Journal of Advanced Research in Technology and Management Sciences
Volume: 01 Issue: 03 ISSN: 2582-3078 November 2019
Available online at: http://www.jartms.org

Technologies of Internet of Things for Healthcare services

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***Abstract*—IoT has been shown as a big potential for qualifying and improving healthcare services; such as monitoring at anytime and anyplace. These services acquire various bio- signals using different sensors, including electroencephalogram (EEG), electrocardiogram (ECG), electrical signal of the heart, electromyogram (EMG), electrical signal of muscles, Respiratory Rate (RR), and body motion. The collected information from these sensors can be processed, stored, or broadcast to a remote device (e.g. Cloud server). This paper provides an overview of the main medical sensors in IoT and a review of the current state-of- the-art of IoT projects, and technologies required for healthcare services. The paper specifically, focuses on the using of IoT technologies in the healthcare area nowadays. A conclusion regarding the current stage of development and open issues are presented.**

Keywords—Internet of Things (IoT); Healthcare; Alzheimer diseases; Cloud Computing; M2M; Quality of Life (QoL); Embedded Systems; Sensors; RFID; NFC; Big data.

I. INTRODUCTION

Today, the use of technology to improve the quality of life is becoming a common attribute of modern society. When the technology is oriented to improve the Quality of Life (QoL), it is referred to the Internet of Things (IoT) [1]. IoT is a network of interconnected 'smart' devices, allowing collecting information and managing physical objects [1]. According to the Cisco research groups, the number of internet connected devices became larger than the number of the people on the Earth, as many suppose, is the actual changeover to the Internet-of-Things [2]. The much consumption of these devices and systems that connect to the IoT affect the business in several industries such as medicine and healthcare [3]. According to the World Health Organization (WHO) study, it is found that from 57 million global deaths, 63 % are dying of diseases such as; chronic diseases, pulmonary diseases, heart failure, cancer, Blood pressure, and Glucose. Obviously, traditional model of periodic care in the clinic and hospital- based settings is suboptimal for improving these disease outcomes [4]. Indeed, in daily life, the prevention and treatment of the vital diseases like chronic diseases, Alzheimer diseases, Blood pressure, and heart failure take place outside of traditional clinical settings. From this point, IoT provides several advantages to the medical area for example; intelligent IoT wearable devices, in combination with mobile medical applications that allow patients to capture their health data remotely as shown in Fig. 1. Further, IoT healthcare services are expected to increase the quality of life and decrease costs [23].

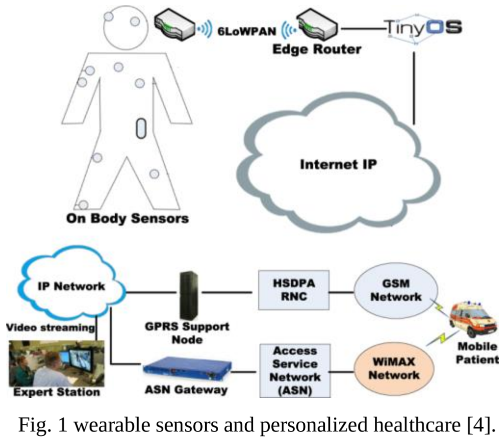

Fig. 1 wearable sensors and personalized healthcare [4].

Healthcare uses IoT for real-time tracking of patients and medical devices. Examples of IoT Healthcare use cases include the following; (1) Fall detection, which is considered a main public health concern. Over recent years, the number of companies that offer systems and services intended at detecting falls has increased radically. Fall detection systems, typically worn around the waist or neck; include intelligent accelerometers that differentiate normal activities from actual falls. These systems are already improving the quality of life of many disabled or elderly people living independently. (2) Tracking of medical devices, it is very essential for hospitals, especially in crowded emergency rooms with large medical staff. IoT solutions are being used to identify the exact location of such devices, identify last user.

The remainder of the paper is organized as follows. Section II shows a brief overview of the most important technologies related to IoT. Section III presents the latest IoT projects in the healthcare area. Section IV provides the IoT architecture for healthcare systems. In section V, a survey about the most important issues in IoT for healthcare. Finally, concluding remarks and future work are reported in section VI.

II. IOT TECHNOLOGIES FOR HEALTHCARE

IoT-based healthcare systems involve a number of technologies that allow IoT devices to obtain data from the physical world;

such as wireless medical sensors, Radio- Frequency Identification (RFID), Cloud Computing, Near- Field Communication (NFC), Big data, Integrated IPv6 core network, Wi-Fi, ZigBee, Bluetooth, two-dimensional code equipment, and so on [5]. This section will focus on several core technologies that have the potential revolution to IoT- based healthcare services.

A. Radio-Frequency Identification (RFID)

The mobile technology, RFID facilitates and assists in improving the applications of IoT healthcare. It reduces the caregiver's loads in home monitoring, and helps them to monitor the patients suffering from chronic diseases [18]. The RFID system in healthcare consists of two main components; radio signal transponder (tag) attached to an object (patient or medical devices) and the reader. The tag consists of two components: a chip to store the unique identity of the object and an antenna to allow the chip to communicate with the reader using the wireless medium. The reader generates a radio frequency field to identify objects through reflected radio waves of the tag. RFID works by sending the tag's number to the reader using radio waves as is shown in Fig. 5 [47]. Finally, the reader passes that number to a specific application called the Object-Naming Services (ONS). An ONS looks up the tag's details from a database such as when and where it was manufactured [47].between medical, physical objects and their digital representations, it cannot provide the condition information that healthcare applications require.

A sensor is a very broad term used to describe an object that can acquire data [51]. Sensor technologies are a big part of IoT in healthcare. It has attracted a relatively recent reputation due to their ability to gather contextual and medical data such as temperature, location, humidity, SpO2, ECG, EMG, and EEG and then transmitting the data to a gateway via a specific communication protocol such as Wi-Fi, Bluetooth, ZigBee or 6LoWPAN as shown in Fig. 6[50].

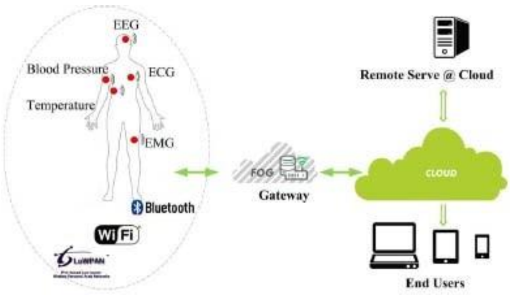

Fig. 6 IoT healthcare sensors [50].

In this regard, recent research efforts pursue the transmission of sensor data through radio links aiming to facilitate sensor deployment. There are several types of medical sensors as shown in Table 1 [50]. Both RFID and sensor technologies are key enablers of the IoT because they provide the means to identify objects and to obtain their condition.

TABLE I. TYPICAL WEARABLE AND MEDICAL SENSORS [48][51][52].

List of Medical Sensors and Their Usage	
Name of Sensor	***Uses***
Heart Rate	To detect the heart rate (and consequently heart rate variability).
ECG (Electrocardiography)	To measure the electrical activity of the heart, this conveys essential information about the status of heart and the function of its muscular contractions.
EMG (Electromyography)	To measure the electrical signal causes by muscular activity for gesture recognition, detection of neuromuscular diseases, etc..
EEG (Electroencephalography)	To capture the electrical voltages which represent the brain activity.
Blood Pressure (BP)	To measure systolic and diastolic pressure
Respiration Rate	To measure the rate of breathing.
SpO2	The arterial oxygen saturation or the amount of oxygen dissolved in blood.
Skin Conductivity	To measure the conductivity of the skin to detect psychological or physiological arousal or the moisture level of the skin.
GSR (Galvanic Skin Response)	Perspiration
Co_2 Gas	Measuring the carbon dioxide level from mixed gas.
Glucometer	Sensors record glucose levels continuously around the clock.
Motion sensors	To trace taking medicine, sleeping, or steps.
Stress sensor	Measuring the pressure changes of the underside of the foot.
Accelerometer	Measuring the human energy expenditure.

B. Medical Sensers

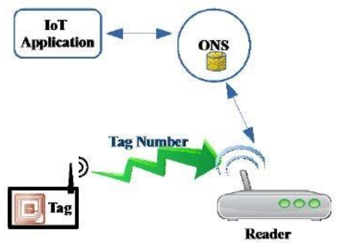

Fig. 5 RFID System [47].

Rapidly evolving new applications for healthcare field are based on knowing the conditions of objects (e.g., temperature, stress, strain, pressure, trace, shock). Even though RFID is an important technology in the recognition of a smooth link

C. Big data

Medical sensors collect huge amounts of essential health data. Big data provide tools for analyzing these data and increasing the efficiency of relevant health diagnosis and monitoring methods. A list of Big data tools which are used by famous companies is presented in Table I [19].

TABLE II. THE MOST USED BIG DATA TOOLS [19]

No.	List of Tools	
	Big data area	***Tools***
1	Data Cleaning	OpenRefine, DataCleaner
2	Data Analysis	Qubole, BigML, Statwing
3	Data Storage and Management	Hadoop, Cloudera, MongoDB
4	Data Integration	Blockspring, Pentaho
5	Data Mining	RapidMiner, Teradata, Kaggle
6	Data Visualization	Tableau, Silk, CartoDB, Chartio
7	Data Languages	R, Python, RegEx, XPath
8	Data Collection	Import.io

D. Cloud Computing

Cloud computing is the concept of internet based technology, which offers a variety of remote services over the internet such as infrastructure, data storage, software, and hardware. The combination of cloud computing into IoT- based healthcare technologies should provide facilities via access to shared resources, delivering services over the internet and allowing users to perform normal tasks as shown in Fig. 2 [6].

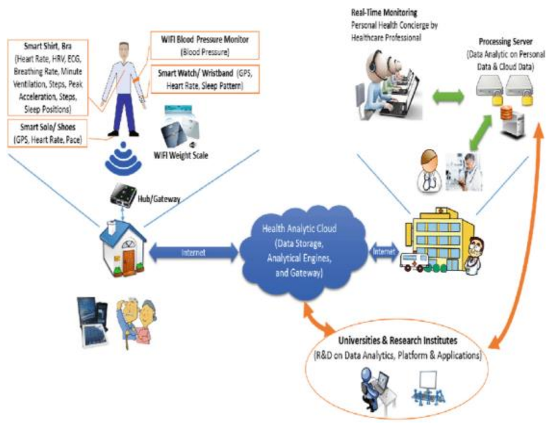

Fig. 2 IoT with Cloud Computing for healthcare services [15].

III. IOT PROJECTS FOR HEALTHCARE

The IoT offers a great market opportunity for equipment manufacturers, developers, and Internet service providers in several fields. By the end of 2020, the IoT smart things are expected to reach 212 billion entities deployed globally [47]. IoT projects and related IoT-based services on the topic of healthcare has been constantly increasing and represent the largest percentage as shown in Fig. 3 [47]. It aimed to deploy IoT in the healthcare area. This section will provide an overview of the latest IoT projects in healthcare.

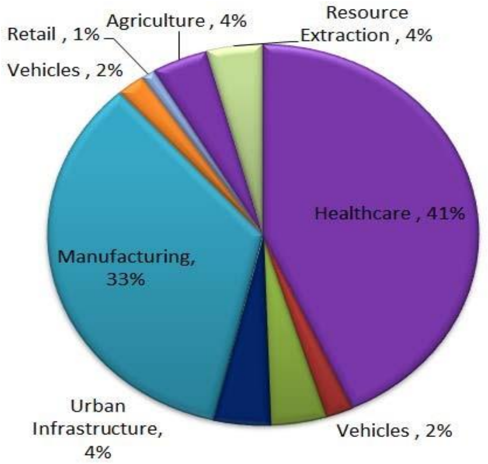

Fig. 3 Projected market share of dominant IoT applications by 2025 [47].

A. E-Care@Home

The purpose of the E-Care@Home project is to construct an infrastructure for IoT with the motivation to provide computerized information gathering and processing on top of which e-services for the citizenry in their homes. The E-Care@Home Project aims to provide an inclusive IoT-based healthcare system, including high-level analysis of data from various types of sensors, and state-of-the-art communication protocols [9].

B. The 'Smart Mirror'

The 'Smart Mirror' project introduces non-contact based technological innovations at the families where its exercise can be as global as 'looking at a mirror' while providing critical actionable insights thereby leading to improve care and results. The key objectives is to detect key physiological markers like Blood Pressure (BP), Heart Rate (HR), Inter-beat-interval (IBI) and Respiration Rate (RR), also drowsiness using the video input of the individual standing in front of the mirror and display the outcomes in real-time. A suitable level of accuracy has been achieved with respect to the sensor signal [10].

C. Technology-Enhanced Emergency Management (TEEM)

TEEM was designed for supporting data recording and transmission during patient transportation by ambulance. Paramedic personnel use TEEM to record the most significant patient data (which gathered via monitoring devices or directly measured), and to immediately send them to the health center, where the specialist physician can check the data themselves, thus having a more complete understanding of the patient' s situation during transportation [12] [13].

D. Embedded Sensor Systems for Health (ESS-H)

The telehealth market was valued at $2.2 billion in 2015 and is predicted to reach $6.5 billion by 2020, with an annual growth rate of 24.2% [35]. The home healthcare industry is also testing tele-homecare and tele-monitoring services that represent a valuable opportunity to balance quality of care with cost control. According to [36], more than 10,000

healthcare applications are available in the Apple/Google store. These statistics also reveal that approximately 85% of doctors use smartphones and medical applications, and 80% of them would like their patients to monitor their health status at home.

The Embedded Sensor Systems for Health (ESS-H) is an important system oriented project in the research area. It uses the needs of the caregivers and patients to identify their problems, and find the solutions while they are at their home. In addition, ESS-H includes five projects [14]:

- Biomedical Signal Processing
- Biomedical Sensor Systems
- Reliable Data communication
- Intelligent Decision Support.
- Software testing

E. Telemetry System for Diagnosis of Asthma and Chronical Obstructive Pulmonary Disease (COPD)

This system is designed for people who live in remote areas or rural, which unfortunately often results in death. Moreover, it increases awareness among people and reduce death rates. Telemetry system plays a very important role in the healthcare area. This system consists of Expert System and mobile application; which interacts with the patient through the user interface in five steps: (1) test is conducted, (2) measured parameters are stored in the mobile phone, (3) symptoms of disease for patients are indicated in mobile application, (4) measurement results and symptom indications are transferred to the server, (5) Input vector for Expert System is formed After that a classification is performed, and the test results are sent to user's mobile phone. The architecture of COPD system is presented in Fig. 3 [17].

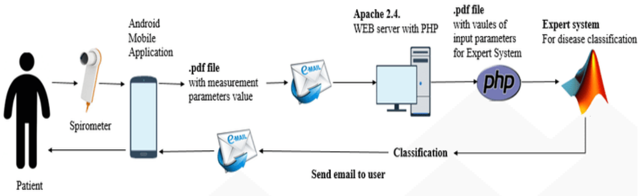

Fig. 3 The architecture of Telemetry System [17].

F. CAMI project

CAMI is a fully integrated solution for healthcare, which supports the major functionalities of IoT-based healthcare systems, like health-data monitoring, supervised physical exercising, fall detection, and smart home facilities. CAMI project includes partners from five countries; Poland, Sweden, Romania, Denmark, and Switzerland [20].

G. IoT- based myOSA system

Obstructive Sleep Apnea (OSA) is one such sleep disorder in which breathing is briefly and repeatedly interrupted during sleep. OSA occurs when the muscles in the back of the throat fail to keep the airway open, despite efforts to breathe. When this occurs, the patient may snore loudly or make choking noises as he/she tries to breathe. Subsequently, the brain and body become oxygen deprived and the patient may wake up. This may happen a few times a night, or in more severe cases, several hundred times a night. OSA can cause fragmented sleep and low blood oxygen levels [21]. For people with OSA, the combination of disturbed sleep and oxygen starvation may lead to chest pain, irregular heartbeats, hypertension, heart disease, stroke, diabetes, depression and mood and memory problems. Therefore, MyOSA is an IoT-based system that collects data of patients with OSA and sends it to the cloud to be analyzed for providing a suitable feedback to lung specialists (see Fig. 4) [22].

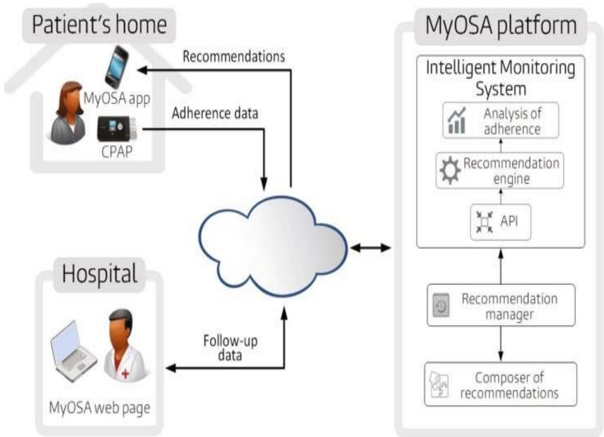

Fig. 4 The architecture of IoT-based myOSA System [22].

H. An Augmented Reality (AR) System

The low vision and blindness had arisen from a wide variety of disease conditions and anatomical anomalies that have been identified by the medical community [25]. One of these diseases is night-blindness, in which a person cannot see when light sources are little, but can see with large amounts of light. The AR system presents an IoT technological device that improves reading capabilities for people with low vision or night-blind [26] [27].

I. UpTech Project

Alzheimer Disease (AD) can be considered a slowly progressive brain disease that, begins before clinical symptoms emerge

[28]. The early symptoms of AD are; difficulty in remembering recent conversations, names or events, apathy and depression. Later symptoms include impaired communication, disorientation, confusion, poor judgment, behavior changes and, ultimately, difficulty speaking, swallowing and walking [29].

According to the World Alzheimer report 2015, it is estimated that over 46 million people live with dementia worldwide, and this number is predicted to increase up to 131.5 million by 2050 [30]. The impact of AD disease on the capability of making everyday life activities is well known, and it has been demonstrated that AD may strongly affect not only the life of the affected person, but also the surrounding relatives [31]. In fact, in the majority of the cases, the caregiver of a person with AD is a family member, who usually loses the possibility to run a normal life, because of the burden of assistance.

As a consequence, a number of research projects has been carried out such as; UpTech [32]. UpTech was oriented to the family caregivers, who are often subjected much stress due to the effort and the worry about the patients' safety. The main project objectives were to reduce the burden of the assistance for the caregivers, maintain AD patients at their homes, and improve the quality of life of all the users [33]. A group of nurses and social health operators performed periodical visits to the patients' houses to provide assistance. In addition, a technological kit was supplied and installed in the homes of a group of participants, with the aim to continuously monitor the safety of the patients [34].

J. Run-Time Assurance (RTA) in the E-care@home system

Making IoT networks more dependable is a critical element in healthcare applications [4]. One way towards achieving this goal is to increase the visibility into the operation of the network to system operators, researchers, and developers [41]. Run-time assurance project offers a service in the E-care@home system. This service continuously tries to discover and report performance problems and system errors. In addition, the core functionality of the RTA project can be summarized as follows: (1) monitor a variety of internal and external operating conditions periodically, (2) analyze the collected data to find current performance degradations, or changes in the environment that might affect future performance, and (3) report important information to a system operator [42].

The challenges of building an infrastructure for RTA are:
(1) identifying which protocols and parameters must be monitored, with low overlapping of data that describe the same condition, (2) the monitoring must be conducted with low overhead and with minimum interruption of regular Ecare@home application-layer data packets, (3) the RTA must comprise parallel monitoring efforts on the server-side.

The infrastructure of the RTA system consists of four different components that address these challenges: (a) RTA for sensor platforms, (b) database storage of RTA information, (c) RTA at the server-side, and (d) a graphical user interface for RTA. These components provide a service for all parts of an e-health system, including static sensor nodes for environmental monitoring, mobile sensor nodes for health parameter monitoring, and the data collection server for the aforementioned sensor nodes [43].

IV. THE ARCHITECTURE OF IOT FOR HEALTHCARE

IoT connect billions or trillions of heterogeneous devices through the Internet, so that there is a critical need for a secured and flexible architecture. In IoT healthcare services, the architecture is one of the most vital elements. It helps to access the backbone, and receipt the medical data by using several applications [23]. It consists of five layers as shown in Fig. 5 [22].

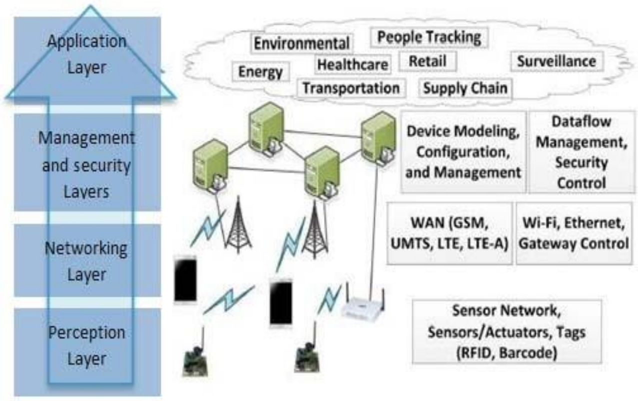

Fig. 5 The Architecture of Internet of Things for Healthcare [22].

A. Perception Layer

In this layer, devices and medical sensors are connected together for patients. It is responsible for converting patient's data into signals that can be transmitted in networks and read by medical applications. This layer needs Standardized plug- and-play mechanisms to configure heterogeneous devices. Moreover, it needs secure channels to digitize and transfer data between other layers.

B. Networking Layer

This layer is responsible for transferring the gathered patient's data from medical sensors and devices to the cloud or any data processing system through various technologies such as RFID, LTE, LTE-A, GSM, UMTS, WiFi, Bluetooth, infrared, ZigBee, etc.

C. Management layer

This layer enables the IoT healthcare applications to work with heterogeneous devices without consideration to a specific hardware platform. In addition, this layer processes the data which received from the Application layer, manages the overall IoT healthcare system, makes decisions, and delivers the required services over the network wire protocols[45].

D. Security Layer

There are vast amounts of sensitive patient's data crossing the IoT healthcare network every minute. Monitoring and controlling these data and the underlying layers is achieved at this layer of IoT network. This layer is extremely important for IoT, it responsible for data handling, data administration, service subscriptions, data transfer, data access control, and identity protection. It also compares the output of each layer with the expected output to enhance services and maintain users' privacy [46]. Moreover, this layer should achieve the IoT high-level security requirements which are: (1) Data Confidentiality: It ensures that the exchanged messages can be understood only by the intended entities. (2) Data Integrity: It ensures that the exchanged messages were not altered/tampered with by a third party. (3) Authentication: It ensures that the entities involved in any operation are who they claim to be. A masquerade attack or an impersonation attack usually targets this requirement where an entity claims to be another entity. (4)

Availability: It ensures that the service is not interrupted. Denial-of-service attacks target this requirement as they cause service disruption. (5) Authorization: It ensures that entities have the required control permissions to perform the operation they request to perform. (6) Freshness: It ensures that the data is fresh. Replay attacks target this requirement where an old message is replayed in order to return an entity into an old state. (7) Non-Repudiation: It ensures that an entity can't deny an action that it has performed. (8) Forward and Backward Secrecy: Forward secrecy ensures that when an entity leaves the network, it will not understand the communications that are exchanged after its departure. Backward secrecy ensures that any new entity that joins the network will not be able to understand the communications that were exchanged prior to joining the network [6] [45].

E. Application Layer

Healthcare providers and patients can interact with devices and query for interesting data and different services via this layer by using healthcare application. It also provides an interface to the management Layer where high-level analysis and reports can be produced. This layer performs complex and enormous computational needs so it is hosted on powerful devices [45]. In other words, this layer provides a common set of services that enables a healthcare application to interface with potentially any device without understanding a priori the specifics and internals of that device.

V. THE CURRENT TRENDS IN IOT FOR HEALTHCARE

Numerous services for healthcare can be implemented by using various IoT standards and protocols. Each service provides a set of healthcare solutions. In spite of these services' advantages, there are some challenges for IoT systems in the healthcare area. One of the main challenges is the cost of deployment due to the expensive process when building physical environment with different sensors and devices [37].

Moreover, patients' data must be secured during transferring, accessing, and storing as shown in Fig. 6[4]. On the other hand, privacy and security issues are the main obstacle in the way of the IoT development. Therefore, security at all levels of IoT architecture is considered an important issue to the functioning of IoT based healthcare systems. Numerous research accomplishments in the IT security concerns implemented in the IoT based healthcare systems [38].

Employing Cloud Computing for the IoT in healthcare is not an easy task due to the following challenges [47] [52]:

- ***Standardization***; Standardizing the Cloud Computing presents a significant challenge for IoT cloud-based healthcare services due having to interoperate with the various vendors.
- ***Synchronization***; Synchronization between different cloud vendors presents a challenge to provide real-time healthcare services since services are built on top of various cloud platforms.
- ***Management***; Managing Cloud Computing and IoT healthcare systems is also a challenging issue due to the fact that both have different resources and components.
- ***Balancing***; Making a balance between general cloud service environments and IoT requirements for healthcare presents another challenge because of the differences in infrastructure.

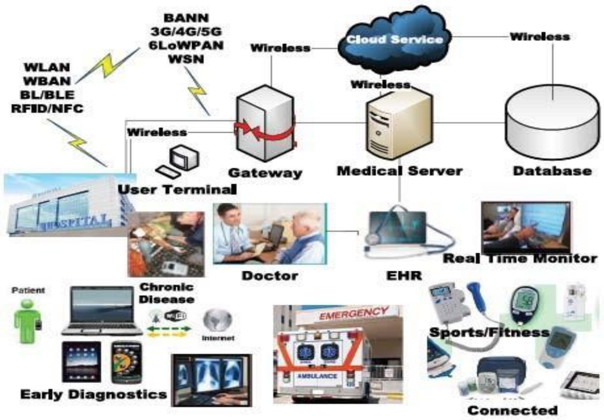

Fig. 6 The security trends of Internet of Things for Healthcare [4].

In addition, the Quality of Service (QoS) guarantees are required for healthcare services in terms of significant parameters such as availability, reliability, maintainability, and the service level [39]. Healthcare system availability and robustness are central to offering QoS guarantees because any type of system disaster can put lives in danger in medical situations [52].

The IoT will connect several sensors to provide healthcare services. Each sensor needs to have a unique identity over the internet. Thus, an efficient naming and identity management system is required that can dynamically assign and manage unique identity for such a large number of sensors. Moreover, the standardization of IoT healthcare is very important to provide better interoperability for all sensors [50].

VI. CONCLUSION AND FUTURE WORK

Due to the rapid advances in technology and industrial infrastructure, IoT is expected to be widely applied to the industries. IoT integrates various devices equipped with sensing, identification, processing, communication, and networking capabilities. Industries have a strong interest in deploying IoT devices in the healthcare area to develop healthcare applications and services such as automated monitoring. The main contribution of this review paper is to investigate how IoT could be useful and contribute to improve the quality of life. It focuses on the latest IoT technologies for healthcare such as; Big data, Cloud Computing, RFID, WSN, Bluetooth, Wi-Fi, and the important medical sensors. Moreover, the latest projects in the healthcare area are discussed. Finally, it highlights the important challenges in IoT-based systems for healthcare. The performance of the exiting IoT healthcare systems need to be improved by introducing enhancement techniques and methodologies. These will be considered as a future work.

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