A Survey on IoT-Based Healthcare System: Potential Applications, Issues, and Challenges

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Abstract Advances in information and communication technologies have led to the emergence of the Internet of Things (IoT). In the modern healthcare environment, the usage of IoT technologies brings the convenience of physicians and patients, since they are applied to various medical areas (such as real-time monitoring, patient information management, and healthcare management). In the incoming world of the Internet of Things (IoT) for healthcare, diverse, and distributed devices will collect, examine, and transfer real-time medical statistics to open, private or hybrid clouds, making it possible to accumulate, pile, and analyze significant data streams in several new procedures, and activate context-dependent alarms. The current development of the traditional medical model toward the involved medicine can be improved by the Internet of Things (IoT) paradigm involving sensors (environmental, wearable, and implanted) spread inside local environments with the objective to monitor the user's health and initiate remote support. This state-of-the-art data gathering paradigm allows uninterrupted and pervasive medical data access from any connected device over the Internet and a novel health application ecosystem emerges. This paper represents a systematic survey of IoT-enabled healthcare system, their potential applications, issues, and challenges.

Keywords Internet-of-Things (IoT) · Health monitoring · Sensing network

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1 Introduction

Internet of Things (IoT) is the fundamental innovation to shape smart cities as they encourage daily items or individuals to deliver services and information to different users by cooperating and communicating with each other. The Internet of Things can be advantageous for medicinal services applications. Different kinds of sensors are used in IoT-based healthcare system to measure and monitor several well-being parameters in the human body. These devices can focus on observing a patients' well being when they are far away from everyone else or when the medicinal facility is out-of-reach. In this manner, they can offer a real-time response to the physician, relatives, or the patient. As many wireless sensing devices flood in the market bear medical sensor. These sensor helps to examine health parameter like heart rate, blood pressure, body temperature, respiration rate, pulse, and blood glucose levels. Medicinal services applications make free-living conceivable and more comfortable for the elderly and patients with severe medical conditions. Currently, IoT sensors are being utilized to consistently record and observe the well-being conditions and transmit alert in case any strange signs are found. If there should be an occurrence of a minor issue, the IoT application likewise has a facility to recommend a remedy to the patients.

Due to the proliferation of diseases, there remains a significant challenge before healthcare services to eradicate. The patients can avail reliable, effective, and smart healthcare support for chronic illness by combining IoT with available medical resources. Various advancements have been made in healthcare monitoring (Alemdar and Ersoy 2010). These accomplishments have exhibited the viability and likely eventual outcome of IoT in healthcare frameworks. In spite of the existent achievement, there is uncertainty, and the technical issues still exist about the inquiry of how to quickly and deliberately set up insightful IoT-based healthcare system (Yuehong et al. 2016). Targeting at exploiting the capabilities of IoT in healthcare systems, an ever-increasing number of researchers furthermore, associations have been committed to the improvement of IoT-based innovation (Sundmaeker et al. 2010; Bui and Zorzi 2011). Also, The IoT has given an opportunity to develop a smart house, hospitals, and many healthcare systems. The technology is still in its infancy where there exists a lot of challenge to obtain safe and secure useful healthcare applications as self-learning and self-improvement, standardization, privacy, and security. It is indeed a critical issue for the integration of IOT with the existing promising technology, services, and communication. The overall architecture and view of IoT-Cloud-based healthcare system are depicted in Fig. 1.

The functional component of the system is given below:

(1) *Sensing Network*: The sensing network creates the backbone for IOT framework. Gathering of information related to patient's health and distributing it using the wireless channel to IoT is the sole responsibility of IoT framework. For implementing this IOT uses specific protocols like WiFi, Bluetooth, ZigBee, etc.

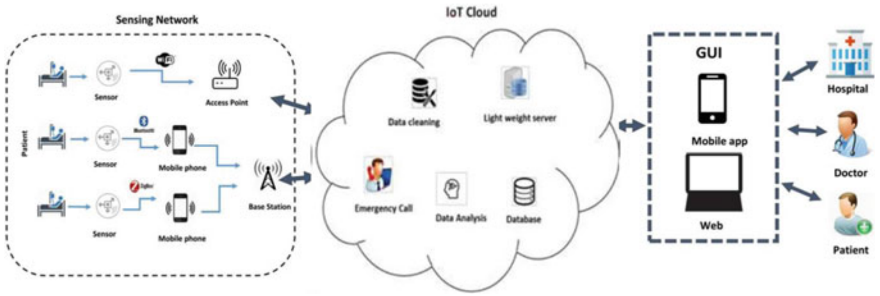

Fig. 1 Architecture of IoT healthcare system (Jaiswal et al. 2018)

(2) *IoT-Cloud*: Due to advancement in storage technology, the information collected through the IOT technique is stored, analyzed, and processed proficiently. It also proved the benefit of data evolution and analysis task using the influential server. The primary responsibility of this server is as follows:

- Data cleaning: The sensing data collected for diagnosis is profoundly affected by noise during the process of communication. The raw with noise may influence the diagnosis process. The cleaning process removes the noise from the data.
- Data storage: Patient's health information is stored in the database for analysis to find out the recovery process.
- Data analysis: Using machine learning or data mining methods the servers provide a platform for data analysis.
- Emergency warning: The edge server also has a provision to recognize the real-time health condition. Based on the results of data analysis the local caretaker receives warning message for providing first aid to the patient.

(3) *GUI*: Data visualization and management are done through the Graphical User Interface (GUI), which offers simple access to the information in the IoT-Cloud. Users can log in the IoT-Cloud and obtain patient's health-related information by just visiting the website or through mobile apps.

The existing literature for the application of IoT in healthcare system has been provided in Table 1. This paper examines the trends in IoT-based healthcare research and uncovers various issues that must be addressed to transform healthcare technologies through IoT innovation.

In this regard, the contribution of this paper is as follows:

- Classification of different IoT technologies available for the healthcare system.
- Bringing out related works in healthcare system using IOT technology.
- Providing open challenges for research work resource management.
- To facilitate novice researchers to work on the research problems.

The rest of the paper is organized as follows: Sect. 2 outlines the issues and challenges associated with IoT-based healthcare system, while Sect. 3 describes the applications of IoT Healthcare. Finally, Sect. 4 provides the conclusion.

Table 1 Overview of existing literature on IoT-based healthcare systems

Authors	Descriptions	Problem addressed	Devices and parameters
Yang et al. (2016)	The author proposes a novel method for ECG monitoring based on Internet of Things (IoT) techniques	Design and implement a wearable ECG monitoring system	ECG Sensor power voltage, ECG sensor output voltage, RR interval, PR interval, QT interval, QRS duration
Gope et al. (2016)	The author proposes a secure IoT-based healthcare system using Body sensor network	Data privacy, anonymity, data integrity, authentication	Body sensor, CPU cycle, execution time
Chatterjee et al. (2017)	The author focused on the aspects of IoT and decision support systems to proffer preventive and intelligent healthcare	Lowered cost of high quality healthcare, Best use of resources	Age, gender, systolic and diastolic blood pressure, g habits, Framingham score, risk score
Hossain et al. (2016)	The author presents a health IoT-enabled monitoring framework, where ECG and other healthcare data are collected by mobile devices and sensors and securely sent to the cloud for seamless access by healthcare professionals	Solution for IoT healthcare system	SNR PSNR, CPU memory and bandwidth utilization
Aminian et al. (2013)	This paper presents a monitoring system that has the capability to monitor physiological parameters from multiple patient bodies	Reduce the energy consumption to prolong the network lifetime, speed up, and extend the communication coverage to increase the freedom for enhance patient quality of life	Body sensor, BP level, end-to-end delay, coverage range, energy consumption

(continued)

Table 1 (continued)

Authors	Descriptions	Problem addressed	Devices and parameters
Yang et al. (2014)	The author presents an IoT-based intelligent home-centric healthcare platform (iHome system), which seamlessly connects smart sensors attached to human body for physiological monitoring and intelligent pharmaceutical packaging (iMedPack) for daily medication management	The proposed system takes the advantages of System onCchip (SoC) technology, material technology, and advanced printing technology, to build a patient-centric, self-assisted, fully automatic intelligent in-home healthcare solution	RFID tags, ECG sensor, controlled delamination materials (CDM) current

2 Issues and Challenges

With the exponential growth in IoT, the health sector is going to adopt it through the IoT application and devices. These applications and equipment might handle individual's private health information. The same can be accessed globally by the use of Internet resources. In particular, the security and privacy issues must be taken into considerations. This may include security requirements, threat models, vulnerabilities, etc. The following are a few challenges and issues need to be addressed concerning IoT-Cloud-based healthcare system:

- *Confidentiality*: It hides the patients' health record and medical information from unapproved users and eavesdroppers.
- *Integrity*: It helps in retaining the patients' health information unaltered while moving in an IoT-Cloud-based network. It never compromises the information with the eavesdroppers.
- *Authentication*: It helps in keeping the information secret by allowing only the authorized users to access the information.
- *Availability*: It allows the availability of patients' health information as and when the users require it. It is going to face a challenge of denial of service attack. This challenge is to be faced in IoT-Cloud-based healthcare systems.
- *Data freshness*: Data freshness mainly infers that individual data set is new and ensures that an adversary does not replay old messages. Since IoT provides estimates which is time varying in nature, so it is imperative to maintain freshness of a message.
- *Non-repudiation*: Non-repudiation ensures that the original sender of the message can't deny the message sent by it.

- *Authorization*: It ensures only the authorized person will access the services a resources provided by IoT-Cloud-based healthcare systems.
- *Security*: We need to deploy standard encryption and decryption method to provide security to the data and transaction takes place in IoT-Cloud-based healthcare system. This is the challenge to the research community to develop an efficient key management protocol. Mišic (2008), proposed an energy-efficient elliptic curve cryptography system. Another problem is to obtain authorization while the patient is in ICU or in an unconscious state, In this case, biometric may be used as a method to get authorization (Zhang et al. 2009). Bao et al. (2005) contributed to this challenge by developing a physiological signal-based authentication scheme. The technique captures ECG measures Photoplethysmogram (PPG).
- *Privacy*: Privacy of patient's health record should not eavesdrop. Ikonen et al. (2008) has proposed autonomy and control over the patient's health record. Besides image processing which is popularly adopted, other techniques should also be developed for the comfort of the patient's privacy. The encrypted image can be sent over the network to keep the privacy of information. Srinivasan et al. (2008) proposed Fingerprint and Timing-based Snooping (FATS) in WSN.
- *Resiliency*: It helps in protecting the patient's information even though the devices and interconnection have been compromised from any further attack.
- *Fault tolerance*: There should be some technology to be developed so that the system retains its functionality even in case of failure.
- *Robustness*: It ensures that when there is network failure or devices run out of energy. The network should have some technology to maintain the security level.
- *Computational limitations*: The IoT-Cloud healthcare uses lightweight protocols and devices which have limited power and computational speed. To run the security algorithm may require high power device which becomes a challenging task for the researchers for maximizing system performance with limited resource.
- *Memory limitations*: The IoT-Cloud-based devices have low memory. Their memory should be sufficient to run a security algorithm, or we should design such a lightweight security protocol to match the memory requirement of the available IoT-Cloud device.
- *Energy limitation*: The low-power devices save power by switching off the devices when not in use. The other way they conserve energy is by lowering the processing of CPU. It throws the challenge to the IoT-Cloud research community to develop energy efficient devices and protocols. The battery has limited power people may go for rechargeable batteries for the purpose, but this may be tiresome for elderly people. Battery rechargeable techniques should also be taken into consideration. This becomes another challenge for the researchers. Several works proposed an idea of using low-power sensing devices, still we need energy scavenging technique. The solar power can be thought as the alternative, but it is also tiresome because it always needs sunlight and cannot be implanted into the human body. So there is also a challenge for the researcher to develop a battery charger that takes the input from human motion, body heat, and other sources (Renaud et al. 2008).

- *Unobtrusiveness*: It is a challenge for the research community that while developing wearable sensors they need to maintain unobtrusiveness. According to Baker et al. (2007) when a patient carries sensors on their body then unobtrusiveness is a significant challenge. This is a hard task to put together different sensors into one platform vizLiveNet and PATHS. These body-worn sensor devices are substantial and highly obtrusive devices whereas ECG and watch-shaped activity recorder are much more comfortable to bear devices (Barth et al. 2009).
- *Sensitivity and calibration*: The sensitivity of the sensors devices is essential in a situation like fire situation or exercising. The sweat coming out of the body may affect negatively to the recalibration of the sensors. Puustjärvi and Puustjärvi (2011) proposed an algorithm for recalibration or self-calibration for the triaxial accelerometer. Still, improved techniques and algorithm should also be introduced for the pervasive healthcare system. Researchers should focus on low maintenance and highly sensitive devices.
- *Mobility*: In general, we deal with mobile devices in IoT-Cloud-based healthcare system. Through Wifi and Internet sensors devices can be connected. As an example, we can attach any wearable sensor and access the detail through the Internet. Body temperature, BP sensors, and so forth can be linked to the Internet to send the sensors readings to concern caregivers. These sensor devices are connected to the home network and these home networks further connected to the caregiver's network to provide service to the patient. The systems are heterogeneous concerning hardware, software, different configurations, and settings. Therefore a platform-independent device is a challenge for the researchers. The primary objective of IoT-Cloud-based healthcare system to people should have an independent life with high-quality healthcare services. The evolution of sensors and sensor-based network enabled the development of the application that ensures and encourages mobility of users. This way the WSN enabled the ubiquity of IoT-Cloud-based healthcare systems.
- *Ease of deployment and scalability*: The researchers always face a challenge to develop user-friendly IoT-Cloud-based healthcare system. With the increase in patient and caregivers in society, the existing system should support scalability and user-friendly application. Sensors, communication devices, and software should be used in parallel in the IoT-cloud-based healthcare system. With the heterogeneity in the component, the deployment of these devices becomes a challenge. We can use Software as a Service (SaaS) for the case of service and scalability with small, configurable sensor devices. The system should also support scalability in runtime to adapt to the ongoing technology. Atallah et al. (2008), Gao et al. (2005) proposed that the system software and distributed system can support the integration of the hardware and application level and interoperability among this different component. The sensor devices are increasing enormously resulting in the increase in devices in a global network. To develop such a scalable security scheme is a challenge for the researcher and academia.
- *User-friendliness*: Casas et al. (2008) propose a model to develop a natural system that provides the interface between IoT-Cloud-based healthcare system and diverse group of people. Jasemian (2008) proposed a survey which is conducted to

check the user-friendliness among a middle-aged group and conducted that they should revisit their work. They also found out that the different age groups should be differentiated clearly, which is a difficult task to be done. When we consider the interface between heterogeneous disease people like cognitive disability has different interaction characteristics than patient with high blood pressure. They must have gesture, visual animation, and voice interface for handicapped and the elderly avoid any particular kind of skills. In IoT-Cloud-based healthcare system should have the user-friendly and natural interface between healthcare professionals and caregivers.

- *Data acquisition efficiency*: This is a challenge for the research community to develop an efficient data processing technique as the rate of collection of data in IoT-Cloud-based healthcare system is increasing enormously. Sometimes the data collected from a few devices like ECG or 3-axis accelerometer may not be sufficient to debit all activities of the patient. This may be overcome by deploying more sensors to collect data. This, in turn, increases the data size. It is essential to implement some techniques to analyze and acquisition of data in realtime. Stankovic et al. (2005) proposed an open research challenge, viz, synchronization of different sensors, time stamping, and ordering of events. The research community should take care of designing a modular architecture which should support multisensory integration like wireless sensors, RFID tags, and printable body sensors.
- *Error resilience and reliability*: Low transmission power and small antenna sizes of wireless sensor devices cause reduced Signal-to-Noise Ratios (SNR) thus causing higher bit error rates and reducing the reliable coverage area. However, the reliable transfer of data in medical monitoring systems is vital. Therefore, error-resilient network coding schemes for medical data transmission should be developed for increasing network reliability. Marinkovic and Popovici (2009) propose a network coding technique for a TDMA-based protocol. It lets every sensor to transfer data through two relays and the relay nodes XOR the packets before sending. Although they have shown the improvements in the packet loss rate through simulations, the real deployments for measuring physiological signals, such as ECG and EEG and improving the proposed system accordingly are left as future works. The reliable data transmission should be studied thoroughly for low-power body area sensor networks.
- *Communications media*: There is a wireless device available such as ZigBee, Zwave, Bluetooth, Bluetooth low energy, WiFi, GSM, WiMax, and 3G/4G to connect health devices to a global network. Due to the evolution of these wireless devices, it becomes in appropriate to the use of wired security scheme to the IoT-Cloud-based healthcare system. It is the challenge before the academia and researchers that can treat wired and wireless channel characteristic equally.
- *The multiplicity of devices*: The devices used in IoT-Cloud-based healthcare network are diverse, this may include PC to low-end RFID Tags. The diversity in embedded software, memory, power, and computation among devices throws a challenge to the researcher to develop a security scheme which accommodates even the simplest devices.

- *A Dynamic network topology*: The IoT-Cloud-based Healthcare device may be combined together to form a network for accessing anywhere and anytime. At the same time, the network connection may exit abruptly or normally. The dynamic network topology is observed in healthcare devices with temporal and spatial admission characteristics. To develop a security model for this kind of environment is a challenge for the researcher and academia.
- *A Multiprotocol network*: The protocols used in healthcare devices are a proprietary in nature. The IoT devices use IP network to communicate with each other. It is a challenge for the research community to devise such a security solution for multiprotocol communication.
- *Dynamic security updates*: It is highly essential for the users to keep update security protocols to overcome the vulnerabilities. Therefore the security patches are required to update always. There is always a challenge to the research community to design dynamic installation of security patches.
- *Tamper-resistant packages*: Physical security is also a part of IoT-Cloud-based healthcare systems. Outsiders may tamper the devices to modify the software, program, extract cryptographic, security, and replace with malicious node. Tamper resistant is defended for this kind of attack which is a challenging task to implement in the real-time scenario.

3 IoT Healthcare Applications

In addition to IoT services, IoT applications are also getting tremendous attention. To develop applications services are used, whereas users and patients directly use applications. Consequently, services are developer-centric, while applications are user-centric. These days in addition to applications, there are many wearable sensing devices available in the market that can be viewed as IoT modernization to prompt different healthcare solutions and are discussed in this section.

- *Glucose level sensing*

Glucose level sensing is a way of testing the concentration of glucose in the blood. Particularly important in diabetes management, diabetes is one of the metabolic diseases. It is caused by the high percentage of sugar in the blood over a long period. Blood glucose monitoring aids in the planning of meals, activities to be carried out, and medication times and also give away patterns of blood glucose changes. For non-invasive glucose sensing an IoT healthcare configuration method is proposed in Istepanian et al. (2011) on a real-time basis. In this technique, sensors at patients' side associated with compatible healthcare providers via IPv6 Connectivity. The utility model proposed in Istepanian et al. (2011) based on IoT networks makes transmission device to broadcast the sensed data on blood glucose. This method includes a mobile phone, computer, processor, and a blood glucose collector. A related novelty is initiated in Wei et al. (2012). Also, a comprehensive IoT-Cloud-based medical acquisition detector is proposed in Lijun (2013) for monitoring the glucose level.

- *Electrocardiogram monitoring*

The electrical activity of heart is recorded by the electrocardiogram. The ECG data includes simple heart rate and determines the diagnosis of multifaceted arrhythmias, prolonged QT intervals, the basic rhythm of the heart, and myocardial ischemia (Drew and Funk 2006). The ECG data recording can be used to the fullest extent in IoT-Cloud-based healthcare system to record patients' data. There is numerous literature available which discuss the application of ECG monitoring for reading patients' heart status (Yang et al. 2014; Agu et al. 2013). Liu et al. (2012) proposed a model where they introduce ECG monitoring to patients' health monitoring that consists of a portable wireless receiving processor and wireless acquisition transmitter. They included alarm-based technique when there are abnormalities in patients' heart data it gives a warning on the real-time basis. In the application layer of the IoT network there exists an exclusive algorithm of ECG for data monitoring.

- *Blood pressure monitoring*

To read the data from the sensors Dohr et al. (2010) has proposed KIT, which is the combination of Blood Pressure (BP) meter and Near-Field Communication (NFC). And to remotely control the blood pressure of the patient an inspiring scheme is given in Puustjärvi and Puustjärvi (2011) by exhibiting the communications structure between a patients' hub and the medical service provider. Tarouco et al. (2012) addresses how the connection to a mobile computing device is operated within the blood pressure device. A mechanism is proposed in Guan (2013) to collect BP values and send it over IoT-Cloud-based healthcare network. This device consists of a BP machinery body with a communication module. Also based on IoT-Cloud a location intelligent end for blood pressure monitoring is proposed in Xin et al. (2013).

- *Body temperature monitoring*

In the healthcare system, body temperature plays a vital role as it is the sign of homeostasis maintains (Ruiz et al.2009). In Baker et al. (2007) IoT-Cloud-based healthcare scenario is verified using the TeloSB mote embedded with body temperature, and also it presented sample obtained from body temperature variations showing the successful operation of the developed IoT-based healthcare system. In Jian et al. (1028) a system for measuring the temperature is proposed based on a home gateway over the IoT. This home gateway with the help of infrared detection transmits the sensed body temperature to the concerned users.

- *Oxygen saturation monitoring*

For oxygen saturation monitoring, pulse oximetry instrument is used which continuously monitor the blood oxygen saturation in a human body without inserting the device into the patient's body, i.e., it noninvasively measures the oxygen saturation. The integration of the pulse oximetry with IoT technologies is profitable for medical healthcare application and services. In Khattak et al. (2014), the potential of IoT-Cloud drove pulse oximetry for CoAP-based healthcare services is reviewed. However, Jara et al. (2013) depicts the functionality of the wearable pulse oximeter wrist OX2. This device comes with Bluetooth connectivity to connect it directly to the money platform based on medical device profile. Furthermore in Larson et al. (2012) for monitoring the patients' health remotely an IoT-Cloud-based optimized low cost and a low-power pulse oximeter is suggested, which is used for constant monitoring of patients' health over an IoT-Cloud-based healthcare system. For telemedicine applications, an integrated pulse oximeter system is described in Larson et al. (2013), whereas in Larson et al. (2011) a wearable pulse oximeter is adopted in IoT-Cloud-based healthcare system for monitoring patients' health using WSN.

4 Conclusion

The healthcare industry is primarily moving toward inexpensive, accessible, and an excellent healthcare. IoT and adopt IoT-cloud driven systems and processes have the potential to mode this kind of healthcare, which heavily relies on patient participation. The survey presented here provides diverse aspects of IoT-based healthcare technologies and reviews on IoT-cloud usage in healthcare that provides access to the IoT backbone and enables medical data transmission and reception. Considerable R&D efforts have been made in IoT-driven healthcare services and applications. The recent technology for investigating, collecting, and switching data in IoT-cloud continues to smart, and in the future, the systems will move to improved IoT-cloud-driven healthcare applications.

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