



An empirical investigation into the altering health perspectives in the internet of health things

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Abstract Healthcare is on top of the agenda of all governments in the world as it is related to the well-being of the people. Naturally, this domain has attracted the attention of many researchers globally, who have studied the development of its different phases, including E-Health and the Internet of Health Things (IoHT). In this paper, the difference between the recent concepts of healthcare (E-health, M-Health, S-Health, I-Health, U-Health, and IoHT/IoMT) is analyzed based on the main services, applications, and technologies in each concept. The paper has also studied the latest developments in IoHT, which are linked to existing phases of development. A classification of groups of services and constituents of IoHT, linked to the latest technologies, is also provided. In addition, challenges, and future scope of research in this domain concerning the wellbeing of the people in the face of ongoing COVID-19 and future pandemics are explored.

Keywords IoHT · E-Health · M-Health · S-Health · I-Health · U-Health · IoT · Covid-19

1 Introduction

Throughout the ages and in all societies, the health sector has witnessed a special and great interest in its direct relationship to people's lives and their pain on the one hand, and its impact on all other sectors on the other hand [1]–[4]. What the world witnessed recently with the Corona pandemic [5], greatly affected all aspects of our lives and its fields such as the economy, education, and even the performance of daily tasks and social relations. Nothing can be better than a healthy life without disease, pain, deficiency, or disability. The healthiest societies are the more capable of giving and developing. But these societies still need more work and research in the health field to face future challenges, as the Corona pandemic has shown the inadequacy of the current situation in dealing with such crises [6]–[8].

With the beginnings of the modern digital revolution and the emergence of various communication technologies via the Internet, the health sector witnessed a similar revolution in converting many manual tasks into electronic tasks [2, 9]. Then computers and medical devices appeared that provided additional services, and then the development of Internet speed and the spread of smartphones created a new dimension of mobile medical services [10]. In the last decade, the Internet of Things came, which changed the concepts, and the search for systems and services became more intelligent and adapted to users, at lower costs, and with higher quality and availability [11], especially with its integration with other technologies such as cloud computing [9], fog computing [13], 5G [11], virtual reality [14], to name a few [13, 14].

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There is no standard (unified) definition of the Internet of Things [15, 16], but we can define it as the concept that seeks to transform everything around us into smart things, with an identity, and ability to sense data, share with others, and integrate Machine-to-Machine (M2M) [15]–[17]. Since the elements of the Internet of things are limited in resources (power, storage, and processing or computing capacity) [18], therefore, all Internet of things systems depend on protocols that consume little power, In addition to their reliance on external computing and storage power such as cloud and fog computing models [19]–[22].

Below, Fig. 1 shows a common architecture of the Internet of Things and its basic layers, as well as the most important protocols, tools, and their application fields, with a brief description of the most important applications and their fields [9, 23].

There are two main elements in IoT, first Wireless Sensors Networks (WSNs) [24], second Radio Frequency Identification (RFID) [25] which have a critical role in the IoHT, it collects data about the patient in real-time (RT) and that produce many new smart services such as online treatment, permanent observing, and tele healing. WSNs are a group of different kinds of sensors that measure the physical conditions in the surrounding environment [26]. Recently WSNs became wearable (WBAN) [27, 28] which enables monitoring the human body’s vital metrics continuously [29]. While RFID can identify objects to contact with them, which enables systems to track these objects everywhere [27]–[29].

In this article, we have provided a comparison of different healthcare phases of development, and a classification of various attributes of the IoHT domain is carried out in detail.

Moreover, the challenges and future trends in this domain are streamlined. The remainder of this paper is organized into Sect. 2, a discussion of the history of health phases and concepts, Sect. 3, classifications of various constituents of the IoHT domain, Sect. 4, significance, and challenges, along with the future trend for the research, and Sect. 5, conclusions.

2 Historical development of health phases

In this section, we provide a brief overview of the stages (main milestones) of development the health domain until IoHT (See Fig. 2):

Over the years, the health sector is the most important sector because it is related to people’s lives. It always attracts researchers to employ any new technology to serve medicine to reach a healthier life and be more resistant to diseases [2, 3]. It helps people with special needs or chronic diseases to live a normal life. With the beginnings of the digital revolution, information technology was employed to develop the health sector [2]. Computers, some medical devices, and software systems were provided to automate some tasks in hospitals and medical centers [9]. In addition, web services began to appear, such as reservations, appointments, inquiring about doctors’ information, departments, offers, etc. [10]. All the above is called Electronic Health (E-Health) [30].

With the increase in progress, the number of electronic services increased, and smart phones and tablets began to spread and develop rapidly [7, 35], in line with the

Fig. 1 General Layers, Phases of Data, Components and Domains of IoT

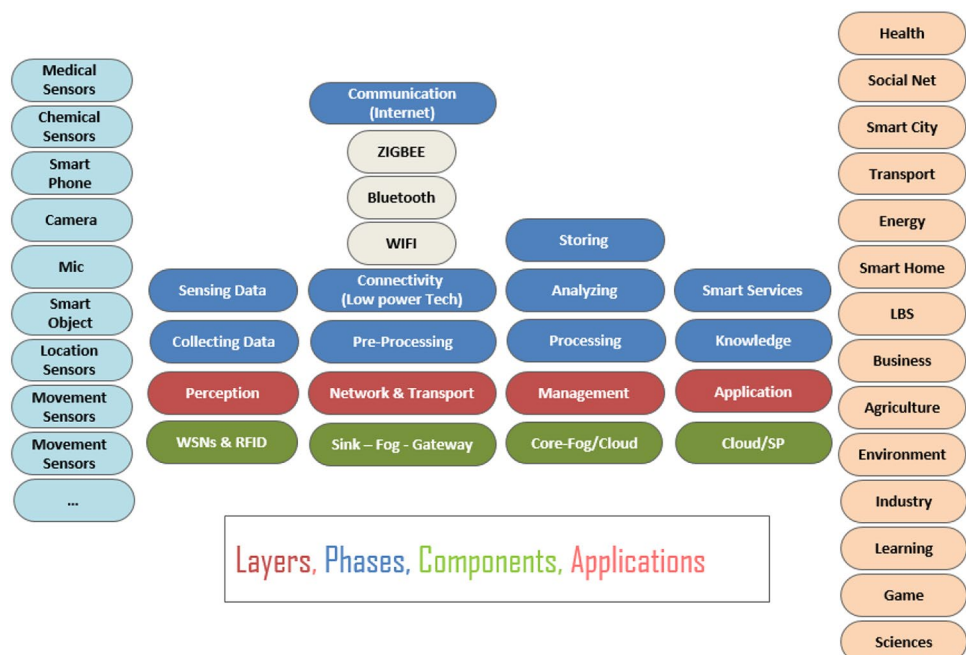
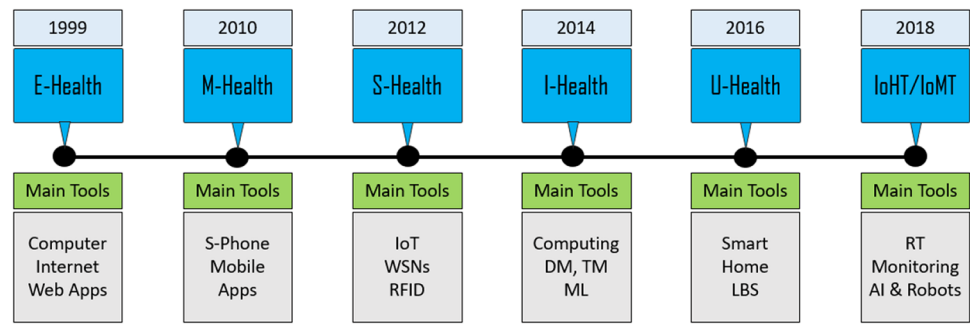


Fig. 2 The Main Milestones of Evolution the Health Domain

development in the speed and availability of the Internet, which enabled the user to make video calls [31]. The concept of Mobile Health (M-Health) appeared, medical centers began to provide their mobile services via smart phones, which provided ease and flexibility in use [33]. The features of these phones have encouraged creating many new useful services. The most important of which are: activating electronic consultations, supporting remote interviews between the doctor and the patient, and enabling the patient to enter and save some of his information periodically [31, 34]. So, the patient can share it with the doctor at the time of need for medical advice [34]. In addition, many mobile apps have appeared to support public health and provide advice and information to the user about a disease, medication, or any abnormal condition [35]. A new type of mobile health is the provision of services through ambulances or mobile medical centers, such as early detection or examination services for a specific disease and others [31]–[35].

The emergence of the Internet of Things [36, 37] also created a new trend and a great development in the health field. Smart Health (S-Health) [38, 42] has emerged in line with the concept of smart cities. The user no longer requires entering his data manually. Radio Frequency Identification (RFID) [27] and Wireless Sensors Network (WSNs) [29] will do the task automatically accurately. In addition to unlimited storage capabilities in the cloud [18, 39], and many useful new medical tools including wearables (such as a bracelet, belt, shoes, etc.), which contain sensors that measure the temperature, pressure, sugar, heart, respiratory, etc. [40, 41, 61]. More than that, S-Health is concerned with measuring the conditions of the environment, not just the person's biometric data to provide intelligent and adaptive services with context [42]. Alert service appeared for any sudden danger indicators in biometric values from the general average threshold. These contributions have raised RFID the level of safety and public health [39]–[41].

With the increase in the number of IoT objects and devices that continuously monitor the health of users with unlimited storage of their data, huge amounts of data have accumulated in the clouds [20]. With the availability more computing power like cloud computing [43], mobile

computing [44], or edge computing such as fog [18, 45], it had become possible to analyze this data with intelligent algorithms (Data Mining, Text Mining, and Machine Learning) [6, 46]–[48]. These algorithms greatly helped in serving the medical field and supporting it with additional knowledge, such as predicting the probability of a particular disease, revealing characteristics associated with a new disease, or like expert systems to describe the patient's condition automatically [48]–[50]. In addition to more powerful applications in processing for medical images to support automated disease detection, and relieve pressure on the medical staff, in addition to more adaptive services. This became known as Intelligent Health (I-Health) [51, 52]

The effects of the Internet of things began to appear in other areas as well, and smart homes [53, 54] appeared and spread widely, in addition to location-based services [56, 57], and others. Health researchers have sought to employ new features to find economic and effective solutions, especially for elderly patients, people with chronic diseases, and people with special needs [54, 55]. To achieve that they depended on transforming smart homes into a special care room for these people, which makes it easier for their families and the medical team to track their condition permanently, obtain continuous information, vital signs, and alert to any emergency directly [58]. all the above have contributed to saving expenses, reducing congestion in hospitals, and improving the level of health care [59] and thus what is known as the concept of Ubiquity Health (U-Health) [60] appeared, especially with services to track the patient anywhere and not only in his home [7, 58]–[60].

Recently, the concept of the Internet of Health Things (IoHT) or Internet of Mobile Things (IoMT) [59, 61] has emerged as a new concept for an integrated and proactive healthcare system based on IoT to provide and process data in Real-Time (RT). IoHT is a container for all the previous concepts. It has other new features such as awareness, smart medical devices, robots, Tele-health, as well as the development of medical education using virtual reality (VR) techniques, the use of holographic sensory communication, and 3D imaging for better diagnosis of the disease [7, 61]. Moreover, the great attention to the health of society by

monitoring and collecting data remotely from everywhere, analyzing it, and finding useful information that helps governments and medical teams to face future medical pandemics and control the health of the crowd [7, 12, 61].

In short, IoHT seeks to create an independent entity for the health sector to distinguish it and its importance from the rest of the sectors to reach an ideal healthy society that is more robust, developed, free of many diseases, and capable of facing future epidemics [62, 63].

According to the importance of IoHT, many researchers provided a review of different aspects of it. Table 1 summarized comparing of this research and a few recent surveys in the IoHT.

3 IoHT definition, domains, and applications

In this section, we have reviewed definitions, characteristics, and application of IoHT.

3.1 Definitions IoHT (IoMT | MIoT)

There are many definitions for IoHT, this research proposes a comprehensive definition by integrating all previous ones. IoHT is a concept that refers to an integrated healthcare system based on IoT [59], so the patient stays connected with the health facilities [7]. IoHT allows collecting data, monitoring it continuously, and making it available in RT when needed, especially for people with special needs, patients, the elderly, or in emergencies [36]. It also refers to the provision of diagnostic and proactive health care adapted to the context and at low treatment costs [38]. Finally, IoHT supports smart hospitals by supporting preventive health, providing patient-centered care with the help of home health systems and digital health systems with the aim of creating a smart health community [59, 64, 65].

3.2 A classification of different levels of the IoHT domain and applications

As we discussed before, IoHT can be considered as an umbrella for all previous phased of development health, so it includes many domains which this research classified into five domains wherein each domain we will refer to many different applications and services (to name a few). Hint, all the domains integrate to provide more adaptive and smart services.

1. Mobile Health & Monitoring in RT [62, 66]: it is the services that are provided by smart phones, or by smart ambulances to enable access services everywhere. in addition to providing monitoring and tracking, data storage, alerting, etc. Many examples of applications and services related to this class are [7, 62, 66]:
 - Medical calculator like help pregnant women to tracking her status by time
 - Medical news and advice
 - Online consultations
 - Early diagnosis like service for prediction about potential infect in diabetes
 - Activities recording like number of steps per day
 - Smart ambulance guides normal users to do the right actions in emergency cases during the time of waiting for an ambulance which will depend on the map to arrive at the accurate location of the case or event [32, 39].
 - Digital Health Systems and medical record (EHR/EMR) for information storage, searching, medication management, etc. [55, 67]
2. Artificial Intelligence (AI) with IoHT: it depends on the new medical devices to provide smart, remote, and automated services [6, 12, 68].
 - Tele-surgeries: now the medical team can do surgery for patients living on the other side of the world without the

Table 1 Comparing contributions of a few recent surveys in IoHT

| Ref No | The main contributions |
|---------------|---|
| [125] | Presented a comprehensive review of sensing devices in the health domain |
| [126] | Discussed the recent technologies, protocols, and applications of IoHT |
| [127] | Focused on the fog computing and its role and applications with IoHT |
| [128] | Concerned about the blockchain for privacy and security in IoHT |
| [129] | Viewed the structure of IoHT which they divided into three layers (sensing, personal server, and medical server) Classified the applications of IoHT to monitoring, assisting, remoting, and analyzing Discussed the challenges in which the security and privacy were the most important one |
| This Research | Provided historical narrative for integration between technologies and health domain starting from E-Health until IoHT/IoMT Posed a more comprehensive classification for IoHT technologies and applications especially for dealing with the health of disabled users or during a pandemic or crowded events Classified most of the challenges which researchers have to deal with it in future |

- need to be in the same locations by depending on very accurate devices and speed stable connection [11].
- Holographic, new technology for 3D image for the human body enable physicians to get more accurate data about cases [12].
 - Haptic medicine, here employs new technology like hologram and VR to transfer virtual sensitivity [12, 69]
 - telemedicine interviews
 - Wearable Devices: There are many wearable sensors (watches, bracelets, glasses, clothes, shoes, hats, etc.) that collect different types of data to enable the log of this data in RT [69, 70].
 - Robots and smart hospitals: to achieve tasks instead of humans, especially in the pandemic situation like a robot for delivering medicines or samples. There are small micro-robots now can enter the body and do some tasks [71]–[73].
3. Data Sciences (DS) with IoHT: we need DS algorithms to analyze big data that is collected by different devices and systems for predictive, and early diagnostic, or to process some data like a medical image for automatic and speed detection to reduce the overhead on physician and decision support.
- Analysis the daily activities [74]
 - Detect the pests and diseases of the skin by image processing [75, 76]
 - Studying and understanding the chronic diseases [77]
 - Predict about infected cases of new virus like covid-19 [78]
 - Voice Recognition to provide voice command and help disabled users [79].
 - Data analysis by machine learning (ML), statistics, reports and visualization, medical image processing, early detection [80]–[82].
4. Ambient Assisted Living: This domain concerns disabled users, the elderly, and people with chronic diseases. IoHT enables them to have independent life without needing assistance from others. Examples of some services in this domain are [54, 60, 83]:
- Ubiquity health which enables systems to monitor and care about elderly or patients in RT and in their homes and outside.
 - Smart home and smart hospital.
 - Monitoring the effect walking on the chronic diseases and rehabilitation
 - Help blind users to do shopping by themselves
 - Rapid response, ambulance management, fast detection of emergencies, etc. [5, 84]–[87].
5. Community Health: The health issue is not related to individuals only [88, 89]. There are many issues linked to community and environment [90, 91]

Monitoring air quality and pollution [92].

Dealing with epidemics like Covid-19 [5].

Raise awareness and cognitive about new disease, infection, bad habits, or food, etc. [90].

Disease prevention

Energy saving

Save health of crowd or in the congestion area [13].

Support the personal health as health monitoring, fitness & daily activities, obesity, preventive, etc. [93]

Cooperation for healing and treatment among health centers and experts for scientific cooperation, studying the characteristics of chronic diseases, confronting pandemics, discovering treatments, developing smart devices and services, etc. [84, 93].

4 Challenges in IoHT domain

After analyzing many of research articles and surveys in health domain and IoHT, we have streamlined the challenges, in tandem with [94]–[96]. The challenges are:

4.1 Interoperability due to heterogeneity between diverse services, devices, and systems in IoHT

Interoperability is one of the most remarkable challenges that must be addressed in IoHT, as it relies on the Internet of Things, which does not yet have a standard architecture or protocols. It also depends on various medical devices of individual ownership, in addition to heterogeneous modern technologies [97]. Therefore, we need a means or method that enables these tools, services, and systems to cooperate, so that this cooperation creates new, more advanced services [98].

Some solutions have been presented in this field, such as relying on standardized protocols and technologies (like Constrained Application Protocol (COAP), Data Distribution Service (DDS)), relying on intermediary structures as a third-party intermediary (like the cloud), using standard technologies (like Extensible Markup Language (XML) or JavaScript Object Notation (JSON)) to represent and share data between different services and applications, or relying on dictionaries and ontology for unifying concepts used to describe future services [98, 99]. But so far, this issue is still open and needs more attention to find more efficient and effective future solutions, especially for the old systems that already exist, while respecting the principle of ownership and privacy [97]–[99].

4.2 Security and privacy of medical data

All technologies depend mainly on data, which has become the real wealth in this era [100]. But, on the dark side,

collecting a lot of data about our lives and our surroundings, storing, and analyzing them make these technologies able to discover a lot of sensitive information about each person, and may also discover information that the person himself does not know about his behavior, habits, and character [94]. Thus, the development in technologies and smart services has accompanied the emergence of a new challenge related to the issue of protecting the security and privacy of this data [101]. No one is satisfied to disclose his data (for example, his medical data [90]) to the public, where its data may be exploited maliciously and greatly affect his life. The most dangerous is dealing with a malicious or hacked service provider (SP) [100, 102], who can exploit users' data to reveal information outside the scope of the announced service, which is called a privacy violation [103, 104].

In general, privacy can be defined as the person's right to determine who, when, how, why, and where his data will be used [105]. As well as his right to access and manage this data completely and ensure that his identity is not revealed to others to make a profile and link it to his identity [106]. Finally, the user must be not tracked [107, 108]. As for security [109], it is an older concept than privacy and it is imperative to protect the confidentiality and integrity of data (not to modify it), in addition to the availability of services [110, 111]. The following Fig. 3 illustrates the most important concerns about data privacy and data security [94, 112]. It clarifies the basic difference between both concepts. For more details, see [113].

Security and privacy are very important and critical issues with IoHT which depends on collecting data in RT [110]. This data is sensitive and private, but at the same time, the user has to share this data with health centers, physicians, research centers, etc. Any attack on health data can cause a threat to the life of the user [111]. Moreover, many countries start applying laws and roles to preserve the privacy of users like GDPR Europe law [114], where security and privacy is a critical issues in the health domain [112]. Many solutions have been provided so far to protect the security of medical data, most of them are based on encryption or blockchain technology [115] to prevent data modification and create transparency in any process that takes place on this data [116, 117]. Many technologies have been presented

to protect privacy in the medical field [94, 113]. But unfortunately, until now there is no comprehensive solution for privacy or security, and all the previous solutions are only discussing a specific application, so privacy and security are an open issue so far [118].

4.3 Health of crowds

Concern for the health of crowd participants is still an open topic for discussion, but with IoHT, we can propose smart solutions to continuously monitor participants' conditions in real-time, track any abnormal condition, early detection of any potential disease and thus reduce the spread of infection and disease within the crowd. So far, the health department needs more contributions, especially in large crowds, such as the pilgrimage [13, 91].

4.4 Threats posed by pandemics

The Corona pandemic showed the fragility of health systems, even in developed countries, in the face of pandemics [84]. Life around the world was affected in all its fields, which prompted many countries to apply precautionary measures to the entire population and to stop all activities, and this had a very severe impact on the economic situation in this country, and also greatly affected education and other fields [78]. The health sector was suffering the most, the medical centers were unable to absorb the large numbers of patients, which raised the number of deaths significantly, and some countries failed to control the infection, and some of them surrendered to the pandemic relying on what is known as herd immunity [85]. All the above emphasizes the need to develop an integrated platform with special scenarios and protocols to work at the time of pandemics to avoid them turning into a disaster and to mitigate and overcome their effects without major damage [6, 84, 85].

4.5 Big data and speed of response

IoHT has created an environment based on collected data from everywhere and all the time through wearable sensors, sensors in the surrounding environment, data that comes from social media, or smartphone applications. Therefore, the amount of collected data will be huge, and since we need a quick response in medical applications as it is sensitive to time delays, this creates a real challenge in finding an effective way to transfer data and process and analyze big data quickly and in real-time [9, 119].

4.6 Mobility and scalability

IoHT must support mobile services strongly, which is considered a challenge especially in environments where the



Fig. 3 General Comparison between Privacy and Security

appropriate infrastructure is not available, also medical systems must be able to accommodate the large increase in the number of users or the increase in the amount of data generated that needs to be processed and analyzed [1, 119].

4.7 Energy issue

The energy problem is fundamental, especially with medical systems, as they are more demanding than other systems to save energy [120]. IoHT is highly dependent on the Internet of Things, and since the purposes of IoT are limited in resources, the issue of energy is also a real challenge facing medical systems and effective saving models must be proposed [22, 121].

4.8 Availability of services with tolerance for errors or failure (Fault-Tolerance)

The availability of medical systems and services is very critical, even if some services fail or some devices stop working, the main medical systems and their other services must remain effective and available at any time and from anywhere, and it is also a challenge that needs to propose alternative solutions that fully support availability and fault tolerance [122, 123].

4.9 Lack of a standard framework or architecture in the field of health

According to the nature of IoT which has many owners, there is no one base framework at least for each domain [4]. Each owner develops his services through his style, platforms, and tools. So, each service deals with a specific issue, and it will not be able to provide complete solutions and management for all issues in a specific domain like the health one. That affects the future of services and limits invention. For that, it is very important to find a comprehensive framework that can manage integration among all services to create a comprehensive and more efficient solution. Where the cooperation between services will enable the development of more adaptive and smarter services [16].

Moreover, the framework will enhance the quality of services, where many services providers generate services for the same goal, and the competition between them will enhance the quality and enable the framework to find new important function "Auto Selection Services" according to qualities attributes, user's preferences, and context [16, 20].

5 Conclusion

This research presented a review study on the history of health systems development, and it explained the

difference between the main stages that they passed (E-Health, M-Health, S-Health, I-Health, U-Health, and IoHT). Then it presented an integrated definition of IoHT and classification for its most important fields. In addition, the research mentioned many important applications and services in each field. Finally, it reviewed future challenges and open problems in the health field that needs effective and standard solutions.

It is very clear the importance of health for everyone or country. That justifies existing all these development stages, technologies, and services in this domain. However, on the other side, there are still many challenges to creating a robust health system, where these challenges affected the ability of countries to face Covid-19 effectively. The IoHT (the latest concept in the phases of health development) promises a lot in the health field through its integration with other advanced technologies, in addition to its interest in many sensitive issues such as pandemics, crowds, people with special needs, chronic diseases, etc.

In the next work, we will focus on creating a comprehensive framework for a smart healthy society that can face any challenge or pandemic and deal effectively with it (pandemic). This framework must address the interoperability issue, in addition to security and privacy issue. Moreover, this framework will enable service providers to cooperate and competed to provide higher quality services. Finally, we plan to implement this framework in Saudi Arabia (KSA) especially in the Mecca and Al Madinah cities which witness the crowded event (Hajj) annually, and the government seeks to transfer these cities to smart health ones.

6 Future research

After determining the challenges in the previous section, in this section we mentioned important future research should be working on them for better and sustainable healthy societies, which are:

- Support enabling interoperability in IoT based on a unified ontology of health concepts, standard protocols, unified development platform, and standard language for representing data.

- Find a dynamic approach for dealing with privacy and security of different applications, in addition, to addressing the open problems (related to performance, needs to trust, and result's accuracy) of current protection methods.

- Use blockchain and non-fungible tokens (NFT) [124] to enhance the trust, transparency, security, and copyrights in the health domain.

- Put policies and solutions for saving and observing the health of crowds.

- Create a framework for auto services selection and better services provider according to context and properties of users to deal with a huge number of services.

- Provide a comprehensive framework to deal with pandemics by employing new technologies (AI, IoT, Cloud, Fog, 5G, ML, etc.) in addition to many of the required services.

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