Internet of Things-Based Healthcare: Recent Advances and Challenges

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Syed Tauhid Ullah Shah
Huazhong University of Science and Technology

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Syed Tauhid Ullah Shah, Hekmat Yar, Izaz Khan, Muhammad Ikram, and Hussain Khan

1 Introduction

The Internet of Things (IoT) is an emerging technology consisting of a set of interconnected objects that connect anything, anyone, anyplace, anytime, any network, and any service. The IoT technologies have the potential to influence the overall business spectrum as each device and object can be recognized uniquely within the modern internet infrastructure, with vast benefits. These benefits normally consist of the advanced connectivity of systems, services, and devices that goes beyond machine-to-machine (M2M) situations [1]. The IoT makes suitable solutions available for a variety of applications and services, including traffic congestion, waste management, smart cities, security, smart health, logistics, disaster services, healthcare, trade, and business control. Medical and healthcare signify one of the most striking application spaces for the IoT [2]. IoT technology has the capability to enhance medical applications such as fitness programs, elderly care, remote health monitoring, and management of chronic diseases. Compliance with medication and treatment at home is another likely vital application. Consequently, different medical and diagnostic sensors and devices may be observed by means of objects or smart devices, establishing an essential measure of the IoT technology. The IoT has the potential to provide enhanced user understanding and improvement in the quality of human life with a minimum cost. From the point of view of healthcare suppliers, the IoT is capable of minimizing device downtime via remote delivery.

Over the past decade, a huge number of researchers have investigated the IoT's abilities in terms of healthcare by considering different real-world problems. Consequently, there are currently various services and applications in the area.

S. T. U. Shah (✉) · H. Yar · I. Khan · M. Ikram · H. Khan
Abdul Wali Khan University, Mardan, Pakistan

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Leading research in the IoT for healthcare consists of new applications and services, network platforms and architecture, security, and interoperability between each others. Furthermore, guidelines and policies have been established for setting up IoT technology in the area of healthcare in various organizations and countries around the world. In the future, a systematic review of the research work presently being undertaken regarding the IoT for healthcare would be worthwhile for the numerous parties interested in further exploration of this topic. This chapter surveys the trends in the IoT-based healthcare field and discovers concerns that need to be resolved to alter healthcare technologies using the IoT revolution. It adds to the knowledge base underlying this revolution by:

- Underlining different industrial endeavors to embrace IoT-based healthcare prototypes.
- Categorizing the current IoT-based healthcare network into various themes.
- Providing a comprehensive discussion of IoT-based healthcare applications and services.
- Discussing fundamental technologies that can reform health technologies.
- Providing a comprehensive discussion of privacy and security issues relating to healthcare frameworks.
- Discussing open research issues and challenges that need to be addressed to create robust healthcare technologies.

2 Networks for Internet of Things (IoT)-Based Healthcare

The IoT network for healthcare (IoThNet) is an important component of the Healthcare IoT. It provides strength to the IoT, aids in the communication of health information, and permits personalized communication in healthcare. Figure 1 shows the IoThNet architecture, platform, and topology.

2.1 IoT Network for Healthcare (IoThNet) Architecture

IoThNet architecture refers to the outline for the design of the physical features, working techniques, and principals and functional organization of the IoThNet. The main concerns relating to this have been recognized and discussed by Zhang et al. [3]. These include the interoperability of the wireless local area network and IoT gateway, secure transmission between caregivers and IoT gateways, and multimedia streaming. Several studies [4–7] have shown that 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks) is the basic architecture for the IoThNet. In the IoThNet concept, wearables and sensors use 6LoWPAN and IPv6 (Internet Protocol version 6) systems to communicate through the IEEE 820.15.4. After that, data are transmitted with the help of the user datagram protocol (UDP) to sensor nodes.

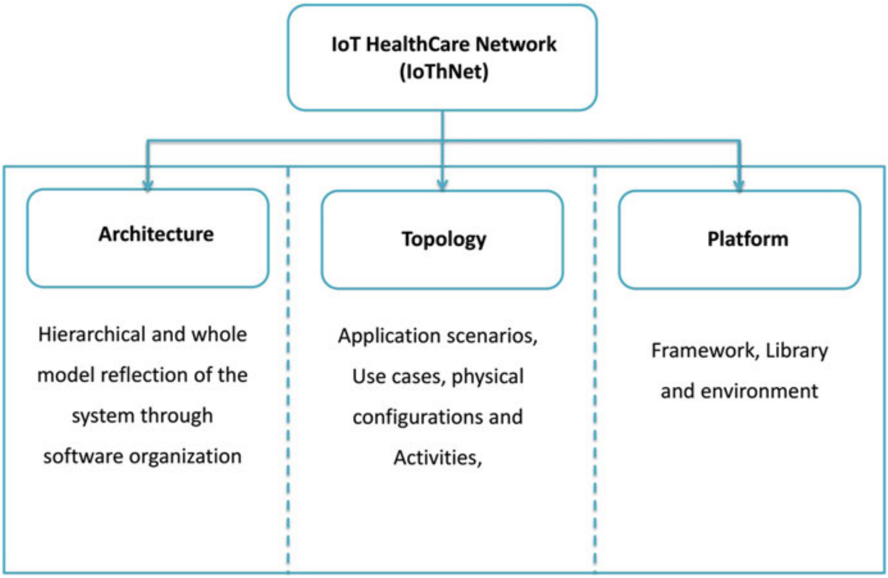

Fig. 1 The Internet-of-Things network for healthcare (IoThNet) architecture

2.2 Topology of the IoThNet

The topology of the IoThNet refers to the organization of various components of an IoT-based network for healthcare and specifies an example of settings found in unified medication environments. Figure 2 illustrates how a computer grid with a heterogeneous nature gathers a massive amount of sensor data and vital signs, such as body temperature, respiration rate, and blood pressure, creating an IoThNet topology. The framework harnesses the storage capability of mobile and static electronic devices, including smartphones, laptops, and medical terminals, creating hybrid computing grids [8].

2.3 The IoThNet Platform

The IoThNet platform consists of both a computing platform and network platform model. The significance of the regulation of boundaries between stakeholders involved in the design of the IoThNet is highlighted in Pang et al. [9]. A number of studies [3, 10, 11] have discussed concerns regarding the IoThNet platform. However, these studies do not provide sufficient generalized and widespread analysis of such frameworks. A platform architecture based on semantics is presented in Miori and Russo [12]. The proposed architecture suggests semantic interoperability between various heterogeneous devices and systems.

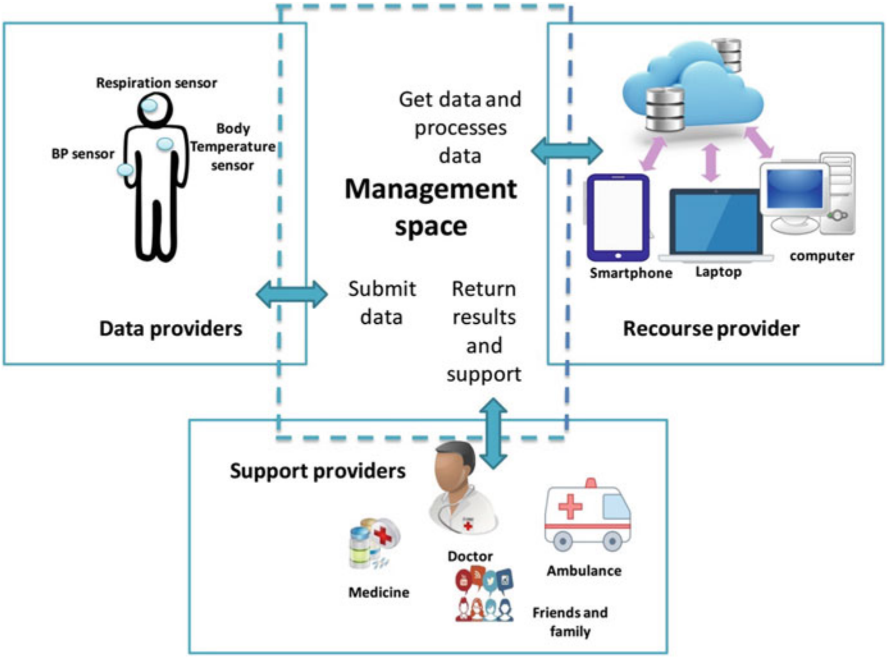

Fig. 2 Conceptual illustration of an Internet of Things (IoT)-based pervasive healthcare solution

3 IoT-Based Healthcare Services and Applications

IoT-based health monitoring solutions are functional in a range of areas, such as observation of prolonged diseases, care for elderly and pediatric patients, and the supervision of private fitness and health, among others. To enhance understanding of this extensive topic, this chapter divides the discussion into two parts: applications and services. Applications are then categorized into two sets: clustered-condition and single-condition applications. A clustered-condition application deals with a large number of conditions or diseases, whereas a single-condition application deals with a single condition or disease.

3.1 IoT Healthcare Services

The IoT is expected to facilitate a wide range of smart healthcare services. These services individually provide a collocation of healthcare support solutions. Each service can be considered a platform for a wide range of applications and solutions. IoT-based protocols and services require minor adjustments to operate appropriately in healthcare environments. These services consist of link protocols, resourcesharing services, notification services, and cross-connectivity and internet services. This section outlines different kinds of healthcare services based on the IoT.

The Internet of m-Health Things m-health is the combination of medical sensors, mobile and communication technologies for healthcare facilities. Istepanian et al. [13] examined implementation issues, Internet of m-health Things (m-IoT) architecture, and challenges of non-invasive glucose level sensing.

Adverse Drug Reactions An adverse drug reaction refers to harm caused by using a medication [14]. This harm may occur after prolonged administration or a single dose of a medication or as a result of a change in its administration.

Community Healthcare Community healthcare refers to the establishment of a network that can cover an area such as a residential location or local community. A cooperative IoT platform-based community for rural healthcare was proposed by Rohokale et al. [16].

Children's Health Information Raising awareness and improving education regarding children with mental and emotional problems and their needs amongst the general public and their family members is essential [17].

3.2 IoT Healthcare Applications

In addition to IoT services, IoT healthcare applications require close attention. It must be taken into account that applications require services, but are used by patients. Hence, applications become user-centric. This section describes the different applications of healthcare based on the IoT, comprising both clustered and single applications (Table 1).

Glucose Level Sensing Diabetes is a metabolic disease that increases the blood glucose level for a certain amount of time. Monitoring of glucose exposes changes in blood patterns, activities and in the formation of meal. A real-time glucose level monitoring scheme was introduced in Istepanian et al. [13].

Electrocardiogram Monitoring An electrocardiogram (ECG) monitors the electrical movement of the human heart, determining the rhythm and heart rate, QT intervals, myocardial ischemia, and diagnosis of arrhythmias. The study by Yang et al. [15] presents IoT-based solutions for ECG monitoring.

Blood Pressure Monitoring Puustjärvi and Puustjärvi [18] use the example of blood pressure monitoring and control in developing countries as an environment in which telemedicine would be a valuable tool.

Body Temperature Monitoring Monitoring of human body temperature is a vital measure of medical services since it may be considered a vital indication of preservation of homeostasis [19]. Istepanian et al. [13] verified the m-IoT strategy using body temperature sensors located in TelosB motes.

Table 1 Classification of Internet of Things (IoT)-based healthcare applications

Category	Task	Location	Applications and devices
Robotics	Monitor and help disabled individuals in daily life activities	Robots	ADL: Meet Mr. Robin, grandma's robot buddy [20] EADL: Social activities based robot [21]
Mobile devices	Mobile health detection and monitoring of user activity	Carried in hands and pockets	HealthWear [22]: health monitoring via the skin Logbook [23]: diabetes monitoring
Smart homes	Centralize and automate home tasks	Home-based systems linked to the local hospital	Home-based healthcare systems [24]
Wearables	Monitoring and helping disabled individuals in daily life activities	Included in shoes, belts, and clothes	Nuubo smart shirt: smart jacket monitoring ECG, respiration, and heart rate [25] Smart watches [26]
Non-wearables	Collect user behavioral information at their homes	Included in home objects	Smart pillow [27] Non-contact heart rate monitoring [28]

ADL aid to daily living, *EADL* electronic aids to daily living

4 IoT Healthcare Security

The IoT is growing exponentially. In the coming years, the healthcare area is predicted to see the comprehensive adoption of IoT technology and flourish as a result of modern eHealth IoT applications and devices. These IoT-based healthcare applications and devices are predicted to be packed with important information, including personal healthcare information. Furthermore, these kinds of devices can be connected to the global information network—access will be available anywhere and anytime. However, this makes IoT-based healthcare a target for hackers. It is both essential and extremely valuable to analyze and recognize the different features of IoT privacy and security, vulnerabilities, countermeasures, and security requirements from the healthcare point of view to enable the IoT to adapt to these challenges.

4.1 Security Requirements

Security requirements in standard communications environments and IoT-based healthcare are similar. Hence, to achieve security facilities, an immediate focus on this topic is required to cope with the security requirements outlined here.

Confidentiality Confidentiality ensures that medical data are not able to be accessed by malicious users or attackers.

Integrity Integrity guarantees the originality of data and that it has not been changed by an attacker during transmission.

Authentication Authentication means that the IoT device must confirm the identity of its pairing device before any communication occurs.

Availability Availability guarantees that the service will survive after a Distributed Denial of Service (DDoS) attack.

Fault Tolerance The system must be able to provide its service even in the presence of a fault.

4.2 Security Challenges

As IoT security needs cannot be certified through traditional security schemes, innovative schemes are required to solve the novel issues encountered in the IoT. Various challenges for the IoT-based healthcare services are discussed here.

Computational Limitations Normally, IoT-based healthcare devices contain low-speed processing units. The core of these devices (the central processing unit [CPU]) is not very influential in terms of performance and speed and does not perform the expensive computational operations.

Memory Limitations The majority of devices are equipped with a lower amount of built-in memory and can be activated with an embedded operating system (OS).

Energy and Mobility Limitations IoT-based healthcare devices are dynamic and equipped with small health devices and batteries. As various networks have different configurations and settings, a mobility–complement security algorithm is required.

5 IoT Healthcare Technologies

There are various supporting technologies for IoT medication frameworks and it is challenging to a clear scope. In this section, key technologies with the ability to transform IoT-based healthcare are illustrated.

5.1 Wearables

Health enhancements and patient engagement can be assisted by using wearable healthcare devices. Using such technology can result in three major advantages: gamification, target-oriented healthcare, and connected information.

5.2 Cloud Computing

The incorporation of HealthcareIoT with cloud computing should offer services with access to mutual resources, allowing different needs to be met via connections through the cloud network.

5.3 Networks

Different networks, including long-range communications (cellular networks) and short-range communications (WLANs [wireless local area networks], WBANs [wireless body area networks], 6LoWPANs, WSNs [wireless sensor networks], and WPANs [wireless personal area networks]), are a vital requirement of the physical infrastructure of HealthcareIoT.

5.4 Big Data

Big data contains large volumes of vital health data created by different medical devices and allows the creation of tools to enhance the proficiency of health monitoring, staging, and diagnosis.

6 IoT Healthcare: Current Issues and Challenges

Various researchers have focused on implementing and designing different IoT healthcare frameworks and solving numerous architectural complications related to those frameworks. However, there are still numerous open research issues and challenges that need to be properly addressed. This section outlines some of these challenges.

Cost Analysis Researchers need to consider the creation of low-cost prototypes of IoT-enabled medication solutions; however, to date, no study has considered this topic.

Continuous Monitoring In some conditions, long-term patient health monitoring is required. To achieve this, continuous logging and monitoring is essential.

Identification Healthcare organizations and hospitals often deal with a huge number of patients, with multiple support staff performing various duties. To achieve proper data management in these situations, accurate identification of patients and staff is essential.

Mobility The IoT healthcare solutions must be capable of assisting the mobility of patients because they are linked anytime, anywhere. The mobility specifications are used to connect different patients to different networks.

7 Conclusion

Researchers around the globe have started to discover numerous technological solutions that will improve healthcare in a way that enhances current services by bringing together the capabilities of the IoT. This chapter investigates various features of the IoT healthcare framework and discusses different healthcare network architectures that support access to this IoT framework and aid the reception and transmission of medical data. Furthermore, the chapter notes research that has been undertaken regarding how the IoT can assist in elderly and pediatric care, private health, fitness management, and chronic disease supervision. To aid understanding of privacy and security issues relating to IoT healthcare, this chapter outlines many security requirements and issues and notes various research problems. In addition, IoT and eHealth regulations and policies relating to various stakeholders that are significant in accessing IoT-based healthcare technologies are presented. To conclude, the outcomes of this chapter are predicted to be beneficial for health professionals, researchers, engineers, and policymakers operational in the field of healthcare technologies and the IoT.

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