IoT based Cloud based Rx Healthcare Expert System

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Abstract. Internet of Things (IoT) is changing the way many sectors operate and special attention is paid to promoting healthy living by employing IoT based techniques. This chapter discusses the use of automated embedded systems for constant monitoring of the patients health, dispensing medicinal dosage in a timely manner and other comprehensive function for the well-being of ill and healthy individuals. The wearable embedded devices can capture the patient's physiological signals including Body Temperature, Blood Pressure, Electrocardiogram (ECG), Oxygen Saturation (SpO2), Pulse Rate, Stress, Sweating and send them to the cloud server for processing. The medicine dispensing system can monitor the patient medicine details and timings, which are stored on the cloud server database. The real-time captured information can be processed and analyzed to check drug effectiveness and adverse effects on patients. Based on the analysis report, physicians can take decision to continue to use the same drug or change it. It can also help to reduce medication errors by the doctors, nurses and pharmacists as all the drugs will be identified and recorded by the medicine dispensing system as patient adhere any drug. The system can also improve the medication adherence and critical care based on the real-time medication and physiological signals notifications to the patients, doctors and family members. The IoT based system exhibits the ability to achieve objectives for continuous health monitoring, timely medication adherence, medication side effect monitoring, emergency health reporting, emergency case prediction and AI based early stage diagnosis and a reporting system for Physicians.

Keywords: IoT based Healthcare, Heath Bigdata, AI in Healthcare, Cloud Computing, Computer Aided Systems, Medicine, Medical Care.

1 Introduction

This chapter documents a wide range of proposed and on-market IoT Cloud-based Healthcare Systems. Additionally, the contribution is to propose a comprehensive IoT cloud based healthcare system that would integrate many of the ideas already existing in previous literature as well as propose the use of Neural Networks and deep learning in order to predict emergency cases before they occur, conduct early diagnosis, etc. In general, all technologically based systems aim at having a digital medical expert that will monitor patients constantly and monitor their health status as well as taking necessary actions including but not limited to calling emergency personnel in case of

emergency that occur or predicted to occur. A smart health monitoring, diagnosis, and medication system using IoT and cloud would alleviate the pressure on hospitals due to crowdedness in hospital care and would reduce the healthcare service delays. In addition, Smart health monitoring system either the proposed system in this chapter or those detailed from literature would help reduce medication errors by the doctors, nurses and pharmacists as all the drugs will be identified and recorded by the medicine dispensing system which is a vital component of a Smart health monitoring system. Before Smart health monitoring systems can be widely adopted for homecare, the systems must exhibit the ability for continuous health monitoring, timely medication adherence, medication side effect monitoring, emergency health reporting, emergency case prediction and AI based early stage diagnosis and a reporting system for Physicians. The comprehensive proposed system in this chapter would be considered the first closed loop IoT health care system that allows interaction from both the patient and doctor (two-way communication).

While all system highlighted in this chapter are a work in progress towards the use of information technology and technology in general for healthcare, the proposed comprehensive system that is proposed will prove to be unique in all aspects and would allow comprehensive theoretical and practical healthcare of individuals aging from 5 years up to those considered to be elderly. Even though the system can be used for ages less than 5 years old but in that case the system might need more features of parental consent, doctors consent, and other features to cover legal aspects associated with the use of technology to substitute partially or wholly for services usually offered by medical doctors and healthcare providers.

IoT Cloud based systems in general not just those dedicated to healthcare will have a huge impact on evolving many sectors to unprecedented levels. The Internet of Things (IoT) has gained its popularity in the global information industry and petroleum explorations industry. The IoT connects all things to an intelligent network for communicating through the devices that senses information according to agreed protocols and for exchanging information. IoT achieves is intelligent in locating, managing things, identifying, monitoring, and tracking. It is considered an expansion and extension of Internet-based network, which is the communication expansion from things or things and things and human and human to human. Many objects surrounding people is going to be connected into networks in one way or another in the IoT paradigm. Technologies such as sensor technology, radio frequency identification (RFID), and many other smart technologies will be embedded into a numerous application. The evolution of technology including storage, battery capacities, and computing power become are now at relatively low size and low cost. Hence, this helps developing small electronic devices with the capabilities like computing, identification, and communication which can be embedded in other systems, facilities, and devices. In this chapter, we discussed the available proposed systems as well as proposed system with a prototype concept of a complete medical system based on IoT. It consists several devices and layers that include; a portable wearable device with sensors, an automatic medicine dispenser with alarm, cloud-based Medical analysis system with accurate short-term and long-term reports for Doctors, and an interface for doctor, patient and devices interaction. In addition to life saving functions, such as automatic communication with emergency medical personnel in cases when readings indicate a

life-threatening situation (using deep learning algorithms that can accurately predict life-threatening symptoms before they actually occur). For example, reading from thousands of patients who suffered a stroke or heart-attack can be accumulated into a database and predict such incidents from reading patients vitals and predict them before they actually occur giving more time for medical personnel to arrive to the scene and thus giving more time to perform lifesaving procedures.

Background

The use of computers and computing to automate, ease and promote efficient healthcare services has been around since computers and computer programs came to existence. In a paper published in 1980 [1], the authors describe a clinical workstation that supplies patient's medical information with attending nurses. The system is able to collect, process and display the patient's information including identification, lab results and radiology results and current medications in addition to supplying the user with the available medical literature databases. In [2], the authors proposed a decision support system for telemedicine using mobile telecommunication platforms. The java-based systems allow practitioners to communicate via the system to consult on patient illnesses and reach to an accurate diagnosis. This would eventually lead to providing better medical care for patients in rural areas.

Current medical information systems are far more advanced, yet in 1980, it was state-of-the-art technology. The concept is utilizing computers in assisting medical personnel in taking vital medical decisions regarding different aspects in the treatment of patients. Even though a lot of research has been done throughout the years with this regard, yet we will mention only a select few in our literature review. In 1994 [3], the authors proposed a system based on machine learning to diagnose a particular medical syndrome called PVM (Prolaps-Mitral-Valve) syndrome. Their system was relatively successful back in that era.

The computing industry since its early beginnings and until today touched on all aspects of the medical field to include Medical Information Systems, Medicine Information Systems, Medical Education, Medical Simulations, etc. As an example, in 2004 [4], the authors proposed the creation of a master table for the checking indications and contraindications of medicine from a knowledge base linked with a thesaurus. This was the type of research done at the time though medicine databases have evolved to more technologically advanced levels nowadays. In [5], the authors proposed a decision support system for telemedicine using mobile telecommunication platforms. The java-based systems allows practitioners to communicate via the system to consult on patient illnesses and reach to an accurate diagnosis.

In [6], a study is conducted on certain strategies to reduce medicine preparation errors in neonatal care units. Medicine preparation errors can also possibly happen in a hospital setting. The study indicated that the use of hospital pharmacy services for the preparation of medicine reduces the rate of errors that occur in medicine preparation. In [7], a review paper is presented that discusses the medication errors that might occur including errors in medication administered, failing to adhere to dose time, complying with legal requirements for prescription writing, and various models to monitor

medication errors. In [8], the paper discusses the medicine preparation errors in neonatal care units in 10 Spanish neonatal units. The study concluded that calculation errors could be eliminated using protocols based on standard drug concentrations. Thus, the SMART Medication system is an integral part of our proposed comprehensive system because medication is as important as monitoring health condition if not more important especially for elderly patients.

In [9], the design of a terminal solution is proposed for integration of in-home health care devices and services towards IoT. The system includes an electronic medication dispenser, which allows electronic interaction with the doctor. However, smart IoT healthcare systems are now moving toward minimal interaction between in-home patients and medical physicians to minimize cost while still providing state-of-the-art quality medical service. Our proposed system provides the required functionalities efficiently, as will be shown in this chapter. In [10], yet another system is proposed to assist elderly patients in identifying their medication and dose using Near Field Communication (NFC) Technology. The information is displayed on the elderly patient's smartphone or television prior to medication intake. This system will ensure that elderly patients know what medication they are taking prior to consuming it. In [11], an intuitive IoT-based healthcare system is proposed for elderly patients, which seems to be a theoretical proposal of combining wearable devices, information systems and interactive interface.

Medicine has had its share of research to utilize the current technologies. In [12], the authors propose a cloud-based system utilizing mobile medical services of Traditional Chinese Medicine (TCM). They developed a medical information system that allows proper scheduling of TCM treatments for patients, verify patient's identity, and remind healthcare providers of the time when treatment should end. Their system also allows communication among healthcare providers within the hospital. In [13], an IoT cloud based wearable ECG monitoring system is proposed in which data collected is uploaded on the cloud and gives the functionality of properly displaying data as well. In [14], the authors propose the use of Inertial Measurement Units (IMU) sensors for IoT based wearable health monitoring systems. An algorithm is also proposed for such measuring units and the system was found to outperform other systems and does not bind the system to be in any particular position to the patient in order to obtain an accurate measurement. In [15], an IoT based health monitor is proposed for autistic patients in which brain signals are constantly measured and reported to the care-giver of the autistic patient. In [16], a smart IoT based system is proposed for Intensive care unit (ICU) monitoring. The IoT based system proved more efficient in monitoring patients during their stay in ICU unit. In [17], the authors proposed an IoT cloud based monitoring system for hospitalized patients. Another system named I-CARES is proposed for health diagnosis and medication through wearable IoT based devise equipped with algorithms to analyze data and assist doctors and physicians in decision making for early treatment of predicted diseases or sickness [18].

The analysis of medical data is an emerging field and in [19], the authors use data analysis to estimate the success rate of Vitro Fertilization (IVF) treatment utilizing a ranking algorithm in particular the RIMARC algorithm. The claim is that their proposed algorithm can be used to accurately estimate the success rate of the IVF treatment. In [20], the authors present a comprehensive review on the utilization of IoT in healthcare systems. Most interesting is the use of big data collected on the cloud for accurate raw

data to predict chronic disease in its early stages. In [21], the study presents the opportunities and challenges of health monitoring and management systems using the IoT sensing with cloud processing. The abundance of data measured and uploaded on the cloud makes for a very lucrative data mining and processing algorithms.

This type of research indicates that utilizing IoT cloud based environment is the right path that healthcare is moving towards and indicates that this field of research will evolve healthcare to the next level.

In [22], the authors propose an architecture for secure health application converging Big Data, IoT and the cloud. Based on Machine-to-Machine (M2M) communications, the authors propose a converged healthcare architecture designed on Exalead CloudView. In [23], a system is proposed in which patient's data is uploaded on the cloud from different hospitals. Patients own their data on the cloud and give access to only authorized persons to view their data. The system ensures complete privacy and security of the patient's health records. In [24], the authors presented a review paper of all existing systems and algorithms for data privacy and security of patient's data in IoT based cloud environment. The paper concluded that there is still more research to be done in order to ensure the data privacy and security on the cloud and that the existing systems and algorithms are not adequate to guarantee the security and privacy of data. In [25], another security model is proposed based on attribute-based encryption (ABE) and anonymous attribute based encryption (AABE). Their proposed model achieves compact security in the prime order groups and has many advantages over previous methods, though it has its own disadvantages as well. In [26], the paper reviews and discusses different security attacks towards health systems and proposes different solutions to bridge the security gap. They identified the security vulnerabilities in E-health information systems on the cloud and in IOT. In [27], the authors explore a solution to ensure the security of Electronic Health Records (EHRs) in the cloud environment during transmission of data to the cloud. In addition, they explore the use of biometric images that allow for unified patient identification across cloud-based EHRs and across medical institutions. In addition to security, one of the main challenges of IoT based health systems is the collection, processing and analysis of millions of measurements from wireless body area network (WBAN) sensors. In [28], a hybrid periodic-random massive access (HPRMA) scheme for wireless clinical networks is proposed employing ultra-narrow band (UNB). This scheme is able to dynamically adjust the resource allocation for co-existing periodic and random services, in addition, to aligning to requests of differentiated services. In [29], a healthcare smart gateway is proposed to prioritize personal health device (PHD) connections based on their state and requirements. The use of artificial intelligence in healthcare diagnosis is widely researched. In [30], the authors use artificial intelligence algorithms for the correct diagnosis of brain tumors. There a lot more example available in literature to show the proof of concept on the use of artificial intelligence in the medical field.

Proposed System

As can be seen in literature review, the concepts of automated healthcare is well documents and the aspiration of researchers and the industry is clear to produce systems that can automate healthcare and reduce cost for both patients and healthcare providers. In this section, we propose a comprehensive IoT Cloud based Healthcare system capable of monitoring, diagnosis, automatic medication dispensing, interaction between patients and system, interaction of system with doctors, and interaction of system with emergency personnel. As part of this comprehensive system, we propose the concept of using barcode based medicine identification so medicine dispensing system can automatically verify the drug for the patient. The complete system also is composed of a health monitor with attached sensors that take different measurements of vitals and other measurements from patients. All data including demographic information, medical history, family history, lab tests, measurements from devices such as temperature, blood pressure, etc. All this information will be uploaded to a cloud based health information system. The health information system is able to compile and view the data from all patients in order to build the smart AI system both using supervised and unsupervised learning. However, each patient data will be secure and only accessible by the patient or the authorized healthcare personnel. The system uses AI for learning from the available database that contains Big Data. The amount of information compiled from one patient alone is vast and includes the information mentioned previously in addition to MRI scans, Xrays, round the clock measurements from attached sensors. When this information is gathered from a large number of patients, it will definitely fall in the range of the so called Big Data. The AI system embedded within the system will be able to use this big data in order to make short-term or long term predictions and decisions. To better understand what is meant by short term and long-term in this system, we provide the following examples: Short-term analysis, when the reading of the patient's vitals are abnormally at dangerous levels, the system will make the decision to call for medical help by informing medical personnel and calling for an ambulance providing the exact GPS location. Long term analysis example, after the system has Big Data readings from hundreds, thousands or even millions of patients who suffered some serious health ailment such as a heart stroke. The system will be able to analyze the vitals with different time parameters such as several minutes, half an hour, and several hours before the stroke, and will be able to build a pattern based on AI machine learning to predict heart strokes before they actually happen. This will give enough time for emergency personnel to arrive at the patient's location and provide medical care to either prevent the heart stroke or be prepared to provide medical care to relieve the effects of the stroke and minimize the consequences. Other examples of long time prediction, would be for example predicting that a patient would suffer from high blood pressure or diabetes in the near future which would require medical intervention to prevent that from happening. The proposed system also provides a secure interface for Electronic Health Record (EHR) integration.

Even though this system is designed specifically for home use and with patients that require constant medical monitoring at home, the assumption is that patients will be at home all the time and the communication link between monitor and medicine dispenser is constant. However if the patient leaves home for a short period to visit a doctor, the

health monitor equipped with a memory to hold recent data recorded on the home system which will upload copy to the cloud until the patient returns home. The data will be automatically transferred to the medicine dispenser as soon as communication link is established again between patient and system. In addition, if an emergency occurs while the patient is still out, the wearable device will is equipped with internet data and will alert the patient and call for medical help providing GPS location. If Internet service is not available, redundancy is provided by allowing the wearable device to send an SMS message providing coordinates of the location.

Though the initial motivation for designing this system was to relieve constant care for the elderly by medical institutions due to cost and over-crowdedness, yet the final designed system is suitable for patients and healthy adults of all ages and can even be used for young patient as young as five years old. However, it can be used by even younger patients but an interface for parents needs to be developed and will be developed in future work. The interface would need to account for legal accountability as well. It is frequent nowadays in which people even in their twenties suffer a sudden stroke that could result in death, yet with this system, lives could be saved by communicating with medical personnel and getting immediate help for the person. Overall, the system would save lives and cost of health by:

1. Encouraging people to lead a healthy life style by giving immediate indications of health status.
2. Detecting health conditions in its early stages where the cost of medical intervention is much lower than late stages of any health condition.
3. By ensuring that people take their full dose of medicine, this will lead to keeping them healthy and reduce cost of healthcare.
4. Constant electronic medical supervision by medical doctors ensure so that end users stay healthy and reduce the possibility of deteriorating health resulting in costly hospitalization.

Overall as can be seen above, the ultimate goal is ensure a healthy population which ultimately means a cost benefit to the healthcare industry and national budgets.

Though the above prototype consists of all wired sensors, yet the system is able to integrate wireless sensors as well. The prototype also consists of the most up-to-date sensors which are light enough to allow portability yet too big to allow the design of a brace that consists of embedded sensors and invisible to the people who can see the system user. However, with the advancements in the sensor technology, it is assumed that such a system as proposed in this paper will contain some day only embedded sensors, wireless mini-sensors, or even Nano-sensors all sending measurements wirelessly to the wearable unit. When that day comes, the system will not cause any inconvenience to the patients as all embedded nanosensors will not be visible neither to the patient themselves nor to anyone who sees the system users. The intent of this chapter and prototype is proof of concept and the authors did not do an extensive search on mini or Nano-sensors available commercially nowadays, yet it is presumed that the technology in that field still stands for a lot of improvement. However, the authors acknowledge that the end product would need to integrate sensors and configuration

that is comfortable for the end user and allow privacy to the user by having concealed sensors.

The complete system would be a SMART system capable of making judgement and decision set around a certain number of rules and parameters within the medical field. For example, if the SMART dispenser dispenses a fever medicine according to a scheduled dose. This medicine is supposed to take effect within one to two hours from dose. However, if a measure after two hours still indicates a high temperature then based on the medical parameters and if medically permitted, the medicine system will dispense an out-of-schedule fever reducer and ensure that the patient takes another dose.

Big data and big data analysis is an established field now and widely used in many systems. The proposed system is proposed integrate Bigdata and big data analysis over the cloud. Big data is uploaded on the cloud, the cloud is then equipped with a novel Big Data Analysis algorithms that integrate Artificial Intelligence able to analyze the measurements, dosage, effects and side effects of medicine based on patient's short-term and long-term readings.

The cloud contains a dedicated electronic health record system embedded with smart big data analysis algorithms. These algorithms aggregate the data and produce reports for the doctor. The algorithms are also based on machine learning that will be able to segregate attributes of the human body measurements prior to emergency calls, attributes that indicate initial stages of chronic diseases, cancer, or any other health issues. The information is kept secure during transmission to the cloud healthcare system. It is also kept secure while on the cloud and during transmission to the doctor. The success of the prediction for a case depends upon the population size of the measurements and the availability of the assigned annotations to the past cases.

As a whole. The proposed comprehensive system is capable of providing continuous monitoring of a person's health status and ensures timely medicinal dosage scheduling based on real-time patient vitals measurements. Previous literature and their proposed methods to cater to healthcare issues have been analyzed to derive a comprehensive theoretical framework that addresses all shortcomings of systems proposed in previous literature. The system is equipped with the latest technologies including an AI system able to analyze short-term and long-term data to predict and provide early stage diagnostics in addition to diagnosis details to doctors with recommended medicine dosage, frequency and type.

Figure 1 indicated the process general process of the proposed system. From the time the patient start the use of the system, the medical information is sent to the cloud to create the patient record and data will then be populated from several different venues including the healthcare providers, the system with integrated sensors, the SMART medicine dispenser and any other location that contains medical health information on the patient. The AI integrated system starts the analysis of incoming reading for short term and long term predictions. If stable, the patients charts and reports are periodically sent to the doctor for follow-up and dosage changes if required. If emergency case, the system will call medical personnel to the address of the patient for early immediate intervention of the medical case or early intervention if the health condition is predicted to happen shortly.

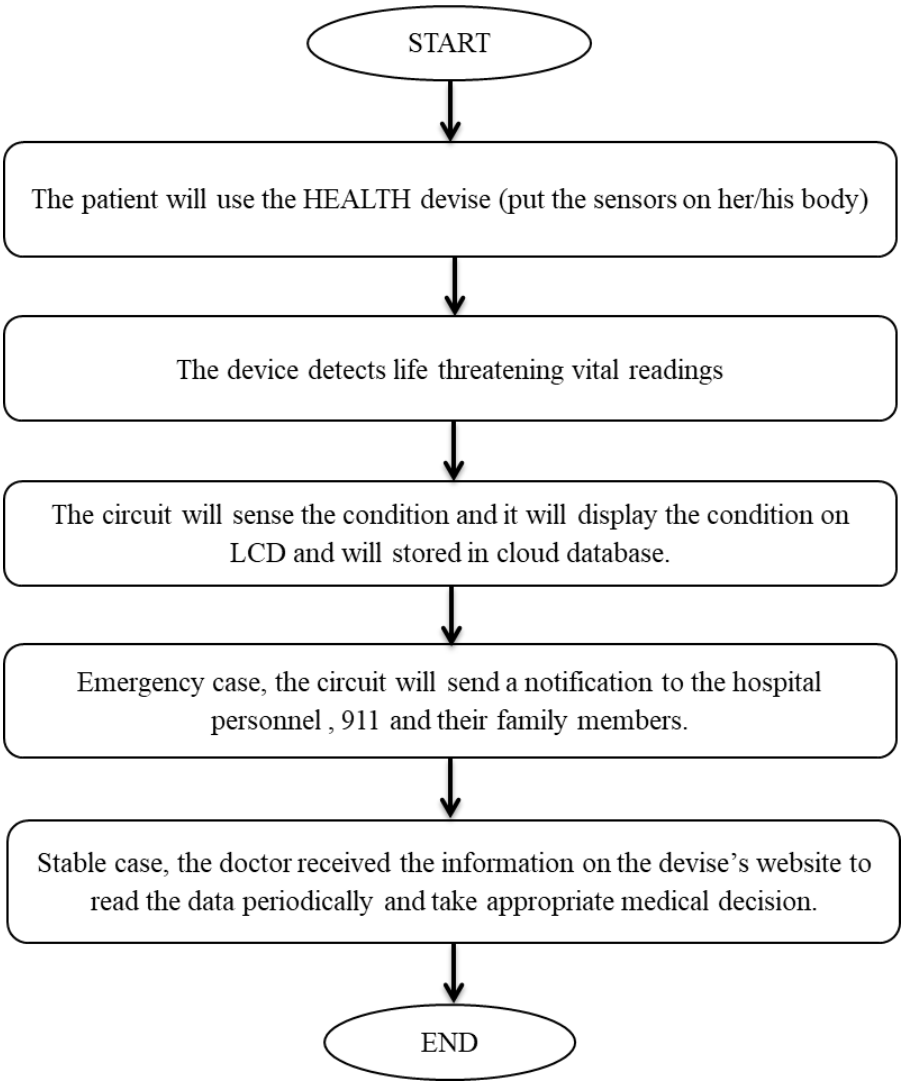

Figure 1: Process model of the proposed system

Figure 2 shows the interface of the proposed system with patient using current technology with the wearable sensors either wired or wireless. This picture is most likely to change in the near future with advance in technology to have nano-wireless sensors concealed and the patient doesn't necessary need to be home all the time to be connected to the complete system.

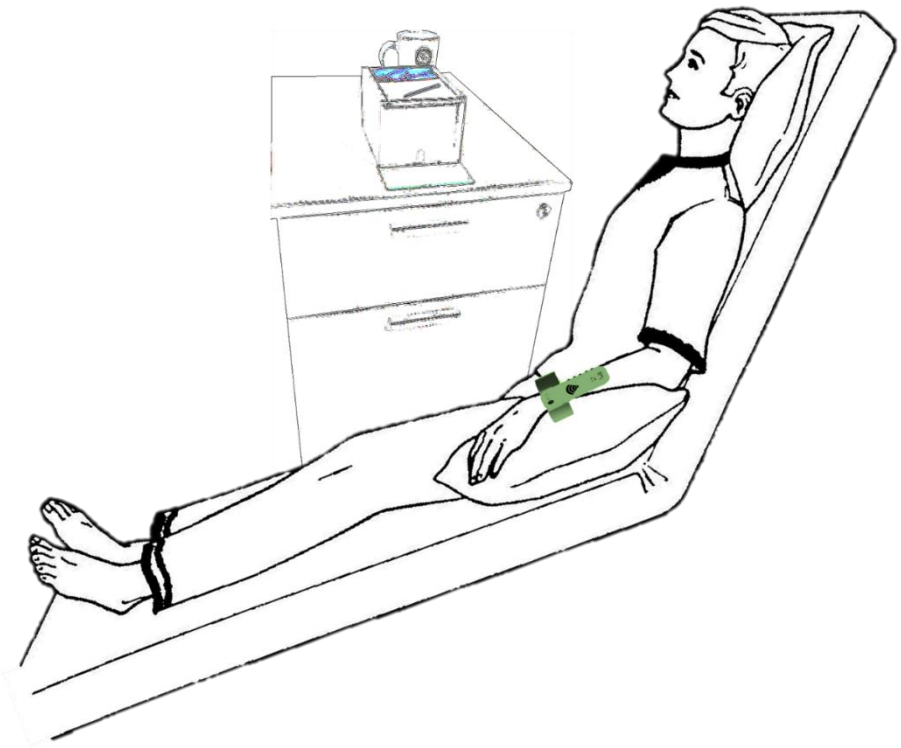

Figure 2: Overall view of the system use using current technology.

Challenges and Impact of IoT based Healthcare System

The proposed system once a reality and widely adopted will change lives and change the way hospitals and insurance companies operate. It will even have an impact on national budgets as well. However, there are certain challenges before we see such a system in mainstream use. The challenges listed below are some of the obstacles from the point of view of the authors, though we realize that the list might not be comprehensive and that other challenges exist that might not appear in the list. The list of challenges:

1. Development of sensors that may be embedded on wearable devices or embedded within chips that can even be inserted into patients bodies.
2. Medical data in medical health records are really Big. With thousands and possibly millions of patient records on the cloud, managing this amount of Big data will become a challenge and a possible expensive process.
3. Data security will always remain a challenge due to patient confidentiality laws.
4. Identifying symptoms for urgent medical problems such as predicting heart attacks, strokes, etc. has not be done yet and will be a challenge in order to train the Artificial Intelligence Algorithms running on the cloud.
5. Constant communication is a challenge especially in less developed countries.

6. User acceptance might be a challenge as patients would prefer to have constant hospital care with doctors and nurses (less trust in technology).
7. Keeping cost of such systems affordable to patients or covered by insurance companies.

However, with all these challenges and if these challenges are overcome, there is a huge positive impact if such a system as the one proposed in this chapter or even some the system detailed from literature review see their way to real life implementation and wide adoption. The impact as depicted by the authors include:

1. Constant 24-hour healthcare monitoring at portion of a cost of hospitalization and hospital care.
2. SMART devices such as smart pill dispensers to ensure timely medicinal dosages. Taking medicines properly ensure patients healthy life style.
3. Early prediction of chronic diseases or emergency case which can be a lifesaving function.
4. Already IoT technology includes smart pills (with IoT devices) that can be swallowed to monitor medication in body and take action and decision to warn patients in case of irregularities. Other include moodles for keeping a constant elevated mood for patients and other wearable IoT enabled devices. IoT is and will make on impact on the healthcare profession and industry.
5. Automatic diagnosis, which will relieve pressure on manual diagnosis done by doctors and would also relieve patients from human errors that sometimes occur when diagnosed by medical doctors.
6. COST- Reduce cost of healthcare for all stakeholders.

Conclusion

In this chapter, we have highlighted the most upto date IoT or Cloud Based SMART system proposed and covered in previous literature. We have also identified shortcoming of existing proposed systems in research which resulted in proposed a Comprehensive IoT and Cloud-Based Healthcare System (CHIPs) that is proven to cover all the shortcoming of existing systems or those listed in literature review. In addition, we presented the proof of concept based on an integrated prototype. Though we have no means for clinical testing of the proposed system, yet, in theory the system which uses technologies are existing thus the system should work the way it is proposed to. Obtaining measurements from wearable sensors, smart pill dispensers, interface, communication, data security, and other functions are already existing in scattered technologies and proven to work as specified. Even cloud based system and the cloud as such with big data is already in use whether in medical field or other fields. However, Cloud based management systems with big medical data and AI algorithms for short term and long term prediction which would have been a privilege to test clinically and using clinical data is not possible and not accessible to the authors. However, the

authors have developed Artificial Neural Network algorithms for diagnosis and early diagnosis of certain medical condition in their previous work.
In the near future, we will see either systems as proposed in this chapter or a more advanced version with advanced sensors, mini-medicinal dispensers, constant connection, secure connection, etc. in use and widespread adoption. These advanced versions, will be constant health monitors on the go, where patients and individual are not confined to home use only. The can have the system fully working while driving, riding the bus, walking, travelling and going on with their daily life while being constantly monitored.

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