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# Internet of Things (IoT) in healthcare: A systematic review of use cases and benefits

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## Abstract

This paper presents a systematic review of the Internet of Things (IoT) in healthcare, exploring its use cases, benefits, and challenges. Through an analysis of diverse sources, including journal articles, conference proceedings, and white papers, we identify critical applications of IoT in patient monitoring, medical supply chain management, clinical operations, and telehealth services. Our findings highlight the transformative impact of IoT on healthcare, offering improved patient care through personalized treatments and early detection, enhanced operational efficiency, and facilitated evidence-based decision-making. Despite the promising benefits, challenges such as privacy, security, and interoperability persist, necessitating further research and technological advancements. This review underscores the potential of IoT to revolutionize healthcare delivery, making it more efficient, accessible, and patient-centered.

**Keywords:** Internet of Things (IoT); Healthcare technology; Patient monitoring; Telehealth services

## 1. Introduction

The Internet of Things (IoT) represents a transformative wave in the healthcare landscape, characterized by a network of interconnected devices capable of generating, collecting, and exchanging data (Aceto, Persico, & Pescapé, 2018; Vermesan & Bacquet, 2017; Vermesan & Friess, 2013). This technological evolution has paved the way for unprecedented advancements in healthcare delivery, patient monitoring, and disease management. IoT in healthcare, often termed Health IoT, has emerged from the broader IoT ecosystem, driven by the need for more efficient healthcare systems, personalized medicine, and the rising demand for better healthcare outcomes. Several factors, including the increasing prevalence of chronic diseases, the aging global population, and the push towards healthcare digitalization, propel the growth of IoT in healthcare (AbuBasim, Kaliappan, Shanmugasundaram, & Muthukumar, 2022; Pramanik, Upadhyaya, Pal, & Pal, 2019; Saha, Chakraborty, Paul, Ghosh, & Bhattacharya, 2022).

IoT technologies in healthcare encompass many applications, from wearable fitness trackers and remote patient monitoring devices to smart hospital beds and connected medical devices. These tools revolutionize how healthcare providers interact with patients, monitor health conditions in real-time, and make informed decisions. The adoption of IoT in healthcare has been steadily increasing, with the market expected to experience significant growth over the coming years (Bhuiyan, Rahman, Billah, & Saha, 2021). This surge is attributed to technological advancements, the decreasing cost of IoT devices, and the growing awareness of the potential benefits of IoT-enabled healthcare solutions

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(Aceto et al., 2018; Aceto, Persico, & Pescapé, 2020; Mondejar et al., 2021).(Aceto et al., 2018, 2020; Mondejar et al., 2021).

This paper aims to conduct a systematic review of the use cases and benefits of IoT in healthcare. It seeks to collate and synthesize existing literature on how IoT technologies are being applied within the healthcare sector and to identify the resultant benefits and improvements in patient care and healthcare operations. The scope of this review encompasses scholarly articles, industry reports, and case studies published within the last decade. The review focuses on diverse applications of IoT in healthcare, including but not limited to remote patient monitoring, telehealth, wearable technologies, and smart healthcare facilities. By examining these areas, the paper seeks to provide a comprehensive overview of the current state of IoT implementations in healthcare and their impact on improving health outcomes and operational efficiencies.

The significance of IoT in healthcare cannot be overstated. Its applications can potentially transform the healthcare industry by enhancing patient engagement, enabling remote care, and improving disease management. IoT technologies facilitate continuous patient health monitoring, allowing for early detection of potential health issues and timely interventions. This capability is particularly critical in managing chronic conditions such as diabetes, heart disease, and respiratory disorders, where regular monitoring can significantly impact patient outcomes.

Moreover, IoT applications in healthcare contribute to operational efficiency by streamlining processes, reducing costs, and optimizing resource allocation. For instance, IoT-enabled asset tracking can help hospitals manage their equipment more effectively, minimizing losses and ensuring that critical tools are available when needed. Additionally, the aggregation and analysis of data from IoT devices can inform evidence-based decision-making, leading to more personalized and effective treatment plans (Iqbal, 2023; Oueida, Aloqaily, & Ionescu, 2019). Integrating IoT technologies in healthcare holds promise for a more efficient, responsive, and patient-centered healthcare system. By examining the use cases and benefits of IoT in healthcare, this paper aims to highlight the pivotal role of IoT in shaping the future of healthcare delivery and outcomes (Al-Jaroodi, Mohamed, & Abukhousa, 2020).

## 2. Theoretical Framework

### 2.1. Concept of IoT

The Internet of Things is a transformative concept that revolutionizes how we interact with our surroundings and empowers devices to communicate and collaborate seamlessly. IoT encompasses a vast ecosystem of interconnected devices and objects, ranging from household appliances and vehicles to industrial machinery and smart city infrastructure. These devices are equipped with sensors and embedded software, allowing them to gather data from their environment, communicate with other devices or central systems, and execute actions autonomously. IoT aims to enhance efficiency, convenience, and decision-making across various domains, including healthcare, transportation, agriculture, and urban planning, by harnessing the power of real-time data collection and analysis (Chataut, Phoummalayvane, & Akl, 2023; Perwej, Haq, Parwej, Mumdouh, & Hassan, 2019).

At its core, IoT relies on four fundamental elements: sensors that capture data, devices that process and transmit this data, networks that facilitate communication between devices and central systems, and sophisticated data processing algorithms that extract valuable insights. This dynamic synergy between hardware and software enables IoT to bridge the physical and digital worlds, offering innovative solutions to everyday challenges and creating opportunities for enhanced automation, predictive maintenance, and personalized experiences. As IoT continues to evolve and expand its reach, it can revolutionize industries and improve the quality of life for individuals and communities worldwide, ushering in an era of unprecedented connectivity and intelligence in our everyday environment (Bello & Zeadally, 2014; Borgia, 2014; Gubbi, Buyya, Marusic, & Palaniswami, 2013).

### 2.2. IoT in Healthcare

IoT technologies have significant applications in the healthcare industry, revolutionizing patient care and healthcare management. Wearable health monitors, including fitness trackers and smartwatches, have become indispensable tools for individuals seeking to monitor their vital signs, sleep patterns, and physical activity. These devices empower patients to actively engage in their health management, promoting a proactive approach to well-being (Estrela et al., 2018; Rayan, Tsagkaris, & Iryna, 2021).

Remote Patient Monitoring (RPM) systems have emerged as a crucial advancement in healthcare, allowing healthcare providers to continuously monitor patients' health data in real-time from a distance. This technology is particularly

valuable for patients with chronic conditions, as it enables timely interventions and adjustments in treatment plans, reducing the risk of complications and hospitalizations. Moreover, smart hospitals, equipped with IoT devices for monitoring patient health, tracking assets, managing energy use, and ensuring medication compliance, optimize service delivery and patient care while streamlining resource utilization. Connected medical devices such as smart inhalers, connected insulin pens, and internet-enabled imaging devices further enhance the precision and efficiency of medical treatments, ultimately leading to improved patient outcomes. IoT in healthcare is transforming how healthcare services are delivered and fostering a more patient-centric and data-driven approach to medicine (Charulatha & Sujatha, 2020; Mohammed, Desyansah, Al-Zubaidi, & Yusuf, 2020; Pramanik et al., 2019).

### 2.3. Related Technologies

The effectiveness and scope of IoT in healthcare are amplified by its integration with related technologies. Big Data is a key component, as the vast amount of data generated by IoT devices in healthcare is harnessed and analyzed using big data technologies (Zeadally, Siddiqui, Baig, & Ibrahim, 2020). This allows healthcare professionals to uncover valuable trends, improve healthcare delivery, and make data-driven decisions. Artificial Intelligence and Machine Learning also play a pivotal role by employing sophisticated algorithms to analyze data from IoT devices. AI and ML can predict health events, personalize treatment plans, and enhance diagnostic accuracy, such as using AI to analyze data from wearable devices to anticipate potential health issues before they become critical. Additionally, Cloud Computing is essential in this ecosystem, providing the necessary infrastructure for storing and processing the immense volumes of data generated by IoT devices. This facilitates scalable, flexible, and accessible data management solutions for healthcare providers, enabling efficient and secure data storage and analysis (Dash, Shakyawar, Sharma, & Kaushik, 2019; Wang, Kung, & Byrd, 2018).

These related technologies collectively form an indispensable ecosystem that maximizes the potential of IoT in healthcare. This integration revolutionizes healthcare by enabling advanced data analysis, real-time monitoring, and personalized patient care, making it more proactive, patient-centred, and efficient. The synergy between IoT and these technologies empowers healthcare professionals with actionable insights, leading to improved patient outcomes, reduced costs, and enhanced healthcare experiences. As these technologies continue to evolve and interconnect, the future of healthcare promises even more advanced and efficient patient care solutions.

## 3. Use Cases of IoT in Healthcare

### 3.1. Patient Monitoring

One of the most significant applications of IoT in healthcare is in patient monitoring, encompassing remote patient monitoring (RPM), wearable technologies, and real-time health tracking (Su et al., 2019). RPM systems allow healthcare providers to monitor patients' health metrics outside of conventional clinical settings, significantly benefiting those with chronic conditions or patients undergoing postoperative recovery. These systems can alert healthcare providers to potential health issues before they become severe, enabling timely interventions. Wearable technologies, such as fitness bands and smartwatches equipped with health monitoring sensors, have enabled individuals to track their health metrics like heart rate, sleep quality, and physical activity in real time. This continuous monitoring aids in the early detection of potential health problems and promotes a proactive approach to health and wellness. Overall, patient monitoring via IoT enhances patient engagement in their health management, improves the quality of care, and reduces hospital readmissions and healthcare costs (Agali, Masrom, & Rahim; Malviya & Goyal, 2023).

### 3.2. Medical Supply Chain Management

IoT technologies are crucial in revolutionizing medical supply chain management by ensuring the efficient tracking and management of pharmaceuticals, medical equipment, and other supplies (Ding, 2018; Sallam, Mohamed, & Mohamed, 2024). Through RFID tags, barcodes, and GPS tracking, healthcare facilities can monitor the location and condition of medical supplies in real-time. This capability is crucial for managing inventory levels, preventing stockouts or overstock situations, and ensuring that critical supplies are available when needed. Moreover, IoT-enabled supply chain management helps ensure pharmaceuticals' authenticity, thereby preventing counterfeit drugs from entering the supply chain. It also facilitates the efficient management of vaccine distributions, particularly those requiring strict temperature controls, by monitoring storage conditions throughout the supply chain. Healthcare providers can reduce waste, lower operational costs, and improve patient care by optimizing supply chain logistics (Haleem, Javaid, Singh, & Suman, 2022).

### 3.3. Clinical Operations and Workflow Management

IoT technologies enhance clinical operations, patient flow, and healthcare delivery. Smart hospitals utilize IoT devices for many applications, including environmental monitoring (temperature, humidity, and air quality), energy management, and security. IoT devices help optimize patient flow in clinical settings by monitoring patient movements and managing appointments to reduce waiting times. Furthermore, connected medical devices can automatically update patient records with the latest health data, reducing manual data entry errors and freeing up healthcare professionals to focus more on patient care. IoT systems can also assist in managing bed occupancy efficiently, ensuring that patients are admitted, transferred, and discharged with minimal delays. Enhanced clinical operations and workflow management through IoT lead to improved patient satisfaction, better resource utilization, and increased overall efficiency in healthcare delivery (Awad et al., 2021; Bhattacharjee & Ray, 2014).

### 3.4. Telehealth and Telemedicine

The advent of IoT has significantly bolstered the capabilities of telehealth and telemedicine, providing patients with remote access to healthcare services. IoT devices support telehealth by enabling remote consultations, diagnostics, and even some forms of treatment, thus overcoming geographical barriers to healthcare access. Wearable health monitors and home health devices can transmit vital health data to healthcare providers in real time during teleconsultations, allowing for accurate assessments and diagnostics. This is particularly valuable for patients in remote or underserved areas, those with mobility issues, or individuals seeking a second opinion. Additionally, telehealth services supported by IoT devices have proven invaluable during public health emergencies, such as the COVID-19 pandemic, by reducing the need for in-person visits and minimizing the risk of virus transmission. Telehealth and telemedicine via IoT not only enhance the accessibility of healthcare services but also contribute to a more personalized and convenient patient care experience (Chidolue & Iqbal, 2023; Johnson et al., 2023; Ninduwezuor-Ehiobu et al., 2023).

In summary, the use cases of IoT in healthcare are vast and varied, offering transformative benefits across patient monitoring, medical supply chain management, clinical operations, and telehealth services. These applications collectively contribute to a more efficient, accessible, and patient-centric healthcare ecosystem.

## 4. Benefits of IoT in Healthcare

### 4.1. Improved Patient Care

IoT technology significantly enhances patient care by enabling more personalized, precise, and proactive healthcare solutions. Healthcare providers can continuously track patient health metrics through wearable devices and home monitoring equipment, leading to highly personalized care plans based on real-time data. This level of personalization ensures that treatments are tailored to patients' individual needs, improving outcomes and patient satisfaction. Furthermore, IoT devices facilitate the early detection of potential health issues through continuous monitoring, allowing for preventive measures and interventions before conditions worsen. This preventative approach not only improves the quality of life for patients but also significantly reduces the need for emergency care and hospital admissions, marking a shift towards a more preventive and less reactive healthcare model (Nausheen & Begum, 2018; Tian et al., 2019; Zeadally et al., 2020).

### 4.2. Operational Efficiency

The integration of IoT in healthcare operations brings about substantial improvements in efficiency and cost-effectiveness. By automating routine tasks, such as patient monitoring and data entry, IoT frees healthcare professionals to focus more on direct patient care activities. Additionally, IoT applications in supply chain management ensure the efficient use of resources, reducing waste and minimizing the risk of stockouts or overstocking of medical supplies. Smart hospital systems, powered by IoT, optimize energy use, manage facility operations, and improve the utilization of healthcare facilities, further driving down operational costs. These efficiencies translate into lower healthcare costs for patients while enhancing the overall quality of healthcare services (Al-Jaroodi et al., 2020; Joyia, Liaqat, Farooq, & Rehman, 2017).

### 4.3. Data-Driven Decisions

IoT technologies are pivotal in the transition towards data-driven decision-making in healthcare. The vast amounts of data IoT devices collect provide a comprehensive view of patient health trends, disease patterns, and treatment outcomes. By leveraging big data analytics and AI, healthcare providers can analyze this data to identify effective

treatments, predict health outcomes, and make informed decisions about patient care. This evidence-based approach ensures that healthcare practices are grounded in empirical data, leading to better patient outcomes, more efficient healthcare delivery, and the optimization of healthcare resources. Furthermore, the real-time nature of IoT data collection supports immediate decision-making, which is critical in emergency and acute care scenarios (Sarker, 2021; Trayush, Bathla, Saini, & Shukla, 2021).

While the benefits of IoT in healthcare are substantial, its implementation has significant challenges. Privacy and security concerns are paramount, given the sensitive nature of health data collected and transmitted by IoT devices. Ensuring the security of this data against breaches and unauthorized access is crucial to maintaining patient trust and compliance with privacy regulations. Interoperability between different IoT devices and healthcare systems also poses a challenge, as seamless data exchange is essential for the effective use of IoT in healthcare. Standardization of technologies and protocols is necessary to overcome these barriers. Additionally, regulatory compliance is a critical consideration, as healthcare providers must navigate a complex landscape of regulations that govern the use of IoT in healthcare (Awotunde et al., 2021). Addressing these challenges is essential for realizing the full potential of IoT in enhancing healthcare delivery and patient care (Uchechukwu, Amechi, Okoye, & Okeke, 2023).

## 5. Conclusion

This comprehensive review has illuminated the multifaceted role of the Internet of Things in healthcare, showcasing a wide array of use cases that span from patient monitoring and medical supply chain management to clinical operations and telehealth services. The evidence underscores a significant shift towards more personalized, efficient, and proactive healthcare delivery models enabled by IoT technologies. The benefits of IoT in healthcare are profound, contributing to improved patient care through personalized treatment plans and early detection of diseases, enhanced operational efficiency by streamlining healthcare processes, and facilitated data-driven decision-making through the analysis of real-time health data. Looking forward, the integration of IoT in healthcare presents numerous opportunities for further research and technological development. Key areas for future exploration include the advancement of AI and machine learning algorithms to better analyze and interpret the vast datasets generated by IoT devices, improving patient outcomes through predictive healthcare models. Further research is also needed to address the challenges of privacy, security, and interoperability, ensuring the safe and effective use of IoT technologies in healthcare settings. Additionally, exploring the potential of emerging technologies such as blockchain for secure data management and the development of new sensor technologies for more accurate and less intrusive monitoring could significantly advance the field.

The transformative potential of IoT in healthcare is undeniable. As we stand on the cusp of a new era in healthcare delivery, IoT technologies offer the promise of a healthcare system that is not only more responsive and efficient but also more attuned to the needs and well-being of patients. The path forward will require not only technological innovation but also a concerted effort to address the ethical, regulatory, and logistical challenges that accompany the adoption of IoT in healthcare. Embracing this complexity and potential, the future of IoT in healthcare holds the promise of significantly enhancing the quality, accessibility, and efficiency of healthcare for all.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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