The Internet of Things Based Healthcare (HIoT): Networks, Technologies, Applications, and Challenges

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ABSTRACT:
The Internet of Things (IoT) is an almost new technology in which different things are connected to the Internet and are available anytime and anywhere. The Internet of Things has many uses, including smart cities, smart industries, smart health, etc., and therefore, has attracted a lot of attention. One of the most interesting uses of IoT can be mentioned in the field of healthcare, which in addition to attracting the attention of patients and medical staff, has also interested industries and researchers. The use of the Internet of things in the healthcare's field provides the possibility of remote monitoring of health parameters, early diagnosis, easy access to patient data, and improving the quality of medical services. This paper examines IoT-based healthcare (HIoT) systems. The HIoT network is described in terms of topology and architecture. Also, new technologies used or have the potential to be used in these systems have been examined. Then, IoT services and applications in healthcare are described. After reviewing IoT-based treatment systems from different aspects, the challenges in the development process of these systems are expressed as open issue and researched topics for further studies.

KEYWORDS: Internet of Things, IoT, Healthcare, HIoT.

1. INTRODUCTION

The Internet of Things means a set of components, including things and humans, that are connected to the Internet and are accessible at any time, any place. The Internet of Things has many advantages and can be considered in the Internet infrastructure as connecting objects and smart devices. The concept of the Internet of Things is much more comprehensive than the machine-to-machine connection, and includes the connection of various devices, services, and systems [1]. IoT has several uses in different fields including smart cities, traffic control, industrial control, medical and healthcare, etc. There are many articles in the field of IoT and its applications [1], [2], [3], [4], [5], [6].

Among the various applications of the Internet of Things, Application in medicine and health is mentioned as one of the most interesting applications [7]. IoT applications in the medicine and health include remote health monitoring, monitoring of chronic diseases, home care, monitoring and control of sports, medical applications, and so on. Diverse medical devices, sensors, and medical diagnostic devices are smart devices in the IoT. By using IoT in healthcare, costs are significantly decreased and the quality of people's life is improved. Nevertheless, HIoT is in the infancy of development, but its limited use has shown its important and optimal effects.

The use of HIoT technologies has many benefits for patients and treatment staff. For example, wearable technologies such as smartwatches and smart clothing can monitor and control health and fitness. The health of the elderly can also be monitored and monitored remotely. Patients and the elderly can benefit from immediate treatment, and as a result, referrals to medical centers will be reduced. Patient health records are available anywhere, anytime for the patient and treatment staff [8], [9].

Typically, a medical body area network (MBAN), for remote monitoring of the patient, includes wearable devices that consist of sensors, actuators, and coordinators and gateways. In this network, the coordinator is a key central controller that determines how the nodes communicate and collects information from these nodes. This information is then sent to the medical staff through gateways or base stations. Smartphones can be used as on-body coordinators or central nodes of an MBAN, to monitor personal health. Using their sensors, these smartphones can measure vital signs including heart rate, blood sugar, blood pressure, oxygen saturation, body temperature and more, and also monitor body activities such as the number of steps, speed, consumed calories and so on. However, there are

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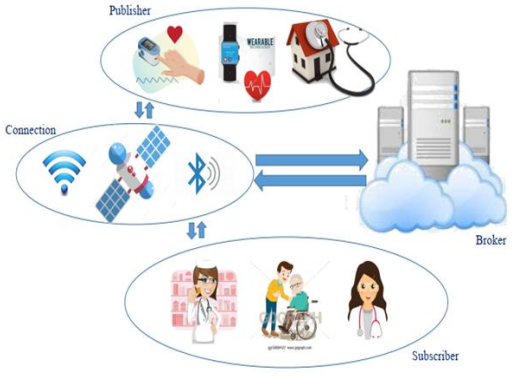

Fig. 1. A typical HIoT network topology.

challenges in terms of reliability, user's privacy, information security, affordable in the extensive use of publicly available technologies [10].

In the following, the paper has sections on HIoT networks, key technologies of HIoT, HIoT services and applications, HIoT challenges, and conclusions.

2. HIOT NETWORKS

To get acquainted with HIoT, it is necessary to explain its network structure. The HIoT network demonstrates the effective use of healthcare applications from IoT, and the protocols required to exchange data between medical and healthcare equipment and patients and treatment staff. This section explains the topology and architecture of the HIoT network. The HIoT topology is including physical configuration, application scenarios, Activities, and use-cases. The HIoT architecture consists of physical components and communication methods.

2.1. The HIoT Network Topology

The arrangement of the various components of an IoT-based healthcare network is called the HIoT network topology. Because the type of demand and healthcare in question determines the topology of the HIoT network, it is very difficult to standardize and provide the same model for all HIoT networks. In the past, various models for HIoT network topology have been proposed [11], [12], [13]. When designing a HIoT network that monitors the patient in real-time, all aspects of healthcare should be considered, and the type of monitoring should be following medical regulations and diagnostic procedures. Fig. 1 shows a typical topology of HIoT networks. The topology of a HIoT network consists of three components: publisher, broker, and subscriber [14]. The publisher is a sensors and medical devices network that record vital patient information such as blood pressure, heart rate, body temperature, oxygen saturation, ECG, EGG, and more. The information is sent by the publisher through the network to the broker. The broker processes and stores this information in the cloud. The subscriber, who is usually the treatment staff, monitors the information sent by the broker, using a smartphone, computer, tablet, etc. By processing the data, the publisher notifies the treatment staff and the patient of any abnormalities in vital signs.

2.2. The HIoT Network Architecture

The arrangement of physical components, common communication methods, and protocols between smart devices, is called the HIoT network architecture. Fig. 2 shows a layered view of the common HIoT network's architecture. This architecture has four main layers, Things layer, gateway or fog layer, network layer, and cloud layer [15].

2.2.1. Things Layer

Using IoT-enabled medical devices, patient health data can be monitored by patients in real time on smart gadgets including mobile phones, tablets, laptops and more. Some of the essential features of these devices are low or acceptable size and weight, protection of patient security and privacy, the ability to work with other devices, and low power consumption.

The devices used in HIoT are divided into two categories, physical and virtual sensors. Physical sensors

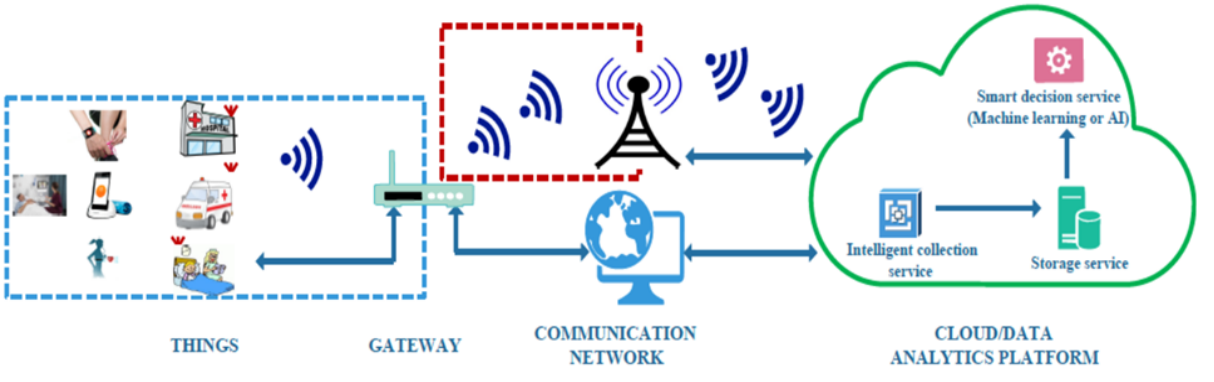

Fig. 2. A typical HIoT network architecture [15].

include all medical devices used wired or wireless to monitor patients' physical health. Virtual sensors can obtain vital patient information using smartphone software and applications. Virtual sensors have many uses, including remote monitoring, remote consultation, diagnosis, patient health records, nutrition, medical reference programs, and so on.

2.2.2. Gateway or Fog Layer

Gateways, or fog nodes, are the interface nodes between sensors/devices and the cloud, these nodes must in addition to communication, security, and network management. In some HIoT applications, the generated data needs to be analyzed quickly. By introducing edge or fog calculations, partial or complete data analysis can be performed on HIoT devices or gateways. By doing this processing, the burden of communication technologies is reduced and more devices can be easily managed.

2.2.3. Network Layer

In the network or fog layer, multi-protocol communication technologies are used between edge devices such as fog nodes, gateways and cloud servers. In this layer, different protocols and technologies are used. It is worth mentioning that the application and the specific use determine the type of connection and communication protocol [16], [17], [18]. Wireless connections for the HIoT network include short-range communications and medium-range communications. Short-range communication is utilized to connect the internal parts of an MBAN, medium-range communication is mostly applied to communicate between the MBAN central node and the base station. In the following, short-range and medium-range communications will be explained.

A. Short-Range Wireless Communications

Short-range wireless communications are used to communicate between nodes that process data, such as gateways/controllers and smart sensors. The communication range for this type of communication varies from a few centimeters to a few meters. MBAN networks use short-range communication including infrared, Bluetooth, and ZigBee. Due to Bluetooth and Zigbee features such as longer range, higher frequency band, and higher data rate compared to infrared, these two communication protocols are commonly used in HIoT networks [19].

B. Medium-Range Wireless Communications

Medium-range wireless communication is used to communicate between the central node, which collects information from the sensors, and the base station. The communication range for this type of communication varies from a few hundred meters to several kilometers. An appropriate network standard for HIoT is the low-power wide-area network (LPWAN), used for IoT applications in industry. LPWAN telecommunication range is several kilometers, consumes little energy, and has a low data rate [20]. LoRaWAN and Sigfox protocols belong to this network. Another protocol that can be the basis of HIoT network communication is called 6LoWPAN [20], [22], [22], [23]. The 6LoWPAN protocol stack is IPv6 compliant, it also complies with the IEEE 802.15.4 standard, so it can be used well on battery-powered and low data-rate systems. The 6LoWPAN protocol connects devices that comply with this protocol and devices based on the IEEE 802.15.4 standard. Also, this protocol can communicate with other Internet protocols. For example, devices based on the 6LoWPAN protocol can exchange data over WiFi networks using a simple bridge.

The cloud architecture used for HIoT today cannot work with large volumes, high variability, and high data rates generated by different parts of HIoT. Therefore, network architecture, data transfer, processing, and services should be reviewed [15].

2.2.4. Cloud Layer

A cloud is a collection of interconnected servers and storage devices. The cloud uses artificial intelligence (AI) and machine learning for data processing sent from objects and HIoT devices to provide the information needed for service and decision making. With the development of machine learning technologies, big data, and artificial intelligence, huge volumes of data can be processed and useful information can be extracted. The extracted information can be used to predict events in real-time, in addition to the stated applications. In this way, HIoT can be used in early diagnosis and ongoing patient monitoring, as well as optimizing the treatment process and reducing costs.

3. KEY TECHNOLOGIES OF HIOT

Many technologies can be used in HIoT, all of which are almost impossible to name. In this section, the core technologies that are further used in HIoT are explained.

3.1. Cloud Computing

Generally, Cloud computing is the provision of computing services over the Internet. These services include servers, storage, databases, networks, software, analytics and communication. With cloud computing, resources can be used flexibly and innovations can be delivered faster. [24]. With cloud computing, operating costs will be reduced, infrastructure will be used more efficiently, and the scale of work will increase. Using cloud computing in HIoT, shared resources can be accessed anywhere, medical and health services through the network, etc. [25].

3.2. Grid Computing

In general, grid computing are performed by a group of interconnected computers as a network. These connected computers act like a virtual supercomputer and can perform massive tasks such as processing and analyzing large data sets. Through the Internet, extensive computer networks can be set up for specific purposes and periods. Grid computing uses the computers that are part of the network when they are inactive. Using grid computing saves money, resources, and time. Because the tasks in question are divided into several computers, the processing time is greatly reduced, efficiency is increased and resource wastage is also reduced [26]. Using grid computing in the HIoT system, the computational weakness of sensor nodes can be compensated.

3.3. Big Data

Big data is data that has a lot of variety, is large in volume, and has more velocity than regular data [27]. Medical and health data obtained from different parts of the HIoT system are among the big data and the methods used in the processing and analyzing the big data can be used for them.

3.4. Networks and technologies

As mentioned before, different networks can be used as the infrastructure of HIoT networks, such as short-range communication networks and medium-range communication networks, and so on. Also, Ultra Wide Band (UWB), Near Field Communication (NFC), Bluetooth Low Energy (BLE), RFID, WIFI, Satellite, etc. technologies can be used to better design communication protocols and design low-power consumption HIoT devices [28].

3.5. Ambient Intelligence (AmI)

The goal of Ambient Intelligence (AmI) technology is to incorporate pervasive computing, artificial intelligence (AI), sensors, and sensor networks into our daily lives. AmI is an advanced human-centric artificial intelligence system that reacts to human presence by recognizing it in the environment. AmI, by constantly learning human behavior, takes the necessary actions for known events [29]. Since the end-users of a HIoT system are humans, it is possible to provide better and more services using AmI, Human-Computer Interaction (HCI), and independent control technologies.

3.6. Augmented Reality (AR)

Augmented Reality (AR) technology provides a composite view by placing digital content including images, sounds, and text in a real-world environment [30]. The use of AR in the HIoT system can be very useful, especially for remote surgeries and remote health monitoring.

3.7. Wearable Devices

The use of wearable health devices can facilitate patient participation in the HIoT system and improve community health. Benefits of patient participation in the HIoT system include connected information; targeted healthcare and gamification.

4. HIOT SERVICES AND APPLICATIONS

HIoT systems can be used in many cases. In general, these uses are divided into two categories: services and applications. Applications are also classified into two categories: single-parameter applications and multi-parameter applications. A single-parameter application is used for a disease or a vital sign, and a multi-parameter application is used for several diseases or general conditions [19], [25]. Table 1 shows these categories. The following describes the services and applications.

Table 1. HIoT services and applications.

Services	Ambient Assisted Living (AAL)
	Internet of m-health Things (m-IoT)
	Semantic Healthcare
	Wearable Devices and Smart Phones
	Cognitive IoT (CIoT)
	Community Healthcare (CH)
	Blockchain
Single-Parameter Applications	Electrocardiogram (ECG) Monitoring
	Temperature Monitoring
	Blood Sugar Monitoring
	Blood Pressure Monitoring
	Oxygen Saturation Monitoring
Multi-Parameter Applications	Rehabilitation System
	Wheelchair Management
	Drug Management
	Smart Phone Solution

4.1. HIoT Services

The use of IoT in healthcare and the provision of new services has revolutionized health and medicine, with each service supporting several applications. However, a full description of HIoT services is almost hard task, the development of healthcare systems will lead to the introduction of new HIoT services, which eventually become an essential platform for HIoT applications. Here are some well-known HIoT services.

4.1.1. Ambient Assisted Living (AAL)

The use of ambient intelligence in HIoT to help and care for the elderly is called AAL. AAL service uses cloud computing to manage, process and analyze data. The main components of AAL include activity recognition, vital monitoring, and environmental

recognition. Activity recognition provides a great deal of research because it is important for the well-being of the elderly to identify the risks that may arise during elderly people's activity [31], [32].

4.1.2. Internet of m-Health Things (m-IoT)

The use of mobile computing, medical sensors, and cloud computing to monitor people's vital signs in real-time, as well as the use of telecommunications technology to send data to a cloud computing infrastructure, is called the Internet of m-Health Things (m-IoT) [33]. By using m-IoT in healthcare, relevant data can be available anytime and anywhere and used to diagnose and treat the disease.

4.1.3. Semantic Healthcare

In research conducted recently, much attention has been paid to the use of semantics and ontology in the processing, analysis, and sharing of large volumes of medical data [34], [35]. HIoT application designers use vast fields of semantics and ontology to introduce new applications. Semantic Medical Access Service (SMA) is on top of the IoT services.

4.1.4. Wearable Devices and Smart Phones

An important and interesting feature of IoT is the use of wearable technologies. Wearable devices are available in both smart clothing and smart accessories. Using wearable technologies in HIoT, people's health data, environmental characteristics, etc. can be collected for real-time processing and uploaded to a database or fog layer. Smartphones support the technology, analyze data collected from wearable devices, and send it to a cloud computing infrastructure for processing, analysis, and storage. Finally, this data is used by the health application on smartphones [36].

4.1.5. Cognitive IoT (CIoT)

The use of computer models to simulate the human thought process in complex situations where vague and uncertain answers are possible is called cognitive computing. Cognitive computing is a higher level of artificial intelligence [37]. The use of cognitive computing devices in the Internet of Things is called CIoT. CIoT can analyze data well by recognizing hidden patterns in big data. Because HIoT devices generate so much data, using cognitive computing can be very useful. In a CIoT structure, all smart devices must work together to diagnose people's health status, to provide appropriate health and medical services to individuals.

4.1.6. Community Healthcare (CH)

Creating a health network that covers all sections of a community is called community healthcare (CH). This network can use the IoT to provide services to a city or a village or a hospital. In a CH structure, different networks can be merged to form a larger network.

4.1.7. Blockchain

Blockchain is a database consisting of a list of records that is constantly growing and increasing in number. These records are called blocks that are connected through a peer-to-peer network using cryptography. The built-in storage repository is called the Digital Ledger [38]. Blockchain features include [39], [40]:

- The Digital Ledger is immutable and it is impossible to change a recorded record, only, records can be verified and controlled.
- Blockchain technology is distributed across multiple computers, so it is very difficult to hack and attack it.
- Blockchain is flexible, although it supports data exchange logic and rules.

Using blockchain can be very useful in storing and securing HIoT network data [41]. Important problems in the HIoT network include data fragmentation, security, and privacy issues. Using blockchain, different parts of HIoT system can connect traditional data repositories and exchange medical data securely. With blockchain, communication between patients and treatment staff becomes clearer and collaboration between research departments and treatment staff becomes more efficient.

4.2. HIoT Applications

HIoT applications are used directly by medical staff and individuals. HIoT applications use HIoT services for development. In this section, several well-known applications are introduced.

4.2.1. Electrocardiogram (ECG) Monitoring

ECG monitoring is one of the applications of HIoT that monitors the electrical activity of the heart, including heart rate, slow and fast heart rate (bradycardia and tachycardia), multiple arrhythmias, etc. via the Internet of Things. Various studies have been presented on ECG monitoring using the Internet of Things [42], [43], [44].

4.2.2. Temperature Monitoring

An important part of healthcare is body temperature monitoring because body temperature affects many human activities and also some health-related issues such as fever and chills are detected by measuring body temperature. The main components of the system, which include the RFID module and the body temperature monitoring module, are proposed in [45] and [46].

4.2.3. Blood Sugar Monitoring

Diabetes is a metabolic disease in which the patient has high blood sugar levels for long periods of time. Monitoring blood sugar levels in a diabetic person shows

the pattern of changes in blood sugar and helps to plan meals, activities and adjust the proper time of medication. The structure of HIoT for blood glucose monitoring or IoT-based blood glucose monitoring devices has been presented in several articles [47], [48].

4.2.4. Blood Pressure Monitoring

HIoT blood pressure monitoring measures systolic and diastolic blood pressure via the Internet of Things and detects high or low blood pressure according to medical definitions, the patient's physical condition, and age. Numerous studies have presented monitoring of blood pressure using the Internet of Things [49], [50] , [51].

4.2.5. Oxygen Saturation Monitoring

Pulse oximetry is used for the non-invasive monitoring of blood oxygen levels. For example, due to the prevalence of Covid-19 disease, pulse oximetry can now be integrated with the Internet of Things, allowing patients' oxygen levels to be monitored remotely. Numerous studies have been presented to monitor blood oxygen saturation using the IoT [52], [53].

4.2.6. Rehabilitation System

Physical medicine and rehabilitation is one of the most important branches of medicine because it improves the ability and quality of life of people with physical disabilities. By combining the Internet of Things and rehabilitation systems, the problems caused by the growing population of people with disabilities, the shortage of physical medicine doctors, and rehabilitation specialists can be reduced. Related works are presented in [54], [55] ,[56].

4.2.7. Wheelchair Management

Fully automatic smart wheelchairs are very important to help people with disabilities. The use of the Internet of Things can be used to develop smart wheelchairs. Intel IoT, for example, provides an example of an IoT-based wheelchair network [57].

4.2.8. Drug Management

Improper use of drugs is a major problem for patients and treatment staff, and at a higher level, it affects the health system. The IoT offers solutions such as smart drug boxes [58] and drug use control using RFID [59].

4.2.9. Smart Phone Solution

Many electronic devices are controlled by a smartphone. The smartphone acts as a stimulator of the Internet of Things. Many hardware and software have been developed to turn a smartphone into a multi-purpose healthcare device. Some applications for smartphones have been extensively reviewed in [60]. On the Internet, IoT-based health applications for smartphones are constantly being offered.

5. HIOT CHALLENGES

There are many benefits to using IoT in healthcare, can lead to create a comprehensive network of all health and medical members around the world. So that the treatment staff can treat patients remotely or consult about the treatment of a disease. But there are several challenges in the development of HIoT, which are explained in this section [19], [25].

5.1. Implementation

Two important parameters in implementing IoT in healthcare are easy accessibility and speed of data exchange. Studies have shown that in large projects, less than 30% of the work is devoted to the use of IoT in healthcare. Also, more than 50% of the projects have problems in using the relevant services [61]. Examining a large number of projects, it was found that for a project to be successful, there must be a partnership between different parts of the project.

5.2. Resource Management

When different technologies are integrated, resource management becomes more important [62]. One of the important issues is the removal or reduction of additional data, a large amount of data is transferred to the cloud by IoT devices to be processed and analyzed, and these large amount of data can consume all resources. On the other hand, many of the data sent by users consume the same or identical resources. Given the importance of resource management in HIoT implementation, the parameters affecting resource allocation must be carefully analyzed.

5.3. Standardization

Many devices and products for healthcare are produced by different companies that are not necessarily compatible with each other in terms of standard rules of relationships and protocols and do not have much interoperability with each other. Therefore, HIoT technologies should be standardized, and the management of various value-added services, such as electronic health records, should be standardized. This depends entirely on the cooperation of network organizations and medical organizations.

5.4. Data Processing

Increasing the number of smart devices and healthcare sensors produces huge volumes of data that make them difficult to process and analyze. In addition to the huge volume of data, data complexity also increases the difficulty in processing and analyzing data. New technologies in the field of fog and big data calculations must be used to solve the problem of huge data volumes. As data rates increase, so does the

complexity. For proper data analysis and processing, computational power should be increased by using fog and edge computational layers. Also, efficient data analysis algorithms should be used.

5.5. Security and privacy

In HIoT networks, as in many other networks, patient data security and user privacy are very important. Strong protocols must be designed to secure health data in all areas of application and sharing, so that collaboration between different parts of the HIoT system remains possible.

5.6. Commercial Model

An important challenge in HIoT systems is that many existing infrastructures are unusable and new infrastructures are needed. On the other hand, many medical centers or people do not welcome new technologies and do not show a desire to learn and use them. Another important issue is the cost required to implement HIoT. Therefore, for HIoT commercialization, a suitable model should be provided considering all the points.

5.7. Technology Evolution

To implement HIoT, healthcare providers must upgrade their various devices and departments to keep up with IoT. They have to upgrade from an old system to a new IoT-based system. In this technological development, compatibility and flexibility between different parts and devices must be considered.

6. CONCLUSIONS

This article examines the various components of the IoT-based healthcare system. Initially, a HIoT network, in general, was introduced in terms of topology and architecture, and the relationship between its various parts was expressed. Then, key and applied technologies that can be used in HIoT, including cloud computing, grid computing, big data, ambient intelligence, etc., were introduced. The use of these technologies can greatly expand the HIoT system and facilitate its application in various areas of health and treatment. Next, the HIoT services and applications are stated, each service supports many applications and applications can be developed using the services, also, the applications are used directly by individuals. Using different applications, different health issues can be diagnosed and monitored. Finally, the challenges faced by HIoT development such as standardization, resource management, security and privacy, large and complex data processing, etc. were described. Addressing these challenges, in addition to advancing HIoT development, provides a broad area of studies.

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