Applicability of IoT-Aware Models in Healthcare Systems: Potential and Challenges

MOHAMMAD RASMI AL-MOUSA[1], ALA'A SAEB AL-SHERIDEH[1], ALA'A AL-SHAIKH[1], MOHAMMAD ALQUDAH[2], AYMAN GHABEN[1], HANI ALMIMI[3], MOHAMMAD ARABIAT[2], SUHA AFANEH[1]

[1]Department of Cybersecurity,
Zarqa University,
JORDAN

[2]Department of Computer Science,
Zarqa University,
JORDAN

[3]Department of Cybersecurity,
Al-Zaytoonah University,
JORDAN

Abstract: - The innovative Internet of Things (IoT) concept has become a worldwide phenomenon. The growing use of IoT devices over the past few decades has changed the way we interact with the embedded devices around us. The exponential rise of IoT devices and the data flowing from these devices is creating an impact on various fields such as healthcare, transportation, smart cities, and more. This paper aims to describe the potential and discuss challenges for using IoT-Aware models in the healthcare domain, identifying threats that should be mitigated to guarantee the successful applicability of those models. The most recent research on each component of the model is then presented, along with an assessment of its advantages, disadvantages, and applicability to a wearable IoT healthcare system. Security, privacy, wearability, and low-power operation are only a few of the difficulties that the IoT in healthcare must overcome. IoT challenges in healthcare include wearability, security, and privacy issues. Recommendations are also offered for future research paths. This paper concludes that IoT might assist governments in enhancing societal health care and business connections.

Key-Words: - Internet of Things, IoT-Aware, health-care applications, Security, health-care services, Iintelligent systems, Smart Cities.

Received: April 14, 2024. Revised: November 11, 2024. Accepted: December 13, 2024. Published: January 7, 2025.

1 Introduction

According to the International Telecommunications Union (ITU), the Internet of Things (IoT) is "a global infrastructure for the information society, enabling advanced services by interconnecting physical and virtual things based on existing and evolving interoperable information and communication technologies". Simply it resembles smart connections of day-to-day objects that can communicate with each other using the Internet, to improve efficiency by saving time and money. It started as a common word but today it contributes to the transformation of many fields including, but not limited to, healthcare. With the convergence of wireless mobile technologies, it can directly connect healthcare systems with patients improving quality of life and reducing costs.

The Internet of Things has the potential to have a significant impact on all business sectors using next-generation technologies, which can be described as the connection between things and smart devices within an Internet infrastructure, such as smart doors, smart cities, wearable health devices, and traffic-congestion control, to name a few. Some applications help in the emergence of the IoT, such as health care, fitness and sports applications, pulse measurement, and other chronic and non-chronic diseases, [1], [2]. Figure 1 presents the basic network architecture of smart healthcare systems.

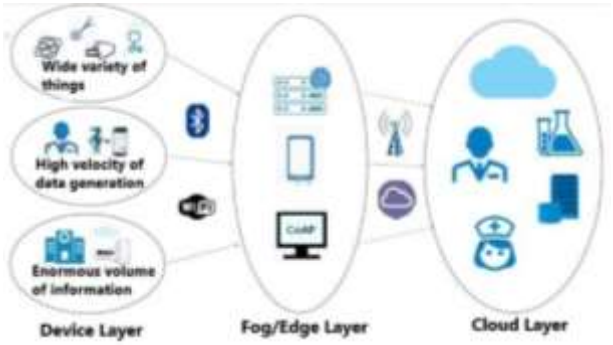

Fig. 1: Basic Network Architecture of Smart Healthcare Systems [3], [4]

Internet of Things healthcare provides continual monitoring of patients' vital parameters and alerts relevant personnel if any emergency occurs. This can help reduce the number of patients visiting hospitals for routine tests, as well as continuous monitoring which creates emergency alerts in real-time [4]. Consequently, efficiency, quality of treatment, and savings are improved for each stakeholder in the system [3]. However, there are also challenges to implementing such systems including security and privacy. Today, healthcare systems are being computerized while there are still many records present on paper. All information regarding a patient as well as their family is very crucial from a socio-economic point of view. It includes the concerning pensions, possessions, and insurance policies. These should not be easily accessible even to family members. All data can be gathered, processed, and analyzed by smartphones via mobile apps in a smart city that is aware of eHealth. Patients would receive all feedback in a smooth manner, enabling them to know the status of their health and the findings of their examinations. In addition, all the medical information of a patient is originally collected and processed by different devices and servers.

Healthcare (HC), Medicine, and well-being are on the top of the application domains where there is a high need for the development of smart services by leveraging the key technological capabilities of the aforementioned technology trends. Nevertheless, despite the promising potential of IoT technologies, devices, and ambient intelligence, the utilization of such technologies and deployed infrastructure in the domain of smart HC is extremely low compared to other domains such as business industries or social networking, where the reliance on the technology is almost total. A comprehensive understanding of the overall perspective and the different aspects of the technology adoption needs to be provided for diverse stakeholders in the respective application domain in order to recognize and respond to the ongoing challenges, trends, and transformations of a relevant technological, economic, and societal landscape.

IoT-based services have a significant financial influence on companies as well. By 2025, healthcare applications are predicted to occupy the largest share proportion of the IoT market, as shown in Figure 2, [5].

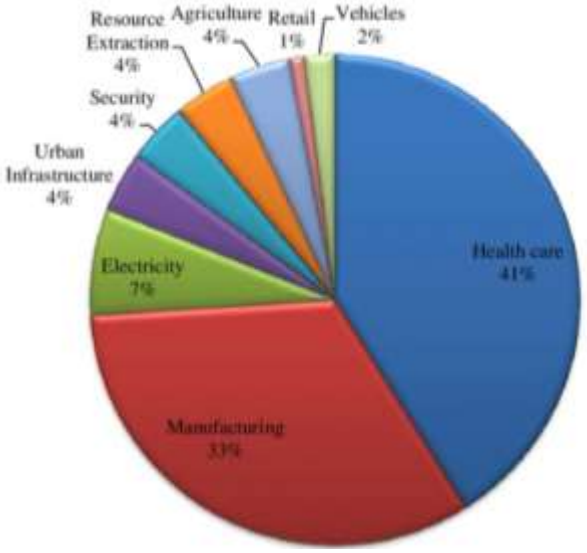

Fig. 2: Projected market share of dominant IoT applications by 2025, [5]

Internet of Things has been the focus of many researchers in recent years, especially in the field of healthcare, and how to benefit from the IoT in this area of application, [6], [7].

This paper explores trends in healthcare research based on IoT and identifies several challenges that need to be resolved in order to revolutionize healthcare technology through IoT innovation.

The main contributions of this paper are summarized as follows; (1) it highlights modern technologies, research applications, and services in the field of IoT and healthcare; (2) it disseminates knowledge on the use of IoT in the delivery of healthcare services.; and (3) it describes the main issues with the delivery of IoT health care services.

The remainder of this paper is organized as follows. In Sect. 2 a review of related literature is presented. The challenges of IoT in healthcare are discussed in Sect. 3. Some case studies are presented in Sect. 4. In Sect. 5, we shed light on some successful implementations of IoT in healthcare systems. The idea, technology, and trends are discussed in Sect. 6. Finally, the conclusion and future work is presented in Sect. 7.

2 Literature Review

This part highlights our reason for producing this work by discussing some review papers concerning IoT and other relevant topics. To further explain why we decided to write this paper, we also looked at several review papers that had been written specifically for our topic.

There are multiple domains where IoT can be deployed, one of which is healthcare. Internet of Medical Things (IoMT) is defined as a subset of IoT that is applied in the field of medical wearables, mobile health monitoring, and patient monitoring systems. IoMT provides connectivity and expands the network of medical device concerns, enabling health monitoring regardless of patients' location. It eliminates manual data recording/entry and allows migration and storage of general information regarding patients' health and medical history. Consequently, potential risks can be foreseen and advisable action can be taken. Initiating reliable and cost-efficient machine-to-machine communication is one of the biggest challenges of the IoT, [4].

To provide the finest service at fair prices, [8], have evaluated the uses of IoT in the healthcare industry. Studies and their results show that the idea of the Internet of Things, which has preoccupied researchers for years in the field of health care, has become a reality, by providing treatment solutions and complete care networks through the Internet of Things. As they said, this revolution can be understood, but it is still not fully organized and clear.

Methods and tools for remote monitoring of healthcare services and medical clinical practice have been disclosed in their evaluation of the status and anticipated future developments. They emphasized the need for solutions to detect, analyze, and visualize issues before the technologies may be completely integrated into clinical practice, [9]. The papers' benefits and drawbacks were not examined, they were not compared to one another, and they were only focused on one area of research, [9].

The authors in [10] have published a thorough literature assessment of recent contributions that have their attention on the IoMT. They have shown that a cyber-physical system improves system control over verification and confirmation as well as robustness and reliability. However, the study is not conducted in a systematic manner, and the selection of the publications is opaque.

We discovered that several issues in this sector include enhancing health care, cost-effective and quality implementation, lowering expenses, and health monitoring and management based on the articles presented in this part This study and survey still do not provide a comprehensive and clear assessment of SLR for IoT and healthcare applications, its analysis and classification, current and future barriers. Despite the need for systematic reviews for conducting solid reviews.

Information exchange is greatly aided by the Internet, which is a new sort of infrastructure. Any modern healthcare system must prioritize public health. The IoT is a mostly wirelessly oriented Internet connectivity tool that provides a real-time solution about the environment and its internal and external conditions to provide comprehensive data, as well as the potential to monitor the environment from a distance, [11], [12], [13].

However, it necessitates the implementation of good public policies and education. So that individuals can be able to use services related to health care with the introduction of contemporary technologies On the other hand, we discovered that logistics, or the absence of fast, accurate, and consistent information transmission during the transit of pharmaceutical items, poses a significant barrier for the pharmaceutical business. On the other hand, the pharmaceutical industry's crucial function in the transportation of medications is to maintain the precise temperature and keep an eye on risk and mitigation factors. All over the world, many temperature-sensitive components are sent delivered, and produced.

3 IoT Healthcare Challenges

Numerous researchers have labored to develop and put into practice numerous IoT-based healthcare services as well as to address numerous technological and architectural issues related to such services. Expanding the use of remote medical monitoring devices and systems eliminates the need for continuous patient presence in healthcare facilities and allows doctors to work in more flexible conditions. Integrating remote patient monitoring into the popular practice of personal health records management, and search services for medical institutions and specialists might lead to a revolution in patient care.

One of the most popular measures of healthcare trustworthiness is its security. With the rise of connected device usage and health records digitization, security concerns are growing as well.

A lot of patients are worried about who has access to their medical records. With implemented proper security measures authorized medical personnel should only use healthcare data. However, still, there are still common attacks like

unauthorized data access, malware distribution, hacking devices, etc. Healthcare IoT also suffers from problems more common to wider IoT systems, for example, DoS (Denial of Service) attacks and bot-net operating with compromised devices, [14].

Going through medical history, medications, drug interactions, allergies, medical test results, or automatically captured warning data from the system takes too much time. More efficient, and suitable for modern-paced life solutions that allow quick and correct interpretations of health data are needed. Due to a lot of specific features and challenges, the Internet of Things (IoT) systems complicated implementation in medical applications, [3]. IoT healthcare systems have to manage devices with varying performance, operating systems, interfaces, and communication protocols. To ensure consistent performance in a diverse environment, standards have to be established. In the context of other industries, IT-related work should not differ significantly. There need to be standards regarding data capturing systems, monitoring devices, similar sensor technology, communication protocols, coding standards in networks and databases, file formats, patient privacy, medical data safety, etc.

3.1 Security and Privacy Concerns

The past decade has witnessed the rapid advent and substantial advancement of wireless sensor networks and mobile health technologies, which have become the focus of intensive research activities in both academic institutions and industrial organizations. The wireless sensor networks constitute a prominent part of the IoTs, and provide a novel environment that connects the physical and virtual worlds, and targets all aspects of human daily life. The emergence of the IoT paradigm is enabling the (non-stop, real-time) monitoring of millions of individuals, as well as ecosystem and environmental observations on a massive scale. In the healthcare domain, the IoT and wireless sensor networks, referred to in some cases as the Internet of Medical Things (IoMT), offer a unique opportunity to change the monitoring of medical parameters of patients from the traditional place-based settings, i.e., clinics and hospitals, to mobility and people-centered settings. Data collected from wearable sensors with continuous monitoring can help in the early detection of various diseases (e.g., respiratory, cardiac, diabetes, etc.) and risk factors via advanced and machine learning-based analytics, herein referred to as big-data analytics. Such analytics may incorporate not just health data, but also the location, mobility, and social network of individuals, and thus better identify the population of monitored individuals and their expected reactions (e.g., likelihood to be sick, to develop an infection, a heart attack, etc). The emergence of such a paradigm with new data modalities, confidentiality, and ownership aspects may have a potential impact on the privacy of monitored individuals. Various works highlighted the concerns of such a potential impact and proposed solutions to address the concerns in a physiological manner, [15].

However, the rapidly increasing development of the IoMT infrastructure has raised concerns about security and privacy. On one hand, the IoMT provides continuous monitoring and thus a better chance to monitor in a timely manner and/or to mitigate unwanted events. On the other hand, it exposes various types of newly available data that may conflict with existing laws to protect individuals' privacy.

3.2 Interoperability Issues

As IoT becomes more prevalent in the healthcare environment, there arises a need for maintaining a level of communication interoperability between disparate devices. Numerous protocols for IoT exist nowadays, many of which are built upon some type of existing standards. Still, key devices that would allow a coherent and manageable network, such as bridges, routers, translators, and gateways have yet to be developed. Currently, each protocol has an ecosystem of components created to support it, leading to a fragmented internet of all things, where no device can communicate. None of this is ideal for the healthcare arena where with each new security concern raised, the IoT application already stands as a vulnerable target, [3].

Currently, IoT devices are often incapable of intercommunicating, necessitating that different systems be used to manage different protocols and the subsequent acquisition of different training for end users and personnel. There is also the issue of disparate data on the available devices, which are examined in different environments across different platforms with different data management capabilities. This makes the finding of commonalities and comparison of effectiveness between devices unworkable. Finally, the inability to classify a device as IoT-aware or not means that a large part of existing technology will be excluded by many healthcare systems hoping to adopt some form of IoT, this is a heavy burden to carry as utilizing smart or internet-aware devices can be expected to cut costs significantly, [16].

3.3 Standardization

The field of health care is an exciting technological field and many new and competing companies are entering it, which produce a lot of equipment and tools for the field of health care. The issue of hardware diversity must be addressed immediately. A committed group may, for example, standardize medical technology using the Internet of Things in healthcare. Another challenge facing consolidation is managing services by enrolling healthcare professionals and competencies, such as electronic health records and access control.

Providing websites or applications for remote health care using the Internet of Things using digital information and communication technologies to access and manage services is important. These applications are designed to help organize medical information such as storing information, calorie calculation, medication reminders, etc. Tougher and tougher. A service-oriented strategy may be used to design a suitable platform such that services can be utilized by utilizing various application package interfaces there can also be a set of useful libraries that help us focus on diseases

3.4 Cost Analysis

The cost of maintaining healthcare devices, software, and protocols that need periodic updating is costly, and a typical IoT cost study may be useful in this regard.

3.5 The Process of App. Development

Preparation, development, debugging, testing, and deployment are the four basic processes in building an android application. On other platforms, similar strategies are used. To ensure an app of acceptable quality, it is often necessary to establish an accredited body or association of medical professionals to co-create healthcare apps, [17].

3.6 Technology Change

By integrating the current network with the Internet of Things, the quality of health care can be improved. These technological developments and changes positively affect the expansion of the market and increase the category that is served, thus leading to updating its devices and obtaining smart sources. The problem lies in ensuring proper access and transition from system to system.

3.7 This Protocol is Low Power

Each communications layer also has a barrier related to power needs in terms of service availability. For instance, it can be difficult to design a mechanism that properly detects devices. It ensures that our servers are available on the MAC layer. Conserve and use less energy.

3.8 Type of Health Care Network

The Internet of Things based on health care has three types, which are data, services, and structure related to the patient. The healthcare system needs a set of characteristics. However, until now, there is no clear picture of the best type of health care.

3.9 Scalability

Healthcare IoT networks, apps, services, and back-end databases need to be scalable since associated processes get more complicated with the addition of different applications due to the exponential rise in demand from both people and healthcare organizations.

3.10 Constant Watching

There are many conditions in which the patient needs continuous monitoring, such as chronic diseases and emergency cases, and availability is very important here.

3.11 New Disorders and Illnesses

Smartphones are thought of as state-of-the-art Internet of Things medical devices. Research and development (R&D) is essential for new diseases and disorders, and finding portable methods for the early identification of rare diseases has long been a top concern, [17].

3.12 Identification

Healthcare companies frequently operate in many patients' locations and where many caregivers perform their jobs. From this angle, it is essential to correctly identify patients and caregivers.

3.13 Internet Business Model

There are many factors that have included new needs, including 1- New operational procedures and policies 2- New infrastructure systems, 3- scattered target consumers, and changing organizational structures, in the healthcare business plan for IoT, which makes it insufficient at this time. Also, medical professionals are generally shy about learning and using new technology. So a new business model is urgently needed.

3.14 The Service Quality

Like any technological system that contains devices placed inside the body such as pulse devices and blood transfusion devices, despite the supporting

studies, it is at risk through malicious software or viruses. Here an interesting question arises as to the feasibility of the proposed plan in the event of a system failure, [18], [19].

3.15 Protection of Data

It is necessary to prevent the access of a third party or unauthorized persons to the data stored on healthcare devices. To avoid this, the devices must have a high level of protection that may threaten people's lives, such as accessing and disabling the heart rate monitor, [20], [21], [22], [23].

3.16 Mobility

In order for patients to be able to communicate and communicate anywhere and at any time through Internet of Things devices, health care must be flexible and capable of accommodating patients.

3.17 Advanced Analytics

Analytics is doing important work in the IoT health sector and could leverage algorithms that analyze data to recommend treatments or create alerts.

3.18 Environmental Impact

Several biosensors embedded in semiconductor-rich devices are needed for the mass adoption of healthcare services using the Internet of Things.

Therefore, it is difficult to get real-time visibility and traceability of the current location of items. The perfect answer to these issues is the Internet of Things. During transit, the IoT collects real-time data from items tagged with sensors and transmits it to the respective location.

Additionally, The Internet of Things can provide useful medical devices in maintaining environmental conditions around sensitive areas, such as medicines that must be kept at certain temperatures, [24].

The IoT contains a wide variety of sensors that can help with the challenging issues in hospital administration.

As a result, Hence, researchers and academics must focus on more matters and issues related to management, because addressing technical and technological matters is not sufficient alone, and among these issues, such as avoiding intrusions, [25], [26].

By reviewing the strategies, It is clear to us that there is no complete and comprehensive solution to all issues related to healthcare based on the Internet of Things. Security is another important and challenging area of study that is not emphasized in many papers. Future research should consider assessing IoT obstacles.

Although there is a variety of wearable health technologies that monitor and record patients' health status automatically and report it to doctors for real-time analysis, there is still a major concern about the applicability of the models developed in these studies. Bear in mind that access to electricity and the internet is limited in some areas of the world, particularly in rural areas in developing countries. Other problems include the high initial investment costs of installing such systems. Also, the arguments presented in this paper are focused on the applicability of wearable health monitoring technologies to accurately monitor, analyze, and classify human health states with limited access to expensive computational units and enduring power sources, [1]. The development of an e-health monitoring system that can automatically detect disabilities and report them to healthcare units without human intervention is a promising application for bettering the quality of life for the elderly and patients with disabilities.

There are several compelling benefits of IoT technologies for healthcare systems, [10]. These models can (a) save costs, (b) allow for better treatment outcomes, (c) help in disease management, (d) reduce errors and improve results, (e) increase patient satisfaction, (f) assist in medication management, (g) increase the operational efficiency of the healthcare system, (h) ease inventory management, (i) reduce the workload of doctors, (j) enable precise and early diagnosis, and (k) account for a patient's complete treatment history. Despite the current limitations of IoT technologies in large-scale implementations, many experts and analysts agree that in the future new applications relying on smart devices will appear in healthcare systems. Some markets will be entirely replaced by market sectors oriented towards IoT devices. However, there are several challenges and fears related to IoT technologies in smart healthcare applications. Many experts and medical professionals are concerned that unjustified treatment could arise and be misunderstood by the patients because of communication delays and false data. They also state that dependence on technology can be dangerous for patients. There can also be a huge risk of hacked devices or networks that would put patients in danger or allow unauthorized access to sensitive data. Most recently, the concern about privacy and the safety of patients' data has grown, underscoring the tremendous need for better data security in the immediate future.

4 Case Studies

IoT technology is widely implemented in the healthcare sector because of its potential applications. Some real-life implementations of IoT-aware models in healthcare are discussed which exhibit IoT smart applications. Connected inhalers have a set of sensors connected to an inhaler or Bluetooth spirometer to provide control of the patient's asthma symptoms and treatment. The sensor is connected to the app, which provides details of the time and date of the inhaler's usage, presenting a complete view of asthma control. Propeller Health's smart asthma technology initiative utilizes this concept, providing inhalers with sensors to assist asthma patients, [27].

Connected cancer treatment is an initiative for patients having head and neck cancer. The treatment consists of using an audio diary tool with a Bluetooth-supported weight scale and a blood pressure cuff. Scales and cuffs send data to an app that will record it, and daily updates are sent to nurse practitioners. Medtronic smart controller takes this Intel MPI approach and creates a symptom-tracking app for analyzing the patients' understanding. A field of study is the research of IoT-connected contact lenses, considering the properties of smart detection of eye movement and temperature shifts.

These lenses are non-invasive; hence, both long-sightedness (presbyopia) and cure after cataract surgery are viable applications. The Swiss company, Sensimed, is working on a smart contact lens known as Triggerfish for glaucoma patients, which detects eye movement. It contains external antennae connected to the computer that determines the IOP, measuring variations within the eye. The research is carried out in cooperation with MIT. A smartwatch app is suggested to monitor the patient's moods and thoughts. Using a new algorithm taking into account physiological data, a major depressive disorder (MDD) could be tracked. Changes in heart rate or sweat could indicate a panic attack onset, cognitive efficiency decline, and ecological momentary assessment (EMA) could also be used.

5 Successful Implementations

The following section covers the successful implementations, an idea for a successful implementation, and lessons learned.

IoT-Aware models have been successfully implemented in various Health care systems worldwide, resulting in meaningful impacts on the delivery of healthcare services. The following are a few of these implementations.

Since its implementation at many hospitals in Zhenjiang, China in December 2013, the "IoT eHealth Applications" project has been operating smoothly. In order to ensure that all users can immediately access medical services via portable devices like smartphones, a smaller version of the Internet of Things will be built using sensors on portable devices for data collecting and secure central servers for processing user requests. This facility can be expanded to include the entire hospital, enabling people to utilize health services, check updates, and monitor their condition via smartphones. If there are sensors to gather data around the city and sophisticated interfaces to provide real-time updates on the status of user requests, then this eHealth model can be expanded to include the entire city. All data may be gathered, processed, and analyzed by mobile apps in a smart city that understands eHealth, and patient feedback can be delivered to them easily. Patients can avoid waiting for appointments and outcomes when they use IoT medical services, [3].

In New Zealand, the "MyCare" eHealth platform has been designed and deployed to enhance the interaction and collaboration among consumers, family members, and health care providers in person-centered care. It consists of a web platform and mobile applications to allow consumers to manage their care needs and communicate with their family members and healthcare providers. The providers can also improve their trust with the consumers and better understand the consumers' needs. MyCare has been pilot-tested in west Auckland, and as the first of its kind in New Zealand, it represents a great advance in enhancing consumer empowerment.

In Singapore, a more vision-driven architecture of IoT eHealth is proposed in which intelligent interface technology is introduced. There are integrated intelligent medical assistants to conduct wearer-centric health management and medical services. All human requests/inquiries can be addressed through voice interfaces. By using the smart headset that contains an earphone and smart eyeglasses, patients can access data and obtain service feedback through this natural way of human interaction and communication. The integrated intelligent assistant is the key enabler for the scalable and sustainable model of IoT eHealth.

In the hospitals of Jeddah, Saudi Arabia, IoT was adopted to enhance the safety and care of patients receiving medications. This app tracks patients receiving medications and alerts them about

their medications and the timings for taking the medications using automated notifications. This will help to reduce Human Errors and ensure patient safety, [28].

Further, to encourage healthcare professionals to use IoT medical devices, implementations of IoT, like Health Tracker, Hematology Rhythm, and Medication Reminder & Dosage Tracker applications were proposed. These applications are safe to use and help professionals provide more timely, effective, and efficient healthcare services. With these applications, patients will experience fewer medication errors, better monitoring, and consistent follow-up of treatments. These implementations of IoT-based medical devices can be expanded on a large scale to hospitals worldwide. With the use of IoT, the world will witness a new era of Patient-Centric Health Care in which the focus is on the needs of the patients and the quality of healthcare services.

Key factors behind the successful implementation and steps taken to implement and make these projects successful: (i) Stakeholders are involved in the design stage: Different stakeholders including clinicians, administrators, information technology staff, and patients are involved in the design stage. All their inputs are included before the implementation. (ii) Easy to use: Simple and easy to use, with as little training as possible needed for its use. When the systems are implemented its functionalities are presented to users (clinicians) by shadowing them during their daily work in the wards. After a week of shadowing, if the users have learned how to use the system, it is considered as a successful implementation. (iii) Easy adaptability: Any system implemented would not block the continuation of the existing traditional paper-based way. In this way the health care professionals can gradually get used to both systems and the implemented system can be adapted to their needs. (iv) A champion mechanism: A small subset of staff is selected to be the champions or 'gurus' of the system implemented. Their role is to understand well the system and be available to their colleagues with any difficulties they may have. (v) Proceed with caution: The implementation is done gradually, and doctors in the wards are offered to use the system for a few weeks during which they can give feedback. The project team always has technicians available to listen to their suggestions and make the needed adjustments.

Implementation of a smart healthcare system based on IoT for remote monitoring needs to address the following issues: (i) Standardization: IoT has sparked questions about standards. IoT applications target domains, and all manufacturers, service providers, and end users want standards for operability both within and between those domains.

The fact that IoT seeks to encompass a broad variety of disciplines that are governed by various regulatory situations contributes to the standardization difficulty. Before IoT eHealth goods start to appear on the market, they must first pass a convoluted multi-agency regulatory structure. (ii) User-friendly devices: The front-end technologies' interface is a crucial component of IoT eHealth. End users' ability to self-train with IoT medical devices becomes crucial when these devices are built for patients who are unfamiliar with using high-tech tools. Device interfaces should be easy to use (for patients) and require the least amount of expert assistance, [3].

6 Discussion and Lessons Learned

The four case studies discussed in this paper helped to identify some key lessons learned in analyzing the applicability of IoT-aware models in healthcare systems. As one of the most critical applications, healthcare has an immense potential to benefit from the use of IoT technologies, where the key focus is to seamlessly integrate healthcare systems with IoT in a way that leads to smart and pervasive healthcare services. This paper tried to support this goal through a systematic review of the applicability of IoT-aware models in healthcare systems, [3]. As a key outcome of the five case studies, a classification of the IoT-aware models is proposed based on the focus on system architecture, services, or both. Each class was reviewed considering evaluation metrics such as correctness, completeness, and effectiveness criteria. Even though the five case studies reveal significant progress in enabling no disruptive integration of IoT devices into the healthcare systems, various challenges remain unsolved or partially addressed.

Healthcare systems are interactions of several distinct components working together to provide healthcare services in a society. As a first step towards achieving smart healthcare systems, it is important to gain insight into how these components interact with each other and how such an understanding can be captured in adequate IoT-aware models. Regarding structures, the focus is on developing models for understanding different types of components within a healthcare system, [29]. Currently, most available IoT-aware models do not properly address the interaction of different components, the types of required sensors for each

component, the indirect services offered by such components, and the limitations of such services.

7 Conclusion and Future Work

Healthcare is a well-known field of purpose as it preserves human life by treating errors within the human body. New technologies are penetrating this field toward easier, less expensive, and more accessible healthcare services. There are numerous emerging technologies within the Internet of Things (IoT) family. This ongoing trend creates and opens new opportunities for monitoring patients using wireless biomedical sensors, wearable devices, ambient devices, and smart homes. These approaches enable automated severe situations reporting to the healthcare team, where they may take remedial action for life-critical situations. This paper provides a survey of the opportunities, challenges, and research perspectives of IoT in the healthcare field. It also lists the key components for reliable healthcare design toward personalized healthcare systems. IoT architecture is presented at the end of the survey showing the integration of devices towards the healthcare application.

Leveraging the potential of the IoT, researchers, and analysts everywhere have begun to explore and experiment with different technology solutions to improve healthcare delivery in an innovative and modern way. This paper systematically reviewed previous and current studies related to IoT applications in healthcare service delivery for this research. Some challenges of such models are presented, either regarding the technical design or the processing rules needed to fulfill the model background descriptions. Challenges such as the computational limit, complexity, and precision space must be deeply understood and managed against the requirements in order to obtain a good intrinsic quality model, able to return both informative insights and predictive results of high quality, thus matching competing on levels. Other challenges point toward the Healthcare domain. Aspects like the ability to monitor seamless vitals, patient care, data collection and processing security, regulations, and standards, need to be understood, synthesized, and mapped on top of the models.

The context in healthcare is complex and contains multiple aspects, dimensions, and context switches. Capturing context is important for the functionality of IoT healthcare systems to operate safely and effectively. Context-aware systems are used to provide a smooth adaptation to the changing contexts in the environment. In relation to IoT, a context-aware IoT architecture is needed at the heart of healthcare IoT systems. Toward this goal, the context and constraints of the IoT healthcare systems need to be explored and enforced. Several healthcare IoT architectures are proposed in the literature, and most research efforts are focused on providing privacy for healthcare (e.g. patient data privacy) and dealing with the problem of security in IoT (e.g. securing the sensors against malicious attacks).

However, several non-security, non-privacy aspects of architecture design for healthcare IoT systems remain to be explored. These include the QoC (Quality of Context) of IoT sensors, the performance of the access and communication protocols layer, the malfunction and trust of IoT sensors, and the dynamic nature of context and mobility of IoT components. System context may be tightly coupled with platform context in a healthcare IoT architecture, and their trade-off in a specific scenario needs to be explored. The design of mid/high-level Machine Learning (ML) based reasoning considering context needs to be studied.

Acknowledgement:
The Deanship of Research at Zarqa University, Jordan funds this research.

References:

[1] Bogatinoska, D. C., Malekian, R., Trengoska, J., & Nyako, W. A. (2020). Advanced sensing and internet of things in smart cities. *In 2016 39th International Convention on Information and Communication Technology, Electronics and Microelectronics, MIPRO 2021* - Proceedings (pp. 632–637). Opatija, Croatia.

[2] Samara, G., Alsayyed, G. M., Aljaidi, M., Almatarneh, S., Almashakbah, F., & Omar, F. (2022, November). Internet of Robotic Things in Early Childhood Education: Domains and Challenges. In *2022 International Arab Conference on Information Technology (ACIT)* (pp. 1-7). UAE.

[3] Farahani, B., Firouzi, F., Chang, V., Badaroglu, M., Constant, N., & Mankodiya, K. (2018). Towards fog-driven IoT eHealth: Promises and challenges of IoT in medicine and healthcare. *Future generation computer systems*, 78, 659-676.

[4] Tunc, M. A., Gures, E., & Shayea, I. (2021). A survey on iot smart healthcare: Emerging technologies, applications, challenges, and future trends. arXiv preprint

arXiv:2109.02042.
DOI:10.48550/arXiv.2109.02042.

[5] Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials*, 17(4), 2347-2376.

[6] Islam, S. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K. S. (2015). The internet of things for health care: a comprehensive survey. *IEEE Access*, 3, 678-708.

[7] Sony, P., & Nagarajan, S. (2022). Semantic Interoperability Model in Healthcare Internet of Things Using Healthcare Sign Framework. *International Arab Journal of Information Technology*, 19(4), 589-596.

[8] Kulkarni, A., & Sathe, S. (2014). Healthcare applications of the Internet of Things: A Review. *International Journal of Computer Science and Information Technologies*, 5(5), 6229-6232.

[9] Hassanalieragh, M., Page, A., Soyata, T., Sharma, G., Aktas, M., Mateos, G., ... & Andreescu, S. (2015, June). Health monitoring and management using Internet-of-Things (IoT) sensing with cloud-based processing: Opportunities and challenges. *In 2015 IEEE international conference on services computing* (pp. 285-292). IEEE. New York, NY, USA.

[10] Gatouillat, A., Badr, Y., Massot, B., & Sejdić, E. (2018). Internet of medical things: A review of recent contributions dealing with cyber-physical systems in medicine. *IEEE Internet of Things Journal*, 5(5), 3810-3822.

[11] KUMAR, S., DALAL, S., & DIXIT, V. (2014). the Osi Model: Overview on the Seven Layers of Computer Networks a Comparat Ive Analysis of Safet Y Measures At Tack in Wi-Fi, Wi-Max and Bluet Oot H the Osi Model: Overview on the Seven Layers of Computer Networks. In *International Journal of Computer Science and Information Technology Research* (Vol. 2, pp. 461–466).

[12] Samih, H. (2022). Smart cities and internet of things. In *Journal of Information Technology Case and Application Research* (Vol. 21, Issue 1, pp. 3–12).

[13] Al-Mashhadani, M., & Shujaa, M. (2022). IoT security using AES encryption technology based ESP32 platform. *Int. Arab J. Inf. Technol.*, 19(2), 214-223.

[14] Bures, M., Klima, M., Rechtberger, V., Ahmed, B. S., Hindy, H., & Bellekens, X. (2021). Review of specific features and challenges in the current internet of things systems impacting their security and reliability. In *Trends and Applications in Information Systems and Technologies,* Vol. 3 9 (pp. 546-556). Springer International Publishing.

[15] Ksibi, S., Jaidi, F., & Bouhoula, A. (2023). A comprehensive study of security and cyber-security risk management within e-Health systems: Synthesis, analysis and a novel quantified approach. *Mobile Networks and Applications*, 28(1), 107-127.

[16] Garai, Á., Péntek, I., Adamkó, A., & Németh, Á. (2017). A clinical system integration methodology for bio-sensory technology with cloud architecture. *Acta Cybernetica,* 23(2), 513-536.

[17] Butt, S. A., Ali, A., Khalid, A., Shaheen, Q., Ariza-Colpas, P., & Shiraz, M. (2023). Patients using real-time remote health monitoring applications: a review. *Computational Intelligence for Medical Internet of Things (MIoT) Applications*, 93-120..

[18] Aljaidi, M., Alsarhan, A., Samara, G., AL-Khassawneh, Y. A., Al-Gumaei, Y. A., Aljawawdeh, H., & Alqammaz, A. (2022, November). A Critical Evaluation of A Recent Cybersecurity Attack on iTunes Software Updater. In *2022 International Engineering Conference on Electrical, Energy, and Artificial Intelligence (EICEEAI)* (pp. 1-6). IEEE. Jordan.

[19] Wang, D., Bai, B., Lei, K., Zhao, W., Yang, Y., & Han, Z. (2021). Enhancing Information Security via Physical Layer Approaches in Heterogeneous IoT with Multiple Access Mobile Edge Computing in Smart City. In *IEEE Access* (Vol. 7, pp. 54508–54521).

[20] Al-Sherideh, A. S., Maabreh, K., Maabreh, M., Al Mousa, M. R., & Asassfeh, M. (2023). Assessing the Impact and Effectiveness of Cybersecurity Measures in e-Learning on Students and Educators: A Case Studyx. *International Journal of Advanced Computer Science and Applications*, 14(5).

[21] Vimala Devi Parthasarathy,Kalaichelvi Visvalingam, "Healthcare Data Security in Cloud Storage Using Light Weight Symmetric Key Algorithm", *The International Arab Journal of Information Technology (IAJIT)*,Vol. 21, Number 01, pp. 57 - 66, January 2024, doi: 10.34028/iajit/21/1/5.

[22] Al-Sherideh, A. S., Ismail, R., Al Mousa, M. R., Al-Qawasmi, K., Al-Shaikh, A., Awwad, H., Maabreh, K., & Alauthman, M. (2024). Development of a Secure Model for Mobile Government Applications in *Jordan. Journal of Statistics Applications & Probability*, Pro. 13, No. 1, 145-155 (2024).

[23] Al-Khateeb, M., Al-Mousa, M., Al-Sherideh, A., Almajali, D., Asassfeha, M., & Khafajeh, H. (2023). Awareness model for minimizing the effects of social engineering attacks in web applications. *International Journal of Data and Network Science*, 7(2), 791-800.

[24] Hernández, A., & Yamaura, M. (2017). Cold chain management with Internet of Things (IoT) enabled solutions for pharmaceutical industry. *Malaysia Institute for Supply Chain Innovation*, 1-6.

[25] Hajiali, M., Amirmazlaghani, M., & Kordestani, H. (2019). Preventing phishing attacks using text and image watermarking. Concurrency and Computation: *Practice and Experience*, 31(13), e5083.

[26] Fantin Irudaya Raj, E., & Appadurai, M. (2022). Internet of things-based smart transportation system for smart cities. In *Intelligent Systems for Social Good: Theory and Practice* (pp. 39-50). Singapore: Springer Nature Singapore.

[27] Arefin, M. S., Rahman, M. M., Hasan, M. T., & Mahmud, M. (2024). A Topical Review on Enabling Technologies for the Internet of Medical Things: Sensors, Devices, Platforms, and Applications. *Micromachines*, 15(4), 479.

[28] Al-Rawashdeh, M., Keikhosrokiani, P., Belaton, B., Alawida, M., & Zwiri, A. (2022). IoT adoption and application for smart healthcare: a systematic review. *Sensors*, 22(14), 5377.

[29] Ouchani, S., & Krichen, M. (2020). Ensuring the correctness and well modeling of intelligent healthcare management systems. In The Impact of Digital Technologies on Public Health in Developed and Developing Countries: *18th International Conference, ICOST 2020*, Hammamet, Tunisia, June 24–26, 2020, Proceedings 18 (pp. 364-372). Springer International Publishing.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

The Deanship of Research at Zarqa University, Jordan funds this research.

Conflict of Interest

The authors have no conflicts of interest to declare.