgrading the quality of life [1]. It helps users by making them aware of their medical status. The transformation of health care to smart health care is a slow process because of the lack of updation of the digital era within healthcare professionals. Smart health care enables users to manage certain emergency situations on their own. The emphasis given on personal health care has switched from traditional hospital care to smart home care. This provides both improved quality and user experiences. Smart health care with the help of IoT devices provides remote health monitoring, emergency notification, cost-effective treatment, and availability of medical services without any geographical barriers. These health monitoring devices range from monitoring health parameters such as fitness trackers to advanced wearable devices that improve the quality of life. Several technologies and constituents are used in Internet of Things for the betterment of health. Smart health care can be accomplished at all stages, starting from monitoring the temperature of pediatric patients to tracing of chronic conditions in the aged population. Just

now, "Personalized and Connected Health" improved the healthcare sector, claiming that people can examine and track their health by using smart devices.

Connected health care refers to remote healthcare solutions with continuous monitoring and emergency notifications. It focuses on improving healthcare quality and efficiency through self-care remotely. The main difference between smart health care and connected health care is that smart health care refers to autonomously operating solutions, whereas the latter provides users with feedback from clinicians. Connectivity technologies play a key role in smart healthcare systems. There are certain security requirements for smart health care. Some of them are data privacy, data confidentiality, integrity, authentication, service availability, access control, location privacy, etc. Monitoring of environmental factors such as humidity and temperature provides improved quality of smart health care.

38.3 IoT in Smart Health Care

IoT-based healthcare systems can be employed for taking care of children and elderly patients, supervision of chronic diseases, and for self-health care and fitness. Monitoring the health of people has now become one of the important applications of IoT devices. IoT is designed so as to provide an extensive range of healthcare facilities in which all of them delivers a set of solutions for healthcare issues. We require IoT–cloud amalgamation to manage high demands in smart healthcare facilities. IoT plays a key role in providing health care, both globally and locally. It is been necessary to have a system at home that helps people to keep track of their health status without affecting their daily life. They help in managing chronic diseases to monitoring daily physical activities helping in maintaining an individual's fitness goals. It comprises of a system for remotely communicating between systems, applications, and gadgets that help both the patients and doctors to track, examine, and record the important medical data and history of a patient.

IoT can be employed as a tool that supports examining and control within a healthy ecosystem, and data analysis technologies can be used to assist decision-making. The central idea of smart health care is real-time communication and patient monitoring. So, it is essential to have IoT-enabled health monitoring systems for this purpose which also generates alerts to healthcare service providers in case of any emergency. Human-like intelligence is introduced to smart health care with the help of artificial intelligence and deep learning technologies. IoT can also be used for tracking the production and delivery of medical equipments.

Internet of Health Things (IoHT) is basically considered as an IoT-based solution that incorporates a network architecture enabling a connection between a patient and various healthcare services [2]; i.e., IoHT provides interaction between the doctor and the patient through remote access. This network is recognized as Intelligent Healthcare Network (IoThNet). It is mainly utilized for sending and receiving information. Specialized doctors are capable of accessing medical reports and records, and providing suggestions. IoHT includes interconnected devices for remote health

monitoring, X-ray, and imaging devices. It also provides smart ambulances or smart clinics like services in case of emergency situations. Moreover, IoT acts as a link between doctor and patient by offering continuous monitoring and consultations through remote access.

38.4 Technologies Used in IoT-Based Health Care

There are numerous technologies available for IoT-based healthcare solutions. Some of the core technologies are listed below.

38.4.1 Wireless Technologies

Wireless technologies are said to be the keystone of any smart healthcare networks. Different wireless technologies are used to gather and send data through specific communication protocols such as Wi-Fi, Bluetooth, Global Positioning System (GPS), Wireless Local Area Network (WLAN), Wireless Personal Area Network (WPAN), 6LoWPAN, Radio Frequency Identification (RFID), ZigBee, and Near-Field Communication (NFC) plays a key role in information exchange among different physical entities within the healthcare network.

38.4.2 Wearable Technology and Medical Sensors

Wearables are smart devices with their supporting environment as either the human body or a piece of clothing. Wearable medical devices have the capability to collect, store, process, and analyze data to provide necessary feedback and generate alerts in case of any emergency situations. Developments in the field of various communication technologies and wearables have led the way to the evolution of numerous instantaneous healthcare monitoring systems. Wearable devices are designed in such a way that they can monitor the vital health parameters of the users and to provide the necessary support and medical aids. These are mainly used for patients with temporary or permanent disabilities, elderly people, or infants. A common use of these wearable devices is monitoring the day-to-day physical activities of the users. IoT wearable devices have reached such a level that it has merged itself making everything possible enabling patients to record their health information on mobile applications.

Sensors on the patient's clothes collect data and provide a digital electrical output that can be used for monitoring their health parameters. A sensor is a small analytical device that combines with a biological component that creates event recognition [1]. Based on the monitoring systems, sensors or actuators vary. It plays an important

role in IoT-based health care as they are accountable for gathering data from any embedded gadgets or machines. These sensors can discover physical, chemical, and biological signals and provide a method for their measurement and recording. They can gather and send data, such as ECG, location, and humidity, to the gateway (i.e., a device that converts one protocol or format to another) via a specific communication protocol such as Wi-Fi, Bluetooth, or 6LoWPAN. Sensors attached to the human body can be used for monitoring physiological or biomechanical conditions that include heart rate and muscle activities, respiration, body temperature, blood pressure, and body posture, motion, and acceleration. The output of smart sensors and IoT devices is usually complicated, and hence, they need advanced technologies like deep learning, cloud computing, and big data analytics for its processing. Temperature sensors, ECG (electrocardiogram), blood pressure, heart rate, etc., are commonly used medical sensors.

38.4.3 Body Sensor Network

Body sensor network (BSN) is a wireless sensor network (WSN) that is used for examining the human body. It is an interconnected assembly of wearable (programmable) sensor nodes that can interact with each other, and also with other smart devices and other ambient sensors. These sensor nodes have the capability of computation, storage, wireless transmission, and sensing. BSNs use cloud computing-based frameworks for adaptable storage and scalable processing facilities. Even though BSN-based systems have a vast range of applications, these can be used for continuous and non-invasive monitoring of essential signs, as tiny wireless sensors are positioned on the skin and sometimes implanted with the clothes. This helps in the early detection and diagnosis of diseases. Data related to human body movement, body temperature, heart rate, skin conductivity, brain and muscle activities, and biomarkers are commonly sensed using these sensors. BSNs are also used in various application areas such as e-Sport, e-Fitness, e-Wellness, and e-Social.

38.5 Edge–Fog–Cloud Network Computing

The architecture of edge–fog–cloud network comprises edge computing, fog computing, and cloud computing.

38.5.1 Edge Computing

Edge computing is a computing framework that exists at the edges of network or data sources. It is a disseminated information technology (IT) infrastructure where the

client data is processed at the network edge (boundary). It performs this as adjacent as possible to the originating source. The concept of edge computing came from the ideas of mobile computing, the dropping cost of computer parts, and the number of networked gadgets in IoT, as per studies. The time-sensitive data in this architecture may get processed either at the origin by smart device or forwarded to an intermediate server which is situated in adjacent geographical proximity to the client depending on its implementation. Later, the data which is less time-sensitive will be forwarded for further processing to the cloud.

38.5.2 Fog Computing

CISCO invented the concept of fog computing which permits software applications to run on the edge of the network devices rather than on data centers of cloud computing. Fog computing (FC) is a computing structure that allows the data and applications to be located anywhere between the data source and the cloud. It is also known as fogging. It is an extension of cloud computing in which the data, storage, and applications are on a distant server. FC acts as an intermediate between IoT devices and cloud computing forming a cloud–fog–thing network. Fog node is the main component in this network. It is located in a smart router or a gateway device allowing the data to be processed on these smart devices. Hence, only the necessary data are transmitted to the cloud. FC is anticipated to assist an extensive range of IoT applications, incorporating inter-device data sharing, wearable cognitive assistance, editing and sharing of videos, vehicular systems, etc.

38.5.3 Cloud Computing

Cloud computing is liable for systematically handling, stowing, and studying the entire data gathered by the system that is used for health monitoring purposes (i.e., cloud computing integrated with IoT-based healthcare technology) as Internet plays a key role in today's technology. It utilizes the remote server networks provided on the Internet for storing, managing, and processing data instead of a local server. Cloud storage consists of a large amount of repository to stow all the intermediate and ultimate outcomes, the medical information of each user, emergency notifications, etc. Memory plays a significant role in smart health care as it requires stowing user-related particulars. The incorporation of cloud computing with IoT technologies in health care provides access to allocated resources, offers facilities based on requests in the network, and executes operations consistent with the varied requirements.

38.6 Big Data Analytics

Big data analytics is a complex process of collecting, organizing, and analyzing large sets of data (called big data) to discover information—such as hidden patterns, unknown relations, market trends, and customer selections that provide decision-making possible. Data mining (also known as Knowledge Discovery or Knowledge Extraction) is simply referred to as the process of extracting functional data from a huge amount of raw data. It is a procedure that uncovers patterns in huge data sets which comprises of techniques that intersects machine learning, statistics, and database systems. This can be applied to any kind of data. For example, data in Data Warehouses, Transactional Databases, Relational Databases, Multimedia Databases, Spatial Databases, Time-series Databases, or World Wide Web. Temporal mining is a data mining technique used for taking out data sets in time series pattern (TSP). Here, the extraction of useful data from fog data services takes place instantaneously. Time-sensitive health parameters of patients used for remote health monitoring are extracted using the temporal mining technique.

38.7 Medical Applications of IoT and Related Work

There are several applications and works available that are related to IoT-based health care. We can divide the applications of IoT into single-condition and clustered-condition applications [3]. A single-condition application refers to a particular disease or any bad state of health like monitoring of blood sugar level, ECG, blood pressure, body temperature, and oxygen saturation. A clustered-condition application refers to numerous diseases or entire conditions. Some of the IoT-based healthcare applications are as follows:

- Blood pressure monitoring
- Pain monitoring
- ECG monitoring
- Sleep monitoring
- Heart rate variability monitoring
- Nutrition monitoring
- Pathology monitoring
- Cardiac auscultation monitoring, etc.

Now, we can see each of these applications and their related works.

The first application we are discussing here is blood pressure monitoring. Blood pressure (BP) problems are found in people if there is a variation in the normal flow rate of blood pumping out from the heart. Hypertension, also five known as high blood pressure, is a worldwide health problem that is produced on account of exalted BP in the arteries. Several circumstances leading to this elevation of BP involve an unhealthy diet, inadequacy of exercises or physical activities, human

emotions, immediate surrounding conditions, and geographical locations. Long-term high BP leads to heart failure, chronic kidney diseases, vision loss, etc. IoT healthcare systems build on the cloud computing platform are trending over the years, which helps patients to monitor and control their blood pressure using IoT devices. The data from IoT-based wearable medical sensors are stowed at the cloud for further computation and examination.

A feasible solution for continuous cuffless blood pressure measurement and calibration that has broad application prospects in the fields of athlete scientific training and medical care was developed in 2020 [4]. In their work, they have developed a blood pressure measuring and calibrating system that was based on a mobile crowdsensing platform named CrowdOS. The system was capable of continuously collecting the blood pressure from the patient, and then they have used the regression model for calibrating the collected blood pressure.

Next application is pain monitoring, which is an important application in treating patients. The detection of human emotions is important for providing emotional care that improves the quality of life. Direct communication with patients or traditional methods used may not provide proper interaction. Mainly children, elderly, and mentally ill people need this type of interaction. Facial expressions are a behavioral indication of pain. Since the experience of pain causes changes in facial expressions, they can be used for assessing human pain as an automatic tool. Thus, it can be used as a substitution method to the traditional self-report methods and for those who are ineffectual to do so, for instance, patients in the intensive care unit (ICU) and infants. Parents often monitor their infants' facial expressions, as they provide information about their health state.

In 2020, an automated acute nociceptive pain recognition system was proposed to objectively measure nociceptive pain using physiological signals and a hybrid deep learning network [5]. This hybrid deep learning network that was used in the proposed system consists of a convolutional neural network that is capable of extracting the essential information related to the pain that is obtained from the physiological signals. The featured matrix that is extracted is then given to the LSTM network for further concatenation of the features. BioVid heat pain database was utilized for this system. Another new postoperative pain assessment model based on pulse contour analysis was developed and also evaluated its effectiveness in postoperative pain assessment [6] in 2019. In their study, they have extracted several candidate features from PPG waveform and then they have developed a model that assesses the pain that is based on multiple logistic regression with a combination of these features.

The next application in our discussion is ECG monitoring. Electrocardiogram (ECG) is an examination that measures the electrical activity of our heart that shows whether it is working normally or not. Sensors attached to the skin are used to detect the electrical signals produced when each time our heart beats. These electrical signals are utilized to monitor the patient's health state by the doctors. Traditionally, ECG is extensively used in clinics by positioning electrodes (up to 12) to the chest. This arrangement is not wearable. Here smart devices came as a solution to this problem.

There are numerous devices and solutions in practice for remote ECG examining purposes. In 2018, an ultra-low-power wrist-worn wearable was proposed for examining the user's heart rate via ECG [7]. It uses some extracted heart rate variability readings and the noticeable morphological components of the ECG waveform. In this, two electrodes are used. One electrode is used for providing ECG monitoring by asking the users to touch the wearable face with a finger. The other one is located at the back of the wearable coming in contact with the wrist which allows it to have connection points on either side of the heart for recording traces of ECG with large amplitude. Another ECG monitoring system based on IoT embedded platform was proposed in 2020. In this method, the features from ECG signals of patients are taken out using a modified version of discrete wavelet transform (DWT) that is implemented using fast Fourier transform (FFT) [8]. These features are then classified with the help of twin support vector machine (TSVM) classifiers that are based on particle swarm optimization (PSO). This method can be implemented as a warning system that can be employed in both hospitals and remote monitoring systems to provide users with a healthier life free from cardiac diseases.

Sleep monitoring is another important application of IoT since nowadays many people are suffering from sleep disorders. Sleep is a natural and periodic state of rest of both mind and body. It is a state of muscle relaxation and reduced interactions with the surroundings. Good sleep is required for the proper functioning of our body. Any interruption of the normal sleep pattern is often referred to as sleep disorders. There are several varieties of sleep disorders, namely insomnia, sleep apnea, obstructive sleep apnea, etc. Obstructive sleep apnea (OSA) is a menacing respiratory disorder that happens in the course of sleep. It affects the quality of life causing behavioral and personality disorders, etc.

There are innumerable systems available for detecting OSA. A wearable in-ear electroencephalography (ear-EEG) for overnight sleep monitoring as a 24/7 continuous and unobtrusive technology for sleep quality assessment in the community was proposed in 2020 [9]. In their study, 22 healthy participants were selected for taking part in overnight sleep monitoring study. The overnight sleep monitoring was done with the help of simultaneous ear-EEG and conventional full PSG recordings. The features that were extracted were used for automatic prediction of sleep stage that was done using supervised machine learning.

Heart rate variability monitoring is yet another important application of IoT. Heart rate can be simply interpreted as the rate at which heart beats. It is measured in terms of the number of heart beats per minute (bpm). The heart rate varies throughout a person's lifetime, according to their age, fitness, and even whether they are frightened or not. This may also vary according to the basic physical needs of body, including oxygen intake and carbon dioxide expulsion. Heart rate variability (HRV) deals with the disparity in the beat-to-beat interval, i.e., the difference in the time interlude between heart beats. It indicates the current heart-related abnormalities and a warning of threatening cardiac diseases. HRV can be used for six diagnosing many intricate cardiac diseases, for instance, arrhythmia, myocardial ischemia, and long QT syndrome.

An automated remote cloud-based heart rate variability monitoring system [10] was proposed in 2018 for this purpose. Web applications were developed by them to extract medical data and some personal particulars like gender and age from the user's wearable sensors. These systems then alert the doctors in case of emergency after detecting any abnormalities in the heart. Homomorphic encryption (HE) technique was used for data encryption to assess the security of remote monitoring. The proposed system was efficacious, reliable, and flexible. It could also extract heart abnormalities from multiple patients simultaneously.

Nutrition monitoring, another important application of IoT plays a key role in today's busy life. Nutrition is the science that deals with the proper intake of food required for better health in all living organisms. It also includes the absorption, metabolism, and excretion of the consumed food. In other words, nutrition is the science of consuming and utilizing foods. A properly balanced diet is very important since nutrient deficiency leads to serious health issues in both children and adults. Imbalanced nutrition in newborns and youngsters can lead to health issues such as weak immunity, cognitive disorders, enfeebled skeletal structure, thinning hairline, and bleeding gums in adulthood. Nutrition imbalance may be either due to undernourishment (i.e., the sufficiency of nutrients in the consumed food) or due to overeating (i.e., excessive consumption of non-nutrient-rich food). So, diet monitoring is an essential part of the healthcare system for maintaining a proper diet and a healthy lifestyle.

An automated nutrition monitoring system, named SmartLog, was proposed in 2018 [11]. It was a consumer electronic system that was used for diet monitoring in smart homes for improving the quality of life. SmartLog consisted of Wi-Fi-enabled sensors for the qualification of food nourishment, and a smartphone application for collecting the nutritional contents of the food ingredients. An open IoT platform was used for performing data analytics and repository operations. It also made suggestions to reduce the risk of an imbalanced diet in addition to the nutritional content in meals. It was mainly designed for infants but can also be utilized for adults by enlarging its food database stored in the cloud storage.

The next application under discussion is pathology monitoring. Pathology is the study of the causes and consequences of disease or injury. It refers to the study of disease in general. Pathology acts as a bridge between science and medicine. Electroencephalogram (EEG) is an examination that is used to perceive issues that are associated with the electrical activities of the brain. This is done with the help of small metal disks with narrow wires attached to the scalp, and subsequently, signals are sent to a computer to store the outcomes. EEG is a commonly used technique for this purpose as it provides economical and non-interfering nature. Certain diseases like epilepsy and stroke which are brain-related diseases are diagnosed using EEG. Patients with such diseases require an instant response in case of emergency because any detain can be life-threatening. In such cases, a smart healthcare infrastructure that helps in examining the patient's status is necessary.

A cognitive smart healthcare model was proposed in 2019 for pathology detection and monitoring [12]. In this framework, communications within smart cities were made possible by using smart sensors, and proper decisions were made with the

help of deep learning. The state of the patients was determined based on the sensor readings such as facial expressions, speech, gestures, and EEG. The obtained EEG signals were categorized as pathological or normal with the help of deep learning-based real-time decisions made by the cognitive module. The results are shared with caregivers so they can take necessary actions.

Cardiac auscultation monitoring is the last application of our discussion under this section. Heart sounds are the noises that are generated when heart beats and resultant blood flows through it. It delivers physiological and pathological evidence about health. Cardiovascular disease is considered to be one of the major health problems as any delay in the proper diagnosis and treatment leads to death. ECG is the most admired method used for examining the proper working of the heart by detecting the electrical signals. In earlier days, physicians practiced heart auscultation by directly placing their ears to the patient's chest. It helps in the early detection of heart diseases since the heart sound contains a lot of information that helps in diagnosis. Electronic stethoscope uses ambient noise reduction (ANR) technology that makes heart auscultation more convenient with reduced noise. The most extensively used substance of the heart sensor is piezoelectric.

A wireless cardiac auscultation monitoring system was proposed in 2018 for continuous cardiac monitoring and analysis of people without any need for manual healthcare services [13]. It involves the integration of Hilbert–Huang transform that was used to study coronary artery disease, and double-threshold method for preprocessing, and extraction of heart sound signal features and physiological parameters. Hidden Markov model was utilized for the categorization purpose. In other words, preprocessing, segmentation, and clustering technique was performed for the proper elucidation of available health information.

38.8 Conclusion

It is transparent that the future of IoT is enormous, and surely, it will reach a stage where people will not be able to imagine life without IoT devices. Progress in the field of various wireless technologies and wearables has led the way to the evolution of numerous instantaneous healthcare monitoring systems. IoT has also enabled the improved performance of the traditional healthcare system and making it adjustable with smart devices. This paper focuses on smart health care and the role of IoT in smart health care. The various technologies that are utilized in IoT-based health care and certain ways of using IoT devices to enhance the health of people were also discussed. Certain examples of such devices were discussed that helps every individual, mainly children, elderly, and physically disabled people in maintaining their physical wellness. The objective of this paper was to give a comprehensive outlook rather than a deep understanding of IoT usage in the healthcare sector and the various healthcare monitoring systems available. Both research works and devices that are commercially and currently available for the purpose of examining and exploring health conditions were mentioned. The discussion on this paper is intended

to impart a basis for each and everyone who is working in the field of IoT and for further advancements of various healthcare technologies.

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