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An Overview of Remote Patient Monitoring For Improved Patient Care and Cost Reduction: The Iot Revolutionizing Health Care

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Abstract: Modern technologies like 5G, the Internet of Things (IoT), and Artificial Intelligence (AI) have just come together, creating previously unheard-of chances for creative solutions. As a result, several IoT use cases have come to fruition, particularly in the healthcare industry, enabling the creation of eHealth and mHealth applications for ambient assisted living (AAL). However, there are practical issues with the current healthcare system, such as service delays and exorbitant expenses, which have had serious repercussions, such the untimely passing of famous people from heart attacks. Real-time patient monitoring and therapy with few delays are necessary to solve these pressing challenges. IoT has changed the game in this area by making it easier to establish Remote Patient Monitoring (RPM) systems. Vital indicators can be sent in real time to clinicians using IoT-enabled wearable devices (biosensors), enabling quick intervention and the start of treatment. This article gives an overview of the state-of-the-art in RPM using IoT, highlighting its potential to save time, lower healthcare expenses, and considerably raise patient quality of life and the caliber of healthcare services. It also identifies research holes and ways to use RPM systems, laying the groundwork for further development in this area.

Index Terms: IoT, Remote Patient Monitoring, RPM, eHealth, mHealth, 5G, Artificial Intelligence, AI, Wearable Devices, Biosensors, Real-time Healthcare, Ambient Assisted Living, AAL.

1. Introduction

Technological advancements, such as the Internet of Things (IoT), play a pivotal role in today's world, impacting both individuals and organizations. These innovations are harnessed in conjunction with other cutting-edge technologies to realize a wide range of applications. For instance, IoT, in addition to various wireless communication technologies, relies heavily on sensor networks and Radio Frequency Identification (RFID). The utilization of IoT leads to the generation of substantial data volumes, making cloud computing and big data essential components of this technology. Furthermore, IoT seamlessly integrates with edge computing and fog computing technologies [1, 2].

The versatility of IoT finds applications across various domains, including transportation, healthcare, and retail. However, this discussion focuses on a specific use case within the healthcare sector: remote patient monitoring (RPM). The age-old adage, "health is wealth," underscores the imperative for innovative healthcare delivery methods. RPM has the potential to revolutionize real-world healthcare services by enhancing patient care, reducing waste, and lowering

costs. The absence of RPM implementation has tragically led to the loss of lives, even among prominent figures in India. With RPM in place, it is conceivable to eliminate deaths related to heart attacks, despite an increase in the number of cases over time. The traditional approach, characterized by a delay between symptom onset and treatment initiation, results in avoidable loss of life. Fortunately, there exist several RPM systems documented in the literature to address this critical issue. Numerous studies, including those referenced in [3, 4], and [5], have explored personalized remote healthcare services, necessitating an ecosystem comprising various technologies, data analytics, and artificial intelligence (AI).

Researchers have leveraged a diverse array of technologies, including IoT, cloud computing, fog and edge computing, wearable technology (as highlighted in [6, 7]), and blockchain technology (referenced in [10, 11], and [12]) to establish robust RPM systems. The profound impact of RPM on people's lives cannot be overstated, and it is through the synergy of IoT and other cutting-edge technologies that this potential is realized. The present landscape boasts numerous RPM systems that incorporate a myriad of technologies to enhance healthcare delivery.

The state of the art must be determined in order to gain knowledge. Our contributions in this work are as follows in order to achieve this.

a. Review of literature is made on IoT enabled RPM systems to ascertain the insights on present state of the art.
b. Research gaps are identified besides bringing out useful insights on RPM and related technology usage in the existing applications including AI.

1.1. Significance of internet of things

IoT is an amalgamation of many technologies working together. It is an emerging technology that enables connectivity among things. In other words, it provides seamless integration between digital objects and physical objects in the real world. It also exploits Machine to Machine (M2M) integration without human intervention. Thus it is going to make revolutionary changes and has impact on the society and contributes to value creation [13]. With Internet of Things it is possible to have integration among businesses with M2M connectivity. It makes use of sensing technologies, communication technologies and others. It is likely to produce huge data. In order to process such data, it needs to use resources of cloud. IoT can also be integrated with social networks and healthcare industry. IoT has emerged with long evolution as presented in Figure 1 (adopted from [19]).

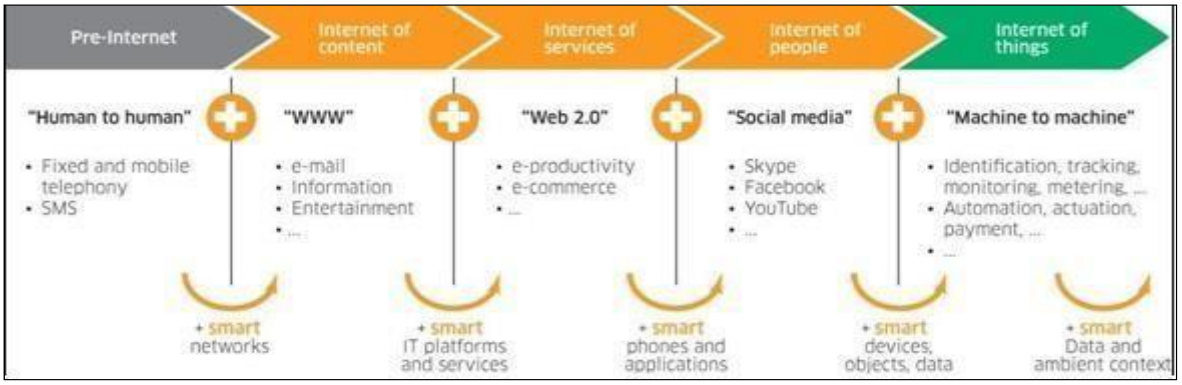

Fig. 1. Evolution of IoT

Internet has been around for many years with growing technologies to connect people. However, through Internet the IoT enables networking of things. Here things may be anything in the world both physical and digital. With Radio Frequency Identification (RFID) any object in the real world can participate in computing. With sensing devices connected to IoT it is possible to have plethora of new applications. New business models are possible. Before Internet came into existing people interacted with other people physically or through mobile communication technologies. Then we got World Wide Web (WWW) to support Internet of Content. Afterwards we got Internet of services and Service Oriented Architecture (SOA) with Web 2.0 technology. Then with social media we achieved Internet of people as Internet is connecting people across the globe seamlessly with virtual communities. The M2M integration with different technologies like identification, monitoring, metering, automation, sensing, actuation, payments etc. are used to realize Internet of Things (IoT). Improvements in the sensing became Sensing as a Service as discussed in [17]. As explored in [37] IoT is the suitable technology for agriculture in terms of decision making and disease monitoring. As discussed in [38] big analytics associated IoT data are useful in realizing many IoT use cases. With IoT technology capabilities to integrate physical and digital worlds, it is explored for remote patient monitoring in this paper.

2. Literature Review

This section covers many existing RPM systems found in the literature covering the approaches used in the systems.

2.1 Remote Patient Monitoring Systems

This paper offers an overview of current patient health monitoring platforms that make use of Internet of Things (IoT) technology and smart devices, as reported by Kang et al. [2]. The authors highlight these platforms' advantages, which include real-time monitoring, data analysis, and remote medical services. They talk about how wearable sensors, smart home systems, and mobile health apps are all examples of IoT-enabled medical technologies that have a variety of uses in healthcare. According to the study, these systems have the potential to enhance patient care and enable remote monitoring in times of a public health emergency like the COVID-19 pandemic.

A cloud-enabled data analytics and visualization approach for forecasting patient health shocks is presented in Mahmud, et. al.'s [3] publication. The authors suggest a system to analyze real-time patient data and forecast potential health shocks using big data analytics and cloud computing techniques. The study emphasizes the significance of such a system in remote patient monitoring, particularly under conditions like the COVID-19 quarantine when ongoing monitoring and the early identification of health concerns are vital.

Neethu et. al.'s real-time patient monitoring and analysis system built on the Raspberry Pi 3 is presented in this conference paper by Neethu et. al. The system's architecture and implementation are described by the authors. It allows for continuous monitoring of patients' vital signs and notifies medical staff when readings are out of the ordinary. The study highlights the potential of IoT devices in remotely monitoring patients, enabling prompt intervention and better healthcare results. IoT and artificial intelligence (AI) implementations in remote healthcare monitoring systems are described in Alshamrani's [5] survey study. Wearable tech, smart homes, and telemedicine platforms are just a few examples of the IoT-based healthcare monitoring technologies the author examines. The paper covers the use of AI methods for processing and analyzing the gathered healthcare data, including machine learning and data analytics. The potential for IoT and AI to enhance the effectiveness and caliber of remote patient monitoring systems is highlighted in the article. Juyal, et.al [6] this study introduces an IoT-based cloud-based smart skin health monitoring system. The system's architecture and implementation are described by the authors, who use wearable sensors to gather real-time information on several aspects of skin health. The gathered information is sent to the cloud, where AI algorithms examine it and offer insights regarding the user's skin condition. The study emphasizes how useful a system like this may be for remote monitoring and the early identification of problems with skin health.

Reza et al. [7] an intelligent IoT framework is presented in this study for illness patient indoor healthcare monitoring. In order to gather real-time patient data, the authors suggest a system that makes use of IoT gadgets including wearable sensors and ambient sensors. To find anomalies and give early warnings to healthcare practitioners, the acquired data is processed and analyzed using machine learning algorithms. The study emphasizes how a framework of this kind could be used for remote patient monitoring, enabling proactive and individualized healthcare. Shahjalal,et.al[8] The system for remote patient monitoring that is IoT-based and uses artificial intelligence is presented in this conference paper. The authors outline the system's architecture and execution, which makes use of IoT devices to gather patient data and AI algorithms for data analysis and prediction. The study highlights how effective a system like this could be at enhancing healthcare, particularly in isolated and neglected areas.

Baig, et.al [9] an introduction of wearable patient monitoring systems is given in this systematic review paper, together with information on the prospects and present difficulties facing their clinical application. The authors examine a range of wearable technology, including fitness trackers and smart watches, that is used to monitor patient health metrics. For wearable patient monitoring systems to be successfully used, they emphasize the significance of addressing issues with data confidentiality, device accuracy, and clinical acceptance. In this study, Uddin et al. [10] suggest a block-based continuous patient monitoring system that includes a patient-centric agent. The authors provide an overview of the system's architecture and implementation, which makes use of wearable sensors and a patient-centered agent to continuously monitor patients' health. The study focuses on the value of a patient-centric approach to remote monitoring and the potential of such a system to enhance patient outcomes.

Su, et al [12] this paper offers a novel architecture for an RPM system that incorporates abnormality detection. In order to remotely monitor patients, the authors suggest a system that combines wearable technology with wireless communication technologies. To enable ongoing patient vital sign monitoring, the framework has components for data collection, transmission, storage, and analysis. The abnormality detection module aids in spotting potential health problems and generates notifications so that medical professionals can take action.

The systematic review by Baig et al. [13] explores the prospects and difficulties for the clinical use of wearable patient monitoring systems with a focus on these devices. The authors examine different wearable technology that is used to track various physiological markers. They emphasize difficulties such data security, device compatibility, and data accuracy. Improved patient outcomes, cost-effectiveness, and personalized healthcare are just a few of the prospects for clinical adoption that are noted in the research. Swaroop et al. [14] Using the Internet of Things (IoT) technology, this study describes a health monitoring system for recording vital signs. Wearable tech, sensors, and a

communication network that is IoT-enabled are all part of the system design the authors suggest. Vital indicators, including temperature, blood pressure, and heart rate, are continuously recorded by the device. In order to be analyzed and interpreted, the collected data is sent to a central monitoring unit. By means of experimental findings, the authors show the viability and efficiency of their approach. Halaliya et al. [15] within the framework of Healthcare 4.0, this conference paper explains how blockchain technology is being used in remote patient monitoring. The authors suggest a blockchain-based system to guarantee the accuracy, security, and confidentiality of patient data.

For remote patient monitoring, Uddin et.al [16] blockchain proposal is patient agent managed and decentralized. They emphasize how the security, privacy, and effectiveness of remote patient monitoring systems could be improved by blockchain technology. Research on the Internet of Things is done by Whitmore et al. [17], who look at trends and issues. They talk about how the Internet of Things is transforming industries as diverse as healthcare, transportation, and smart cities. For smart patient monitoring and recommendation (SPMR), Motwani et al. [18] describe a unique architecture built on deep learning and cloud analytics. They have developed a framework that makes use of cutting-edge technology to enable individualized and intelligent patient monitoring. For smart cities backed by the Internet of Things, Perera et al. [19] proposal suggests a sensing as a service approach. To enable data-driven decision making and better services in smart cities, they talk of integrating sensor networks and IoT technology. Using smart contracts for safe automated remote patient monitoring, Griggs et al.'s [20] healthcare blockchain system is introduced. They stress the potential of blockchain technology and smart contracts for boosting data security and automating medical procedures.

These studies collectively contribute to our understanding of the potential benefits and challenges associated with technologies such as blockchain, IoT, and deep learning in healthcare, smart cities, and remote patient monitoring. They highlight the significance of security, privacy, and personalized approaches in leveraging advanced technologies for improved outcomes in these domains.

2.2 Remote Patient Monitoring for Covid-19 Patients

Taiwo and Ezugwu [1] proposed a smart health monitoring system meant for Covid-19 patients who are in quarantine. Their system is known as “a remote smart home healthcare support system (ShHeS)”. IoT is integrated with the system with many wearable sensors to monitor patient’s vital signs. It has provision for remote monitoring of patients and thus patients get advice from doctors without burdening hospitals in the pandemic situation. It also includes smart home feature to control appliances at home and also support for health information in smart phone. Patient is able to use the mobile application that provides notifications. Sharma et al. [11] proposed an ontology based IoT integrated system for remote patient monitoring, particularly for Covid-19 patients. They used wearable sensors with patients to capture health data and provide IoT based remote monitoring mechanism. They designed the system in such a way that it gets Covid-19 related health conditions and thus it helps doctors to suggest treatment to monitored patients. It is supported by an Android mobile application to serve the stakeholders of the system.

3. Technology Usage Dynamics

a) Internet of Things: It is crucial for combining physical objects and digital world leading to plenty of use cases including RPM.
b) Cloud Computing: It is the technology that enables users to make use of shared computing resources through Internet without time and geographical restrictions.
c) Edge Computing: It is the computing phenomena that bring computing resources closer to the data for improving performance.
d) Fog Computing: It is similar to edge computing which enables nearby resources to be used by devices. It helps IoT use cases to have workflow applications and improve performance.
e) Wearable Technology: It is the technology that enables wearable sensors that can be used to obtain patient’s vital signs.
f) Data Analytics: It is the domain which covers machine learning, deep learning and even AI for discovering knowledge from data.

Table 1. Shows summary of technology usage in RPM

Technology Usage in RPM	References
Internet of Things	[1], [2], [4], [5], [6], [7], [8], [10], [11], [12], [16], [21], [22], [23],[24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37]
Cloud computing	[2], [3], [6], [8], [23], [24], [27]
Edge Computing	[16], [28], [32], [33]
Fog Computing	[16], [28], [32], [33]
Wearable Technology	[1], [9], [11], [15], [16], [21], [23], [25], [26], [31]
Data Analytics or AI	[3], [5], [6], [7], [8], [16], [18], [22], [26], [27], [28], [29], [32], [33],[34]
Blockchain Technology	[15, 16], [21]

As presented in Table 1, the technology usage dynamics in the RPM systems found in the literature are provided. It, by a glance, lets us understand the utility of each technology as reflected in the literature.

3.1. Relevance of data analytics for rpm as IoT use case

Data analytics is the domain which helps in mining data and providing required knowledge or business intelligence (BI). In healthcare systems including RPM, it is essential to implement data analytics to reap its benefits. Mahmud et al. [3] advocated the need for data analytics and visualization. They proposed a framework towards this end. Alshamrani [4] explored ML algorithms to detect anomalies in health data. They envisaged that AI based methods play vital role in healthcare industry. Juyal et al. [6] proposed a skin monitoring system with AI based methods for data analytics. Particularly, they explored CNN model for skin health monitoring. Raza et al. [7] explored AI for finding abnormalities in Alzheimer's disease patient's health condition. Shahjalal et al. [8] used AI for finding discrepancies associated with smart home system. Uddin et al. [16] used data analytics in the RPM based on blockchain technology. Motwani et al. [18] implemented deep learning in their RPM for data analytics. Fazio et al.[22] used data analytics with ensemble approach to know the probability of recurrence of stroke in stroke affected patients. Hassan et al. [26] explored the utility of AI in RPM systems. They discussed the need for ML algorithms for acquiring knowledge from healthcare data. Azimi et al. [27] used several ML algorithms like SVM with Map Reduce programming paradigm in distributed environments for discovering knowledge from healthcare data. Azimi et al. [28] performed data analytics to know health condition of patients and monitoring trends in health from time to time. Dillon et al. [29] focused on big data analytics in health monitoring system where the data is subjected to analytics to arrive at useful knowhow.

4. Summary of Important Findings

This section presents the summary of findings of the literature in terms of techniques used for RPM and their advantages and limitations.

Table 2. Summary of important findings

Reference No/ Author, Year	Techniques	Advantages	Findings
[2] Kang et al. (2018)	Technology for tracking patient health using the Internet of Things (IoT), cloud computing, and big data.	Exchange of health data from many sources that is extremely safe, effective, and scalable.	More of theoretical in nature. No practical approach.
[4] Mathew and Abubeker(2017)	Raspberry Pi 3 and IoT integration for remote patient monitoring.	Remote observation of patient's vital signs.	It still needs some data analytics module for required intelligence.
[9] Baig et al. (2017)	Wearable technology, RPM, eHealth and mHealth.	Affordable healthcare solution to patients.	More of theoretical in nature. No practical approach.
[11] Sharma et al. (2021)	RFID, RPM, ontology based technique.	Monitoring patients remotelyand Preserving privacy.	It has no machine learning and data analytics.
[12] Su et al. (2019)	Remote patient monitoringmethods.	Provides overview of different approaches to remote patient monitoring.	Medical knowledge basedsystem is Yet to be realized.
[18] Ahmed and Kannan(2021)	IoT based RPM	Improving QoS withability to monitor Patients remotely.	Focus is on secure communications and privacy.
[27] Hassan et al. (2018)	RPM realized with hybridapproach.	Faster and accurate RPMsolution.	It depends on the synthetic data and simulations.
[32] Verma and Sood(2020)	IoT enabled RPM and notification techniques.	Temporal mining improves real time statistics.	Needs enhancement to have real time alertingsystem.
[33] Rajan et al. (2019)	IoT, Fog computing and Data Mining for RPM.	Accurate and reliablediagnosis.	It still needs to be improved for different workloads of the application.
[36] Plageras et a. (2017)	IoT and semantic technologies for personalizedhealthcare.	Patients can view their health information.	Data mining is not used.
[38] Chaomin et al. (2019)	RPM using IoT	Improved healthcare	Lacks in required dataanalytics.

As presented in Table 2, the techniques used in the health monitoring research and their merits and demerits are provided.

4.1 Research gaps

a) High cost of IoT-based RPM solutions: Literature [4, 5] highlights the issue of high costs associated with IoT-based RPM systems from the patient's perspective. There is a need for a cost-effective approach that ensures affordable access to remote patient monitoring services.

b) Absence of knowledge discovery and strategic decision-making: Su et al. [12] proposed an RPM system with multiple roles and an agent-based communication system. However, the system lacks the incorporation of knowledge discovery or BI for making strategic decisions. Integrating BI and its underlying methods can enhance the system's utility and enable informed decision-making.

c) Lack of multi-mode communication and comprehensive features: Elijah et al. [38] proposed an RPM system with multi-mode communication options, addressing the limitations of single-mode communication. However, the system lacks important features such as patient fall detection and the utilization of business intelligence (BI) through machine learning approaches.
d) These identified research gaps highlight the need for further investigation and development in the field of IoT-enabled RPM systems. The proposed research aims to address these gaps by incorporating patient fall detection, reducing costs, and leveraging knowledge discovery techniques for improved strategic decision-making.

5. Conclusion and Future Work

This paper reviews literature on present state of the art associated with IoT enabled RPM systems. It provides significance of the IoT technology and its influence on different industries and related use cases. It reviews many of the existing RPM systems and their benefits and their technology usage perspective. Different technologies are identified to be most significant in realizing RPM systems. They include IoT, cloud computing, edge computing, fog computing, blockchain technology, wearable technology and AI. It also throws light on the utility of data analytics or machine learning for RPM use cases. It is ascertained that AI based approaches like machine learning and deep learning have their role to play in healthcare applications associated with RPM for discovering hidden knowhow from data. It provides summary of important findings besides covering significant research gaps. There are many directions for future work. First, it is desirable to build cost-effective usable RPM with minimal overhead. Second, there is need for incorporating data analytics by defining appropriate algorithms for health data analysis. Third, it is also desirable to have mechanisms for secure end to end communications in RPM use case.

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