



UNLEASHING POWER OF IoT IN HEALTHCARE: A COMPREHENSIVE SURVEY ON FUTURE TRENDS, APPLICATIONS, SECURITY ISSUES AND CHALLENGES

Navita Research Scholar, Department of Computer Science & Applications, Maharshi Dayanand University, Rohtak, Haryana, India

Pooja Mittal Assistant Professor, Department of Computer Science & Applications, Maharshi Dayanand University, Rohtak, Haryana, India

Shanayaa Student, B.Tech CSE-AI, Department of Artificial Intelligence and Data Science, Indira Gandhi Delhi Technical University for Women, New Delhi, India

V.Dhilip Kumar Department of CSE, Vel Tech Rangarajan, Dr. Sagunthala R & D Institute of Science and Technology, Chennai, India

Abstract.

The Internet of Things (IoT) is one of the most innovative technology that has the potential to revolutionize the healthcare system by bringing interconnected devices, sensors, and data analytics tools into the realm of healthcare practice and patient care. Integration of IoT in the healthcare system can improve patient monitoring, enhance patient outcomes, optimize operations, and enable highly personalized and proactive healthcare services. Along with that, the privacy and security of personal health information must be ensured during data transmission. To ensure this, serious legal and safety rules must be applied on security beaches of the healthcare system. In this context, this comprehensive survey explores the profound impact of IoT on the healthcare system. This paper also highlights and discusses the current trends and applications of IoT in healthcare systems including remote monitoring, and predictive analytics. The integration of IoT into the healthcare system not only improves computation speed but also provides profitable and pervasive healthcare services available to anyone, anywhere and at any time. In last, this paper also identifies the major security issues and challenges with suitable suggestions that assist academicians and researchers in exploring better healthcare services.

Keywords: Healthcare Systems, Internet of Things (IoT), Smart Technology, Sensors, Security.

INTRODUCTION:

A significant representative of the new generation of information technology is the Internet of Things (IoT). It is a network that spreads over the internet and is the result of fast development in the area of wireless communications in the past few years (**Atzori et al., 2010**). It offers connectivity among various information sensing devices (like infrared sensors, Radio Frequency identification, laser scanners, etc.) to the Internet to realize the concept “Internet of Everything” (**Stankovic, 2014**). Currently, IoT has been widely used in different fields including smart home, smart city, smart agriculture, intelligent logistics, smart healthcare, etc. Among all these applications, smart healthcare is gaining high popularity. Every year many people lost their lives due to different diseases and health issues. It is reported that 60% of people lost their lives due to cardiovascular disease every year in comparison to other diseases worldwide. Along with that, the healthcare service provides are under a lot of pressure to provide better health services with limited resources like medical equipments, low doctors to patient ratio, medicines, etc. So, there is an urgent need of a solution that can manage healthcare costs and can provide better, more efficient, and reliable healthcare services to the people (**Q. Zhang et al., 2020**). Along with that people need more attention to their health issues (**G. Zhang et al., 2019**). Therefore, IoT technology can be seen as the major solution to resolve various health issues. IoT is a virtual world of the Internet in which all physical objects like household equipment: thermostats, air purifiers, etc. are connected to the Internet, automobiles machinery, medical equipment, etc. Applying IoT technology to the healthcare system will help improve the life quality of people, the level of chronic disease management, life-saving interventions and danger warning, etc.



Such technology will support the realization of a smart healthcare system. It involves employing internet-connected intelligent devices and wearable medical sensors to oversee patient well-being, validate adherence to prescribed treatments, anticipate an impending cardiac event, and promptly access diagnostic data (**Esther Omolara et al., 2020**). The existing literature provides an overview of Internet of Things (IoT) technologies and their diverse applications.

(**Almotairi, 2023**) described the current trends and technologies in the healthcare domain and they also investigate the future trends that could be adapted to the existing trends. They also discussed numerous challenges that can hamper the development of an efficient and reliable healthcare system.. (**Akhigbe et al., 2021**) presented a comprehensive review of IoT technology applications in livestock management. The authors widely outlined IoT ecosystems, presenting enhanced architecture and technical issues. Furthermore, the paper discussed the present state, potential opportunities, and anticipated research trajectories for IoT-powered livestock management systems. (**F. Javed et al., 2018**) conducted a survey that encompassed IoT operating system, their supportive applications, functions, and challenges. Along with that a comprehensive survey is also conducted between different IoT devices depending on their architecture, management of power, memory handling and scheduling. Along with that this study presented various case studies and also highlight the major challenges that realm to IoT. (**Pirmagomedov & Koucheryavy, 2021**), presented an outlook on the comprehensive of different IoT technologies towards augmented human technologies. Along with that a comprehensive examination of emerging IoT facilitated human augmentation, design methodologies, devices, and various security issues (**Kumar et al., 2020**). (**Gómez-Chabla et al., 2019**) demonstrated a methodical review of IoT applications in agriculture. This study highlighted diverse categories of IoT-powered software applications prevalent in the agricultural sector, encompassing soil sensors, and discussed the advantages rendered by these technologies.

Extensively discussed research in this field mainly focuses on highly related IoT technologies, challenges and potential research trends in the future. They also discussed the applications of IoT in ocean and agriculture environment without counting the IoT-enabled healthcare system established in medical hospitals to improve real-time information that leads to the timely treatment of major critical diseases. Therefore this study addresses the gap in the existing research by deeply investigating the applications of IoT-enabled technologies in healthcare domains.

The major contribution of this research is as follows:

1. This study aims to highlight the purpose behind the development of IoT-enabled smart healthcare systems by emphasizing its major significance.
2. A comprehensive exploration of smart IoT-enabled technologies within healthcare is also presented here.
3. This research also identifies and extensively discusses major security and privacy issues which not only highlights them but also provides a way direction for future research in this domain.

The structure of this paper is as follows: Section 2 provides an overview of IoT-enabled healthcare systems with deep insights into the paradigm toward smart healthcare systems along with its major applications. Section 3 discusses the scope of utilization of IoT-enabled smart healthcare systems. Section 4 described the future research trends in IoT-enabled smart healthcare systems. Section 5 tackles the major challenges surrounding IoT-enabled applications. Section 6 concludes the study by offering better remarks and recommendations for shifting the traditional healthcare system to an IoT-enabled healthcare system.

IoT OVERVIEW IN HEALTHCARE:

The IoT paradigm empowers smart devices like sensor devices, mobile phones, and Raspberry Pi to monitor, sense, and react to the connected environment. Its primary objective is to establish a border network by connecting numerous devices to the internet concurrently(**Ahmadi et al., 2019**). Therefore

machine-to-machine and human-to-human interactions could be possible. By providing this facility humans can interact with machines for performing various healthcare-related tasks like surgery and monitoring patients from their remote locations. Furthermore, machines engage with their counterparts to facilitate the storage and retrieval of information. For instance, sensors transmit their data to a cloud system for short-term storage. A representative illustration of an IoT-enabled healthcare platform is represented in Figure 1. IoT is associated with different healthcare platforms like disease monitoring, hospitals, embedded medical sensors, etc.

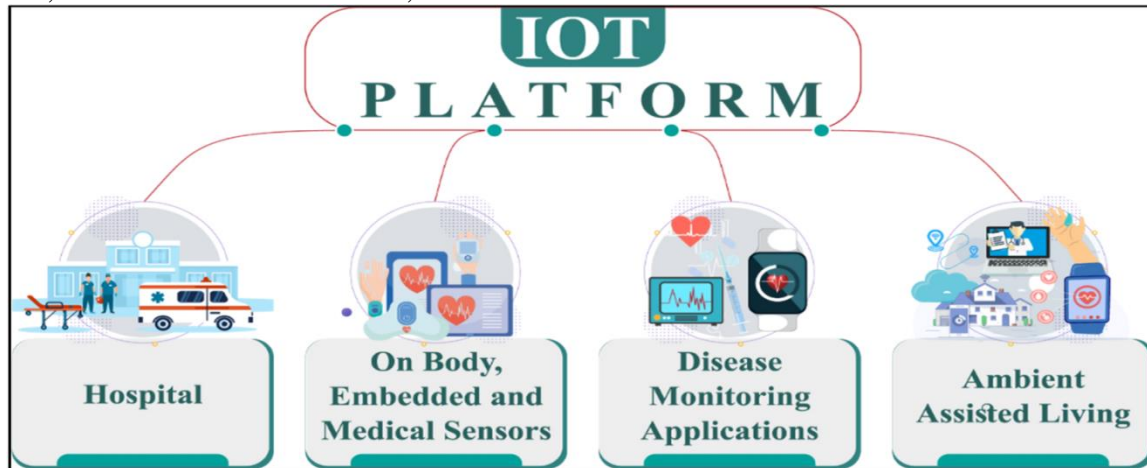


Figure 1. IoT-Associated Healthcare Platform

As shown in Figure 1. Conventional IoT-enabled healthcare systems are composed of four basic components. The first component of the healthcare system is the hospital which gives accommodations to healthcare service providers and In/Outpatients (Kelly et al., 2020). Such components closely monitor and observe the well-being of hospitals as well as the recovery process of outpatients in their respective places in real time. Such a facility is achieved through wearable and embedded medical body sensors. The recorded sensor recordings are transformed and manipulated into useful information that assists the medical staff to visualize the outpatient current health status. On the contrary, individuals who are recovered from their illness and are not under close monitoring may be provided medical assistance through “IoT-enabled assistant living devices”. Thus, such an approach not only enhances patient well-being but also provides efficient tools and timely information to the caregivers for optimal health services to the people and such a concept is generally referred to as smart healthcare.

IoT-Enabled Smart Healthcare System:

The idea of a smart healthcare system originated from the concept “Smart Planet”, which was first introduced in 2009 by IBM (Tian et al., 2019). “Smart planet” encompasses an intelligent infrastructure that utilizes sensors to collect data. All collected information is transferred to the Cloud data centers through IoT-enabled devices where it is further processed and transformed into useful information and can be easily accessed by healthcare services providers and authorized persons. Along with that, the main motivation behind the emergence of smart healthcare is to provide effective, timely services to patients from anytime and anywhere. Smart healthcare systems can provide effective communication between patients and healthcare service providers. Additionally, smart healthcare entails an advanced form of data interpretation for medical purposes (Vatandsoost & Litkouhi, 2019). The major services supported by IoT-enabled healthcare system include monitoring, diagnosing, tracking, and storing crucial medical and statistical information.



Figure 2. IoT Enabled Healthcare System (Sahu et al., 2022)

Application opportunities provided by smart healthcare mainly include handsets for measuring brainwaves, blood pressure (BP) monitoring devices, Electrocardiogram (ECG), glucose monitoring and pulse oximeter, etc. One of the common examples of smart healthcare is a “smart bed” developed by “Aby Medical Center in Norway”. This bed is equipped with smart sensors and has the ability to inform healthcare service providers about the current status of patient’s conditions.

Advantages of IoT-Enabled healthcare system:

IoT-Enabled healthcare system offers numerous advantages, encompassing “enhanced quality of treatment, efficient management of disease and security and safety of medical facilities” as depicted in Figure 4.

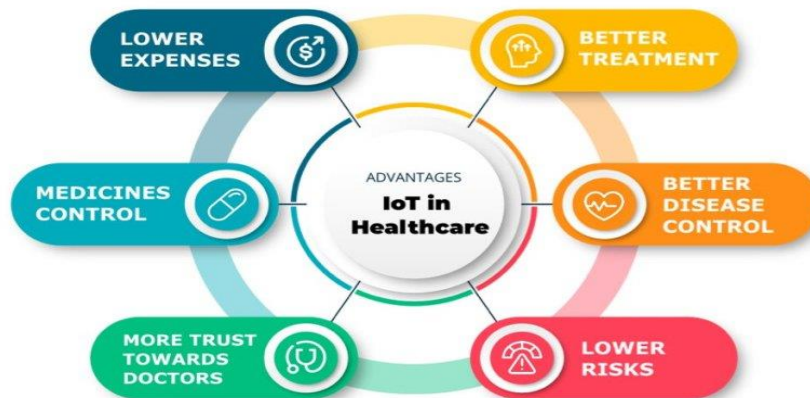


Figure 4. Major Advantages of IoT in Healthcare(zivost_wp_admin, 2022)

Better treatment service facility is achieved with the assistance of error-free diagnostic information captured through smart sensors and processed by intelligent techniques. When patients feel better and quality treatment, it enhances their confidence and trust in the personal and health facilities of the hospitals. Along with that, can have access to healthcare facilities at an affordable rate at any time and anywhere in real-time via the Internet. Smart healthcare also enables the maintenance and safety of various healthcare facilities by constant monitoring with the help of embedded camera devices. In addition to that, smart healthcare systems assists aged people in managing critical health issues without visiting hospitals.

SCOPE AND UTILIZATION OF IoT IN HEALTHCARE MANAGEMENT SYSTEMS:

Deployment of Internet of Things technology in different departments and units of the healthcare domain delivers better healthcare services to people in real time. The healthcare sector is known for

its constant exploration by adopting different ways to improve its services, mitigate costs and enhance the integrity of health services. Because of all these facts, it becomes possible to provide healthy living with the support of IoT enabled healthcare system. Along with that, IoT-enabled healthcare systems can be applied for remote monitoring of psychological health parameters. Advancements in the smart healthcare system can be achieved through the collaboration of different IoT architectures (**Tsourela & Nerantzaki, 2020**). In order to observe the health condition of any patient, IoT-driven applications are highly effective. Therefore, the existing technology used for hospital management can be improved with the help of IoT system. Due to this, the ability to reach out the medical consultants and healthcare professionals is increasing rapidly. However, the size of the data gathered through a real-world scenario in size and the accuracy of medical data (**Suganthi et al., 2021**). However, the precision and accuracy of healthcare delivery services can be improved by incorporating modern healthcare technologies in the management of hospital systems. Major applications of IoT technology for the management of smart healthcare systems are represented in Table 1.

Table 1. IoT Healthcare Applications

Reference	Application Area	Healthcare Devices/Sensors	Protocol
(Kim & Kim, 2018)	Guide to different technologies for IoT Healthcare service providers and provide a reliable disease management system	Smartphone's and independent handheld devices	-
(Jimenez & Torres, 2015)	New architecture for health monitoring system integrated with sensors having reliable cost and energy consumption	Smart Phone	XMPP
(Atlam & Wills, 2020)	Guide about safety management standards for developing a secure healthcare system	Body Sensors	-
(Güvenir, 2000)	Developed an expert system by using different classification techniques for the diagnosis of different diseases	Clinical devices	-
(Bacco et al., 2020)	Proposed health monitoring architecture for remote monitoring by integrating it with virtual reality	-	Path routing protocol for WSN
(Shahidul Islam et al., 2019)	Developed a healthcare management system through MySignal and virtually collect human body data	Biosensors attached to the Human body	LoRa
(Dauwed et al., 2017)	Developed a healthcare system for observing patient's chronic conditions outside the hospitals	Wearable sensors	-

IoT-ENABLED HEALTHCARE SYSTEM WITH FUTURE RESEARCH TRENDS:

The adoption of IoT technology continuously increases in the healthcare sector and is extensively utilized for monitoring patient health symptoms. Despite that, still, the existing healthcare system has enormous potential for transforming healthcare facilities with more advanced features. The future research trends associated with the healthcare system are:

- **Machine Learning Algorithms:** With the growing aging population number of diseases is growing rapidly and when observed with smart sensors generate a vast amount of data. To support the real-time prediction of diseases, such data must need to be analyzed in a real-time environment. So the adoption of effective and advanced machine-learning techniques can provide real-time effective prediction about disease status. So, it can be counted as an important field of research.
- **Prosthetics sensors:** This is one of the major applications of the healthcare system. There is always



a need to implement feasible sensors that can effectively capture environmental events by eliminating redundant events to obtain valuable information. So, prosthetics can be considered an important field for future research and implementation(Qadri et al., 2020).

• **Blockchains:** The emergence of blockchain technology is progressively gaining significance in the realm of IoT-enabled healthcare applications. Security is one of the major issues related to the development of IoT-enabled healthcare systems. Blockchain technology comes with the capability to resolve such issues. In the future, providing better security and safety to the stored data and providing authentication to devices can be counted as the major trends of research(Srivastava et al., 2020).

• **Internet of Nano Things:** The progression of the Internet of nano things in the healthcare domain is impeded by different shortcomings (Alabdulatif et al., 2023). Due to the limited energy bank of IoNT, an efficient harvesting technology must be required that can deliver better solutions for power-constrained IoNT networks. Different issues associated with IoNT technology like design, signal interfacing, and standard protocols for communication must be resolved in the future to support effective nanorobotics technology for better healthcare services.

CHALLENGES IN IoT-ENABLED HEALTHCARE SYSTEMS:

Major challenges faced by IoT-based healthcare systems are divided into two categories: infrastructural and security challenges.

1. Infrastructural Challenges: These challenges are further classified into different categories as follows:

• **Generation of large amounts of data:** In accordance with the established guidelines of a smart healthcare system, the healthcare sector must be very careful about the way of handling the patient information generated through smart IoT devices. Such an enormous amount of information may cause unexpected obstacles when the institution is not already prepared for managing and establishing authenticity to that data.

• **Obsolete infrastructure:** It poses a significant obstacle to progress in the medical sector: IoT poses highly advantageous to the healthcare system if its infrastructure facilities are good, properly functioning and outdated. Unfortunately, the prevalence of outdated facilities within hospitals and healthcare settings is a common issue [30]. The absence of up-to-date resources can lead to substantial challenges in terms of staffing and implementing essential advancements.

• **Vulnerability:** The use of IoT devices in the healthcare domain is continuously increasing, due to which numerous possibilities arise for hackers that can hack the computer system and access valuable storage data. Highly skilled hackers can easily break the system and can alter the measurement of patients. Therefore this study highlights that more improvements must be needed to handle such types of issues.

• **IoT presents various unrecognized challenges:** Various studies show that monitoring patient health parameters through IoT technology is highly utilized in clinicians, healthcare institutions, and hospitals. As IoT networks in hospitals are set up by humans, and the error caused by humans cannot be eliminated by more advanced technologies. Due to this IoT systems can cause fallible performance.

2.Security Challenges: IoT technology is broadly adopted by different application areas, and with the continuous adoption of technology new security issues will be continuously encountered. Some of these issues are discussed below:

• **Increased Number of IoT-connected devices:** A large number of private as well as public organizations are connected to IoT due to which the number of devices connected to IoT is growing day by day. It is estimated that around 20 billion devices would be connected to IoT by 2025. A large number of devices will lead to more security issues.

• **Botnet risk on IoT network:** The risk of botnet attacks is continuously increasing on IoT network; in which malware infect the network while the owners of IoT devices are unaware of this



attack. Due to this, the patient's useful and private information may be hacked (S. H. Javed et al., 2022).

- **Encryption Techniques:** Despite being an efficient way of denying access to information to hackers, it is becoming the most important security challenge. Because hackers can easily manipulate the algorithm that was designed to offer better safety and security (Abunadi et al., 2022).
- **Ineffective Methods for Detecting Threats:** Several organizations employ methods such as identifying breach indicators, monitoring user activities, or implementing security protocols to detect data breaches. However, these techniques have become inadequate due to the proliferation of IoT devices and their growing complexities.
- **Inadequate Default Passwords:** A major prevalence issue with IoT devices is the utilization of weak default passwords. Despite the recommendation to reset these passwords, certain IT managers overlook this directive. When passwords lack robustness or are easily guessable, the vulnerability of IoT devices to brute-force attacks escalates. This concern persists in specific regions and necessitates prompt intervention. For example, countries like the United States of America have taken measures to prohibit the use of default passwords.
- **Preserving User Privacy:** Providing security of data from internal and external users is mandatory for enterprises. Because all these devices are provided by the organization to the staff. Any flaw in the security of an organization poses a substantial risk to its reputation
- **Irregular Software Updates:** One of the important methods of ensuring security is to regularly update the software. There exist some IoT devices that do not receive regular updates and while others receive them. Such updates may cause insignificant security to these devices.

CONCLUSION:

Maintaining individual health is becoming a global health issue for the overall humanity. In the past few decades, the healthcare industry has attracted this scholarly attention. In this direction, the introduction of IoT technology in the healthcare environment can offer a new way of monitoring individual health parameters without visiting hospitals. So, this study introduces the current trends and their potential benefits for the implementation of IoT-enabled healthcare systems. Along with that this study also discovers future trends through which the most emerging technologies can be adopted to further improve the efficiency and effectiveness of IoT-enabled healthcare applications for offering reliable healthcare services for effective treatment. Major obstacles that hamper the development of efficient, effective, reliable, and scalable IoT-enabled healthcare applications are highlighted and discussed in this paper. Consequently, more opportunities can provide better perspectives and solutions for improving the quality of treatment for improving the lifetime of humans. In the future, some effective reinforcement algorithms must be developed with the capability to resolve major security issues and challenges incorporated with sensor data generated from different sensors. Along with that, the developed algorithm can be implemented in IoT-enabled healthcare systems to offer better healthcare services.

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