Assessment on Different IoT-Based Healthcare Services and Applications

Rashi Rastogi and Mamta Bansal

Abstract The Internet of things (IoT) is the most advanced IT technology. All industries are attempting to capitalise on the benefits of this technology by incorporating it into their operations. The most common application area that has seen the benefits of implementing this technology and is benefiting greatly from its evolution is healthcare. This paper provides an analysis of services, software, and methodologies established on the foundation of IoT for the healthcare system, known as the Internet of health things (IoHT). IoT is heavily overlapping with the healthcare industry, transforming it into a smarter healthcare system. This paper attempts to perform a systematic assessment on various existing IoT-reliant healthcare systems based on parameters such as application area, hardware software requirements, and algorithms used. We present the IoT healthcare architecture, various healthcare services, applications, and different technologies in detail. Furthermore, future perspective challenges have been discussed.

Keywords Internet of things · Internet of health things (IoHT) · Healthcare system · Disease and monitoring

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1 Introduction

Over the years, the medical management industry has showcased instant development and has been a foremost contributor to profit and business. In recent years, the healthcare revolution has shown fast growth and has been a major contributor to revenue and employment [1]. A couple of years back, the analysis of illness and deviations in human anatomy was only practicable after having a physical examination in a hospital. On the whole, convalescents had to linger in the health centre throughout their course of medication. The leading edge that has been attained over time has now authorised the identification of numerous ailments and keeps track of health using miniaturised tools like smart watches. Furthermore, automation has transformed hospital-centric medical management into a patient-centric organisation [2]. For instance, quite a few medical examinations (like blood glucose level, blood pressure count, pO_2 level, etc.) can be carried out at home without the assistance of a healthcare executive. Further, medical facts can be passed on to healthcare centres from rural areas using modern telecommunication facilities [3].

IoT has increased self-sufficiency while also varying the human's ability to connect with the external environment. IoT, by means of advanced mechanisms and processes, has grown into a leading provider of international engagement. It links a huge number of appliances, wireless sensors, home appliances, and electronic gadgets to the Internet. The implementation of IoT can be done in the fields of agriculture, automobiles, homes, and healthcare. The flourishing demand of the IoT is due to its dominance in presenting higher accuracy, lower cost, and its capability to anticipate forthcoming events in an efficient way. Furthermore, improved understanding of operating systems and applications, as well as improved mechanisation of mobile and computers, easy accessibility of Wi-Fi mechanisation, and improved Internet economy, has all contributed to the rapid revolt of IoT. The IoT gadgets (sensors, actuators, and so on) have been united with other substantial gadgets to record and interchange data by utilising the distinct communication conventions such as Bluetooth, ZigBee, IEEE (Wi-Fi), and so on [4]. In medical management applications, sensors either implanted or wearable on the human body are utilised to gather mental data like warmth, pressure rate, electrocardiogram (ECG), electroencephalogram (EEG), and many more like that from the patient's anatomy [5]. In addition, ecological data, namely temperature, humidity, date, and time, can also be reported. Collected statistics can be useful in creating substantial and accurate reasoning about the health issues of patients. Because a large number of facts are obtained from a variety of sources (sensors, mobile phones, e-mail, software, and applications), fact retention and ease of access play an important role in the IoT system. The details of the above-stated sensing instruments are put forward to doctors, caretakers, and approved associations [6]. The sharing of the aforementioned information with wellness programme providers via cloud/server allows for quick analysis of patients and medical intervention if necessary. The mutual support between the users, patients, and linked coursework is kept in existence for efficient and reliable communication. In particular, IoT structure makes use of a user's configuration that performs as a progress report for medical caregivers and brings off user authority, data visualisation, and trepidation [7].

Many countries have accepted the latest machinery and courses of action, making the most of the functional ability of IoT in medical management structures. This changed the existing investigation in the medical management structure into an overly encouraging field to walk around in. Numerous nations have implemented new infrastructure and regulations to increase the usefulness of IoT in healthcare delivery. Due to this, healthcare research is now a more fruitful area of study.

1.1 IoT-Based Healthcare System Architecture

There have been many studies conducted for the framing and crafting of what the architecture of H-IoT should look like. One such five-stage framework is illustrated in Fig. 1 [8].

(i) *Physiological Sensor:* The projected architecture begins with physiological sagacity. In this phase, sensing of a variety of physiological actions and constraint by a refined electrophysiological sensor like pulsation velocity, body warmth, blood force, ECG, EEG, EMG, respiration pace, etc. The improvement of a flourishing IOT-supported healthcare system works on the basis of the physiological sensor.

(ii) *Processing and controlling:* Data that is pre-acquired through sensors and processed by the use of a microcontroller or processing unit is initially processed. Single-circuit integrated, small, and self-contained computers are called microcontroller boards with memory and a range of secondary devices

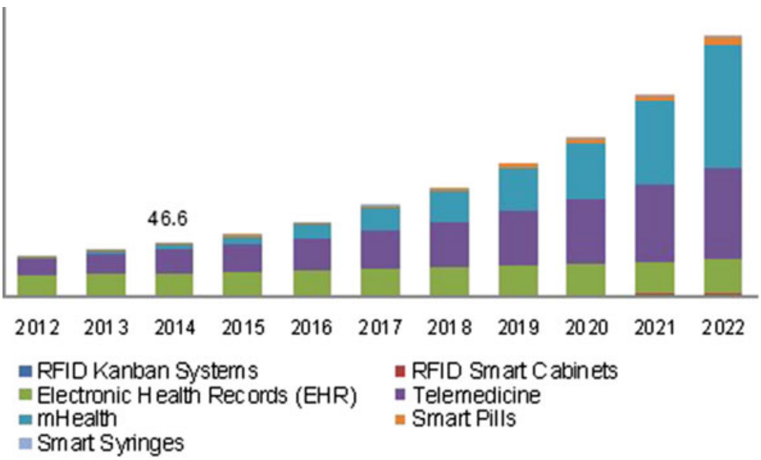


Fig. 1 Five-stage IoT-based smart healthcare system [11]

for input and output roles. Even with a restricted range of functions and power, it is eligible to carry out a variety of functions that are sovereign rational and arithmetical [9].

(iii) *Communication and transmission:* Union of the network to the applications is only possible through IoT's foundation, which is communication technology, enabling the coupled devices to transport information over the set of connections. The exchange of information among systems and devices configured in the healthcare setup is also done with the same medium. IoT's application and services identification can be short-range communications or long-range communications.

(iv) *Storage and computing:* It is an important aspect of the IoT healthcare device in terms of pre-attained data from the sensor. An on-demand facility and a great deal of space are provided by cloud computing. The information of each patient is required to be stored in order to re-access it as and when the patient re-visits the healthcare station, and subsequently, the information needs regular updating on every visit.

(v) *Data analytics and decision support system:* Once collected through sensors from patients, physiology-based data must be kept safe in order to be used in the future [10].

1.2 Contribution of Paper

The purpose of this paper is to provide a comprehensive review of the technologies, services, and applications that make the Internet of things possible in the healthcare sector and to summarise the progress of state-of-the-art studies in this field. Figure 2 depicts the rate of growth of the worldwide smart healthcare market from 2012 to 2022 [12].

1.3 Classification of Smart Healthcare System

The healthcare system is characterised as a conservative healthcare arrangement and a smart healthcare system, which aims at supporting and supplementing the systems that were followed traditionally in terms of ambient assisted living, remote healthcare systems, wearable healthcare systems, and smart phone-based healthcare systems. The intelligence and advancement are evident through IoT-based SHCS as all the systems are inter-linked and advanced medical techniques collect data and thereafter forward it to the cloud, where eventually, the data can be reached out to from any place, anytime. The experts in these fields no longer make personal visits to the patients and facilitate remote diagnosis and trace assets of medicine [13]. Figure 3 depicts the categorization of smart healthcare services. The full forms of used terms are as follows:

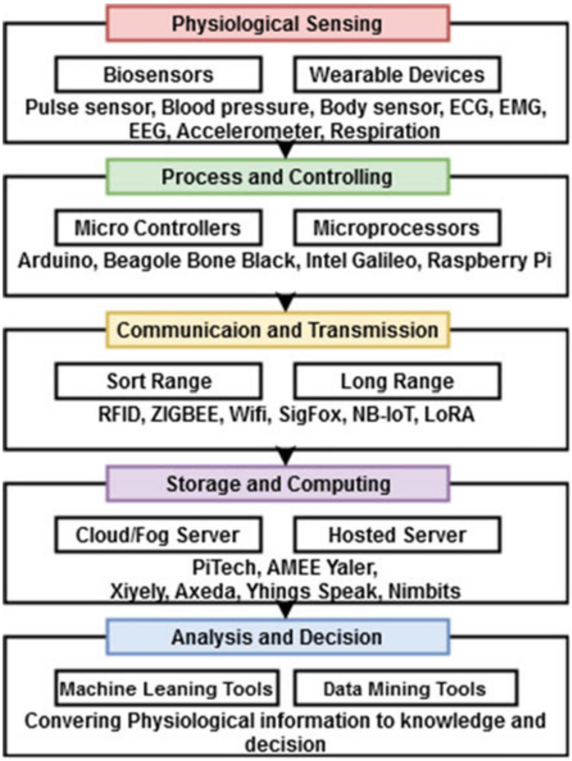


Fig. 2 Smart healthcare system based on the product [12]

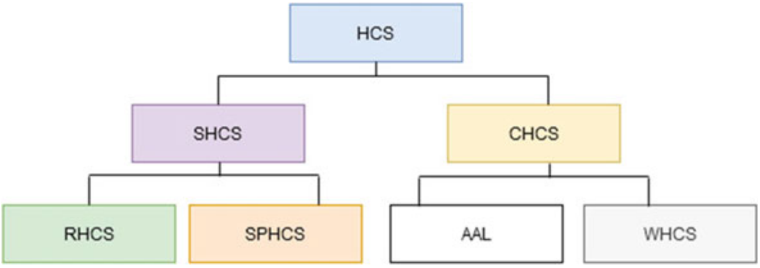


Fig. 3 Categorization of smart healthcare services [13]

HCS: Healthcare system
SHCS: Smart healthcare system
CHCS stands for conventional healthcare system
RHCS stands for remote healthcare system

SPHCS stands for smart phone healthcare system
ambient-assisted living
WHCS: Wearable healthcare system

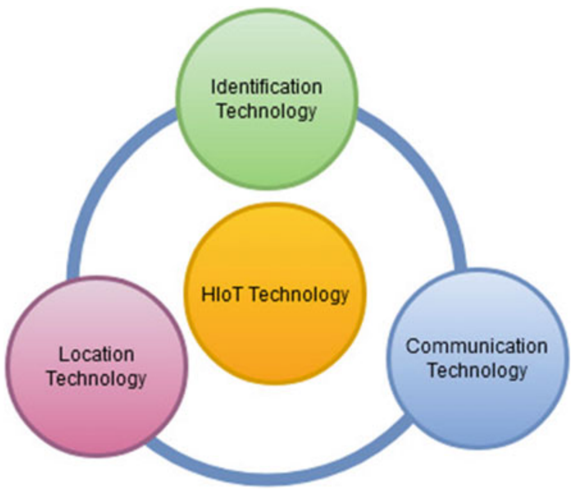
Real-time information is conveyed to experts of the domain from a remote location with the help of multiple updated and advanced communication technologies. As the name designates, SPHCS employs a smart phone and smart applications for patient health monitoring either in a hospital setting or in home surroundings [14]. The goal of the individual healthcare system is to develop the self-rule of elderly, disabled, or incapacitated people in their space of living by providing services as a personal assistant [15].

1.4 IoT Technologies

It is not an easy task to integrate two entirely different domains to draw out the best outcome for both the chosen fields. Collaborating IoT with healthcare was too much of a tough nut to crack [16]. It required the adoption of multiple technologies to achieve the targeted outcome. The development of H-IoT is extremely complex, as this particular path of development flourishes the capability and efficiency of IoT. Such skills can roughly be characterised into three sets, namely identification, communication, and location technology [17]. Figure 4 depicts the technologies used in the healthcare system [18].

(i) *Identification Technology*: The work begins with the identification of sensors placed and allocated in the areas that are remote and distant from one another. It is basically the criteria to access the patients' information through a sanctioned

Fig. 4 IoHT technologies [18]



node. It is then followed by the allotment of a UID to each of the sanctioned authorised sensors so as to ease the process of identification and thereafter assist the exchange of unmistakable data.

(ii) *Communication Technology*: Technologies under this category support and facilitate smooth links between the various bodies involved in the H-IoT set of connections. There are two distinct types that we can divide this kind of technology into; namely short-range and medium-range communication technologies. Short-range ones are utilised to access links between objects in a restricted space or body area network. However, the other category assists communication over wider ranges, say the one between a station of base and a BAN's central sensor. In the case of short-range, the range can range from a few centimetres to a few metres.

(iii) *Location Technology*: The healthcare sector too has multiple bodies spread over different domains. Real-time location systems or location technologies are what help to judge and relocate the placement of something considered under the range of healthcare's set of connections and also serve as a support system for tracking the stage at which the treatment plan lies along with ascertaining the availability of resources at hand. The global positioning system is one such technology used in this specific domain, which takes the support of satellites to track specific things. But its applicability is possible as long as the object, and the four distinct satellites have a clear line of sight between them. It can be put to use to track the position of mobile healthcare services like ambulances, patients, or caregivers on their way to healthcare centres.

2 Services and Application of IoT

2.1 Services

There are many services being added on daily basis that add to the development of healthcare which has turned the tables upside down in regard to the solutions for the existing variety of problems. With the uplift in the demand, these all now have an essential role to play in entire H-IoT framework. Each and every service that relates to this domain brings to the forefront a big deal of healthcare solutions along with them [19].

(i) *Ambien-Assisted Living*: Not every aged person has someone to look after them, and, in that case, AAL serves the purpose right. It is a branch of IoT integrated with AI to assist ageing people. It works to make sure that elderly too have some independence in the premises of their homes so as to live in the way they want along with concerning about the safety and comfort too. It avails the elderly with real-time monitoring technique to ensure human-like serving assistance at the times of emergency.

(ii) *Mobile IoT*: It is now not always necessary to move physically to a healthcare centre to register for an appointment or wait for longer hours to get access of the service. Introduction of M-IoT has eradicated all such hindrances, and the healthcare officials can now get an access to the patients' information through the online data mode where the patient has already added all the required details.

(iii) *Wearable Devices*: Nowadays, many of the health assessments can be done through a device tied to the wrist of an individual. The innovation has made it possible. The sensors so attached to these devices are the ones that collect the information and ease the process of data collection. The collected data is influenced by the environment and the health conditions of the patients. The information so collected is then uploaded on the healthcare servers for further use. Some devices also avail connectivity to mobile phones as well, and the cost of healthcare is hence reduced to a great extent.

(iv) *Community-Based Healthcare Services*: In this domain of healthcare-based on IoT; the operations and the services are carried out and rendered to specific set of people or a group belonging to a particular community. It might also be based upon some confined areas of a city or town say a tiny area of residence, a hotel or so. The administrating medical experts at such centres or such networks are supposed to judge and take care of the people coming under their area of work. Multiple set of connections work together in this type of service to provide better services.

(v) *Cognitive Computing*: In this field of study and eventually practice; the system sensors are framed and formulated so as to replicate the processing of a human brain. The sensors so installed work in a way to first analyse the problem and then imitate the way a human brain works to resolve a problem and come out with possible solutions. With the advanced sensors and AI; it is possible to draw out conclusions or solutions from a complex and large set of healthcare data. Cognitive computing enhances the functioning in the further steps and corresponds effectively to the surroundings.

(vi) *Adverse Drug Reaction*: Every human body reacts differently to a certain drug or medication. In case of overdose or even when two medicines are taken at the same time; the effect can be noticed and is evaluated in terms of adverse drug reaction. This reaction can be observed in one go or even might take some regular intakes of doses to reflect the side effects of medicine taken. ADR does not rely upon the kind of medicine or even the ailment it has been taken for, but it does vary according to every different person. In this particular type of service; to ascertain each prescribed medicine for a patients' terminal; a distinctive bar code is brought into practical implication.

(vii) *Blockchain*: Anything that is available in fragments cannot yield an outcome that is reliable. Thus, in the field of healthcare as well; the need for secured and complete transfer of patient information between entities involved in the process of care-giving is immensely high. The issue of broken or fragmented information across the domains of healthcare can lead to delayed or inappropriate treatment given to the patient. Blockchain assists to remove such barriers and create a link amongst the present data storeroom of the network.

2.2 Applications

(i) *ECG Monitoring*. It is a system that allocates the abnormalities in the functioning of the heart by evaluating the rate at which the heart muscles rhyme. It denotes the activity of heart in electrical format that is caused because of atria and ventricles' repolarisation and depolarization.

(ii) *Glucose Level Monitoring*. Amongst many other diseases existing among humans, diabetes is the most common one. The monitoring of level of glucose in the blood is done in case when the same sustains at a higher level for an elongated duration of time and the condition so formed is called diabetes. Type-I, type-2, and gestational diabetes are the commonly found types.

(iii) *Temperature Monitoring*. The first thing that a patient's condition is accessed upon is the temperature of the human body as it is indicative of preservation of homeostasis. It is an integral part of numerous investigative procedures. The doctors keep a regular check of the ups and downs in patient's body temperature to draw conclusions and make decisions on the health of the patient and provide the required treatment thereafter. It can be a warning sign in a few sicknesses like sepsis, trauma, and more like that.

(iv) *Blood Pressure Monitoring*. The evaluation of the pressure of blood in human body has become one basic step whenever a patient visits a doctor no matter what illness he/she is there for. The advancements in the IoT applications have brought a revolution in the way blood pressure is evaluated now as compared to the way it was done in the past. It is supposed to be accessed in a way where at least a person records it for the patient.

(v) *Oxygen Saturation Monitoring*. An essential parameter to be accessed while judging the overall health status of a patient is to see where the level of oxygen of the patient actually lies in medical terms. In healthcare diagnosis, it has become an important thing to analyse as it works on the basis of real-time monitoring and eradicates the traditionally existing issues in its evaluation process. The development of IoT devices related to this domain has accelerated its potential application in the field of medicine.

(vi) *Asthma Monitoring*: It is about monitoring the persistent difficulty in breathing and other issues that might hinder the airways; commonly termed as asthma. The windpipe might face shrinkage due to swelling at that specific area. The health issues that co-exist with this condition can include breath shortness, pain in the chest, continued cough, and many such. We still cannot be predictable about the time a patient might suffer from an asthma attack and the only solution we have at hand for this is the nebulizer or the inhalers meant for the same.

(vii) *Mood Monitoring*: Mood tracking provides vital information regarding a person's emotional state and is used to maintain a healthy mental state. It also assists healthcare professionals while dealing with various mental diseases such as depression, stress, bipolar disorder, and so on.

(viii) *Medication Management*: The elderly usually ignores the suggested medication due to several reasons. They might forget about it as per ageing effect or even might neglect deliberately. But, faithfulness towards the medicines being allocated by the doctors as a part of the treatment plan is highly recommended or else the illness may sustain for a longer duration or even might turn out to be more risky to the health of the individual. Medicines should not be missed by person of any age if he or she is under any medical treatment.

(ix) *Wheelchair Management*: IoT developments are now centred towards a new field of medical science that might prove out to be a boon to those with disability in moving and particularly the ones that are a result of brain damage. Wheelchair becomes an essential one for a patient with disability as it helps the patient to feel bit boundless mentally and physically too. But, a normal wheelchair cannot serve the purpose entirely in case of disability caused by damage in brain functioning so the above mention advancement needs to be paced up to ensure the achievement of this goal.

(x) *Rehabilitation System*: The solicitation of IoT rehabilitation is evident in many domains like while treating cancer, stroke, and injury caused by sports and few other disabilities too. It is a helping hand to the physical medicines prescribed to the patients as per their ailment. It helps the patients with disability; in restoration of their functional ability. Rehabilitation includes identification of the difficulty and thereafter assisting the patient to gain a normal life all over again.

(xi) *Other Notable Applications*: With the advancements in technology and also the way IoT has grown; its potential application has widened even throughout the fields that initially were untouched by its existence. The H-IoT applications are accelerating every day. Its use is no more restricted to the above-mentioned domains only; rather, it has crossed that line (Fig. 5).

3 Literature Survey

See Table 1.

3.1 *Inferences Drawn from Literature*

In this paper, a literature review of various IoT-based smart healthcare systems from 2018 to 2022 has been presented. The literature survey covers the applications, services, and technologies used for smart healthcare systems. The authors proposed

Fig. 5 Application of IoT [19]

various solutions such as HIDS and IoMRT. They analysed prose mechanisms using UCI datasets. Some researchers have proposed IoMT-based architectures.

4 Challenges, Limitations, and Future Scope

(i) *Servicing and Maintenance Cost*: Upgradation indeed is necessary for everything that we are surrounded with and so is the case with H-IoT-based devices. Belatedly, there are swift hi-tech progressions in this field that ask for the same every now and then. This system like any other system demands a great deal of maintenance, updating, servicing, and cost to be invested upon it to ensure required changes. The cost thus falls upon both the entities including the providers and the users of the particular apparatus. Setups that call for a low maintenance are highly preferable as the complete IoT system is network of multiple inter-linked sensors and devices. So as to keep the costs from crossing the budget line, it is required to keep a check on it [37].

Table 1 Existing techniques

Ianculescu et al. [20]	2018	Explained the use of several 'smart' products used for the detection and treatment of skin-related diseases
Ud Din et al. [21]	2019	Designed 5-layered architecture for IoT systems comprising of several components of IoT
Baig et al. [22]	2019	Review undertaken that presents development in wearable technology, the limitations, and challenges associated with wearable devices
Bhawiyuga et al. [23]	2019	Recommended an IoT system architecture that incorporates a middleware that functions as a bridge between wearable devices and cloud platform
Boulos et al. [24]	2019	Built up a model called geo AI that merges AI and geographic information of patients to provide better solutions in several healthcare segments
Darwish et al. [25]	2019	Developed an IoT cloud assimilation platform to healthcare, and analysed the associated issues and challenges
Das et al. [26]	2019	Developed a framework that is useful specifically for visually challenged patients using IoMT
Deshpande et al. [27]	2019	Carried out a detailed analysis of various tools and techniques used to analyse the data generated via 'smart devices' for decision-making purposes
Dhanvijay and Patil [28]	2019	Proposed real-time monitoring system and architectural framework for H-IoT
Dwivedi et al. [29]	2019	Proposed IoT topology and a conceptual model to tackle risks to the confidentiality and privacy of clinical data using hybrid technology
Guntur et al. [30]	2019	Proposed a conceptual paradigm, called IoMRT, which uses healthcare robotics. Analyse the subject and challenges concerned with the same
Yoon [31]	2019	Described the worth of using blockchain technology in healthcare sector
Koshimizu et al. [32]	2020	Developed a model that uses deep neural network to variation of blood pressure and predict the progress of the disease
Arulanthu and Perumal [33]	2020	Built OMDSS for the prediction of CKD by using classifier techniques to provide efficient healthcare and evaluated the performance of different classifier techniques using UCI dataset
Javaid and Khan [34]	2021	Studied various IoT technologies that were beneficial in COVIDpandemic
Johri et al. [35]	2022	People's understanding of skin disorders, awareness of IoT-based smart skin monitoring systems, and awareness of the benefits of adopting IoT-based smart skin monitoring systems were all critically examined. The study employs a quantitative technique
Saif et al. [36]	2022	Offers a hybrid intelligent intrusion detection system (HIIDS) based on machine learning and metaheuristic algorithms for Internet of things-based applications such as healthcare

(ii) *Power Consumption*: Self-power generating setups are the ones that sciences are looking forward to. The count of medical devices that work on batteries is very high. Each one needs battery to work. As and when a sensor is turned on it is highly restricted to not to make any alterations in the battery. So, to let such systems work efficiently batteries that are high on power were installed. Energy breeding systems that are renewable to the core can be an option. The problem of global warming can be dealt with this proposed solution.

(iii) *Standardisation*: Authenticity in the medical field is the first and foremost priority for the operators and also to those at the receiving end of the service. With a wide range of entities producing health equipment's which allege legitimacy of their produce but end up violating the given norms that they are supposed to follow in terms of the quality, structure, and design. Therefore, it all needs a set of people so committed to make sure that no adulteration takes place in this regard, and maintenance of standard is highly assured through devices that rely upon set of rules of communication, statistics aggregation, and access boundary. The standardisation can be pulled off through formation of cluster of people or organisations that can merge with the experts of research to ensure standardised and validated devices with no lack in its genuineness.

(iv) *Data Privacy and Security*: The way monitoring is done presently which is entirely different from the way it was done in the past. And supposedly, it is an outcome or after-effect of cloud computing. But just like while mining for gold many more impurities too come along in the process; this advancement has also brought along many loopholes for the medical systems [34].

(v) *Scalability.* Everything this world consists of; is supposed to walk hand in hand with the changes that happen around. And, so is the case with IoT. The devices so formed and designed to be used in IoT should inculcate some alterations as per the environment. The resources at hand can be efficiently used if they are adjoined with devices that are scalable. A big list of setups is used; such as sensors, which facilitate transfer of information. It thus makes things sorted for the present along with the future. If a system is low at uniformity, it ends up at less scalability as well; thus, efficient management is essential.

(vi) *Identification.* Exchange of information in terms of identity of all the entities involved in the process of medical assistance is fundamental.

Table 2 exhibition assessment between the formerly programmed papers from the point of application area, detection device, wireless communication technology, HW, and SW desires to control and sustain remote monitoring [38].

5 Conclusion

The current assessment looked into many areas of the H-IoT system. The architecture, components, and inter-component communication of an H-IoT system are discussed in detail. This study also examines current healthcare services that have been explored

Table 2 Comparative analysis between existing systems [38]

System	Application area	Detection device	Wireless communication technology	Algorithm	HW and SW need to operate
Voice pathology monitoring	Automatic voice pathology monitoring	Smart sensors like microphones	Bluetooth and radio access network or 5G wireless technology	Parallel deep learning	Smartphone downloads the app, cloud computing, server, and AlexNet
IAAS	Collision-resistant alarm system for blind, elderly, and patients with eye diseases	Wearable RFID	Radio frequency identification (RFID)	Locally weighted linear regression (LWLR) algorithm	COTS UHF RFID, R420 RFID reader, 8 dBi directional antennas, RFID tags, software
Wearable ECG	Electro-cardiograph monitoring system	Wearable territory of sensors	Bluetooth, 4G LTE, RF, wireless communication	Threshold training algorithm	MCU, ECG, SoC, analogue front end, BLE, cloud
Sensors heart disease mentoring	Heart disease mentoring	Sensors wear in wrist or carried by patients	Bluetooth, GSM, and GPRS, ADSL	Not specified	Blood pressure, ECG, SpO_2 sensors
Diabetes management based on IoT	Self-management of diabetes	Sensors used at regular intervals	GSM network and/or Wi-Fi network, Internet, Bluetooth	Not specified	Blood sugar, weight scale, and blood pressure
Aiding ambient-aided livelihood	Putting off fatness	Sensors attached to the body	Wi-Fi, Internet, Bluetooth	Administered learning	HR sensor, smart watch or smartphone

for potential IoT-based solutions. Internet of things (IoT) technology has helped healthcare professionals monitor and diagnose a wide range of health issues, measure a wide range of health indicators, and provide diagnostic services in previously inaccessible locations, thanks to these ideas. In doing so, it has reorganised the healthcare industry around patients rather than hospitals. We also addressed several H-IoT system applications and their recent trends. After that a comparative analysis of various existing healthcare systems has been presented with different performance parameters such as hardware and software requirements, algorithm, technologies, and application areas. Furthermore, the challenges and issues linked with the design, manufacture, and use of the H-IoT system have been addressed. These challenges will serve as the foundation for future advancement and research focus in the next few years. Furthermore, we present a comparative analysis between existing systems such as diabetes management sensors for health monitoring with various performance parameters.

In the future, it is intended to continue working on it and propose a mechanism to detect diseases in an automatic manner with high accuracy using machine learning.

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