Chapter

IOT Service Utilisation in Healthcare

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Abstract

Utilising the new trend technologies in healthcare sector could offer alternative ways in managing the patients' health records and also improve the healthcare quality. As such, this chapter provides an overview of utilising the Internet of Things (IoT) technology in healthcare sector as an emerging research and practical trend nowadays. The main benefits and advantages have been discussed in this chapter. On the other hand, it has been found that most of the hospitals in different countries are still facing many issues regarding their health information exchange. Recently, various studies in the area of healthcare information system mentioned that the fragmentations of the health information are one of the most important challenges with the distribution of patient information records. Therefore, in this chapter, we gave an in detail overview regarding the current issues facing the health sector in line with the IoT technologies. Additionally, a full description of advantages and disadvantages has been highlighted for using IoT in healthcare that can be considered as solutions for the mentioned issues.

Keywords: IoT, Internet of Things, healthcare, e-Health, health information exchange

1. Introduction

The Internet of Things (IoT) is a new technology that aims to connect the world via smart devices or objects with capabilities of collecting and sharing various types of information at any location, time, media and environments. By assigning a unique identification to each object in the network, IoT allows its users to live smart, safe lives. In healthcare systems, IoT is mainly used to gain quick access to health information. IoT can be defined as an interconnected network that links a large number of devices to one another for purposes of making large-scale information accessible to all. This technology can be seen as a grid of computers that deliver software and data via the Internet. As illustrated in **Figure 1**, Cisco defines IoT as a revolution of the 'Internet of Everything' that involves people, processes, data and things [1].

Many health organisations need to exchange data with one another to address their problems and to improve their performance [1]. Health-related data are especially important for these organisations to provide their patients with better healthcare services. The exchange of health information among these organisations has been termed 'health information exchange (HIE)', which has become a pervasive global phenomenon [2, 3]. Although not a novel concept in the health industry, HIE needs to reinvent itself every 2.5 years to adapt to the current technological advancements and the changes in the environment [4]. According to the 'Evolution of State Health Information Exchange in the U.S. (2006)', HIE offers

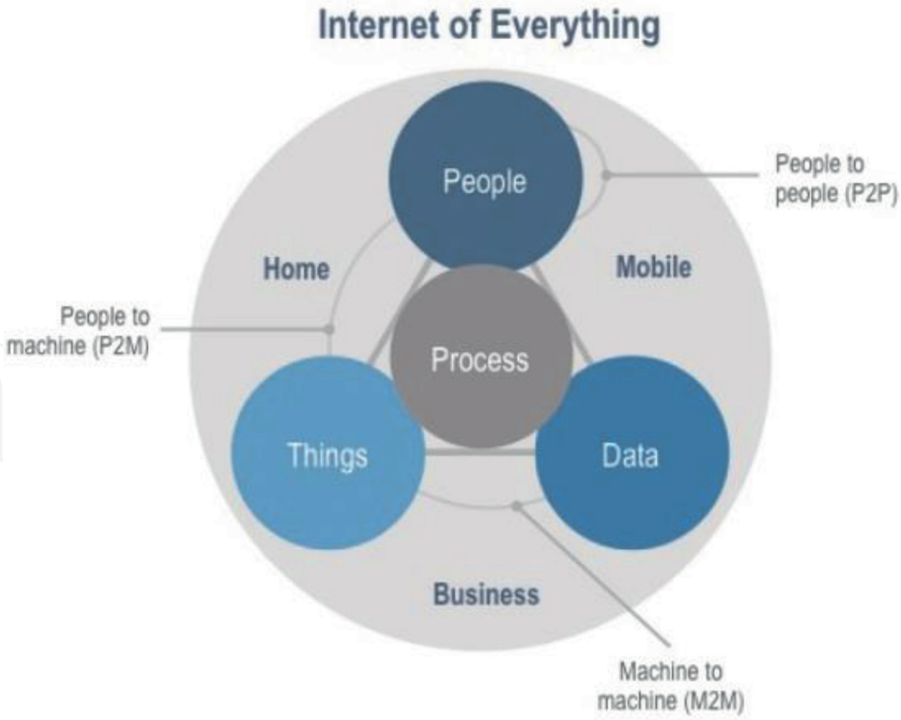

Figure 1.
IoT revolution [1].

many significant contributions to the designing of different projects, such as financing, identifying patterns of success, ensuring programmatic sustainability and highlighting challenges, trends and best practices [5]. HIE also provides many opportunities to improve the quality and reduce the cost of healthcare, improve the workflows of clinical organisations and facilitate the administration of data within the healthcare system [5]. However, HIE also poses one of the most complex problems in electronic health record (EHR) management [6]. Therefore, dissemination and communication are essential attributes of health information systems [7].

The medical records of each patient are stored in physical and electronic databases. However, when patients decide to move to new healthcare providers, the latter have no tools or directories that they can use to check where the medical records of these patients are stored. Such inaccessibility of medical records can lead to unnecessary procedures, duplicate tests and many other problems, such as adverse drug interaction. According to Tharmalingam et al. [8], Canada faces many difficulties related to HIE, including complex systems, lack of knowledge as to the location of patients' medical records, lack of access to information and lack of data standards that allow the exchange of clinical information. Some non-technological barriers also exist, including care burden, issues related to patient consent, differences in business models, limited understanding of procedures and loss of competitive advantage [2, 9].

Virtually storing patient data and making them ubiquitously accessible to all healthcare personnel is the first step in HIE [10]. Recent years have witnessed an increasing interest in the application of sensing technologies and widely available smart devices for monitoring personal health, fitness and activity. Continuously recording key physiological parameters via sensors can provide healthcare practitioners with the necessary data to produce rich longitudinal records [11]. Meanwhile, data from physical examinations provide doctors with comprehensive information that allows them to measure the physiological and metabolic states of their patients. Accessing a large number of observation data via health information systems can also help doctors improve their prognosis for their patients and recommend effective treatment, intervention and lifestyle choices to improve their health quality [12].

With the massive advancements in communication and computer technologies, organisations must urgently apply and utilise these technologies to compete effectively and survive in the market. IoT cannot improve the performance of hospitals if such technology is not being utilised to measure the success of a system [13]. A vast and multi-layered infrastructure of ubiquitous computing technologies and applications is also emerging. Mobile phones, laptops, Wi-Fi, Bluetooth, personal digital assistants and various forms of sensing devices based on digital and radio frequency identification (RFID) technologies have also penetrated the healthcare industry. IoT establishes connections among different entities, including humans (e.g. patients and medical staff), medical devices, intelligent wheelchairs, wireless sensors and mobile robots. People in the healthcare industry also rely on this technology to provide high-quality and affordable healthcare services, minimise medical errors, guarantee the safety of their patients and optimise their healthcare processes [14].

However, despite the wide availability of smart devices and novel communication technologies, healthcare professionals and patients are still generally unwilling to exchange health information while a large number of hospitals are yet to implement advanced technologies to promote their HIE capability [15–17]. IoT provides new opportunities for healthcare professionals to deliver health information to hard-to-reach populations. Utilising such technology often requires an organisation to spend a considerable amount of resources at different stages [18]. Unfortunately, most health organisations in developing countries only have few resources to spare for using new technologies, including IoT [19]. Many other issues also prevent these hospitals from receiving financial incentives that will enable them to adopt new technologies for facilitating HIE.

In sum, using IoT is in great demand in the healthcare sector. To effectively utilise IoT, hospitals must possess the necessary resources to produce the maximum value possible and to prevent failure [20]. Therefore, this chapter focuses on those problems being faced by the healthcare industry in its implementation of advanced technologies. Over the past 5 years, many health information systems have faced several concerns with regard to medical records. Most of these systems have focused on accelerating their provision of services to patients and improving the performance of hospitals by reconstructing their current workflows.

2. Internet of Things (IoT) in healthcare

The rapid proliferation of smart devices offers unprecedented opportunities for patients and health care professionals to exchange health information electronically [16]. The IoT is one of the smart technologies to integrate the smart devices on network. On the other hand, IoT is a global information infrastructure that enables advanced services by interconnecting devices based on existing and evolving interoperable information and communication technologies [21]. Thus, it is a collection of several opportunities that have wellness providing for the hospitals such as optimising the resources through automated workflows as well as process excellence. For instance, a majority of hospitals use IoT services for asset management and controlling humidity and temperature within operating rooms [22]. The collection of health data has multiple benefits to interdisciplinary healthcare collaboration, while most of the research focuses on the personal fitness plan and has a lack of compatibility and extensibility among a large number of devices and their business models. Compatibility involves in information exchanging, communication and events processing. There is a strong need for an efficient interface mechanism to simplify the management and interconnection of things. However,

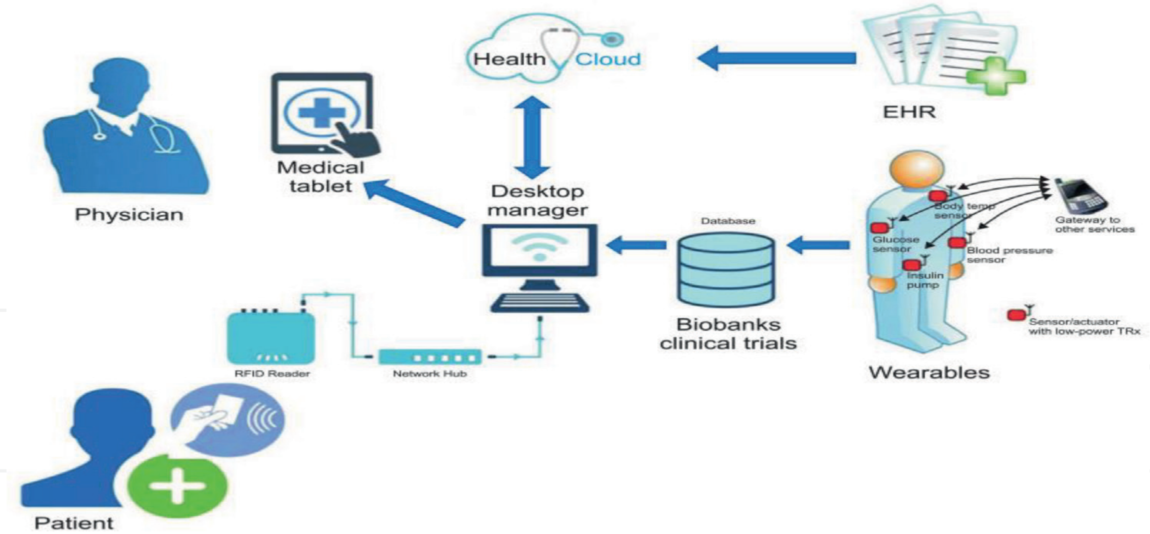

Figure 2.
IoT-hospital scenario [66].

the compatibility issue among the heterogeneous devices should be taken into consideration and addressed for the interactions among things [23].

Figure 2 illustrates how this revolution in the medical will look in a typical IoT hospital, in practice. The patient will have an ID card, which, when scanned, links to a secure cloud which stores their electronic health record vitals and lab results and medical and prescription histories.

The IoT has the potential to several benefits for health applications such as remote health monitoring, fitness programs, chronic diseases, children care and elderly care. Furthermore, it allows sharing and controlling the information between human to human or human-object or between objects using the Internet via ubiquitous sensors [24]. Therefore, various medical devices, sensors, and diagnostic and imaging devices can be viewed as smart devices or objects constituting a core part of the IoT [12]. The IoT-based e-Health monitoring method will help in reducing the number of visits to a doctor, and even the doctor can monitor his or her patient from anywhere. As this is a technology not so feasible now, but in coming years, this technology will meet the physical world definitely. The e-Health solutions provided through IoT devices are more accurate and accountable in the emerging IoT business landscape, which offers and provides various opportunities and challenges to an industry [25].

The IoT technology is still understudy to utilise it in the health sector in different regions in order to combine the information with control and monitoring such as China, US, Canada, etc. As a historical background, the Internet of Things was discovered by Kevin Ashton in 1998 to facilitate information exchange over the wide-world where every physical object connected through the Internet with a unique identification and can be monitored everywhere. One of the facilities of IoT for information systems is that it can provide services anywhere, anytime, and on any media [24]. In healthcare, the Internet of Things enables the potential benefits to achieve a high rate of exchange of massive information among organisations and organisation itself.

Some advantages of using Internet treatments included self-paced, interactive, of tailored service, multimedia format, greater accuracy reporting symptoms, timely information, accessibility, low cost, standardisation and increased user and supplier control of the intervention. Sensor technology and automated data collection enable passive monitoring of psychological states that can alert patients and healthcare providers to acute and chronic stress states [26]. These sensors

		Explanation	Sources
Advantage	Monitoring	Remote patient monitoring continues to grow and help physicians diagnose and treat illnesses and diseases with obtaining reliable information with a negligible error rate.	[27, 28]
	Sensing	IoT with intelligent medical sensors will enhance the quality of life significantly and prevent the occurrence of health problems.	[22]
	Low-cost solutions	Reduce unnecessary visits by doctors, and readmissions come from patients with chronic diseases and reduce testing cost.	[29]
	Ubiquitous access	Allow and increase the accessibility from anywhere, any time and any media allowing flexibility and mobility to the users. Enable real-time access services to the healthcare provider to access patient information and help them to make better decisions.	[30]
	Better quality of healthcare management	Increase the care quality and control by enhancing the management of drugs, reduce the medical error, enhance the patient experience, improve the disease management and improve outcome of treatment.	[31, 32]
	Unified information	Automated data collection enabled from health information resources such as monitoring, first aid, tracking, analysis, diagnosis, alarm-triggering, locating and collaboration with medical healthcare under unified communication platform and exchanged the health record.	[27]
	Time	This facilitates the interaction among the parts of an enterprise and allows for reducing the time necessary to adapt itself to the changes imposed by the market evolution.	[33]
Disadvantage	Complexity	The IoT is a diverse and complex network. There is a need of multiple services to grow device counts, massive increases of Internet bandwidth with a need to drive requirements for lower latency, greater determinism and processing closer to the edge of the network. Thus, any failure or bugs in the software or hardware will have serious consequences. Even power failure can cause a lot of trouble.	[34, 35]
	Compatibility	Although different manufacturers will be interconnected, the problem issue of compatibility when manufacturers do not agree to a common standard will make the people buy appliances from a certain manufacturer, leading to its monopoly in the market.	[23]
	Security and privacy	A location tracking and collect inappropriately information for any person considering as a challenge in the using of IoT services in the healthcare system. The patient concern of attacks his personal identity and privacy maybe arise. Therefore, bring big data from millions of things in a healthcare system can cause many security challenges.	[36, 37]
	Massive health data	In IoT, devices assemble and communicate information directly with each other via Internet and the cloud manages to collect record and analyse data blocks. But the 'things or devices' which are producing a massive amount of data are blowing out day-to-day, which needs to be treated and managed.	[38, 39]

Table 1.
The IoT advantages and disadvantages.

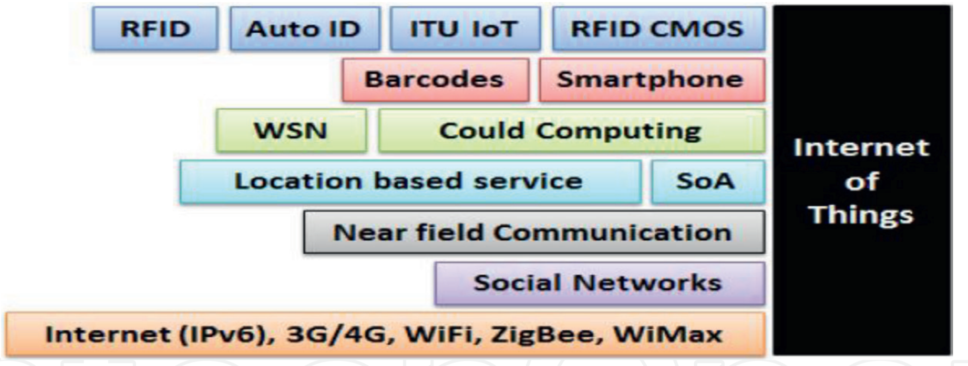

Figure 3.
Technologies associated with IoT [67].

can be used in monitoring patients, tracking daily activities, and caring for the chronic disease people or patients who have special states [27]. This information offers treatment that is evidence based from the information obtained from sensors and monitoring activities. All the applications of this technology culminated in increased comfort, convenience, and better management, thereby improving the quality of life. **Table 1** shows the multiple advantages and disadvantages of Internet of Things-based healthcare monitoring and management of health system.

Many open challenges need to be addressed by new research and investigation, mostly due to the complex deployment characteristics of such systems and the stringent requirements imposed by various services wishing to make use of such complex systems. Thus, it becomes critically important to study how the current approaches to standardisation in this area can be improved and at the same time better understand the opportunities for the research community to contribute to the IoT field [36]. In addition, many other technologies and devices such as barcodes, smart phones, social networks, and cloud computing are being used to form an extensive network for supporting IoT [12, 23] (as shown in **Figure 3**).

3. HIoT applications and device features

The healthcare applications and system have adopted several types of innovation technologies/devices in order to enhance the performance of healthcare services delivered. Most of these systems and applications are contributing to use IoT or smart technology devices to perform better advantage in healthcare services. These IoT applications and healthcare devices are called HIoT. The healthcare device implements dedicated sensor, and holds high collecting precision advantage, while it is also having a number of disadvantages such as insufficient portability, high cost and usability. This type of device possesses the following features:

- Wearability: most of the HIoT applications offer sensing on the human body so they collect data exactly and take vital signs of the human body as collecting targets. Thus, most of the existing medical health devices make the wearability as the basic requirement of collection of human body vital signs. On this vein, the users feel more comfortable and can be enhanced and the accuracy of the collected health data can be guaranteed through the collecting procedure. The layout of common human body sensors is shown in **Figure 4**.

- Long working time: the ways of dedicated health collecting data are several for instance universal mobile devices, wearable devices, pedometer, etc. The

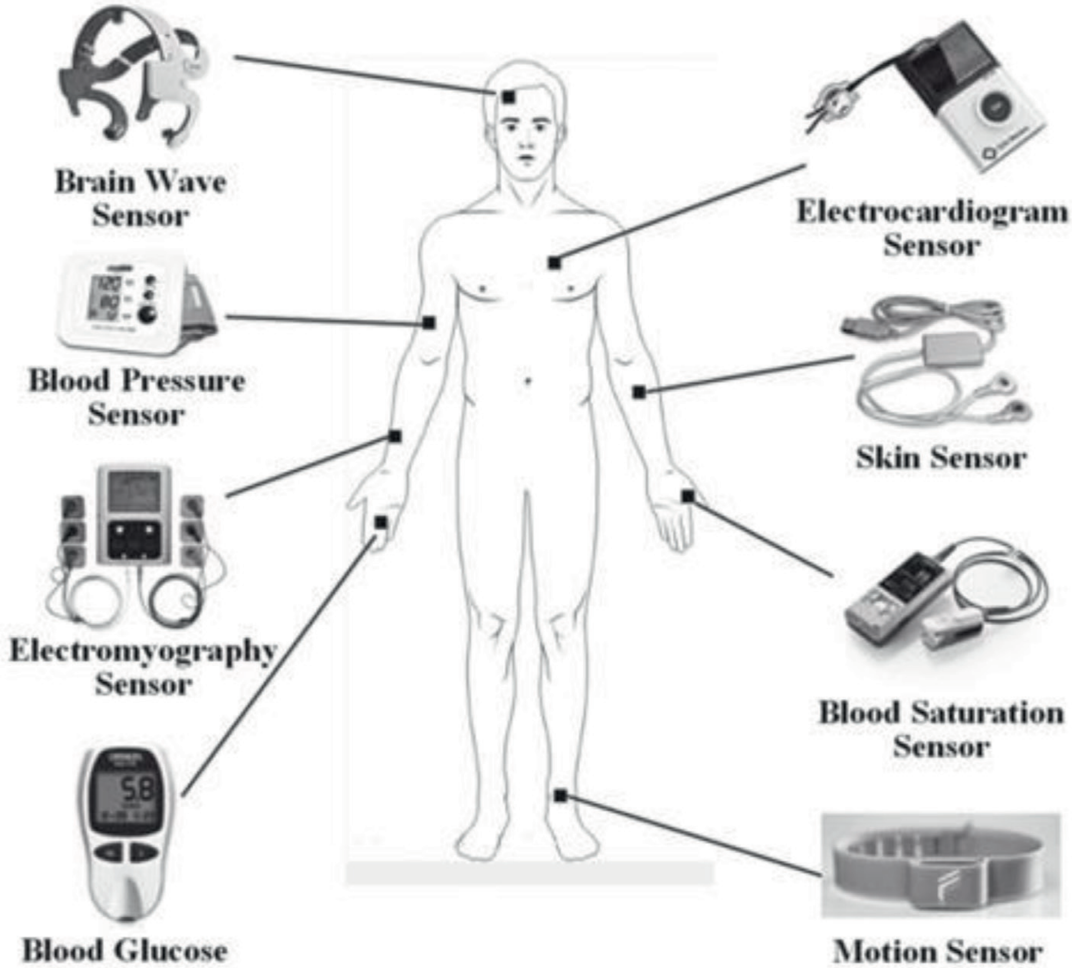

Figure 4.
Layout of common human body sensors.

purpose of these devices is to collect data from the human body for a relatively long time period that requires high power and capability.

- Constancy or stability: HIoT has high ability to collect data very normally even though the users are under strenuous exercise or in an extreme environment.

- Low participation degree of users: the functionality of HIoT applications and devices are relatively independent, as well as most HIoT devices do not require the intervention of users during the collecting data procedure. In addition, the users need to start up the power source only, and the HIoT device will start collecting data.

- Possessing data interim storage mechanism: the dimensions and weight of HIoT maybe limited strictly in order to meet the wearable feature. Thus, most HIoT devices do not integrate the data transmission module, but can select the data storage module with relatively small dimensions and adopt the data interim storage mechanism in order to store the collected data in advance, and then transmit the data through other network access devices accurately.

4. IoT scenario in the healthcare industry

Using IoT can improve and modify the delivered healthcare services in the following aspects:

1. Relying on sensing-based screening and assessment technologies in home and community environments can reduce the physical pressure on the environment of hospitals and turn this information into an electronic flow of information.

2. Changing the medication process from a reactive model to a proactive and preventative model can significantly minimise the hospital admission expenses for acute events.

3. Improving the personalisation of healthcare processes allows individuals to monitor and identify their risk factors, seek preventative intervention and treatment and live independently. In this way, personalising healthcare processes has a significant positive impact on the psychological and physiological states of patients.

4. Improving the management of clinical workloads can allow healthcare systems to effectively prioritise those patients who have the highest need for medical services.

5. Supporting self-care diagnostic processes for monitoring vital signs and other various measurements can produce data that are shared with physicians either personally or by phone in order for them to make effective diagnoses. These diagnoses can sometimes be automated for simple illnesses, such as flu.

Point-of-care tests can be optimised by reducing the time of diagnosis, which in turn can be achieved by reducing the requirements for sending samples to be tested. For example, automatic testing by using blood pressure cuffs and digital thermometers can help physicians review the history of their patients while performing the necessary measurements. Among its practical advantages, IoT can encourage the development of smart systems that support and improve biomedical and healthcare processes. Monitoring the physiological parameters of patients in real time can also facilitate the early detection of clinical deterioration, automatic people identification and tracking by using biomedical devices in smart hospitals and monitoring drug-patient associations [40].

Figure 5 illustrates the IoT scenario in smart hospitals. A patient with an emergency case is given a wearable device that detects the nearest ED that offers the required services. Upon being notified of an emergency case, the ED dispatches an ambulance to the location of the patient and delivers the necessary care services.

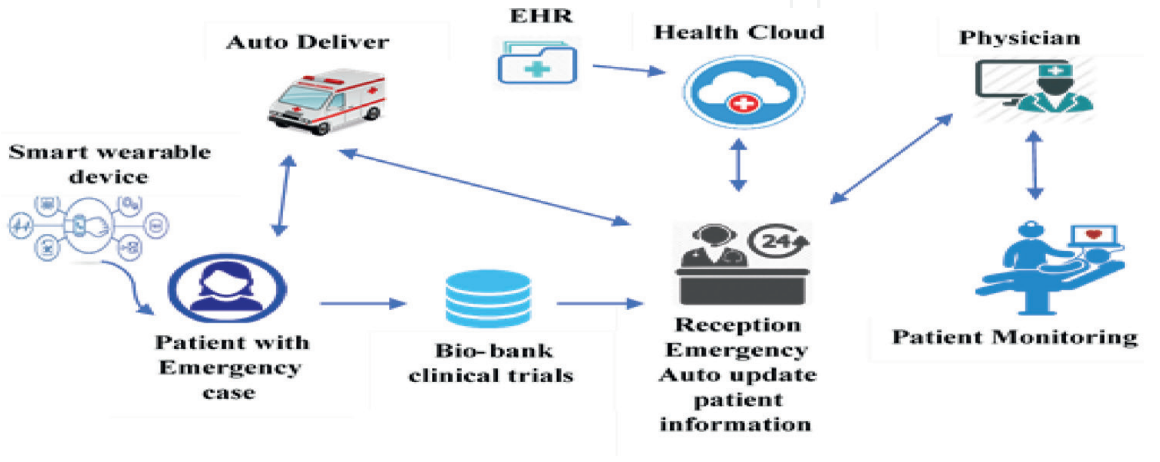

Figure 5.
IoT in the healthcare scenario.

Upon its arrival, the ambulance links the bio-bank of patient information to a secure cloud that stores the EHRs, laboratory test results and medical and prescription histories of the patient. This process can help health practitioners understand the status of their patients quickly, easily and effectively.

IoT in HIE systems is mostly designed to store, enter, receive and exchange health information. This system increases the number of devices and enhances the mobility of information to support health professionals in their consultations. Despite the benefits of using IoT in hospitals, several challenges related to availability, reliability, mobility, performance, management scalability, interoperability, security and privacy must be considered during its application [41].

5. Healthcare system challenges

Collecting and exchanging health information have become challenging due to the increasing population and demands for health services. These challenges can hinder the successful adoption of HIE. The following issues and challenges related to HIE adoption have been identified from the literature:

- Unified patients' data: this challenge refers to the combination of patient's data that are obtained from EHR systems that are being operated by healthcare providers (e.g. aged care providers, hospitals and healthcare specialists) for the purpose of sharing information. The unification of patient data provides excellent opportunities in continuing care, improving care quality and analysing and monitoring care service delivery and patient health outcomes.

- Teamwork of care: teamwork refers to collaboration among healthcare practitioners with the shared aim of exchanging information [42]. The communication deficiency among groups of healthcare professionals, departments or clinics has been identified as the main driver of critical safety incidents in tertiary care clinics. However, with the growing complexity of healthcare provision, the availability of patient information has been considered highly significant in the healthcare industry. Therefore, teamwork places less effort in promoting the availability of information. A survey of primary care doctors from 10 countries identified the overall communication, coordination of healthcare and teamwork as common challenges in HIE adoption. The lack of integration among primary care, specialty care and hospitals can also put patients at risk and lead to duplicative care, particularly for those patients suffering from complex chronic illnesses [43]. The full potential of teamwork is seldom realised due to training problems and the lack of trust in the reliability of healthcare services. Physicians are also often blamed for the errors that may occur during the provision of these services.

- Security and privacy: due to security and privacy concerns [44–46], many physicians and healthcare providers prefer to store patient records on computers or local systems that are not connected to the Internet [47]. Despite the benefits of large-scale HIE, a comparative study of the medical record exchange practices in Australia, Canada Germany, Netherlands, New Zealand, the UK and the US [48] revealed that Germany lacks a single approach for HIE and that healthcare software companies have achieved minimal success in their development of infrastructures where physicians can exchange clinical data due to security concerns. Similar to other countries, the substantial privacy and security concerns in the UK and the Netherlands have driven the resistance of healthcare professionals to HIE despite the benefits of this practice.

- Address shortage: another important issue that hinders the adoption of HIE is the storage of health information in a single pool. Cloud computing or other related technologies may be used as storage to allow healthcare practitioners to access and utilise health information at any time and place. Storing information online emerges as the most popular choice even though most users have expressed their concerns about storing their personal information on the Internet. In addition, the collected data must be managed and comply with standard formats and protocols in order for them to be retrieved and used by other healthcare providers. However, a common standard protocol for these data is yet to be devised [45]. Furthermore, patients should be allowed to access to their own data and be given the right to dispose of these data freely and ensure that their information is kept secure.

- Patient consent: the success of HIE also depends on public support, the willingness of patients to share their health information and their consent to have their health information shared with other parties via HIE [49, 50]. A study that examined the attitudes of patients towards giving consent revealed that the majority (91%) of the participating adult patients expect to be asked for their consent before their identifiable records are accessed and used for health provision, research or planning while only 9.2% of these respondents do not expect to be asked for their consent [51].

- Compatibility: compatibility refers to the degree to which the potential adopters perceive innovation as consistent with their values, previous experiences and needs. Therefore, based on physicians' expectations, the HIE system should be compatible with their work style and needs to motivate them to adopt such technology. This issue has a significant effect on the usage of innovation to promote HIE among hospitals [52].

- Hospital workflow: Healthcare professionals need to transform the HIE system to satisfy their demand for a faster access to patient information, which in turn can reduce their workflow. Issues related to workflow are important barriers that prevent the implementation of technologies in some health practices. Physicians in practices without EMR are generally reluctant to use computers to write prescriptions because these technologies are unavailable in many examination rooms. Therefore, HIE must promote consistency in workflows by facilitating staff training to improve their efficiency and by providing clinical information with minimal effort at any time or location [53, 54].

- System capacity: in order to facilitate HIE, the systems being used in hospitals should be effective and sustainable. Zhang et al. [15] attributed the limitation of system capacity to the following causes:

    - The failure to implement tecihnological advancements in most hospitals and the need to upgrade the HIE system to improve its capability.

    - The delayed development of a standard-compliant HIE system in many hospitals.

    - The overlapping functions among the needs of several regions, which reduce the need for information exchange.

However, exchanging patient records, including summaries and test results, among healthcare practitioners is not yet considered a norm in many countries. In the US, New Zealand and Canada, the current capacity of healthcare practitioners to share health information only ranges between 14 and 55% [43, 55]. With the technological advancements in networking, EHRs can be accessed by using various devices and stored in remote data centres.

6. Models/frameworks for IoT use in healthcare

To further understand the current utilisation of IoT in the healthcare sector, the related models/frameworks are reviewed as follows:

6.1 Tyagi et al.

Given the increasing demand of health organisations for access to patient records around the world, Tyagi et al. developed a cloud IoT-based healthcare framework and proposed *Platform as a Service* (PaaS) and *Infrastructure as a Service* (IaaS), which help patients find the best care at the optimal cost by allowing them to securely store and share their health information to healthcare organisations [56]. Patients can perform self-assessment to monitor their conditions and find hospitals that provide the healthcare services they need the most. However, the benefits of the cloud-IoT-based healthcare framework are offset by issues related to trust, privacy and security, all of which must be addressed before healthcare providers decide to adopt this framework. Moreover, the security requirements for the implementation of this model are yet to be fulfilled and its results need to be tested [56]. **Figures 6** and **7** summarise this framework.

6.2 Manate et al.

Collecting data from things, devices and multiple sources presents a significant problem. Patients can be classified into those patients who are having elective treatment and those emergency patients who require immediate treatment [57]. Those elective patients who do not require emergency treatment may experience health deterioration and eventually require emergency treatment or tests. A hospital setting is characterised by dynamic uncertainty and a frequent need to dynamically change the treatment pathway. Manate et al. proposed the intelligent context-aware

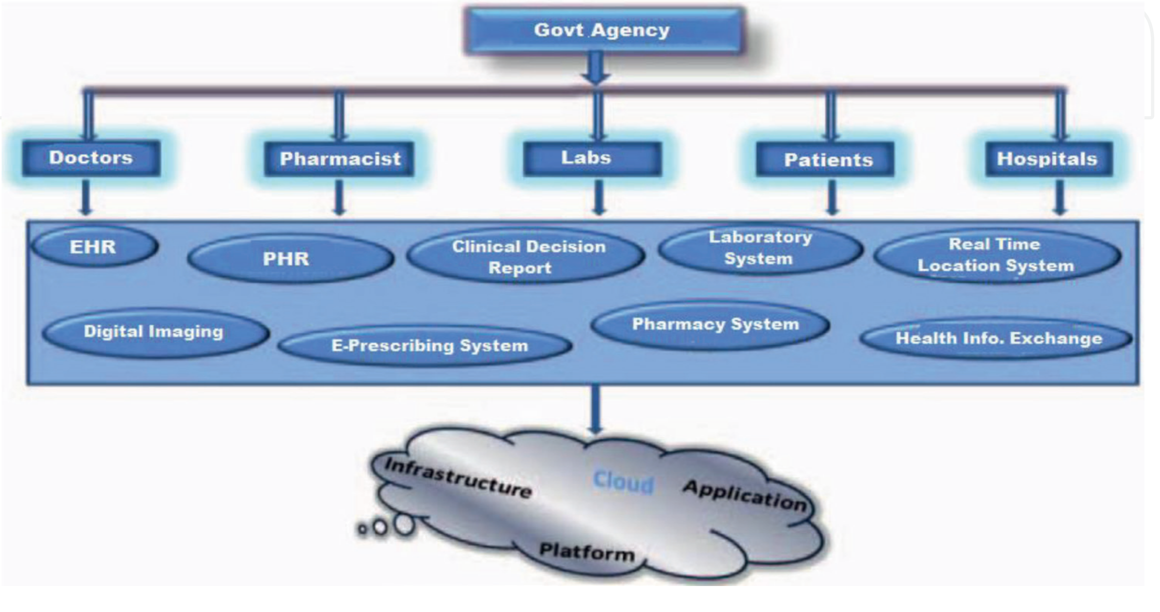

Figure 6.
Cloud-IoT-based healthcare framework [56].

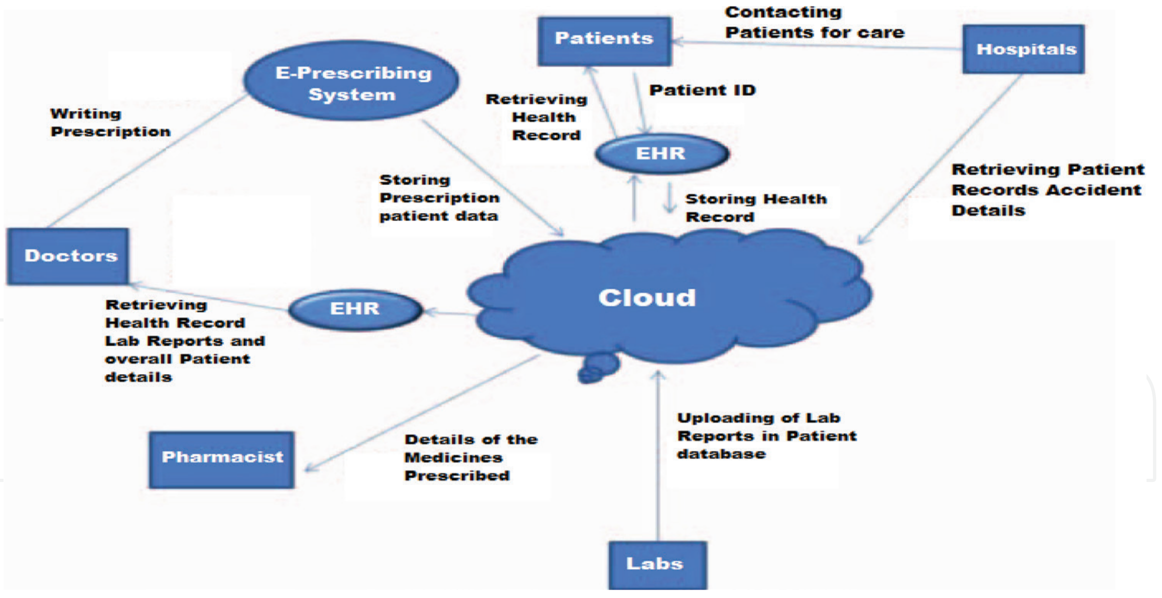

Figure 7.
Actors in the cloud-IoT-based healthcare framework [56].

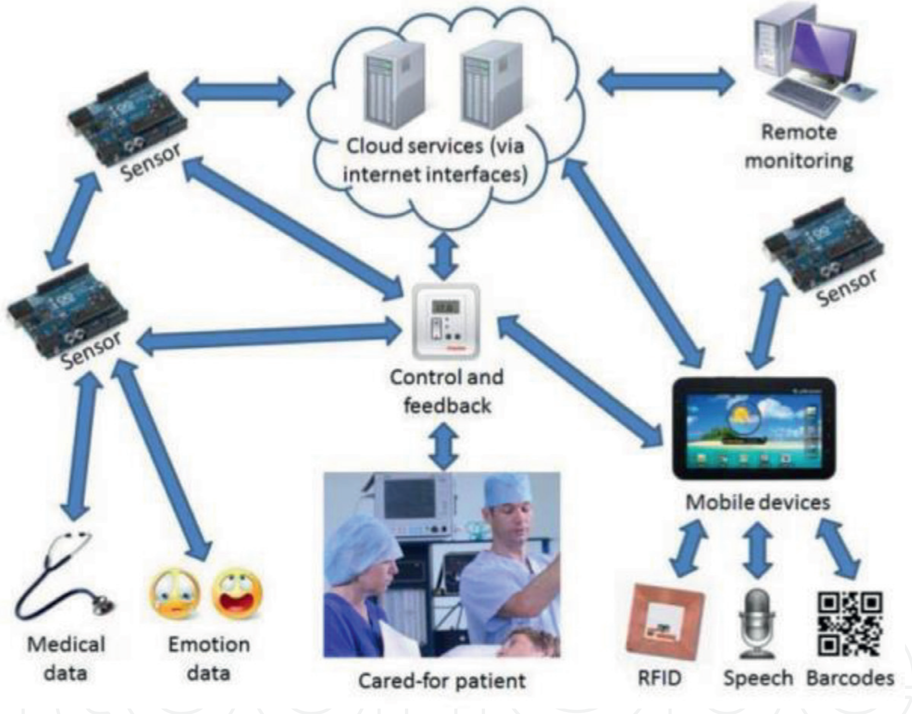

Figure 8.
Model of a typical ICADS [31].

decision support (ICADS) system, which provides an effective basis for rescheduling and prioritising essential services while maximising the effectiveness of the staff in knowing the health status of their patients, planning emergency treatment requirements and providing quality care. Even though this system can produce exciting benefits for the stakeholders of the healthcare industry, several complexities and challenges in hospital settings need to be addressed before implementing ICADS [31]. **Figure 8** summarises this system.

6.3 Datta et al.

Many mobile health applications are still operating offline and are yet to be integrated into the semantic Web technologies for e-Health services [58].

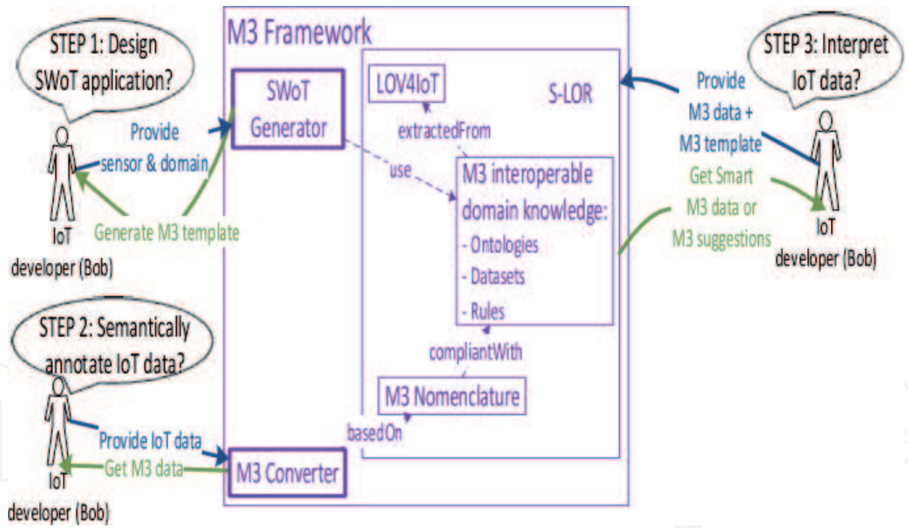

Figure 9.
Operational flow of the M3 framework [58].

Moreover, a unified rationale for developing healthcare development applications and middleware solutions is lacking. Therefore, users must build generic IoT applications to combine several domains. Datta et al. proposed the machine-to-machine (M3) framework, which enables the provision of smart, connected and personalised healthcare and wellness services to people living in smart homes [59]. This framework involves the use of wearable devices that collect patient data, which are then transmitted to smartphones that act as intermediate gateways. These data are then transmitted to remote cloud Web interfaces to maintain end-to-end security. The cloud computing platform is mainly targeted to manage patient data. However, this method does not allow patients to receive a high-level abstraction of the data collected by wearable devices [58]. **Figure 9** summarises this framework.

6.4 Prayoga and Abraham

Prayoga and Abraham iteratively tested, applied, refined and validated the behavioural intention in technology acceptance model (TAM) as one of the most prominent models used in Greater Jakarta to identify those variables that could predict the intention of individuals to utilise IoT health devices and integrate them into a theoretical model [60]. They analysed technology acceptance from the perspective of TAM and used perceived usefulness as the main predictor of behavioural intention. They also proposed a theoretical model to outline some important predictors of the behavioural intention of individuals to use IoT health devices. They performed a questionnaire survey among 186 college students from different faculties to test the hypothesised relationships between factors. As shown in the survey results, 91% of the respondents agreed that health trackers can help them achieve their personal health goals, 89% believed that these devices can change their health patterns and 90% thought that these devices will revolutionise healthcare systems. Although 87% of these respondents had searched for health-related information online while 35% had heard about such technology, only 13% of them had actually used health trackers [60]. **Figure 10** summarises the IoT behavioural intention model.

6.5 Roy et al.

Roy et al. proposed a model that facilitates the adoption of IoT-based innovations in urban poor communities [21]. This model identifies five sources of innovation,

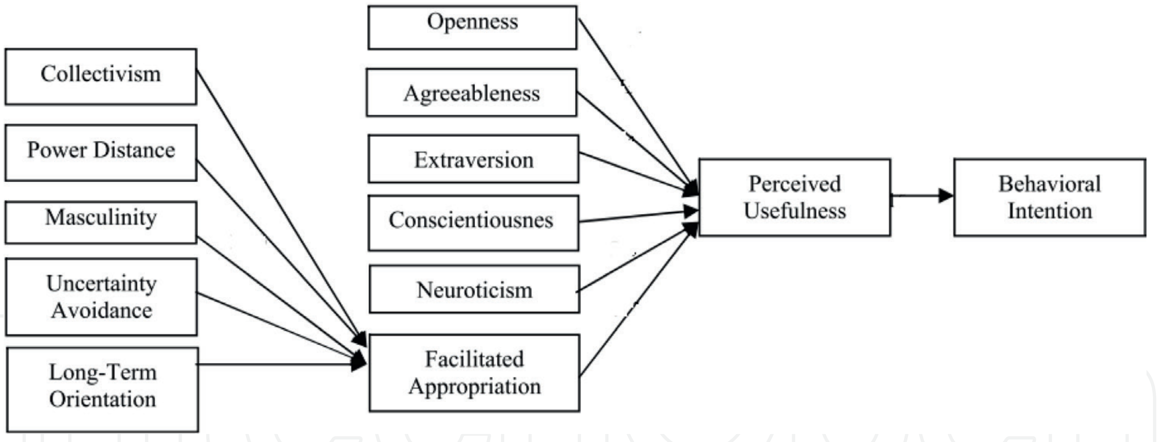

Figure 10.
IoT behavioural intention model [60].

namely, nutrition, healthcare, employment, education and finances. They also argued that IoT can positively affect the urban poor by providing them access to various types of services, including healthcare, education and food security. Their study was conducted in four stages, including a literature review, a survey of the target users, interviews with experts and a usability test of a prototype technology system. They assumed that the implemented system needs to provide quality service to its users and that users should experience tangible benefits and receive some training. These factors can help service providers deliver excellent services to their consumers and subsequently drive a higher consumer satisfaction [21]. This model is summarised in **Figure 11**.

6.6 Jagatheesan et al.

Jagatheesan et al. argued that multiple sensors with various applications from each manufacturer are easily configurable yet are generally not preferred by their users [61]. Therefore, they proposed the multiple producer multiple consumer (MPMC) network that aggregates human interfaces to allow users to control any part of the data distribution framework. This framework includes a scenario where IoT-based multiple sensors are used as producers of data and multiple IoT services are used as consumers of these data. Their findings highlighted how the experiences and perspectives of users affect the data framework design in MPMC environments by using the drop data framework infrastructure. However, this network does not serve the needs of IoT users, and service providers are unable to choose among multiple options and the security or actual data transfer protocols are usually lacking [61]. The MPMC framework is illustrated in **Figure 12**.

6.7 Bui et al.

The researchers investigated a case of a diabetic patient in an emergency situation [29]. They proposed the IoT communication framework as the main enabler of distributed worldwide healthcare applications. The main actors in this model include the monitored patients, physicians and distributed information databases. Their findings contribute to the actual implementation of a comprehensive healthcare system within IoT. They also highlighted the importance of using different devices, networks and processes in analysing diabetes progression. However, this framework is not yet completely available, the components presented in the use case are at different stages of realisation and the proposed framework does not integrate runtime sensing information into healthcare records [29]. This model is summarised in **Figures 13** and **14**.

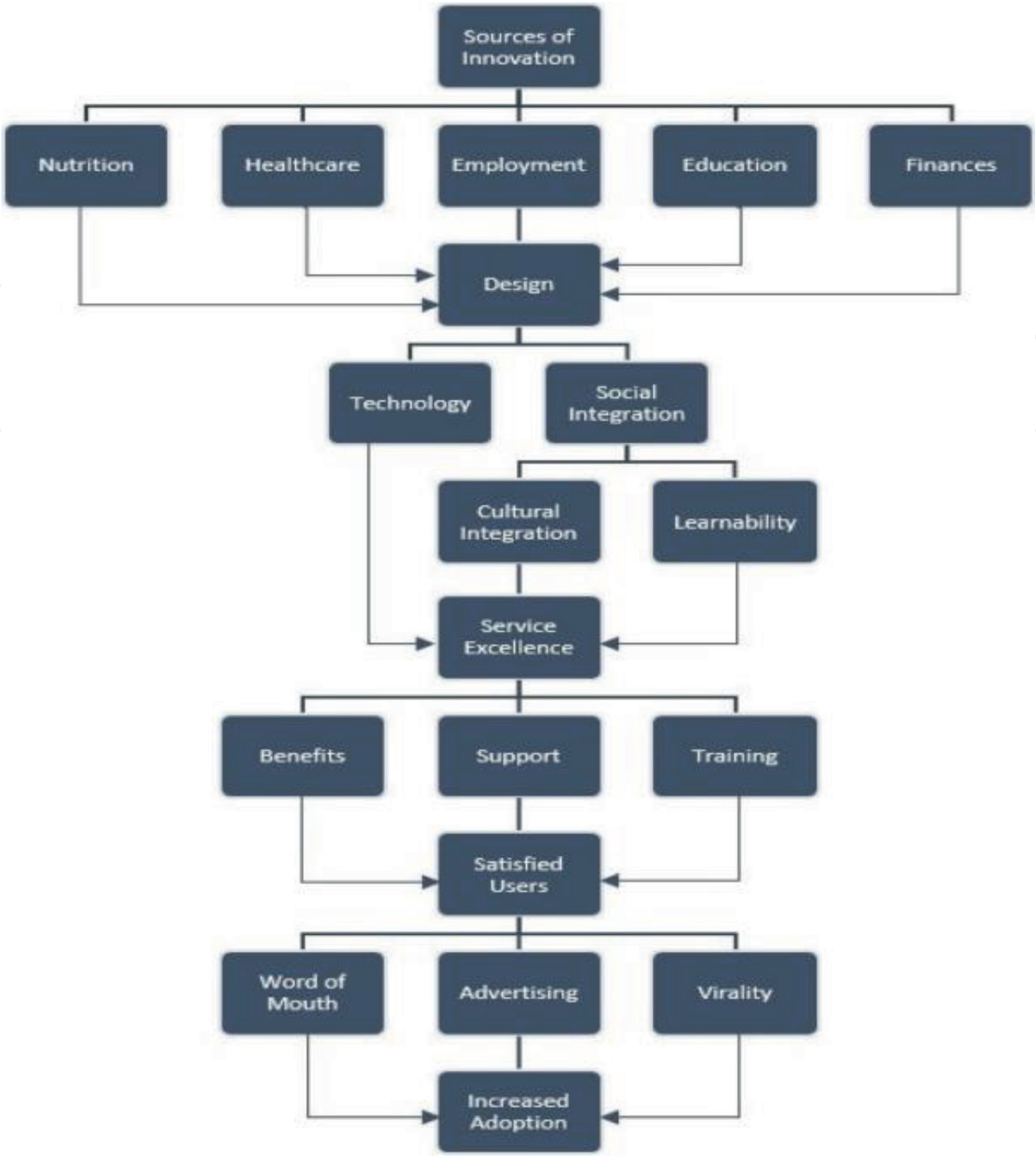

Figure 11.
Model of IoT-based innovations for the urban poor [21].

6.8 Manashty et al.

Manashty et al. aimed to fill the gap between symptoms and diagnosis trend data in order to predict health anomalies accurately and quickly [62]. Not one of the existing systems can act as a bridge between different systems to facilitate knowledge transfer and to enhance their detection and prediction capabilities. These systems are also unable to use the data and knowledge provided by similar systems due to the complexity involved in the data sharing process. Storing information also presents a challenge due to the high volume of data generated by each sensor. Therefore, Manashty et al. proposed the healthcare event aggregation lab (HEAL) model, a platform that provides services to developers and leverages the previously processed data and the corresponding detected symptoms. The proposed architecture is cloud-based and provides services for input sensors, IoT devices and context providers. The HEAL platform is an integrated system for high-level behaviour monitoring that supports many users and systems in their long-term analysis, thereby bridging the gap among many systems. However, Manashty et al. did not

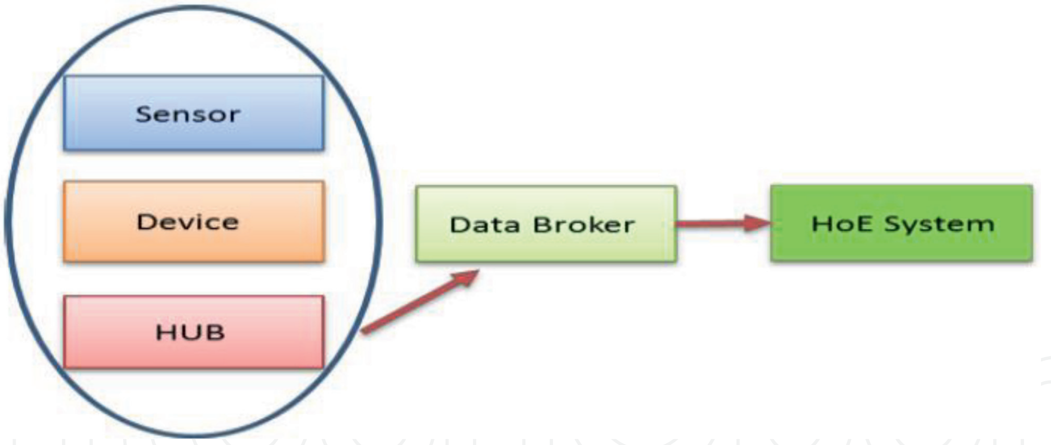

Figure 12.
MPMC framework [61].

Figure 13.
IoT e-Health system model [29].

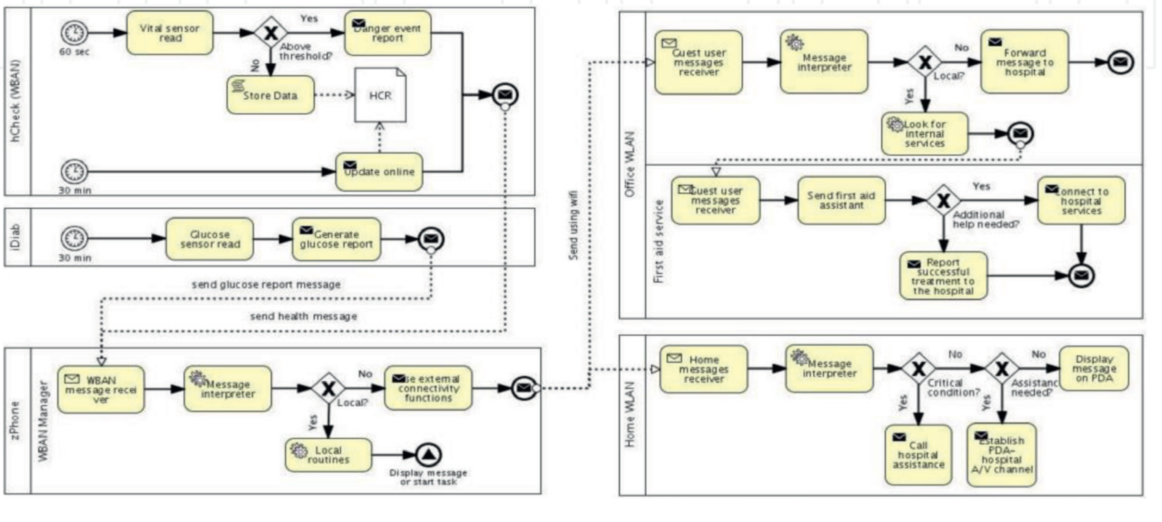

Figure 14.
IoT e-Health process model [29].

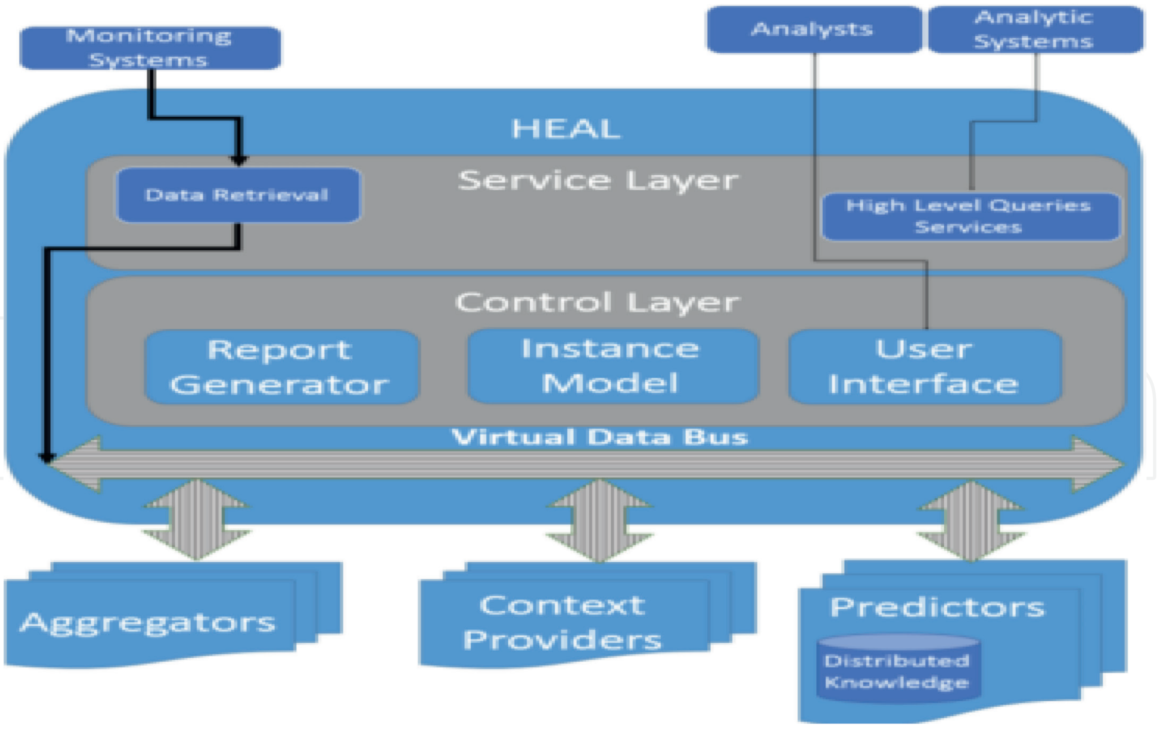

Figure 15.
Cloud-based HEAL platform model [62].

perform multiple case studies to evaluate the performance of the proposed system in complex heterogeneous scenarios with knowledge sharing [62]. This model is summarised in **Figure 15**.

6.9 Sheriff et al.

Sheriff et al. proposed a reference framework for healthcare informatics and analytics by integrating IoT, complex event processing (CEP) and big data analytics [63]. This framework can serve as a reference in implementing a holistic healthcare informatics and analytics ecosystem. Integrating IoT, CEP and big data analytics technologies can solve specific problems. Specifically, CEP can support the real-time and near-real-time analytical processing of patient events from different sources by using big data and ubiquitous communication via IoT. In the future, Sheriff et al. are planning to use this framework as a foundation for developing a healthcare application system that can address the informatics and analytic needs of healthcare and other dependent industries. However, they did not test the performance of this framework [63]. This framework is illustrated in **Figure 16**.

6.10 Pir et al.

Pir et al. developed the HMIS framework with context awareness for developing the management systems of smart hospitals based on IoT [64]. They introduced context awareness as a middleware of the IoT architecture to overcome the problems in large data management. This framework consists of three layers, including a physical layer, network layer and application layer. The physical layer, also known as the perception layer, collects data and communicates them to the network layer. The network layer then processes and transmits these data to the application layer. Context awareness, which is located above the network layer as middleware, analyses the data and transfers only the required data to the application layer. Afterwards, the application layer defines the context of the data based on the

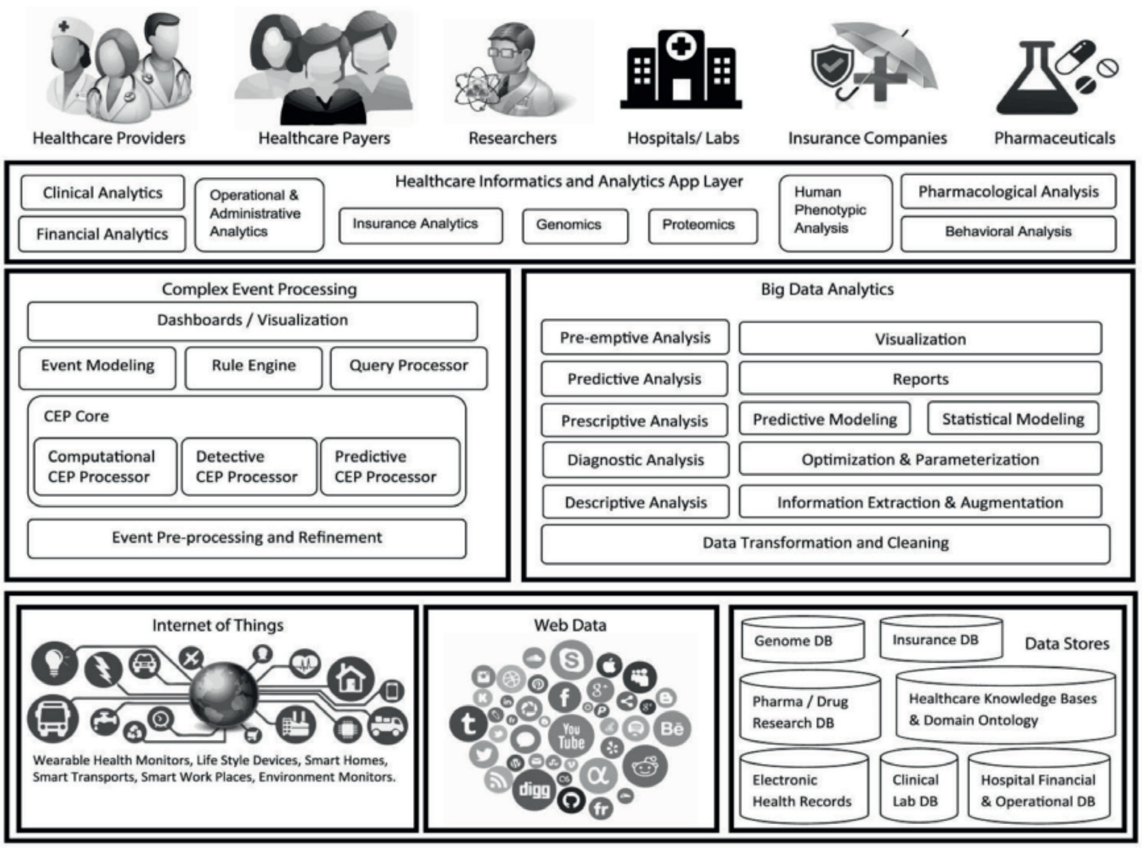

Figure 16.
Reference framework [63].

Figure 17.
HMIS framework [64].

problems faced by users when interacting with the system. However, Pir et al. did not test the applicability of this framework for users from a specific hospital [64]. Their proposed HMIS framework is presented in **Figure 17**.

6.11 Chatterjee and Armentano

Chatterjee and Armentano identified several issues, such as the availability of a live data connection and the security structure of a system, which prompted them to

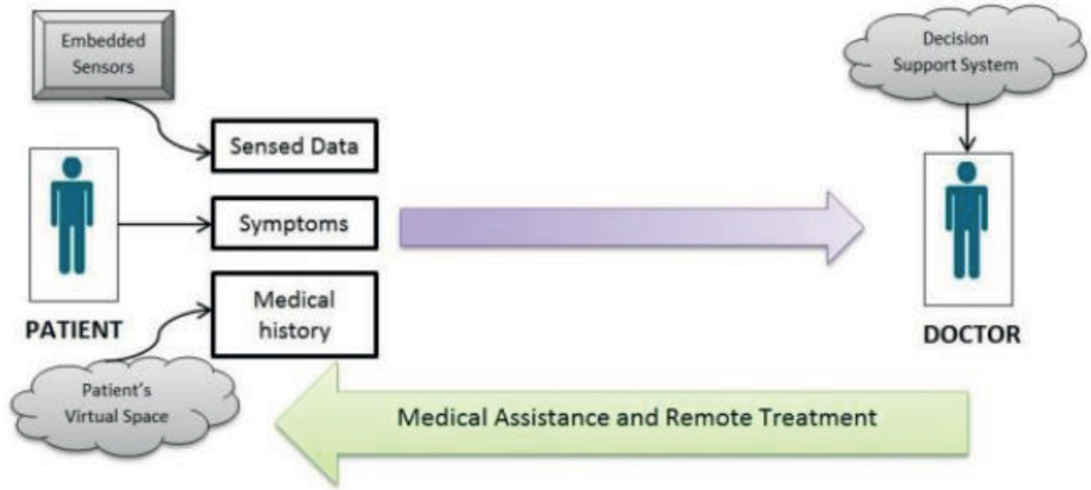

Figure 18.
Schematic diagram of the IoT-based remote treatment model [10].

develop a system for a smart medical environment that provides ubiquitous services [10]. Specifically, they proposed a model with an inclusive approach for applying IoT in a smart medical environment that provides ubiquitous services. This model virtually stores patient data and makes them ubiquitously accessible to the concerned healthcare personnel in order to be shared. Another important aspect of using these data lies in the design of an intelligent clinical decision support system that can help doctors when delivering treatment. However, Chatterjee and Armentano failed to address the requirements for adopting IoT and only focused on the inclusion of technologies in the healthcare sector, thereby limiting the generalisability of the factors that they proposed for different types of hospitals in various countries [10]. The schematic diagram of their IoT-based remote treatment model is summarised in **Figure 18**.

6.12 Gupta et al.

Gupta et al. examined the design and implementation of an IoT-based health monitoring system for emergency medical services [65]. This system demonstrates the flexible collection, integration and interoperation of IoT data that can provide support to emergency medical services. Their proposed model allows users to improve health-related risks and reduce healthcare costs by collecting, recording, analysing and sharing large amounts of data in real time. This system uses smart sensors that collect and send raw data to a database server where they are further analysed and statistically maintained to be used by medical experts. The results are deployed and tested on a patient whose personal details are inputted into a Web portal. This patient is then connected to a health monitoring system that includes a heart rate sensor and a temperature sensor. However, Gupta et al. did not consider in their work some factors in the organisational and system domain as identified in the literature review. They also did not consider the actual examination of healthcare professionals [65]. The proposed health monitoring system is illustrated in **Figure 19**.

The aforementioned models/framework for IoT use in healthcare can be classified based on the technological, system and individual aspects as summarised in **Table 2**.

In sum, most studies on IoT use in healthcare have some limitations related to their context of use, antecedents of implementation and need of use. Moreover, these studies have only focused on specific domains to achieve certain needs for using IoT in the healthcare context. Their models/frameworks are only designed for certain circumstances and environments related to the context and needs for which they are developed. Meanwhile, very few researchers have examined the actual

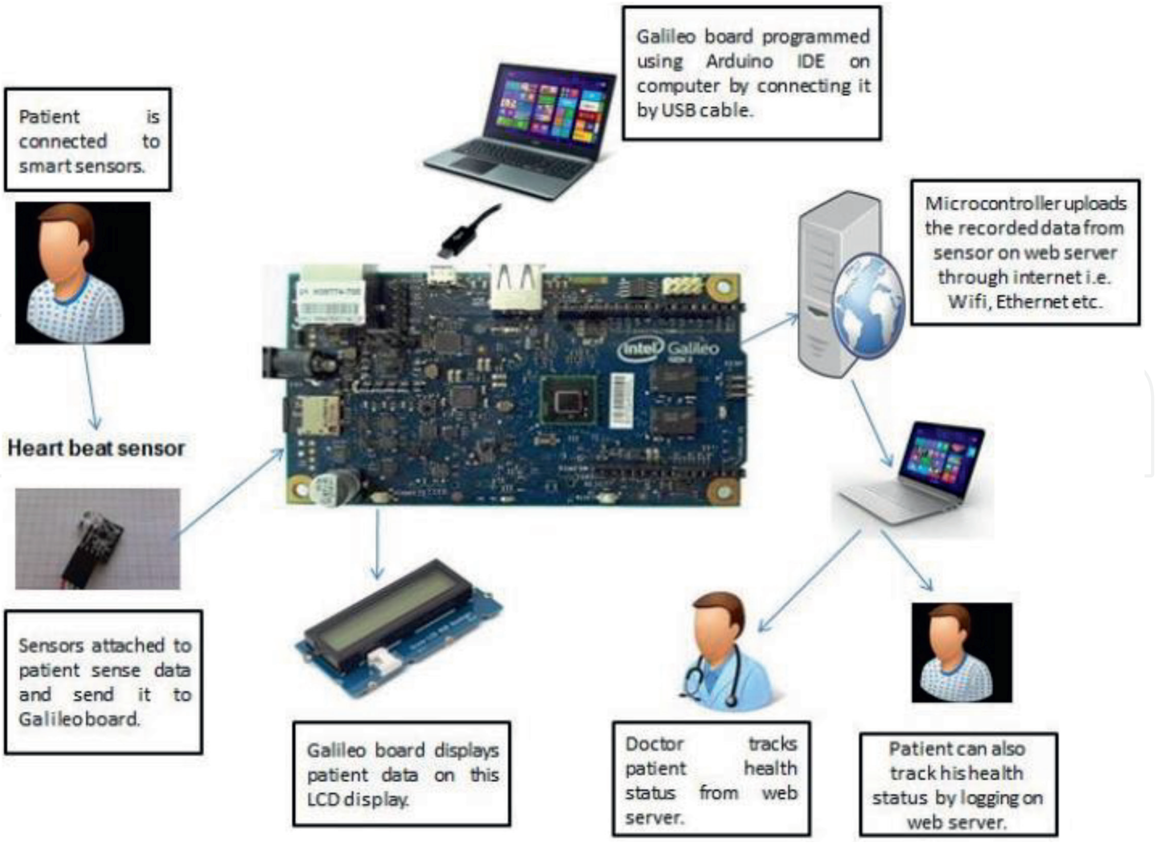

Figure 19.
IoT-based smart healthcare kit model [65].

Source	Technological	System	Individual	Context
[56]	x			Healthcare-based cloud computing network
[31]	x			Intelligent support system in hospitals
[58]	x	x		Healthcare in smart homes
[60]		x	x	Behaviour of using IoT health devices
[21]	x			Use of IoT in urban poor communities
[61]	x			Controlling via a human interface system
[24]	x			Monitoring via smartphones
[62]		x		Knowledge-based healthcare system
[29]		x		Healthcare application process
[63]	x	x		Healthcare informatics and analytics
[64]	x	x		Context awareness
[10]		x		Remote treatment
[65]		x		Healthcare monitoring

Table 2.
Models/frameworks for IoT use in healthcare.

implementation of IoT in hospitals. Therefore, further study must be conducted to generalise the application of these frameworks for hospitals. The literature review shows that the direct effect of technological and system-related factors on the utilisation behaviour of individuals has received no to limited input from previous research. The limitations of the aforementioned frameworks/models are summarised in **Table 3**.

No.	Source	Limitation
1	[29]	Requires the availability of several elements, including interoperability, reliability, privacy, authentication and integrity for exchanging EHRs across the network.
2	[31]	The system should identify the patients' conditions and notify the responsible staff who then review if the case of a patient needs to be treated as an emergency case depending on the information collected by sensors. Hospitals are facing several challenges in their implementation of IoT that should be acknowledged when designing an ICADS system.
3	[58]	This model focuses on smart home healthcare and the data collected from individuals must be managed and stored by decision makers in hospitals.
4	[61]	This study did not examine the requirements of IoT users and some issues related to data security transfer protocols.
5	[63]	This framework only focuses on the health information scenario and ignores those critical issues and challenges that may be faced by healthcare professionals.
6	[56]	Despite offering the benefits of trust and privacy to healthcare providers, several issues related to security remain unaddressed. This model needs to improve its security and test its results.
7	[60]	Model behavioural intention has been tested, applied, refined and validated many times in TAM to identify those variables that can predict the intention of individuals to use IoT health devices and integrate them into a theoretical model.
8	[21]	This model focuses on the use of IoT in urban poor communities, which is not considered part of a healthcare context.
9	[24]	This model focuses on the collection and uploading of health data by using smartphones as part of personal monitoring. The full utilisation of IoT has not been taken in consideration in this model.
10	[62]	Multiple case studies are not performed to assess the performance of the actual system in complex heterogeneous scenarios with knowledge sharing.
11	[64]	These results may satisfy certain hospitals in which no testing is performed in order to address the issues that they are facing.
12	[10]	This model only focuses on the inclusion of technologies in the health sector. Moreover, no experimental study has been performed, thereby limiting the generalisability of the proposed factors for different types of hospitals in various countries.
13	[65]	Those factors identified in the previous literature have not been considered and no actual examination of healthcare professionals has been performed.

Table 3.
Limitations of models/frameworks for IoT use in healthcare.

7. Conclusion

IoT use has become an urgent need for public hospitals and their technical and management activities. A successful IoT use is influenced by how well this technology fulfils the expectations of its users. The implementers of this technology must identify the implementation requirements from the management's perspective and align the implementation with the goals of hospitals in order to ensure a successful implementation and utilisation. **Table 3** shows that most studies on IoT use in healthcare have some limitations related to their identified factors as well as their context and purpose of use. These factors are also limited to certain developed and developing countries. In addition, the actual use of IoT in HIE has never been reviewed in the literature.

Specifically, some models and frameworks have been designed only for specific contexts, circumstances and environments. Meanwhile, other scholars have merely proposed models/frameworks without any post examination or evaluation, thereby making these models/frameworks unsuitable for examining IoT use in HIE for different reasons. These studies also do not focus on the HIE context and ignore the organisational, technological and individual aspects. Some of the proposed models have merely focused on security and privacy concerns and ignored all the other aspects related to organisational and technological issues. Very few studies have examined e-Health and m-Health architectures that use smartphone sensors and wearable devices to sense and transmit important patient data.

As a summary, this chapter shows that a model/framework specifically for IoT use in HIE is yet to be developed and that only few studies have examined the use of IoT in this type of exchange. However, most of the extant studies have identified HIE as a huge challenge for most countries and that the HIE among healthcare providers is very limited at present.

This study was motivated by the gaps in the literature and several issues related to HIE, including the limited capabilities of clinical centres and the perceived need for early detection. Another concern related to the interoperability of various smart electronic devices has also been raised. The findings presented in this chapter offer a foundation for future work on this topic. Proposing a process or framework may also be considered in future research from the perspectives of healthcare providers and management to offer solutions for the development of successful IoT services in the health sector.

This finding offers a foundation for further researchers in several ways. The success factors and proposed IoT implementation process identified and revealed in this study may be considered in future research from perspectives of healthcare providers and management, and thus offer a solution to develop successful IoT services in the health sector.

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