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RESEARCH ARTICLE

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Health care service delivery based on the Internet of things: A systematic and comprehensive study

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Summary

Today, the Internet of Things (IoT) becomes a heterogeneous and highly distributed structure which can respond to the daily needs of people and different organizations. With the fast development of IT-based technologies such as IoT and cloud computing, low-cost health services and their support, efficient supervision of the centralized management, and monitoring of public health can be realized. Therefore, there has been increasing attention in the integration of IoT and health care both in academic and the business world. However, while the health care service industry fully holds the welfares of information systems for its personnel and patients, there is a need for an improved understanding of the issues and opportunities related to IoT-based health care systems. But, as far as we know, the detailed review and deep discussion in this field are very rare. Hence, in this paper, we presented a literature review on the IoT-based health care services from papers published until 2018. Moreover, the drawbacks and benefits of the reviewed mechanisms have been discussed, and the main challenges of these mechanisms are highlighted for developing more efficient IoT techniques over health care services in the future. The results of this paper will be valuable for both practitioners and academicians, and it can provide visions into future research areas in this domain. By providing comparative information and analyzing the current developments in this area, this paper will directly support academics and working professionals for better knowing the progress in IoT mechanisms. As a general result, we found that IoT could help the governments to improve health services in society and commercial interactions.

KEYWORDS

health care, health service, Internet of Things, literature review, service delivery

1 | INTRODUCTION

In this section, we will discuss the research motivation, the research contribution, related works, and the research objectives.

1.1 | Motivation

Recently, health care services management has been recognized as an information-based discipline.[1] That is, information systems are essential for improving health care services management. Despite recent advances in this domain, many challenges in the current health care services are faced.[2,3] For responding to increased life expectancy, aging population, and inevitable population growth challenges, innovative technologies such cloud, fog, and Internet of things (IoT) can provide new service to patients and migrate them from traditional methods of health care management to the new IT-based methods.[4] The health care services management includes a potential partnership between health professionals and patients (or individuals seeking help to increase their health and happiness) at many levels.[5,6] On the other hand, lack of regular and inconsistent use of the new health care systems based on novel paradigm such as IoT has often caused limitations in their success and may increase the costs.[7,8] Although IoT has a significant role in health care service delivery, there is not any planned and general review about investigating its essential methods. This research is, therefore, trying to review and investigate the IoT applications in health care service delivery and outlines the critical challenges that might be addressed in these fields.

1.2 | Contribution of research

A systematic literature review (SLR) is one of the famous paper reviewing methods which can classify and construct all related studies about particular research, subject zone, or important phenomenon.[9,10] It is a critical valuation and evaluation of all research papers that address a specific issue. It helps to limit regular errors, lessen chance effects, and increase the validity.[11] A systematic review can describe the findings of the group of research studies.[12,13] All of these welfares cause more reliable results that form the basis for drawing the correct decision.[14,15] Briefly, this paper tries to review the relevant articles systematically and suggest a complete instruction for further studies. The main goals of this study are:

- Presenting an SLR and studying the current approaches for IoT in health care service delivery;
- Providing valuable information about IoT in health care service delivery;
- Describing the main challenges about the IoT health care service delivery;
- Illustrating the classification of the reviewed techniques and highlighting their main features.

1.3 | Related work

Some review papers about IoT and other related areas are discussed in this section to highlight our motivation for writing this paper. Also, we examined several review articles that have been prepared for our subject matter to highlight our motivation for writing this paper.

Kulkarni and Sathe[16] have reviewed the applications of IoT in the health care sector to offer the best service at reasonable costs. They have clarified how IoT acts and how it is employed in conjunction with wireless and sensing systems to implement the wanted health care applications. The results showed that the long foreseen IoT revolution in health care is already ongoing. Besides, as novel use-cases are emerging, they can address the vital requirements for accessible care. They stated that revolution is known by providing end-to-end processing and connectivity solutions for IoT-based health care. However, the study is not systematic, and the process of selecting articles is not clear. Also, the selected papers have not been compared.

Hassanalieragh, et al[17] have reviewed the present state and expected future directions for mixing the remote health monitoring tools and the clinical practice of medicine. They have shown that wearable sensors, mainly those prepared with IoT, can provide attractive choices for enabling observation and recording. They highlighted some challenges in sensing, analyzing, and visualizing must be addressed before the systems can be designed for complete integration into clinical practice. However, the study is not systematic, and the process of selecting articles is not clear. The advantages and disadvantages of the articles have not been studied, the comparison between the articles has not been done, and it focused on only one domain of the research.

Furthermore, Pourghebleh and Navimipour[18] have surveyed the present data aggregation methods in the IoT in a systematic way. The data aggregation methods are classified into three groups, including tree-based, cluster-based,

and centralized. They have explored the main issues about the IoT data aggregation. In addition, the comparison of the important techniques in each class brings a recommendation for further research. Finally, they have provided a precise valuation using some important metrics such as energy efficiency and latency. However, their study does not include all the articles on the subject, and it also does not review the role of the IoT in health care.

The Internet of Medical Things (IoMT) describes the interconnection of communication-enabled medical-grade strategies and their integration to wider-scale health networks to enhance patients' health. Hence, Gatouillat, et al[19] have presented a wide-ranging literature review of present contributions focused on the IoMT. They have described the practical application of the democratization of medical devices for both patients and health care organizations. They have demonstrated that the cyber-physical system (CPS) advances the control of not only system robustness and dependability, but also the verification and confirmation. Also, a complete list of the usage of CPS methods in the IoMT was discussed, and potential research guidelines for the IoMT were determined. However, the study is not done systematically, and the process of selecting articles is not transparent. Finally, new materials have not been reviewed.

Finally, Mohapatra, et al[20] have reviewed literature for reasonable quality health care service using IoT. The results of the literature review are described in two portions. In the first one, it recognizes the antecedents that affect affordable quality health care and developing an IoT enterprise network. In the second one, it integrates some factors that affect both affordable health cares with IoT. Also, the results showed a reduced cost of health care while avoiding chronic diseases. However, the article is not systematically written. In addition, the process of selecting articles is not clear, and the selected papers have not been compared. Finally, the main features of selected papers have not been considered.

Based on the discussed articles in this section, we found that different topics in this domain are improving health care, cost-effective and quality implementation, reducing costs, and health monitoring and management. Some review research has been done in the field of IoT and health care service delivery. While systematic reviews are very important for performing a sound review, these surveys did not present a complete SLR-based review of the IoT applications in health care service delivery with an analysis of their taxonomy and future challenges. Also, there have been few reviews on this topic. Table 3 lists the advantages and disadvantages of the related articles. As shown in Table 1, the most weakness in the examined articles is unsystematically written and lacking the selection process articles. Therefore, in the rest of this paper, we try to solve the mentioned issues and provide an up-to-date analytical review paper in this domain.

Finally, this paper explains the following issues: Systematic review is discussed in Section 2. Section 3 reviews the introduction to the IoT and its applications. Analysis of IoT in the pharmaceutical industry is discussed in Section 4. Section 5 reviews IoT in health monitoring. The review of IoT in e-health is presented in Section 6. In Section 7, the results are presented. Discussion, open issues, and future trends are provided in Section 8. Eventually, Section 9 concludes the paper.

2 | SYSTEMATIC REVIEW

In this paper, the article selection strategy consists of three main stages as follow:

2.1 | Stage 1: Automated search

In step 1, we used the electronic databases such as Google Scholar, Science Direct, Emerald, Web of Science, ABI/Inform Global ProQuest, IEEE, and Springer link to discover relevant articles based on keywords. The keywords are (health care delivery, IoT) or (health care delivery, IoT) or (health care service, IoT) or (health care service, IoT) or (health service, IoT) or (health service, IoT) or (pharmaceutical industry, IoT), and (pharmaceutical industry, IoT). So, 45 articles are found, and we have classified the articles in each publisher (see Figure 1). In addition, we have classified the articles over time and journals (see Figure 2). As these figures show, in 2018 and by IEEE, the published articles are highest, and until 2010, no article has been published on this topic.

2.2 | Stage 2: Paper selection

Stage 2 begins by eliminating the editorial notes, reports, working papers, and non-English papers.[26] Finally, the 28 articles were considered for more analysis.

TABLE 1 Comparison of discussed articles about the role of IoT in health care service delivery

Article	Main idea	Advantage	Weaknesses
[16]	Health care applications of the IoT	■ Explaining how IoT functions and how it is used in conjunction with wireless and sensing techniques	■ Unsystematic structure
			■ Weakness in the process of selecting articles
		■ Proposing a future works	■ Lack of comparison of selected articles
[17]	Health monitoring and management using IoT sensing with cloud-based processing	■ Reviewing of the opportunities and challenges health management	■ Unsystematic structure
		■ Providing the systems integrating wearable sensor technology into clinical practice	■ Weakness in the process of selecting articles
			■ Lack of comparison of selected articles
			■ Failure to check the advantages and disadvantages of articles
			■ Focusing on only one domain of the research
[18]	Data aggregation mechanisms in the IoT	■ Categorizing the data aggregation mechanisms into three main groups	■ Failure to check the role of the IoT in health care
		■ Exploring the primary challenges and issues	■ Weakness in the presentation of all related articles
[19]	A review of recent contributions dealing with cyber-physical systems in IoMT	■ Improving the IoMT Describing the practical application of the democratization of medical devices	■ Unsystematic structure
		■ Providing a comprehensive list of the use of CPS approaches in the IoMT	■ Weakness in the process of selecting articles
			■ Lack of reviewing new articles
[20]	Exploring the affordable and quality health care using IoT	■ Presetting innovative health care solutions	■ Unsystematic structure
		■ Providing an appropriate theoretical structure	■ Weakness in the process of selecting articles
			■ Lack of comparison of selected articles
			■ Failure to check the advantages and disadvantages of articles

2.3 | Stage 3: Selection based on the reputation and validity of the journals

In the last stage, to verify the relevance of the article, the obtained articles are reviewed in detail.[27,28] The subject, publication year, and rank of the journal are the key issues to decide the including or excluding of the articles.[29] This time-consuming procedure resulted in eliminating eight articles that did not meet the inclusion criteria. The 20 related articles have remained for further analysis (five articles are analyzed in the related work section, and 15 articles are analyzed in the next sections).

Figure 3 shows the selection process with regard to the number of articles in each category.

Finally, in this section, the related articles to the IoT applications in health care service delivery have been divided into three major categories (pharmaceutical industry, monitoring, and e-health) and Review articles according to Figure 4, which we will explain each of them in following. Moreover, Figure 4 shows the analyzed articles in this study.

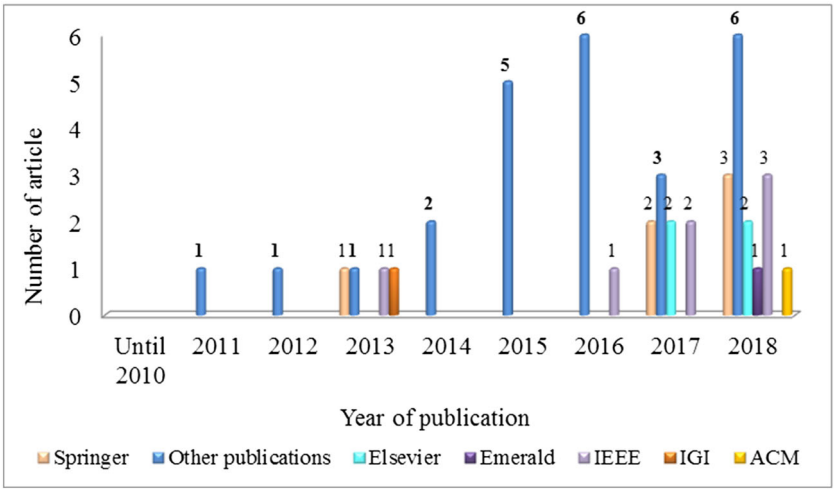

FIGURE 1 Distribution of articles by publisher

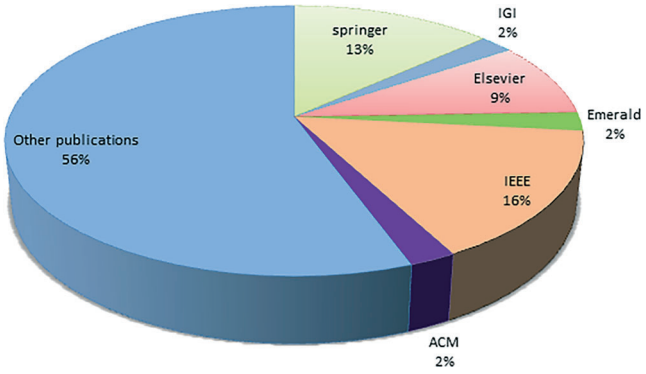

FIGURE 2 A pie chart of the percentage of the health care service delivery in IoT articles based on different publishers

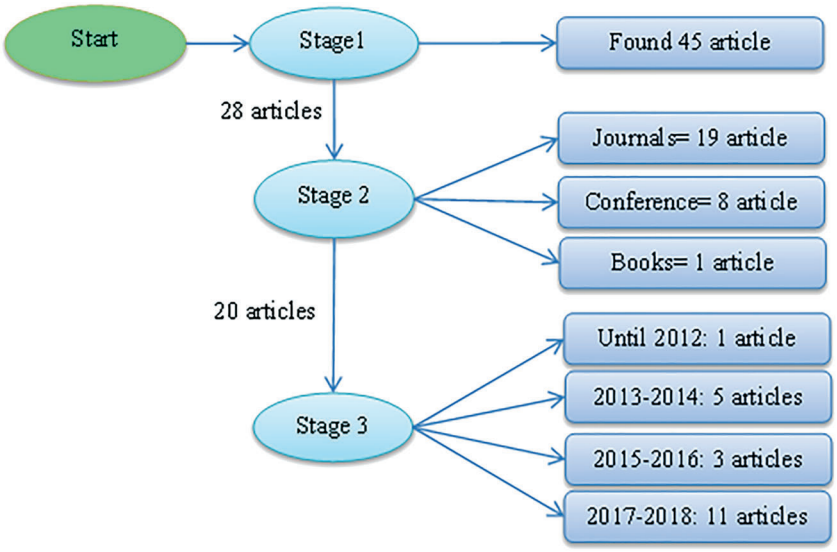

FIGURE 3 Paper selection process in each category

3 | INTRODUCTION TO THE IoT AND ITS APPLICATIONS

Today, everything is going smart, and smart power grids, smart devices, smart homes, and smart health care systems become very popular. The common viewpoint for these systems is usually related to one single idea, known as IoT.[30,31] The IoT has become more important to the practical world due to the rapid growth of mobile devices,

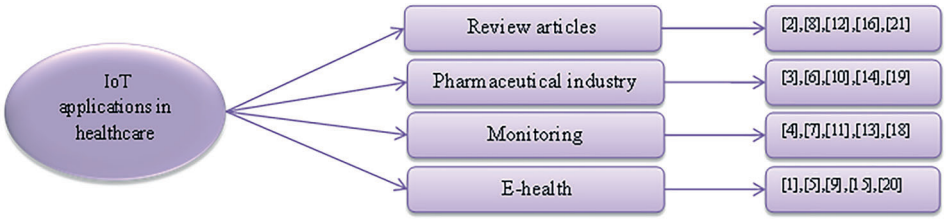

FIGURE 4 The classification of the analyzed articles

embedded and pervasive communication, cloud-based systems, and data analytics.[32] It is intended as a global network of sensors and devices which can interact with each other without merely needing human-to-human or human-to-system interaction.[33,34] Actually, the IoT refers to a kind of network to connect anything with the Internet-based on specified protocols over information sensing equipment to realize smart recognition, positioning, tracking, monitoring, and administration.[32] It can be realized from two viewpoints, Internet-centric and thing-centric. The Internet-centric style will focus on Internet services, while in the objects contribute data, the smart objects take the center stage.[35] So, IoT has been recognized as one of the latest technologies in the IT domain which can be realized in four main essential layers such as sensing, networking, service, and interface.[36] IoT technologies can be grouped into three categories such as technologies that enable "things" to get contextual information, and/or to process contextual information, and also to enhance security[37] and privacy.[32] On the other hand, IoT contains several architectures, such as the service-oriented architecture (SOA) that can provide interoperability among heterogeneous IoT devices in physical networks.[38] The value of the IoT for organizations can be realized when the devices can be connected with each other and integrate with customer support systems, business applications, and commercial analytics.[39,40] In addition to manufacturers' acceptance of the IoT, many service businesses try to adopt the IoT for increasing revenue through improved services and become leaders in their marketplaces.[33,41] Despite all of this, the main and most important role of the IoT can be in health services, which are briefly described in following.

3.1 | Health care service delivery and IoT

Access-to-care is very important and must be addressed by managers and health care providers to enhance the quality of delivering service and patient satisfaction. The challenges that can be considered in this regard can be the quality of health care service delivery, access to core treatment and opening hours, treatment time, time taken to get appointments, getting attention from doctors, etc..[42,43] Hospital administrators are becoming more and more concerned with waiting time since it is a measure of organizational efficiency.[44,45] Research has shown that waiting time affects the service-satisfaction relationship and can moderate the satisfaction-loyalty relationship. So, extreme waiting time is a lose-lose strategy in that patients lose valued time; hospitals lose their customers and reputation.[46,47] Hence, hospital staff needs a fast and reliable method to check their patients' status and to provide specific analysis tools.[48,49] Quick advances in ICT are enabling the wide diffusion of health care systems, which let a continuous remote patient monitoring by hospital staff. The desire for pervasive and universal health care services has enhanced the development of different communication styles that integrate many kinds of wired and wireless network technologies such as those used in the Internet, wireless body networks, and ad hoc systems.[50]

Over the past years, patient contribution to health care services has received serious attention. Their active participation in discussions is vital in improving medical management decisions and results.[51,52] Also, the upsurge of consumerism in health care, whereby patients search for information from multiple sources, is altering the way of clinical encounters and provider relationships.[53] Online resources play a critical role in the health of people and the entire health care system.[54] Technological progress can provide a platform for easy access of patients to information.[55] These advancements which are integrated with IoT, fog, and cloud technologies make cloud-based health care services a good selection.[56,57] On the other hand, Internet-based health care services, such as IoT health care solutions, have the potential to become valuable tools for public health organizations to improve their effectiveness.[4] IoT can decrease costs, improve power consumption, and facilitate maintenance operation in hard-to-reach zones.[58]

4 | IoT IN THE PHARMACEUTICAL INDUSTRY

In the pharmaceutical business, fake drugs cause a costly and potentially deadly problem. Infrared[59] and radio frequency identification (RFID)[60] technologies is a method of tackling some similar problems that can track and monitor drugs, without physical contact. In addition, the RFID can manage the drugs-related processes updating the inventories fastly, and it has a very low response time.[61] Doctors can use all legal health patient information using IoT-enabled access. Therefore, the more widespread use of RFID-enabled things can increase many e-health services and definitely can enhance patient medication control.[62] Therefore, the IoT brings more opportunities to the pharmaceutical business. Five related articles have been analyzed in this section.

Laranjo, et al[62] have presented an e-health service architecture with the corresponding IoT prototype implementation that use RFID tags and Electronic Product Codes (EPC) standards to form a medication control system. The system has a web interface and provides a first evaluation of the e-health service. The presented prototype can get EPC information related to several e-health entities and objects: eg, doctor, patient, nurse, caregiver, drug, hospital, pharmacy, etc. The prototype can translate EPCs query to the Object Naming Service (ONS) and processes the returned Naming Authority Pointer (NAPTR) records, using the Uniform Resource Identifier (URI) to access much information such as a Web server and EPC Information Services (EPCIS). The system prototype was verified with a simulated cycle from medical prescription to patient drug control. With a portable RFID reader over the Internet, the service can be utilized by mobile users. Despite being a digital certificate, the web interface has still some security flaws.

Pachayappan, et al[63] have designed an IoT-based smart logistics system for the pharmaceutical industry. The two-layer network architecture of IoT infrastructure is introduced. The first layer is RFID, and the second is the WSN layer. The RFID layer works as an asymmetric tag-reader link, and the WSN layer is an ad-hoc network between readers/master nodes. By adopting the proposed system, pharmaceutical companies can easily track and monitor the goods during transportation at a lower cost of investment. The system will avoid physical damages, moisture, humidity, and counterfeit drugs. The sensor devices are connected through the internet, and real-time data transfer will provide an opportunity for the pharmaceutical organization to react immediately if any changes are required in the logistic process. Despite the high advantages, the accuracy of the proposed system has not been measured.

Limited technologies, unreliable temperature monitoring devices, and human errors are the primary causes of temperature excursions.[64] Hence, Hernández and Yamaura[65] have presented how IoT enabled solutions which are used to minimize the wastage risk of pharmaceuticals due to temperature excursions. They built up the propositions for IoT implementation and identified the impact of each of the challenges identified. They proposed a framework based on the IoT and three main topics (pharmaceutical industry, cold chain, and IoT). The interview method was used to collect data, and human error, technology, temperature control, infrastructure, and business challenges were also identified. Literature and semistructured interviews showed the needs and challenges of the pharmaceutical industry. Technical mapping showed the limitation of exciting technologies to prevent temperature excursions. Therefore, companies can attach IoT devices to secondary package and upload the data for temperature, GPS, humidity, shock, etc. instantly via mobile network anywhere and anytime. Finally, they showed that IoT-enabled solutions are beneficial to improve the risk mitigation for temperature excursions. Consequently, they concluded that new IoT technologies would improve cold chain management in terms of data gathering, data sharing, and decision-making performance. However, the study suffers from security issues and device management. These limitations need to be considered for better IoT implementation.

A high volume of medicines makes the management operation more complicated because of its diverse types and functionalities. To optimize the pharmaceutical inventory management, Chen and Chang[66] have presented a systematical concept of pharmaceutical inventory management that employs the IoT to form a theoretical framework of smart inventory. The conceptual framework is based on Arduino boards, sensors, and near-field communication (NFC) to enhance the performance of pharmaceutical inventory management. IoT architecture includes communications, computation, and terminal devices. For data exchanging, the NFC reader connects with the host and sends the data to the database simultaneously. After reading the database, the parameter signifying the right location will be sent to the personal computer (PC). Through the completion of the event-condition-action rules operated, the total operation can be categorized into three main scenarios, storing, picking up, and inventorying the medicines. The results showed that the proposed framework is efficient and can improve the management of pharmaceutical inventory. However, the proposed framework should be further implemented as some prototype to be verified in a real area using some experience feedback approach.

Furthermore, Machhale, et al[67] have proposed a pervasive and preventive medication management solution using iMedBox based on IoT. The intelligent pharmaceutical packaging is sealed by the controlled delamination material and WSN. Wearable biomedical sensors based on the wireless link can also collect various vital parameters. Furthermore, a friendly user interface is highlighted to comfort the operation for the aging, disabled, and patients. The Health-IoT iMedbox system integrates the health social network, telemedicine, treatment, and medication management services. It will accelerate the transformation from hospital-centric medical treatment to home-centric one and finally can provide universal and personalized health care. The focus in the implemented project is to regulate and optimize the accessibility of medicinal drugs and provide home-based health care services. The proposed methodology has an advantage, such as effectiveness and monitoring; however, costs are not considered.

The results showed that with the IoT technology, we could improve the efficiency of pharmaceutical care, reduce medical errors, control medical costs, save time and develop more innovative ideas for helping patients and providing services to them, and improve the patient's medical experience. In addition, IoT offers great opportunities for supporting medical-related decision and training. Table 2 shows a side-by-side comparison of the important criteria IoT mechanisms in the pharmaceutical industry.

5 | IoT IN HEALTH MONITORING

Today, the influence of smart devices and communication apps on the activities of health care professionals, patients, and the health industry is increased. An increasing number of wearable IoT-based devices, tools, and apps are being used for various monitoring applications to evade preventable death because of a hospital or other related errors. IoT-driven health care monitoring may potentially transform the health care industry with regards to access improvement to patient information and offering qualified patient care through continuous monitoring from anywhere at any time. By means of IoT, doctors can access patient information, store it, and analyze the stored data to monitor and track the patients.[23]

Rohokale, et al[21] have proposed a cooperative IoT method for the better health monitoring and control of weak health parameters like blood pressure (BP), hemoglobin (HB), blood sugar, etc. The distinctiveness of the method is that node location information and source transmit power for data are not required. The approach is dependable for critical health care applications like continuous monitoring and control of the health parameters of human beings. Energy savings of 57% are achieved via this method, which is the first step towards green IoT. The result showed a substantial enhancement in the whole system. Simulation results also showed the tradeoff between energy consumption, latency, and throughput. However, the work suffers from authentication and authorization issues in cooperative IoT systems.

Lei-hong, et al[22] have investigated a new health service architecture based on the IoT in health care. Proposed technology provides intelligent, personalized, and integrated medical services to the aging people living alone or have a chronic disease. It lets users stay at home and get better medical services. So, it can decrease the cost in many aspects. The proposed design enables users not only to get continuous remote health care but also to get remote analysis and treatment. It also decreases the users' trouble to queue for registering in the hospital so that the user can get better health care services. The system provides a reference for other intelligent application of IoT in health care. While the proposed architecture has the benefits of monitoring, privacy offering, quality controlling, and timesaving; however, the focus is on a research area only.

Hossain and Muhammad[23] have described a cloud-integrated health care industrial IoT (HealthIIoT) monitoring framework where health care data are watermarked before being sent to the cloud. They have also used electrocardiogram (ECG) monitoring to diagnosis disease by a health care professional and prescribe medications to evade

TABLE 2 A side-by-side comparison of the important criteria IoT in the pharmaceutical industry

Article	Accuracy	Speed	Security	Cost
[62]	✓	✓	✓	×
[63]	×	✓	×	✓
[65]	×	×	✓	✓
[66]	×	×	×	×
[67]	×	×	×	✓

preventable death. On the client side, a smartphone application eliminates unwanted noise and inserts a watermark for security and authentication purposes. The watermarked ECG signal is then conveyed to a cloud server, where temporal and spectral features are extracted and categorized using a one-class SVM classifier. The result has shown that IoT in the health care industry could ease care monitoring with low costs, reduced direct patient-staff interaction, and ubiquitous access to qualified care. The study suffers from testing the proposed HealthIIoT monitoring framework for data security and notification functions, as well as realizing a test trial on a real-world scenario.

Furthermore, Andriopoulou, et al[24] have presented a new model for the integration of cloud, fog, and IoT technologies to highlight the benefits and usages of them for health care service delivery. They showed how integration and cooperation can be achieved among the cloud, fog, and IoT technologies. The key component of the proposed system model is the fog server that exploits the cloud computing to enable protocol adaptation, data storage, processing, and assessment. They have shown that the integration of IoT and fog computing for health care can provide many advantages such as accurate and faster treatment delivery, improvement of doctor-patient relationships, reduction of medical costs, and the delivery of treatment. In this study, use cases explain the opportunities and the welfares that the integration of IoT, fog, and cloud computing approach suggests for cost-effective, well-organized, and high-quality ubiquitous health care service delivery. These use cases contain daily monitoring and health care service provisioning as well as extended eCall service delivery.

Lastly, Lin, et al[25] have presented the home health care matching service system based on the IoT. The system takes a balanced method by satisfying preferences of the patients, rather than just concentrating on satisfying requirements of health care providers or professionals. Correctly, patients can rank their particular preferences, and the system will try to meet them as fully as possible. The deployed service meets the labor regulations that apply to health care professionals. Also, it schedules health care specialists to service locations that can be traveled to in a specific time. Finally, the proposed system not only provides more satisfaction for health care professionals but also lets patients receive better health care services. The ability to overcome logistics limitations and obey with regulations is critical in deploying such service to home health care patients.

We found that IoT could make a platform to monitor real-time health position of the patients by leveraging interconnected sensors and manage the treatment process. While IoT-based patient's health monitoring systems are standard, monitoring them outside of hospital needs augmenting the abilities of IoT for health care data processing and storage. Therefore, IoT can offer many social, business, and governmental services.[68] Table 3 compares the important factors in the discussed mechanisms for monitoring the treatment studies. As the results show, improving efficiency and performance, reducing costs, and maintaining security are among the most important issues that researchers can address in this regard.

6 | IoT IN E-HEALTH

E-health is a developing arena in the intersection of medical informatics, public health, and business. It refers to delivered health services based on the Internet and related technologies. In the broader sense, the term describes not only a technical development, but also a state-of-mind, a way of thinking, and a commitment to enhancing health care services employing Information and Communication Technology (ICT).[69] The IoT technologies enable patients to have a high-quality life, in a location with which they are familiar and calm, and among family members, and reduce the burden on overcrowded health care facilities. IoT-enabled health care devices make home health care carefully viable, just through recording the readings of health care devices to remove the desire for health care professionals' frequent periodic visits.[25]

TABLE 3 A side-by-side comparison of the important criteria IoT in monitoring

Article	Accuracy	Speed	Security	Quality	Cost	Satisfaction	Energy Saving
[21]	×	×	×	×	×	×	✓
[22]	×	✓	✓	×	×	×	×
[23]	×	×	✓	✓	✓	×	×
[24]	✓	✓	×	×	✓	×	×
[25]	×	×	×	×	×	✓	×

Suraki and Jahanshahi[70] have investigated the various visions of IoT for public health, and they showed how IoT can change lives. They have studied IoT for a public health approach in three levels: public level, personal level, and object level. They have shown tendencies and some issues that the researcher would encounter with them in the future. Besides, they have demonstrated how IoT can be employed to increase public health and how IoT aids people and governments to enhance daily actions in personal and public level. However, their study has some limitations in terms of security.

Xiao, et al[71] have provided a cloud health service system using the IoT; hierarchical design is presented including cloud service layer, perception layer, the support layer, network layer, and application layer. The system is separated into six units. The system can subordinate all hospitals and medical institutions to offer hospital management and health file management application services using a mobile terminal to gather community and clinical health data entry. The proposed system has some advantages such as security, flexibility, and cost reduction. However, it does not evaluate the proposed method in a real environment.

Zhai, et al[72] have constructed the index system of key influencing factors on the aspect of IoT on the concept of health services. They have proposed a new model that includes a five-layer structure of Physiological Sensing Layer (PSL), Local Communication Layer (LCL), Information Processing Layer (IPL), Internet Application Layer (IAL), and User Application Layer (UAL), which constitutes the Internet health care service framework. Combined with the summary of the service model, a complete network of health services adoption factors was come up using literary analysis and Delphi method. Also, the adoption of key factors affecting the identification model is proposed. They have analyzed the relationship between the various elements (external point of view, usefulness, and perceived ease of use) using DANP method and build the improved model by introducing the concept of expectation level into the preference function. In addition, it makes an empirical analysis taking the similar service of three companies as the research object and finds out the gap between the three companies' services and expectation levels, and suggestion are given. The results have indicated a reduction in costs, innovation, awareness, security, and educational upgrade; however, it does not evaluate the proposed method in a real environment.

Martínez-Caro, et al[4] have proposed a new model for exploring the relationship between patients' abilities for effective use of ICT and the success of IoT-based health care services. The validation has been done using data gathered from a randomly selected sample of 256 users of Internet-based health care services of the public health care system in Spain. The proposed model shows that end-users' e-skills are an example of the perceived benefits of the Internet-based health care service. In addition, perceived usefulness of the IoT-based health care systems plays the main role in the formation of a positive environment. However, the results of this study cannot be generalized to the whole society. The utilized data have been collected during a short period, and, therefore, it is hard to assess the causal direction when explaining relationships.

Silambarasan and Kumar[73] have investigated the health care service in the cloud and IoT using cuckoo search and particle swarm optimization (PSO) techniques. PSO tries to find the near-optimal solutions of complex optimization problems.[74-76] They have proposed an architecture consisting of different steps stakeholder's devices, stakeholder's request, cloud broker, providers, and network administrator. The results have shown the details about the optimization techniques, execution time, and data processing time and system efficiency. By using this method, the total execution time rate has been decreased, and the system efficiency has been improved. However, it does not evaluate the proposed method in a real environment.

The e-health makes increasing efficiency, improving quality, reducing costs, empowerment of patients, teaching of physicians over online sources, enabling information exchange, and spreading the scope of health care. Also, e-health can help the construction of a new relationship between the patient and health professional, where decisions are made in a shared way. Also, it solves new issues such as online professional practice, informed consent, privacy, and equity issues.[69] Table 4 shows a side-by-side comparison of the critical criteria about discussed IoT applications in e-health.

TABLE 4 A side-by-side comparison of the important criteria about discussed IoT-based mechanisms in e-health

Article	Accuracy	Speed	Cost	Security	E-Loyalty	Personal Innovativeness	Self-Efficacy	Perceived Usefulness	Satisfaction	Flexibility
[70]	×	×	×	✓	×	×	×	×	×	×
[71]	×	×	✓	✓	×	×	×	×	×	✓
[72]	✓	×	✓	✓	×	×	×	×	×	×
[4]	×	×	×	×	✓	✓	✓	✓	✓	×
[73]	×	✓	×	×	×	×	×	×	×	×

TABLE 5 Comparison of the IoT in health care service delivery

Article	Main Idea	Main Features
IoT in the pharmaceutical industry		
[62]	E-health architecture and service implementation IoT for medication control	■ Low security ■ Quick access ■ High accuracy
[63]	The designing IoT-based smart logistic system for the pharmaceutical industry	■ Faster ■ Low cost
[65]	Cold chain management with IoT-enabled solutions for the pharmaceutical industry	■ Low security ■ Low cost ■ Lack of management
[66]	Improving the management of pharmaceutical inventory by using an IoT	■ Facilitates management ■ The space optimization for inventory shelves
[67]	Presenting an intelligent medicine box for medication management using IoT	■ High comprehensive and preventive management ■ Facilitating the operation of patients and disabled people ■ High pharmaceutical management services ■ The optimizing access to medications
IoT in monitoring		
[21]	A cooperative IoT for rural health care monitoring and control	■ High energy savings ■ Low latency
[22]	Providing a new architecture to improve the quality of treatment for patients based on IoT	■ Faster ■ High Security
[23]	Cloud-assisted IIoT-enabled framework for health monitoring	■ Low security ■ Low cost ■ High quality
[24]	The presenting a new model for integration of technologies cloud, fog, and IoT	■ Accurate and faster treatment delivery ■ Improvement relationships ■ Low costs and delivery of treatment
[25]	Presenting a home health care matching service system using the IoT	■ High satisfaction ■ Receiving better health care services
IoT in E-health		
[70]	Investigating the IoT benefits to improve service delivery in the public health approach	■ Low security ■ Increasing public health
[71]	Proposing a new health cloud service system based on IoT by six modules	■ High security ■ High flexibility ■ Low cost
[72]	The identification of key factors in health service adoption based on IoT and empirical test	■ Accurate ■ Low cost ■ High security
[4]	Exploring the health care service evolution towards the IoT	■ High personal innovativeness ■ High self-efficacy

(Continues)

TABLE 5 (Continued)

Article	Main Idea	Main Features
		■ High perceived usefulness ■ High satisfaction ■ High e-loyalty
[73]	Presenting new architecture by using Cuckoo Search and PSO techniques	■ Faster

7 | RESULTS

In previous sections, 15 selected articles are analyzed. The focus of researchers in the selected papers is improving some parameters such as performance, cost, monitoring, security, etc. However, most of the research does not test the proposed method in a real environment. Table 5 presents the main features of each study about IoT in health care service delivery. In addition, we compared the achievements of the three groups of the selected papers in Table 6. The results showed the most significant benefit of IoT in health care service delivery by improving performance and reducing costs. Also, the results have shown that most methods do not use a real environment for testing the proposed method. Future research should do a lot of research on other benefits of IoT to make the users more aware of the benefits of this technology. Eventually, the results of the survey showed that the main challenge and issues of this field are security. Also, trust is a key factor that researchers consider in their research. Therefore, IoT-related issues and problems must be addressed before it is considered by health providers.

8 | DISCUSSION AND OPEN ISSUES

The Internet, as new infrastructure, plays a critical role in information sharing. With the fast development of communication tools connected to the Internet, the requirements for further utilization of these tools are very vital. Today, public health is essential in any health care system. IoT can be employed as a structure for public health of society. The IoT is an Internet connection tool that is mainly wireless-oriented and provides a real-time solution to provide complete data about its surroundings in both indoor and outdoor situations, and the capability to monitoring the environment distantly. Using IoT brings many welfares for social and economic environments and a high level of service quality and delivery. However, it requires the adoption of education and healthy public policy.[70] Hence, the creation and education of appropriate culture is a central point in this matter so that people can use e-health services with the adoption of new technologies.

On the other hand, we found that the serious challenge for the pharmaceutical industry is logistics, which means a lack of timely, accurate, and inconsistent information transfer during transportation of pharma goods. On the other hand, the vital role of the pharmaceutical industry is to maintain the accurate temperature and monitor the mitigation and risk factors through the transportation of medicines. Daily millions of tons of temperature-sensitive goods are created, transported, stored, and distributed worldwide. For these products, temperature monitoring is the key point in cold chain operations (certain products need to be kept during storage and distribution), and the most important factor in the avoidance of temperature changes which affects the properties of the products.[77,78] As a result, it is hard to obtain real-time visibility and traceability of the current position of the products. IoT is the best solution to these problems. The IoT generates live data from the goods tagged with sensor devices in the container during transportation and communicates the updates to the concern location.[63] Also, the IoT provides the possibility of having programmed sensors that can automatically send alerts if the pharmaceutical products storage is out of a specified temperature range and real-time monitoring offers a timely warning for operators and can assure quality & efficacy.[65]

In other words, how to efficiently manage the pharmaceutical inventory is an essential issue for modern hospital management. The IoT has many sorts of sensors to help deal with complex problems of hospital management.[66] Therefore, addressing technical and engineering issues about health services alone is not enough, and researchers should try to focus on more managerial problems, such as preventing the attacks.[79]

By discussing the mentioned techniques, it has been observed that there is not any method that addresses all issues involved in IoT in health care service delivery. For example, some of them consider energy savings, speed, and personal

TABLE 6 A side-by-side comparison of the important criteria about applications of IoT in health care service delivery

Articles	Energy Savings	Accuracy	Speed	Personal innovativeness	Self-efficacy	Perceived Usefulness	Satisfaction	E-loyalty	Security	Flexibility	Quality	Cost
IoT in the pharmaceutical industry												
[62]	×	✓	✓	×	×	×	×	×	✓	×	×	×
[63]	×	×	✓	×	×	×	×	×	×	×	×	✓
[65]	×	×	×	×	×	×	×	×	✓	×	×	✓
[66]	×	×	×	×	×	×	×	×	×	×	×	×
[67]	×	×	×	×	×	×	×	×	×	×	×	✓
IoT in monitoring												
[21]	✓	×	×	×	×	×	×	×	×	×	×	×
[22]	×	×	✓	×	×	×	×	×	✓	×	×	×
[23]	×	×	×	×	×	×	×	×	✓	×	✓	✓
[24]	×	✓	✓	×	×	×	×	×	×	×	×	✓
[25]	×	×	×	×	×	×	✓	×	×	×	×	×
IoT in e-health												
[70]	×	×	×	×	×	×	×	×	✓	×	×	×
[71]	×	×	×	×	×	×	×	×	✓	✓	×	✓
[72]	×	✓	×	×	×	×	×	×	✓	×	×	✓
[4]	×	×	×	✓	✓	✓	✓	✓	×	×	×	×
[73]	×	×	✓	×	×	×	×	×	×	×	×	×

innovativeness, while some disregard these issues. Also, security is a vital, challenging research zones that are not considered in many articles. Designing a robust method to enhance the performance of IoT will become a challenging problem. Future studies should consider assessing the barriers to IoT, as it is equally essential to develop insights on what hinders the IoT and pay attention to the costs related to IoT rather than just benefits.

9 | CONCLUSION AND LIMITATIONS

A health care service delivery is considered as one of the relevant research directions for many purposes in IoT. Hence, in this paper, we have surveyed the past and the state-of-the-art articles about IoT applications in health care service delivery systematically. We classified 20 selected papers in four classes that five of them are review articles, five of them are a Pharmaceutical industry, five of them are a Monitoring, and five of them are an E-health. We comprehensively reviewed and compared these mechanisms, and the results were collected. According to the SLR in IoT applications in health care service delivery until 2018, the number of published papers is determined very high in 2018. IEEE with 16% has the most top published papers. Also, all selected approaches are compared using some factors such as efficient, energy savings, timely, accurate, faster, personal innovativeness, self-efficacy, perceived usefulness, satisfaction, e-loyalty, security, flexibility, quality, cost, and monitoring. The results have shown that most of the papers tried to improve efficiency and remote monitoring and cost, but the security issue is not considered in many articles. As a general result, IoT can help the governments to enhance health space of social and business connections. So, the main benefit of this research is its ability to use the Internet-based health care service landscape to advise future strategies for the implementation of new generations of health based on IoT technologies.

This paper has several limitations. Firstly, this paper is limited to search only seven online databases. There might be other journals or publishers, which may provide a complete picture of the IoT applications in health care service delivery. The present literature review excluded publications in languages other than English. This may lead to the omission of some parameters in our findings. Also, the focus of the current study was exclusively on the main body of literature of IoT applications in health care service delivery while it was an unnoticed large part of studies that have conducted over different zones such as Economic, social, urban intelligence communities, etc. Thus, it could be worth considering these studies conducted over different areas by future studies. Finally, publications that cover the topic of health care service delivery IoT may not always be published in high ranked journals because it is still an emerging topic.

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