

# A Review on IoT-Based Healthcare Monitoring Systems for Patient in Remote Environments

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## Abstract

*The Internet of Things (IoT) is a powerful technology that can enable users' smart devices and sensors to link each other and access the internet for daily usage. It is a platform that can be used by end users to access many smart application fields, such as smart city, smart home, and smart healthcare. In recent years, the healthcare monitoring systems are becoming the major development field that use the IoT as advanced technology enabler. This review is discussing more about the design, functions, and the main uses of the IoT-based healthcare monitoring applications and systems for remote patient environments. Therefore, a deep review has been made to identify the usage, efficiency, and acceptability for the current applications and systems to become more efficient to patients. Different healthcare monitoring systems have employed the IoT to integrate the different wireless interfaces with the cloud-based healthcare services. These services are including the sensing, gathering, processing, storing, and learning more among the patients' data. The various IoT healthcare applications will help to develop useful and effective solutions by using these systems in practice. From this review it can be proof that the IoT-based healthcare monitoring applications are growing faster to build more healthcare solutions that useful for different healthcare conditions and environments.*

**Keywords:** *Internet of Things, IoT, Smart healthcare, Remote healthcare monitoring.*

## 1. Introduction

With the increasing population in the globe along with the rise of chronic diseases, there has been a demand for developing efficient healthcare systems that manage and deliver the diverse healthcare services with less expenditures [1]. In order to maintain healthcare services for patients like elderly individuals or people with chronic diseases, remote healthcare monitoring is playing an important role as can reduce hospitalization and increase healthy lifestyle. The Internet of Things (IoT) technologies are the most enabling communication paradigm that make the possibility to gather, record, and analyze the patients' data more accurately and also share the knowledge directly among the healthcare service providers [2], [3]. These IoT systems can support the doctors to monitor their patient remotely and manage their consultation time accordingly. Patients also can improve their home healthcare facilities to reduce doctor consultation and the chances of redundant and inappropriate healthcare from the hospitals or the clinics [4]. This matter can improve the healthcare and safety of the patients with the reduction in overall costs for care.

The ability of various healthcare applications to collect the patients' data remotely can remove the limitations of the manpower and process the data automatically for the patients care whenever they needed. The automation of the smart healthcare monitoring systems reduces the risk of human error that can caused risk to the patients and doctors together [5]. These IoT-based healthcare monitoring systems are including sensors to collect healthcare data, IoT gateways for data distributing, and the cloud for information analysis and storage for further examination by the doctors and healthcare service providers.

Current IoT implementations and research studies are mostly unstructured and concentrate on deployment and infrastructure at particular situations and environments. Researchers in [6], for instance, were concerned with introducing a mobile health care framework. An assessment was carried out to determine the program's design with patients using IoT-based service-oriented approach. The system was tested with findings indicate that the program is convenient and user friendly. Although the incorporation or ongoing use of the system was limited with inactive clinical assistance techniques. In [7] for example, a comprehensive framework detection and warning is suggested using wireless technologies. However, these methods are not widely adopted. Therefore, this paper is evaluating related research about the design and implementation of an IoT-based healthcare monitoring systems, which are mainly using IoT devices and sensors to link the patient with their respective health providers.

## 2. Remote Healthcare Monitoring Architectures

Although remote healthcare monitoring has not quite achieved common medical care, numerous projects were established for academic activities in various medical settings. During the rapid advancement in ICT, the way of remote healthcare monitoring is achieved has now been strongly influenced [8]. In this section, the key architecture designs are examined by way of gathering patients' data, focusing on the context of remote healthcare monitoring systems.

### 2.1 Service Oriented Architectures

In the new century has notice the differentiation of service-oriented architectures (SOAs) as telemedicine systems were deployed via secure network links and finally accessible via smart devices such as smartphones [9]. Almost every device that targets a particular range of features was not allowed by previously devices. The transition to the simple client-server model, for example the one used by web apps, permitted pervasive access to a variety of centralized resources that prevailed SOA. The SOA also permitted the exponential deployment of new technologies, eliminating the need to expose each patient to specific facilities or configurations [10]. In addition, it supported integrative access using technological advancements like communication protocols over network to improve the interconnectivity across elements.

Early designs of remote healthcare monitoring architectures are still decision supporting for automated remote diagnosis of healthcare. All other features and functionality were however, made available through a web application that is accessible anywhere with smart devices or computers capable of running a web browser [11], [12]. Meanwhile the M2DM project was a step ahead since it has been built on a simple SOA architecture and was implemented using the Roche Acculink Framework to connect glucometers [13]. Even after using patented modem technologies, the distant transmission of patient data has been streamlined and the SOA model of this project has been completely maintained. By the meantime, it can be seen that healthcare monitoring tends to lag behind even existing ICT practices in these other facilities and in most instances, may not follow such expectations. In reality, some countries certainly lack simple wireless capability to track healthcare and still only dedicated terminal connectivity supported of its interface. Any ventures gradually started to use a smartphone to incorporate patient-side facilities, such as feedback and reminders and hence combine the SOA as it happened in [9], [14], [15].

### 2.2 Body Sensor Network Architectures

Interestingly, ICT developments have once again led to a paradigm change in data gathering and uploading of networks of remote healthcare monitoring systems [6]. A new architectural design called Body Sensor Network (BSN) was formed based on Body Area Network (BAN) because of the requirement to obtain bio-signals utilizing various smart sensors connected to the corps and probably operates from specific actuator devices [16]. BSNs include wireless sensor network which have a very small range of connectivity and typically use multiple small equipment for the patient that are only very few distance [17]. In this context, it is impractical to link every device back to the internet. Furthermore, they are very small in size and are even inserted together inside human body, with serious limits on their practical capacities and the accessibility of power sources. In addition, a sensor like a cardioverter will be engaged based upon the intention of the BSN and its communication module should be subject of that same BSN itself to reduce congestion or reactive issues in case of weak communication.

It is important to remember, for proper performance, that perhaps the risk statements are appropriate requirements for BAN. The choice of intermediate distribution platforms, like mobile gateways, external nodes, network coordinators and cross communication hubs, provides a variety of deployment techniques and strategies. These requirements, in combination with the chosen data gateway, are variables that have a significant effect upon on Cloud or health care system providers. A dedicated part like the body gateway is therefore needed to organize all equipment. This part would be to link toward a baseband unit, which communicates through Wireless Network via RFID, Wi-Fi, ZigBee over IEE 802.15.4, Bluetooth IEE 802.15.1, or 3G/4G, typically smartphones that is the best approach to the network connection for remote monitoring [18]. A limited workload can be reconfigured to sustain a BSN architecture that utilizes multiple devices and applications for the healthcare contexts.

Very advanced features can be worked on the body gateways as it can be used efficiently as usable input instruments for telemedicine systems that serve as network hubs [6]. They are also used more and more as test machines with advanced capabilities. Body IoT gateway is used as a network hub with components together in the remote healthcare monitoring systems [6]. However, all body-connected sensors should be able to communicate using ICT technologies as this approach is accepted. The Diabetic Assistance is a fascinating example, which is mainly an industrial platform used mostly for producing an experimental drug.

Table 1: Summary of IoT-Based Remote Healthcare Monitoring Systems

Reference	Study Type	Application	Intervention	Architecture	Outcome
[6]	Research study	Patient health status monitoring	IoT-WBAN-based	BAN	Framework
[9]	Literature survey	Home healthcare	Telemedicine and healthcare	SOA	Evaluation
[10]	Research study	ECG Signal Processing	ECG monitoring, analysis and storage	SOA	Distributed service-oriented system
[17]	Research study	Smart clothing-based applications	Green cognitive BSN (Green-CBSN)	BSN	Architecture
[19]	Research study	Smart healthcare system	Diagnosis and monitoring	SOA	Framework
[20]	Research study	Ubiquitous Driver Stress Monitoring	ECG monitoring, random forest classification approach	BSN	Monitoring system
[21]	Research study	Telemonitoring	Plantar pressure measurement feature	BAN	Telecare system
[22]	Research study	Telemonitoring	Self-configurable IoT gateway	BAN	Telecare system
[23]	Literature survey	Medical industry	IoT-based service-oriented and security	SOA	Evaluation
[24]	Research study	Medical diagnostics	Multi-agent system by neural network	SOA	Architecture
[25]	Research study	Smart health service	Health information and service control	SOA	Smart health service system (SHSS)

### 3. IoT-Based Remote Healthcare Monitoring Systems

Smart healthcare monitoring systems have constantly evolved in the industrial healthcare sector during the last decade and have the potential to change the current healthcare delivering methods. Although, smart health monitoring systems can automate patient monitoring tasks and at the same time it will improve the patient procedure management and their efficiency in clinical procedure are still debatable. Furthermore, a deep analysis of the efficiency, clinical acceptability, strategies, and recommendations on improving the current healthcare monitoring systems will be executed. The modern concept of new IoT-based healthcare monitoring can be done wirelessly for the patients in their remote environments. Therefore, the remote healthcare monitoring systems will be the major development in healthcare industry arena [26]. The major advances in the design level of IoT-based healthcare monitoring systems have been discussed according to the current issues facing by the healthcare providers. From this result, we can see that there will be potential of challenges to healthcare monitoring field for identified and compared to other similar systems.

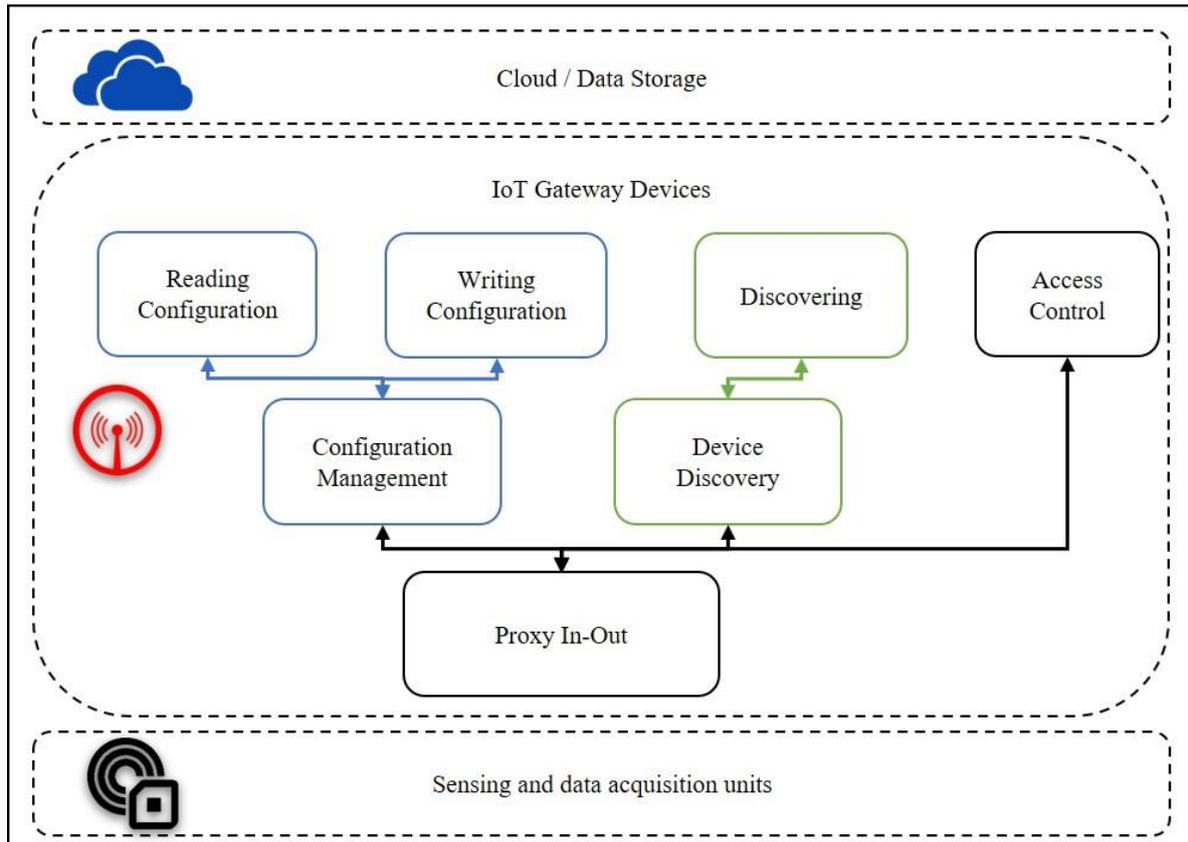
Typically, the IoT-based systems for remote healthcare monitoring involve three major elements i.e. Cloud, IoT gateways, and data acquisition units [27]. The first element that relies heavily on the smart devices and sensors of the end-system users is data acquisition. Patient data is gained from the smart devices and sensors of the users and then having undergone for pre-processing levels in the IoT gateway before getting transmitted to the cloud. In order to collect and interpret valuable information, diverse data analysis methods are even so applied in the cloud. Then this information is being used for more analysis and evaluation by medical professionals. The three elements of IoT-based remote healthcare monitoring systems and their characteristics are further clarified in this section and shown in Figure 1.

### 3.1 Data Acquisition

Data acquisition can be identified as the process for collecting biological data for practical uses of IoT-based networks for remote healthcare monitoring. The biosensors output, which normally achieved in the form of analogue signal as a captured data. Biological signals are most commonly low in amplitude and polluted by noise. These signals are therefore preprocessed and converted to the digitalized form. Typically, the pre-processing stage involves procedures for enhancement and filtration that is important to ensure the information is very well-persistent and not damaged during data acquisition, or it could lead to incorrect decisions while treatment.

The smart sensors that used in IoT-based remote healthcare monitoring systems for biomedical signal acquisition are known as biosensors. Such smart sensors could perhaps produce an incredible amount of data and distribute it to the healthcare services providers. The biosensors are also can be classified into wearable and non-wearable smart sensors and devices. The wearable smart sensing devices can be mounted on the patient body as supplementary attachments. Numerous creative firms have developed wearable smart sensing devices to decrease hospital visits and clinical treatments on the way to alleviate chronic diseases. Correspondingly, non-wearable smart sensing devices are mounted around the patients' places to sense their environmental conditions. These smart sensing attachments provide large condition data without human interference to deliver health condition information besides interacting with the various applications. Therefore, smart sensing networks can be the most influencing technologies with smart healthcare monitoring for detecting patient activities at their remote environment. A typical example of real-time healthcare monitoring system is performed by Luis et al. in order to support living of older adults in their geriatric residences [28]. A prototype system is developed using a mobile application connected with biometric bracelet that enables all information generated by the sensors (blood oxygenation, pulse rate, and body temperature) to be predicted upon this bracelet in real time.

Figure 1: IoT-Based Remote Healthcare Monitoring Systems



### 3.2 IoT Gateways

The IoT gateways in remote healthcare monitoring systems could be physical or virtual interfaces linking the detectors, smart devices with the cloud. Since, data that are sent to the cloud or conversely would be through the IoT gateways, it can therefore be a bridge between smart objects and application. However, the IoT gateways roles may include data normalization, data preprocessing, and network connectivity. As several sensor categories are gathering data, the IoT gateways provides data normalization by taking the diverse data sets and translating them into common data formats. Furthermore, the IoT gateways carry out data preprocessing before transition of the information to the cloud. This reduces the volume of data needed to be transmitted to the cloud and further reduces the requirements for transfer, retrieval and storage. Also, the IoT gateways provides network connectivity for the sensors in the IoT-based remote healthcare monitoring systems to diminish its limitation in link up extensive networks.

### 3.3 Cloud

The key component of IoT-based healthcare monitoring systems is the data storage and retrieval servers for the identification and testing of abnormal healthcare interventions. The IoT gateway transmits healthcare data to the cloud for further data mining after preprocessing the signals collected from related sensors. The data mining process in IoT-based healthcare monitoring systems include classifying critical healthcare information from bio-signals. Therefore, we will discuss most challenges and design factors for knowledge extraction in the following section.

## 4. Discussion of Related Challenges and Design Factors

IoT-based remote healthcare monitoring systems represent a platform of medical devices which can collect and share data among each other for the distribution of different healthcare applications and services. According to Dwivedi et al. [29], healthcare professionals are now accepting IoT-based wearable technology to accelerate the diagnosis and health recovery process. However, certain limitation complexities and relevant factors which really complicate its continuous improvement. Therefore, some challenges and development issues are addressed as the following:

- Decision Support

Artificial Intelligence and machine learning enable the interdisciplinary development and processing of analytical techniques that are crucial for the growth of future smart healthcare including monitoring and decision support. A significant quantity of research efforts is currently being conducted on artificial intelligence and machine learning to support decision-making [30]. Such studies provide considerable opportunities to resolve plenty of the challenges identified. Recent artificial intelligence and machine learning technologies may not replace physicians but improve their opportunities to carry crucial important knowledge that a patient needs to care about and deliver in a succinct, easily understandable way [31]. Such technologies would not only enhance decision-making support, but also ensure the integrity and reliability of all the components that comprise the ecosystem of smart healthcare monitoring.

- Usability

The purpose of remote healthcare monitoring systems would be to make diagnosis and treatments much easier. Usability is always the significant functionality consideration in order to improve safety of patients and health care delivery. Usability is generally evaluated through feedbacks from users and performance problems are reported. Although the IoT represents a complex cooperation among healthcare equipment, requirements must be adjusted in order to bring the components in the network together and further improve remote healthcare monitoring systems usability. The IoT technology is going to achieve the era of remote healthcare monitoring systems that would predict and interact with the growing requirements for patient experiences.

- Accuracy and reliability

Remote healthcare monitoring systems are critical to the accuracy and reliability of healthcare information. The accuracy and reliability mechanisms must be assured over everyday utilization because misleading information might become unreliable and disruptive to patients. The IoT technology has a really powerful vested interest, for example to incorporate and interpret different forms of clinical information in professional decision-making processes in remote healthcare monitoring systems. In this manner, physicians will have an analysis of the state of health for every patient and hence more effective interventions can be done. This has all achieved with diagnostic tests, where progress accuracy remained essential to the rescue the patient.

- Security and Privacy

A highly secure health technology assessment process is very important in smart healthcare. As remote healthcare monitoring systems are more widely spread, confidentiality of patient data must be guaranteed. Security vulnerabilities allow hackers to access personal data which result to misdemeanors including Fraud and identity theft, exposure of unauthorized substances and fake payroll records [32]. A major concern of remote healthcare monitoring systems has now been the stable protection from infections, vitality and data obtained from embedded sensing devices. Security vulnerabilities in the healthcare services can then lead to severe, and even in some cases fatal, mass casualties to the patients. Authentication of the network is one of the essential aspects for ensuring the structure of remote healthcare monitoring systems. Some healthcare monitoring systems do not support advanced encryption algorithms due to inadequate computing capacity and resources [33]. Therefore, efficient and low-power processing with modern authentication mechanisms are important for addressing security risks.

- Energy Efficiency

Typical remote healthcare monitoring systems include smart sensors and devices that able to operate continuously onsite using perceived energy. A new challenge seems to be the consumption of renewable energy for sustainable healthcare monitoring practices. In order to minimize the power consumption of numerous connected smart sensors and devices, the IoT has empowered researchers to conduct emerging innovations. Therefore, numerous routing protocols, algorithms, and techniques have already been proven minimize total consumption of energy needed for operating the network. However, the volume of produced data must also be controlled for further decrease the power being used for processing and transmission. Energy-efficient remote healthcare monitoring systems can significantly minimize the energy usage in healthcare facilities and produce substantial power savings. The effect of these mechanisms also is environmental optimistic by decreasing electromagnetic impact.

## 5. Conclusion

While several observations on the determinants of remote health surveillance technologies, rising data about how such systems may use healthcare is still missing to influence strategic decisions. Hence the potential for broad trials with innovative designs to help explain the impact on patient monitoring, satisfaction level and operation costs. As the area evolves quickly, diverse forms of expertise are still required – for example a greater emphasis on socioeconomic analysis methods of remote patient health monitoring projects, on the experience of patients and the perception of health monitoring as dynamic mechanisms of growth and productivity and further outcomes as continuing cooperative results. Thus, foundational evaluations for a field of limitation and significance are mostly clarified.

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