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Chapter 10

Internet of Things and cloud computing

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10.1 Introduction

Over the years, a continuous decline in the healthcare sector has been witnessed. Increasing number of old-age patients, rise in chronic diseases, and increasing world population have been leading causes of additional stress on the healthcare sector \cite{1}. The limitations of conventional healthcare sector were further highlighted with the recent episode of coronavirus (COVID-19). While the healthcare system was barely sustaining day to day pressure, COVID-19, brought it to the verge of collapse. Let alone the developing nations, even in the most advanced countries in the world, the healthcare infrastructure was not developed to cope with such scales of health disasters. In the current health crisis, the healthcare institutes are under immense pressure, primary healthcare staff are highly vulnerable, and medical equipment is scarce. This prevailing situation urges immediate action to transform the conventional healthcare infrastructure to a more resilient, technology driven and self-sustainable healthcare system.

In the current healthcare systems, while the technology has penetrated up to some extent, yet it is a long way to reach the desired outcomes. While there are some case studies presenting the use of medical sensors, remote healthcare support and intelligent solutions for diagnosis and monitoring \cite{2–5}, the implantation of such systems is only limited to very few and privileged healthcare services. Besides, most of such solutions are isolated and stand-alone solutions fail centralized approach. In addition, these solutions lack benchmarking and thus integration of such systems is a major challenge.

Internet of Things (IoT) is an emerging solution which offers communication framework necessary in any technology driven healthcare system. While the IoT can be used in diverse fields and limitless applications, their significance in the healthcare systems is undeniable. IoT offers basic communications framework which can facilitate communications, whether it is from sensors sampling patients’ vitals, healthcare machinery, hospitals, care centers, recovery wards, old-age houses, or smart homes \cite{6}. The ability of IoT to communicate necessary information in near real-time can offer sustainable solutions in healthcare industry where the patients and medical staff can both benefit from it. Some of the potential benefits the IoT can offer, are listed as follows:

10.1.1 Low-cost solution

The recent developments in microelectromechanical systems has resulted in low-cost IoT solutions for healthcare. The low-cost IoT devices are not only equipped with suitable sensors, radios, battery, processing, and memory but also offer sustainable operations for extended periods of times, bringing the cost factor much lower than the conventional techniques.

10.1.2 Ease of deployment

IoT can be deployed in any environment with relative ease. The mature routing and communication techniques allow the sensors to establish ad-hoc on-demand networks and communicate sensory data to data sink by forming multihop networks \cite{7}. The self-healing abilities of IoT make it more resilient and fault tolerant in sensitive healthcare applications.
10.1.3 Scalability

The IoT can virtually grow to infinite sizes. The low communication power, while on one hand offers improved battery life, on the other allows frequent reusability and interference avoidance in larger networks [8]. In addition, the use of hierarchical architecture allows IoT to exponentially expand the networks and enable large healthcare infrastructures for collective intelligence.

10.1.4 End-to-end connectivity and effective monitoring

IoT offers end-to-end connectivity between the sensors and control center. Thus, the IoT can be effectively used in off-hospital premises monitoring and analysis of the patients. This ability of IoT allows the elderly and vulnerable patients continually monitored in home environments, minimizing the exposure and discomfort for such patients. End-to-end connectivity, low latency, and reliability enhanced solutions in IoT offer simultaneous monitoring of the vulnerable patients without dedicating the healthcare staff for such purposes.

The IoT offers low-cost, scalable, self-forming self-healing networks which enable data collection from large number of sensors by efficiently routing that information to the data sink using various routing protocols [7,8]. While the benefits of IoT are immense and potential limitless, it cannot work as a stand-alone solution. Rather, IoT serves as an enabling platform to facilitate implementation of artificial intelligence (AI), cognitive decision support systems, big data analytics, machine intelligence, and smart healthcare.

The effective development of smart-health solutions, that require IoT, also need cloud storage and processing facilities to manage and process the raw data, collected by the IoT-enabled sensors. Cloud computing serves as a fundamental component in realization of smart healthcare solutions. Like IoT, cloud computing is also essential for AI driven healthcare solutions including remote diagnosis and monitoring, intelligent patient profiling, decision support systems, smart hospital formation, load management and redistribution of patients among hospitals, elderly care and support, patient records maintenance and vulnerability prevention measures. The cloud computing not only provides a storage of massive data generated by the IoT devices, but the computing facilities allow the implementation of complex classical and deep learning algorithms. Some of the available cloud services such as Amazon Web Services (AWS) cloud compute services, offer dedicated solutions for the IoT such as AWS IoT [9]. AWS IoT and similar cloud services offer seamless connectivity of large number of IoT-enabled devices, allow AI integration, data security and deep IoT services by incorporating edge computing. A block diagram of IoT-enabled and cloud computing based smart healthcare systems is presented in Fig. 10.1.

In the following sections, a detailed discussion on IoT, healthcare applications of IoT and cloud computing is presented. Medical case studies are also discussed to highlight the use of IoT and cloud computing in healthcare.
10.2 Internet of Things

IoT is a new communication paradigm which consists of various interconnected smart devices like sensor nodes, actuators, and low power appliances. Nowadays every object of daily use is connected to the internet. From a tiny device to an industry oriented large device, everything is equipped with a small micro controller, a transmission module, standard communication protocols and memory [10]. Even in larger devices, every part is connected to a separate IoT sensor. The reason behind using tiny micro controller is that most of IoT devices are battery operated. To use existing battery efficiently, it is important to design micro controller and communication module in such a way that it can work on low battery power. Multipurpose IoT devices are used these days, which can perform multiple tasks using a single sensor [11].

Like other fields, IoT is playing a vital role in healthcare. In healthcare, IoT offers various application including routine check-ups, health monitoring, personal fitness, and elderly care. IoT sensors are also used to monitor the functionality of different organs of the body. These IoT sensors usually lies in the category of Wireless Body Area Networks (WBAN) [12]. In comparison to traditional healthcare devices, IoT based devices are economical and user friendly.

10.3 Communication framework for Internet of Things-based healthcare

The communication module in every IoT based system is the most critical part. The whole functionality of IoT device is dependent on communication framework. Depending on the purpose of the IoT device, communication framework may vary. Like, in weather monitoring application the IoT based device battery is the most important and monitoring sensor must work for longer period. Similarly, in fitness applications the accuracy of sensor is important. In healthcare based IoT applications where monitoring is involved, efficient communication is critical part [13]. Since IoT sensors have smaller and embedded battery, therefore, suitable energy efficient solutions are required [14]. Although IoT based health devices are rechargeable, but still it is useful to design algorithms and frameworks which can prolong battery life of these devices [15].

Emerging machine learning technologies [16] in wireless communications is delivering a great service. Reinforcement learning is a branch of machine learning, where an agent takes certain action from provided action list. With every action, an agent gets certain reward. Depending on the action, it can be a positive or negative reward. Initially, the environment is unknown to environment. The agent takes certain action into environment and learn from its actions. Here, we discuss reinforcement learning IoT based communication framework for healthcare applications. Emerging reinforcement learning technology in IoT healthcare can be of great use. Considering the fast learning approach of reinforcement learning and robust decision-making, it can be used in scenarios where a long-term monitoring is required, or critical communication is needed.

The role of reinforcement learning in remote health monitoring is of great use in scenarios where critical monitoring is required. A general structure of IoT scenario in healthcare application is presented in Fig. 10.2. In the initial step the sensor is trained in the provided environment. In healthcare scenarios, environmental aspect as well as health parameters of patient can assist in decision making. The primary parameters can be weight, height, age, etc. The decision variable which

![FIGURE 10.2](image_url)
can also be called as critical variables will be heart rate, blood pressure, sugar level, etc. These parameters may vary, depending on each scenario in healthcare application. The agent which is a sensor is initially trained in the environment and various testing are performed in training stage to check the accuracy of agent as well. In the training stage, the agent will take certain action in every state and against every action agent will get a reward. Usually agent gets a positive reward for actions which will benefit the patient. Once a critical situation is monitored based on provided parameters, it can be placed into two categories. It can either be of high priority or of low priority. In case of low priority, the health professional will be informed to carry out necessary check-up or diagnosis. In the latter case, emergency services will be informed to take necessary action in response to the generated alert. This framework can be applied in the situations where critical health monitoring is required. The challenging task in this framework can be to train agent according to different environment and identify a critical situation correctly.

10.4 Applications of Internet of Things in healthcare

In the later part of the 20th century medical rehabilitation was established as a subject of importance for the enhancement of medical care, which later became a new branch of therapy. The conventional methods involve a long-term and intensive therapy, requiring additional assistive facilities, and becoming high in demand due to rapid increase in aging population in the current society. Using IoT alleviates the problems by making the medical healthcare system intelligent. IoT helps by acquiring real-time data by making radio frequency identification tags (RFID), sensors, and personal digital assistants ubiquitous [17]. In a conventional healthcare service, an on-site rehabilitation service is required to be present at a local hospital facility and all related resources need to be present locally on-site. An IoT based service makes it possible to provide a “one-stop” service to the residents conveniently even in remote locations as the resources can be shared within communities through smart rehabilitation thus, providing flexible and convenient treatment to patients. This helps in maximum and efficient utilization of the available healthcare resources. The importance and benefits of IoT in healthcare is being rapidly recognized and more researchers are devoted towards maximizing the capabilities of IoT in healthcare systems, that also involves big data management.

It is very recently that the IoT based rehabilitation has been introduced, so that the problems of scarce resources can be addressed to cater the increasing population. It can possibly be placed as a subsystem of the concept of an ideal smart-city. IoT in healthcare brings together and connects healthcare activities like diagnosis, patient-monitoring and vulnerability prediction that can be life-saving. An ideal IoT healthcare system can be divided into three parts: Master, Server, and Things. Master comprises of doctors, nurses, and patients; server is the central part of the entire healthcare system and things are all physical objects that are connected by technology [17,18].

Here few important applications of IoT in healthcare are discussed in comparison to their conventional counterparts.

10.4.1 Medical nursing system in hospitals and care homes

The medical nursing system faces many challenges in the conventional system such as inadequate human resource, not very suitable working environment conditions, patient assistance and record keeping. In any ideal smart healthcare system for hospitals, the following points used are indispensable.

- Periodical clinical reassessment
- Neonatal monitoring
- Sleep detection and monitoring
- Patient alert system for fall monitoring
- Nursing calling system
- Medication monitoring system
- Physiological parameter monitoring

The area of nursing informatics is usually concerned with the integration of nursing information combining its knowledge with the information management technologies. This has been made possible with the use of IoT in this sector. IoT has offered an entirely new approach that provides real-time wireless health monitoring making use of cloud computing. IoT has also enabled the basic nursing capable of intelligent decision-making. In hospitals patient’s vitals can be monitored in real-time and this does not require an all-time manned attendance by the nurses [19,20].

One among many advantages of using IoT solutions in healthcare is the automation of patient data collection and processing. This is made possible by the utilization of low-cost sensors, devices and technologies making it all very economical in time and money. Formalization of health data can be easily done by hospitals with the help of IoT. Thus, allowing
healthcare staff to use their time more effectively by focusing on patients’ with critical needs. A new means of patients’ safety emerged because of IoT applications with automated tracking of patients and staff, fall detection and nurse-calling systems (cf. Fig. 10.3). It has also facilitated to provide quicker updates to members of family of the patients if they are not able to be present in the hospital. Use of personalized smart devices clubbed with IoT in hospitals enable the healthcare staff to provide personalized care by personalized decision-making approaches, which subsequently minimizes mistakes [21]. Equipped with data analysis algorithms and state-of-art machine learning, and pattern recognition technologies, IoT has also been proposed for prediction of certain diseases like the Parkinson’s disease. All these would not be possible with the conventional healthcare techniques being used by the hospitals and healthcare centers [22].

### 10.4.2 Emergency services of healthcare

The outcomes of the emergency care are influenced by time, availability, and accuracy of any contextual information. Its success is dependent on the quality and the accuracy of the information received and the data collected during that emergency transportation. IoT and its applications to care the needs of the emergency healthcare services are gaining confidence. Although it seemed daunting to the public safety agencies initially but the benefits that have been depicted in practical case scenarios have restored the confidence. Information captured by sensors and cameras around the site of an accident can provide real-time information to the emergency services to act promptly [23]. With the use of LTE and 5G enabled emergency vehicles the response teams can make maximum use of the IoT services. Smart traffic management and connected vehicle technologies have taken a leap forward towards providing faster than ever life-saving contributions.

Smart ambulances that have been equipped with high-definition video and medical data transmission capabilities are enabling medical specialists to provide remote diagnosis of patients. This can be started from the point of emergency and helps medics and ambulance staff to treat the patients in a much better way as they are being transported to the hospitals. Patient emergency data is a very vital piece of information that can be sent to the hospitals while the patient is being transported. This enables the hospital to be all prepped-up to provide personalized treatment to the arriving patient. The patient vital stats are recorded via sensors and transmitted to the hospitals in real-time. IoT based smart technology can provide additional data from the smart database. This requires access to the electronic medical record system of the hospitals and this data can be embedded with the patient data in lieu of an emergency response. An IoT based emergency response will be able to the injured patient’s emergency data, geographical information of the place of accident, other relevant data from the place of incidence, personal data of the caller, and then forward all this information to the emergency doctor and the emergency transportation team.
this would not be possible with the conventional methods of the emergency medical services and thus IoT based smart-health system is indispensable in saving lives in the most critical of situations and patient transportation [17,24].

10.4.3 Biomarker data monitoring

There have been advancements in molecular techniques with the most celebrated in the history of molecular biology research being clustered regularly interspaced short palindromic repeats. It is the most widely used DNA and gene editing tool. It is cheap with a DNA starter kit costing only $65, and a short RNA template can be created using the free software. IoT has the similar potential to revolutionize molecular monitoring with use of sophisticated biomarkers. This can allow us to track states of specific diseases and even identification of some diseases even before appearance of symptoms [17].

Most clinical identification methods are based on invasive techniques with the most common being a blood analysis but the limitation of it is that a continuous blood sampling is not very practical. Noninvasive measurements can be very well taken from saliva, urine, sweat, tears, menstrual fluid, breath, etc. Biomarkers can be easily picked from these bodily fluids to trace the disease, well before symptoms are visible. Sensors and physiological markers combined be machine learning or AI may be highly capable of recognizing relevant biomarkers. This can only be achieved with the use of an IoT based smart monitoring system [17,25].

10.5 Cloud computing

IoT offers a seamless platform integrated with various wired and wireless communication capabilities to connect people and objects for enriching the data collection which offers a vast amount of e-health applications. There are several wireless communication technologies such as Bluetooth Low Energy, Wi-Fi, ZigBee, Long Range, Narrowband IoT, Long Term Evolution for Machines (LTE-M), etc. Selecting the best communication technology and protocol depend on specific use-case and application (cf. Fig. 10.4). For example, BLE best fits for short-range low power communication. On the other hand, Wi-Fi is ideal to transfer a large amount of data. IoT coupled with fog computing and cloud empowers handling of

![Diagram of Cloud computing and its role in Internet of Things-based smart healthcare system.](image-url)
complex data to provide a patient-centric IoT eHealth ecosystem rather than a clinic-centric treatment [26]. There are several researches that have used IoT and cloud computing to develop applications based on big data and AI:

- Wearable 2.0 smart clothing with sensors to obtain electrocardiogram (ECG) signals [27].
- Seizure prediction for epilepsy patients using deep learning with electroencephalogram (EEG) big data via IoT and cloud computing [28].
- Parkinson disease monitoring system using wearable computing and cloud technology [29]. This study has used Decision tree, Random Tree, signal vector magnitude (SVM), Naïve Bayes and K-Nearest Neighbor classifier algorithms.
- Wearable sensor system for real-time cutaneous pressure monitoring with cloud computing assistance for early diagnosis of cardiovascular diseases [30].
- Wireless wearable oximeter using cloud computing for the diagnosis of obstructive sleep apnea [31].

10.5.1 An introduction to cloud computing

The cloud computing services are generally classified into three types:

- Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). These services are deployed in any one of the four different models which is based on the concern targeted user: public cloud, private cloud, community cloud and hybrid cloud.

10.5.2 Infrastructure as a Service

Cloud computing is now a very popular paradigm for provision resources based on demand. IaaS provides computing, storage, network, security, and operating systems virtualization technology as a service [32]. IaaS gives users full control to customize the environment which includes the operating system application, middle ware, development platform, and the required resources such as central processing unit, memory, storage, etc. IaaS aims at provisioning resources on demand, therefore, does not require long-term commitment and majority of the IaaS providers offer “Pay-as-you-Go” basis plans. Here, the users have no idea regarding the underline environment such as the hypervisor, physical server, etc. AWS Elastic Compute Cloud and Secure Storage Service (S3), Azure IaaS, IBM Managed IaaS, Google Compute Engine, Oracle Gen 2 Cloud Infrastructure are some of the popular examples of IaaS offerings.

Recent research efforts have stretched IaaS by adapting cloud metaphors to the IoT infrastructure and viewing IoT as a natural extension of the datacenter. Therefore IoT devices coupled with standard IaaS resources offer facilities such as computing and storage. In near future, IaaS would be complemented by standardized access to sensors and actuators, without resorting to ad-hoc, application-level, and remote Application Program Interfaces [33]. IoT-IaaS service models for cloud computing promises to facilitate the deployment and execution of applications on the IoT devices in true fog/edge computing fashion [34].

10.5.3 Platform as a Service

PaaS provide a virtualized computing platform, including an operating system, programming language execution environment, database, and web server. It facilitates the users to customize the platform, which includes the application and middleware, to develop their own application. PaaS level is the most suitable for IoT application developers to use. The IBM Bluemix Platform, Parse developed by Facebook, Google IoT, Amazon IoT, Cloud-Foundry are some of the IoT-enabled PaaS solutions in the market [34].

Advantages of provisioning IoT applications in hybrid cloud/fog environments have been demonstrated in [35]. The study shows that provisioning in these hybrid environments enables processing performance enhancement and latency reduction. The authors have also proposed that the application components should be distributed that will be running in a distant cloud and running in the fog, closer to IoT devices to further reduce the latency. In addition, migration of IoT functions have been demonstrated in [36].

Authors in [37] have developed an application called “Critical Patient Management System” to observe critical patient’s health condition with Machine Learning (ML) and PaaS. The system was designed to train and deploy ML models in real-time by retrieving the data from IBM cloud. PaaS model was exploited to develop a platform for IoT distributed applications over socially connected objects in [38]. To improve network scalability and information discovery efficiency the objects establish social relationships in an autonomous way with respect to their owners.
10.5.4 Software as a Service

SaaS is a software distribution model where the applications are hosted in the cloud and makes them available to users over the internet. Some of applications that are widely used are email, financial management, billing, customer relationship management, human resource management, and collaboration. Leading SaaS providers include Salesforce, Oracle, SAP, Intuit, and Microsoft. SaaS gives users minimal control over the cloud resources. The underline environment is kept hidden from the users and therefore, users can only use the rented software service.

In [39], the authors have proposed a Docker container-based framework for virtualization to provide SaaS in a hybrid cloud environment. A plug-and-play mechanism was introduced in [40] for IoT devices to instantiate a SaaS application in a private cloud, built up with OpenStack. This mechanism aims to simplify programming and enable devices to be smarter.

Diversified SaaS compatibility regardless of underlying cloud infrastructures and platforms has been a challenge as highlighted in [41]. The authors therefore have proposed a new approach called OverCloud where three razor-thin overlay layers namely DevTower, DataLake, and logical clusters along with container-based on micro-services architecture to address the compatibility issues. A SaaS based architecture was proposed in [42] to address the issues of connected data in IoT domain with the unification of three open source technologies: apache spark, ejabberd, and neo4j database and to achieve real-time processing.

10.6 Healthcare case studies

The inclusion of IoT in healthcare initiated the bright vision of smart-health, where data is transferred seamlessly from personalized wearable sensors, smart homes, and smart hospitals to a data storage and computing platform, commonly known as cloud computing. While the cloud is a more centralized data storage and computing platform, its counterpart known as fog computing is decentralized and localized to data sources. The complete IoT-enabled healthcare paradigm comprised of wearable sensing, fog computing, cloud computing, and healthcare is shown in Fig. 10.5. Each of these platforms have their pros and cons. Cloud computing can be deployed faster with more flexible source while, fog computing is cost effective and target is real-time processing on edge devices. However, both these methods provide enormous benefits to healthcare sector by sending their live activity profile and health status to healthcare professionals, which can then make informed decision about the possible intervention to improve the individual’s quality of life and well-being.

The following subsection provides different context in which IoT-enabled healthcare systems are developed in the past as shown in Fig. 10.5 and Fig. 10.6.

10.6.1 Remote heart failure monitoring

This study developed a congestive heart failure monitoring system which continuously monitors the patient’s heart rate and perform real-time feedback to healthcare services to make informed decision about the patient’s health [43]. The noninvasive monitoring of congestive health failure is accomplished through continuous recording of ECG waves, and

FIGURE 10.5 Internet of Things-enabled healthcare paradigm.
then performing data analytics and machine learning to detect the underlying disorders. The system was composed of ECG acquisition setup, personal server, cloud server, and monitoring center. The healthcare staff (including nurses, doctors, or clinicians) at monitoring center initiates real-time data gathering request from patient's location and the data transmission is started after fulfilling necessary security and privacy measures. The continuous ECG data transfer is also possible in critical situation where it is important to send live updates to healthcare professionals. The ECG device after successful setup start transmitting raw data to personal server where all the data is combined. The recorded data is then transferred to cloud server for visualization and further processing. The personal server supports both push and pull operation to generate the raw ECG data on request from monitoring center as well as to push the raw data from ECG device to cloud. Cloud server is capable of performing: (1) Data visualization to enable physician to inspect raw heart rate data, (2) data analytics to perform dimensionality reduction, signal processing, and machine learning to profile ECG recordings, and (3) alert system to alert the healthcare and emergency services in case of critical situations.

### 10.6.2 Fog computing enabled Internet of Things framework for diabetic patients

The study [44] developed an intelligent decision support system to diagnose and monitor type-2 diabetic patients. The study combined fog computing paradigm with cloud computing instead of using cloud alone to better cope with real-time application, mobility, and location awareness. The system consists of wearable IoT sensors, fog computing paradigm and cloud layer. The IoT data sensing platform is developed through WBAN, comprised of several wearable devices sending data to a wireless module to perform early diagnosis of type-2 diabetic patients. The WBAN consist of motion sensors, heart rate sensors, respiratory sensors, hypertension monitor, and glucose level indicator. The patients IoT devices are smart gateways responsible to collect and manage biological data of WBANs. The WBAN’s biological data is sent to fog gateway via cluster head and edge gateway for further processing. Fog architecture consist of six layers to handle data, that is, (1) physical and virtualization layer to handle physical and virtual sensor networks, (2) monitoring layer to monitor activity, service power, resource and response, (3) preprocessing layer for data trimming, preprocessing filtering, (4) temporary storage layer for data replication, distribution, and managing storage devices, (5) security layer to handle privacy, encryption and decryption, (6) transport layer to transmit the preprocessed and secured data to cloud server. After these
operations, the data is stored to cloud server for further processing and broadcasting. Then the proposed decision support system is run on the cloud service to analyze several symptoms such as fatigue, increase thirst and hunger, sores and dark skin, blurred vision and coupled with medical specialists feedback and data analytics pipeline diagnose type-2 diabetes. The system then updates patients through electronic health records about their health status and the severity of the disease if diagnosed positively. The proposed decision support is also capable of alerting emergency services such as ambulance through priority gateway (build within fog gateway) in case the patient’s situation becomes critical.

10.6.3 Cognitive Internet of Things-cloud for seizure detection

Alhussein et al. [45] proposed a cognitive IoT based system for the detection and monitoring of epileptic seizures. The proposed cognitive system monitors patient’s health status through a variety of wearable IoT sensors, that is, EEG headband, ECG, electromyogram sensor, accelerometer, altimeter, visual sensor, microphone, pressure sensor, and sociometric badges. The configured local area network (LAN) is responsible of short distance communication between IoT and smart data storage devices such as laptops, tablets, or smartphones. The LAN’s communication infrastructure can support several modalities such as Zigbee, near field communication, RFID, Bluetooth, low power wireless personal area network and Zensys wireless network (Z-wave). The smart devices then transmit the sensors’ data to the cloud via wide area networks such as Wi-Fi, 4G or 5G. The received data is first checked for authentication and verification, and then further data processing is performed on cloud server. Cloud server is composed of data analytics server, data detection server, data storage facility, feature engineering server, and cloud management server. The cognitive decision support model investigates the sensing modalities data and if it suspects a possible seizure events, the EEG data [46,47] is further processed by the proposed deep learning model to accurately detect the occurrence of epileptic seizure. The decision support system is also connected with healthcare stakeholders such as medical staff and emergency services and inform them accordingly about the patient’s health condition to make informed decision.

10.6.4 Internet of Things-based bed-egress alerting in an elderly care environment

A wearable motion sensors-based bed-egress alerting paradigm is proposed to monitor the movement of elderly patient in an elderly care environment. Two separate sensing modalities are used in the form of smartphone and RFID to capture the patient’s body movements. The works also proposed a low latency IoT platform capable of establishing effective communication between the wearable devices and the data sink with very low latency to meet real-time requirements. The data sink is a centralized data storage and computational platform which gathers data from multiple patients resided in various facilities within elderly care environment. The work also proposed an AI-enabled bed-egress monitoring algorithms which computes variety of signal processing and statistical features and developed SVM [48,49] to classify movements, that is, off-bed, on-bed, and lying with high performance of above 90%. The IoT paradigm keeps end-to-end delay of 0.1 ms to send, process, classify the movement, and provide feedback. The proposed system has implications in reducing falls by monitoring the elderly movement and alerting the healthcare staff.

10.7 Summary

The healthcare sector is going through difficult times. The increase in the elderly population, rise in chronic diseases, increase in mental disorder and new diseases are affecting the quality of healthcare services throughout the world. The recent episode of COVID-19 outbreak has severely impacted the healthcare institutes and agencies worldwide, highlighting the inability to cope with similar threats in future with conventional techniques. In this time of need, the collapsing healthcare system can be supported with IoT and cloud services. While the work on developing healthcare solutions using IoT and cloud services is ongoing for years, yet the need for rapid prototyping and development is ever clearer with changing world perception of healthcare threats.

IoT offer means to effectively communicate the information from different sensory elements to IoT hub/control center where these can be used for monitoring, diagnosis, support, and intelligent decisioning. The data collected from patients, medical equipment, hospitals, ambulances, recovery centers, old-age houses, and nursing homes can help in formulating smart environments. These smart environments possess the capability to support in: patients’ monitoring, regular vitals check, appointment management, after care, elderly support, vulnerability analysis, disease diagnosis, and priority management. However, all these systems remain localized and isolated unless effective cloud-based solutions are introduced in IoT-enabled healthcare. The cloud services allow integration of these small isolated IoT solutions to form truly intelligent healthcare infrastructure. Integrated IoT-cloud healthcare solutions can analyze changes on larger scale and can foresee
epidemics, healthcare crisis, system limitations, and future needs in time, thus leaving healthcare system better equipped to deal with crisis. Joint IoT and cloud-based solutions can bring new era in healthcare, patients’ monitoring, post procedure observation, patients’ prioritization, diagnosis, support, vulnerability analysis, threat forecasting, and future needs.

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