Review Paper

# Challenges and opportunities in IoT healthcare systems: a systematic review

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Received: 1 November 2019 / Accepted: 11 December 2019 / Published online: 30 December 2019


**Abstract**
In this study, the latest research articles which are involved in the Internet of Things (IoT) based healthcare system are analyzed as the IoT is growing enormously in the healthcare systems such as health monitoring, fitness programs, etc. Numerous research has been carried out in the IoT based healthcare system to improve monitoring efficiency. The architecture used in the IoT especially the cloud integrated systems are investigated in this work. The factors such as accuracy and power consumption are the important concern in the IoT, hence the research works which are involved in improving the performance of the IoT based healthcare systems are discussed. Data management methods in the IoT based healthcare system with cloud facilities are also systematically analyzed in this study. The performance of the IoT based healthcare system along with its advantages and limitations are reviewed. Most research works are efficient in detecting several symptoms and can accurately predict the diseases. The IoT based healthcare system designed especially for elders is an efficient solution in monitoring their healthcare issues. Major limitations in the existing systems are high power consumption, availability of fewer resources and security issues due to the utilization of many devices.

**Keywords** Cloud · Healthcare · Internet of Things · Security and power consumption

## 1 Introduction

Nowadays Internet of Things (IoT) is widely adopted in many applications that its importance is extending in our daily life. The IoT technology is also developing in the healthcare monitoring system for providing effective emergency services to patients [1]. It is also being used as E-health application on different aspects such as early detection of medical issues, emergency notification and computer-assisted rehabilitation. The Smartphones has become the indispensable part of the people's daily life and these are connected with the sensor to monitor the health of the subject [2]. This sensing based surveillance system acquires various data from the wards and diagnostic equipment, and mines these data for efficient and automatically control of healthcare [3]. The IoT healthcare system provides an efficient monitoring and tracking that helps to improve the resource management of people [4]. Cloud computing is used to handle the healthcare data and provides resource sharing facilities like, flexibility, data service integration with scalable data storage, parallel processing and security problems early [5].

The wearable or sensor implanted in the patients in the IoT based healthcare system has very limited battery supply. The frequent charging of these devices and mobile devices may fatigue the patients and require engagement of the nurse, which affects the user experience [6]. The energy consumption of the cloud data center is also very large and thus increases the cost of cloud computing. But actually, a health monitoring system requires cloud services with low latency and energy consumption [7]. Another issue in healthcare monitoring is the security that

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SN Applied Sciences (2020) 2:139 | https://doi.org/10.1007/s42452-019-1925-y

the data can be easily corrupted by the attacker or hackers. Hence, it is necessary to develop a privacy-preserving IoT based healthcare system and has to be integrated with patients for efficient data transfer [8]. Few pieces of research were involved in improving the security of data transmission in the IoT system [9, 10]. In this context, studies related to the IoT based healthcare systems are investigated in terms of accuracy, computational time and current difficulties in the development. One of the considerable and important research is to monitor the heart patients, which is achieved by using the sensor devices. ECG data are used to monitor the patients and the data has been directed to the professionals for analyzing the signal.

The remaining portion of the paper is organized as follows, IoT based healthcare architecture with its applications is presented in Sect. 2, the IoT system integrated with Cloud is given in Sect. 3. Security analysis of IoT is given in Sect. 4, Sect. 5 contains Quantitative comparative analysis and challenges in healthcare is discussed in Sect. 6. The conclusion of this paper is presented in Sect. 7.

## 2 IoT healthcare architecture and applications

IoT is the growing technology in the internet environment in conjunction with realtime connected objects. It is popular in many different industries because of convergence from the simple object into a smart object. This has a long term impact on the health monitoring, administration and clinical service to patient's physiological information. Patients are connected with sensors and the data has been associated with control devices, then it forwards to the health-monitoring unit. Sometimes data are stored in the cloud, which helps to manage the number of data with security. An important area in the IoT is security because when dealing with data transmission from the sensor to cloud center it is a possible loss of integrity and confidentiality and also it is complex to encrypt the data received from low resource devices. Cloud is a distributed environment so that it is the best option to store the medical data which more flexible for remotely caring patients accessed by doctors and Vice Versa. The IoT and cloud start handshake for realtime processing which turns to give complexity in architecture to sending and receiving data. To reduces the complexity in IoT and cloud a novel framework is proposed to manage the IoT realtime data and scientific-based unrelated IoT data then tested the cloud environment provides Software as a Service (SaaS) in the hybrid cloud environment [11]. This research proposed a Service Management Framework for IoT devices in Cloud (SMFIC) that contains three types of layers and five important components such as consumer layer which is used to collect data from smart home, patient, social network and smart healthcare service, next type is service provider layer which provides the sharing of physical resources, service management, virtualization and security and privacy, the final layer is middle layer it is managing the services between provider and consumer based on available resources.

Kumar and Gandhi [12] proposed an IoT architecture with a machine learning algorithm for early detection of heart diseases. It involves three-tier architecture for collecting sensor data from wearable devices, storing the data into the cloud and regression-based prediction model for heart diseases. This proposed framework is implemented by using Apache HBase and Apache Mahout for cloud storage and data prediction analytics. The outcome of this research completely a patient can find early detection of heart diseases.

Parthsarathy and Vivekandan [13] designed for monitoring a patient who affected by arthritis and diagnosis at the early stage. The proposed designed framework comprises three levels, the first level collecting the data from sensors. Second level stores the data in the cloud. The third level is used for optimizing the collected information, which contains swelling and uric acid (UA). Implementation of this proposed model by using Apache red-shift and Openstack.

Kim and Chung [14] developed and plotted the sensor devices in the normal household in the living room and other rooms where chronic disease patients lead daily lives as the context. The real-time data is not processed in this experiment and this method involves the high cost. The architecture of the method can be considered and the sensor can be used instead of a camera to reduce the expense of the overall process. The overview of the IoT architecture is shown in Fig. 1 [14].

Temporal Fuzzy Ant Miner Tree (TFAMT) classifier is developed in [15], which is the combination of the Ant Colony Optimization (ACO), decision tree and fuzzy rules and this are applied to classify the medical records. This study is used to help the aged people with the incidence of age-related illnesses and medication needs. The IoT involves collecting real-time data from the advanced sensors and the health problems are detected by analyzing physical and behavioral trends in homes.

Few existing research is involved in helping the elderly people using the IoT devices and that helps in monitoring the people [16–18]. The elderly monitor services are a module of the socializing platform and it can be effectively monitored by using IoT devices. The falls are a major problem to elder peoples, which present in long-duration time may lead to death. To avoid this circumstance of uncertainty, a fall detection algorithm was proposed to detect the people who fall on the specified area. The specified area contains RFID information and location identification

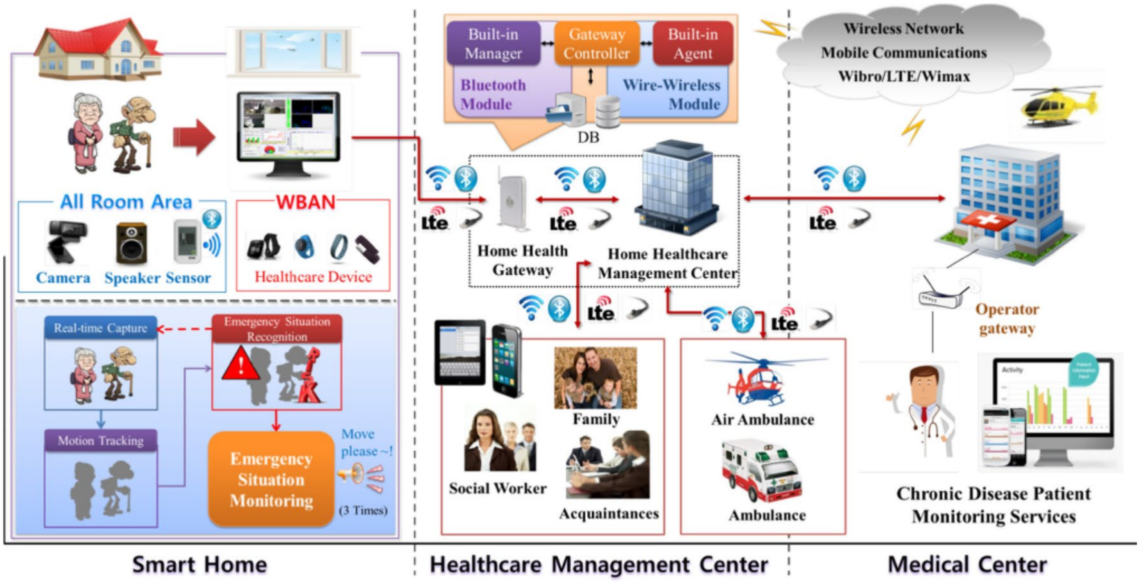


**Fig. 1** IoT healthcare architecture (*Source*: [14], p. 5)

data. Based on that information detect the elders where they fall in the specified area. These researches help the elders to live in their homes where they can feel safe and comfortable and effectively monitoring them for health care and provide the alert to the hospitals and the family members if the device found any urgent situation [18].

## 3 Cloud integration

The mobile application based remote health monitoring IoT data are stored in the cloud platform and cloud computing offers flexibility, scalability and more resources to process the data. Since the IoT data are obtained from a different sensor, it is effectively stored at the cloud side server called a cloud storage repository. By using cloud technology few researcher's medical processes are integrated into the cloud and enhance healthcare. The physiologically based attributes of students are measured and this is stored in the cloud storage in a different type of format. Once the user subsystem has completed the data collection from IoT medical devices that are sent to the cloud subsystem for diagnosis. Based on the emergency alert message sent to the doctor, hospital, and caretakers. This process as shown in Fig. 2 [19]. The research [20] developed the hierarchical computing architecture (HiCH)

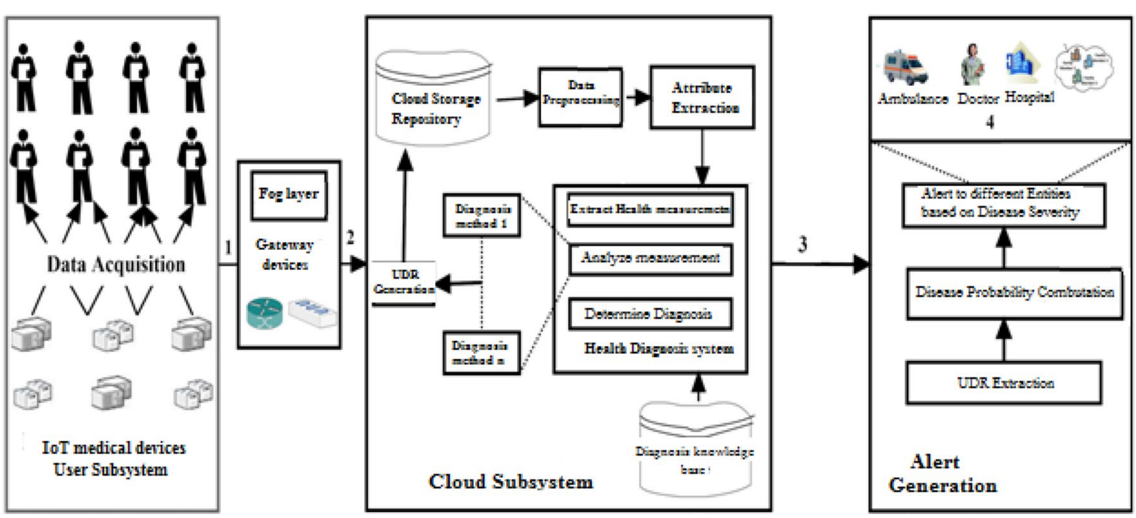


**Fig. 2** Cloud integration with Healthcare IoT system (*Source*: [19], p. 29)

for a patient monitoring system that involves autonomous data management and processing at the edge of the layer.

The network delay is a major problem in remote health care monitoring system and to provide a solution for the network delay in healthcare processing by remotely a framework is proposed known as UbeHealth to analyze challenges in network delay and QoS (Quality of Service) parameters such that it provides performance enhancement in healthcare at smart cities [21]. The fuzzy rule-based neural classifier has been proposed for diagnosing the disease and reducing the seriousness of the health disease. This method analyzes the data processing from the cloud by a secured storage mechanism, which comprises different phases such as data retrieval, data aggregation, data partition and data merging [22].

### 3.1 Big data in IoT healthcare

In recent years, Big data storage technology is essential to store huge volumes of clinical data. The cloud storage becomes huge its manage by the technology called Big data. The recent studies say the combination of Big data and cloud influencing remote healthcare. Amazon Elastic MapReduce (EMR) provides a different method to handle the big data and get onto the cluster. The Amazon EMR has a different function to load the data into Hbase cluster. Loading the sensor data from Amazon S3 to Hbase by using the tool as an Apace pig. Apace pig is used for analyzing the data in the distributed database hence healthcare application can dramatically extend the scalable feature [23]. A lightweight model is developed for semantic annotation of the Big data in the IoT heterogeneous data [24]. The novel method is proposed for predicting the air quality in urban areas and to provide a more healthy life at the urban resident. The proposed UHBigDataSys is implemented using Spring Framework and analyzed the Air Quality Indicators (AQIs) parameters for Urban Healthcare [25].

## 4 Security in IoT

Security has been the major concern in the IoT because the hackers or the attacker can easily access the sensor data, so it is important to analyze the recent security methods in IoT. The IoT-oriented data placement method with privacy preservation named IDP is developed in [26]. In this proposed method main aim is to optimize the data access time, increase resource utilization and reduce energy consumption by satisfying the constraints of data privacy. The privacy-preserving and energy saving is achieved using the algorithm called Non-dominated Sorting Genetic Algorithm II (NSGA-II). The trusted computation is processed locally over the real health data on the user's health profile and the recommendation process has been carried out at the cloud healthcare recommender service [27]. Radio-frequency identification encryption technique is used in [28] provides security to the medical data in IoT. Network environment data flow is critical for health information. This research goal to develop a framework for data privacy based on a biometric-based security system with a resource-constrained wearable health monitoring system [29]. Internet of Medical Things (IoMTs) information is analyzed for optimizing security in medical applications.

The Cloud Service Provider (CSP) consists of three servers, namely: the Authentication Server (AS), the Key Generation Center (KGC), and the Database Server (DS). In smart healthcare, to secure the data, Lattice-based Secure Cryptosystem is used. This consists of four phases, setup phase, key generation phase, data encryption phase, and data decryption phase. The three phases, the lattice polynomial vectors are used as input in the first phase and the KGC is generated i.e., the private and public key, in the second phase and shared with the Database Server (DS). In the last phase, the message is used as an input parameter and combines it with the random polynomial. If any user sent a request to access the medical data, the KGC transfers the secret key pair to the DS using a secure channel. The DS process the plaintext message using the input parameters and the secret key pair. The architecture of the LSCSH is shown in Fig. 3., which also consist of the key exchange process [30]. This proposed method has been compared with existing reasonable schemes attributes like communication and computation cost.

## 5 Quantitative comparative analysis

IoT can be applied to the healthcare system and this has the ability to continuously monitor the patient condition. The wearable IoT devices play a huge role in monitoring the patient's condition. IoT in healthcare is developing and recent research involved in health monitoring using IoT are analyzed in the Table 1.

IoT based healthcare system is much helpful in monitoring the heart disease of patients and its efficiency can be increased for medical emergency alert by using machine learning. Most of the studies have higher efficiency, but the power consumption is needed to be reduced.

## 6 Challenges in healthcare IoT

IoT has been adopted in the different types of applications and provide different support for the healthcare system such as patient monitoring, a smart home system for the

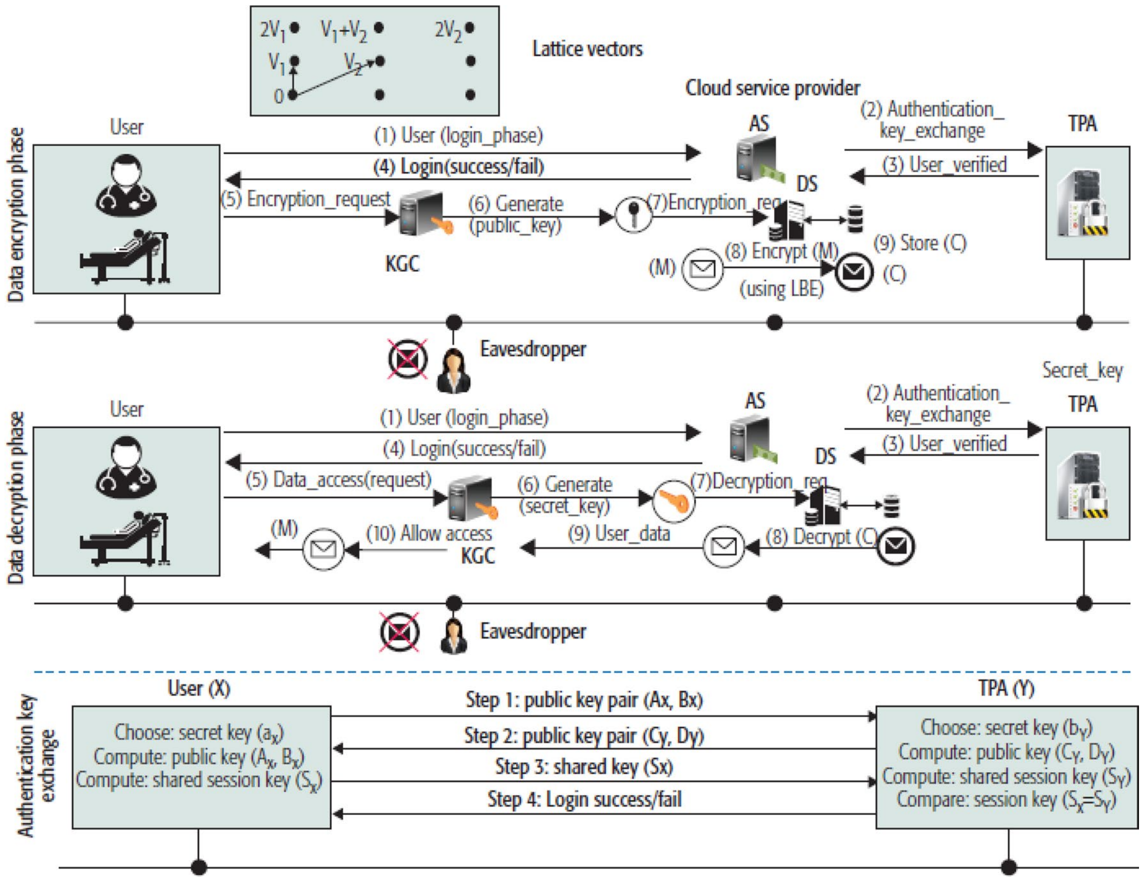


**Fig. 3** LSCSH architecture in healthcare IoT (*Source*: [30], p. 27)

diabetic patient. Major problems occur in the healthcare system are listed as follows.

- IoT paves the way for high flexibility, i.e., the patient requires constant care and he/she can live in the home instead of the hospital and be monitored regularly using IoT technology. Some wearable devices like sensors make uncomfortable for the patient's body.
- The data transmitted from the sensor to the control device and further transmitted to the monitoring center, which will affect the quality of the data due to noise. Better architecture helps to transmit the data without affecting its nature. Noise removal technique can also help to enhance the data signal.
- Most of the existing method in ECG monitoring involves analyzing the signal in a supervised manner. This increases the cost and it may produce the error in detection. Machine learning can be applied in analyzing the signal, which helps to improve efficiency and reduce expenses.
- An increasing number of sensors and the devices require higher energy to process, and it increases the power leakage and energy consumption. An optimization algorithm can be used to reduce the usage of energy.
- Monitoring many numbers of users in the IoT requires more storage and mainframe, which can be overcome by storing the data in the Cloud. However, the IoT integrated with the cloud increases the complexity.
- Another important problem in the IoT is privacy as the devices are more vulnerable to the attack. These devices are low resource constraints and are difficult to apply encryption techniques on them.

## 7 Conclusion

IoT can efficiently monitor the patients from the remote area and provide emergency services especially for heart patients. The major objective of this review work is to analyze the various research activities involved in the IoT based healthcare system. Most existing researches are efficient in monitoring the patient and provide the data to the monitoring center. The research involves the ECG monitoring system that can use the machine learning method to easily predict the symptoms of diseases. Some researches

**Table 1** Quantitative comparative analysis of various methods

| Methods | Limitation | Performance analysis |
|---|---|---|
| This study proposes a pervasive patient health monitoring (PPHM) system infrastructure. This involves in monitoring the patient health from remote area [31]<br>PPHM integrates the IoT with cloud and stores the patient's ECG data in the cloud. The data are clustered and sequential minimal optimization is applied | Machine learning can be used to analysis the ECG data instead of manual monitoring. This helps to unsupervised the process and also involves in reducing the cost.<br>Security has to be improved and IoT is very vulnerable to the attacks | Average response time of 50 request is 45 ms<br>F-measure is approximately 98 when the number of clusters is 2 |
| This research involves in the detection of voice pathology through IoT. The voice signal is represented using the local binary pattern (LBP) on a Mel-spectrum representation of the voice signal [32] | Scalability can be further increased by using the smart devices, and microphone<br>This method doesn't involve in handling large amount of data | Accuracy LBP + ELM = 98.1% and LBP + GMM = 95.7% |
| This research involves in Health IoT-based monitoring framework<br>The framework transfers ECG and other data related to the healthcare professionals. Monitoring is based on the mobile devices and sensors [33] | Machine learning can be applied to monitor the signal and involves in reducing errors and increases the accuracy<br>Extracting more features from the data involves in increasing the execution time | PSNR: existing = 58.38 and proposed = 64.35<br>Classification accuracy: While extracting 37 features = 91.1%<br>Execution time: while using three instance server = 3.3 ms |
| This is a privacy preserving framework based on the IoT healthcare data. IoT messages are encrypted using the IoT group key and shared to the patient [34] | Flexibility and scalability are need to be increased | When number of attributes is 60, Encryption cost = 0.025 s and access policy update query cost = 0.0011 s |
| This research involves in solving the complexity and heterogeneity of data in IoT by tracing the data back to the router using Petri Nets [35] | This method needs to develop an unsupervised model to process in the real-time system effectively | Accuracy = 96%, sensitivity = 95%, and precision = 97% |
| ECG data are monitored for the patient with Cardiovascular diseases. Although the relationship between the both is very high [36]. To overcome this issue, the proposed method monitors the ECG, glucose and body temperature along with fall detection | Regular battery replacement is required for the wearable devices<br>Size of data has to be reduced | Latency of the smart gateway = 43<br>Power consumption with AES-256 = 717.82 mW |

minimize the power consumption by using optimization algorithm and it is necessary to design a system which consumes low power to achieve considerable efficiency. Privacy is the major concern in the IoT due to its less storage space to process some encryption methods. Cloud storage helps in handling large data from the system and the complexity is increased when integrated with the IoT. The existing IoT system provides effective monitoring of the patients in terms of scalability and reliability. This technology helps in monitoring the elder patients by using a camera, speaker and sensors. IoT can be further improved by increasing security, flexibility and power consumption.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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