World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(REVIEW ARTICLE)

Check for updates

Telemedicine integration with cloud-based IoT: A literature review approach

Uzondu C. Dike [1,*] and Victor M. Jackson [2]

[1] *Department of Data analytics, School of computing, Portsmouth University, England.*
[2] *Department Data Science, Business School, Digital Regenesys, South Africa.*

World Journal of Advanced Research and Reviews, 2024, 24(02), 723–731

Publication history: Received on 12 September 2024; revised on 31 October 2024; accepted on 02 November 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.2.3355

Abstract

This paper discusses the possibilities of integrating cloud-based IoT with telemedicine as the ways to advance the healthcare industry performance and change its context for the better. This paper aims at exploring how these technologies can be integrated to enhance the existing solutions to the present problems of health care access, patient interactions and use of analytical data in practices. Possible ways in which IoT devices and cloud technology can enhance patient care and assist clinicians in their process of arriving at diagnoses are problems that the research seeks to uncover. The method used is a qualitative systematic review of prior studies related to telemedicine, IoT, and cloud computing, accompanied by a thematic analysis to reveal emerging patterns and the gaps in the literature examined in the study. The new model ‘‘Telemedicine Integration with Cloud-Based IoT,’’ was categorized thematically by differentiation of real-time severity, data privacy, patient interaction and technological difficulties. This model considers layers for acquiring IoT data, storing and analysis, a healthcare remote interface, a machine learning based analytics, and security, which offer a holistic way to enhance healthcare services. Real-time IoT, cloud-based storage, AI for early diagnosis, secure telemedicine platforms, data protection, and complete os compatibility. Based on this study, the authors posited that the convergence of IoT and cloud is capable of redesigning telemedicine by delivering better quality, efficient, and accessible healthcare solutions. However, they lack socio-economic factors for example, the feasibility cost for implementing it for the health companies and difficulties faced by the patient in the less-developed regions. The main limitation observed in the current research is related to the barriers hindering its implementation and future studies are suggested to address these challenges by exploring improved cost-effective approaches to overcome these and other barriers and analysing the issue of data security and patients’ privacy regulation. Studies should also aim at the long-term implications on the user satisfaction in order to introduce or show the long term positive and negative effects of cloud IoTs in telemedicine.

Keywords: Telemedicine; Cloud-Based IoT; Systematic Literature Review; Thematic Analysis; Remote Monitoring; AI-Driven Analytics; Data Security; Healthcare Accessibility; Interoperability; Digital Health Solutions.

1. Introduction

Telemedicine as an advancement of technology in medical field has brought about the dynamic of healthcare service provision where diagnosis, consultation and monitoring of patients are done remotely. Over the years, the growth in development of cloud computing and rendering healthcare service has triggered new ways in the delivery of medical services especially in the evolvement of telemedicine [40]. The nexus of internet of things (IoT) and telemedicine has become necessary to provide new solutions to overcome distance barriers and enabling the needed assistance to improve efficiency of health service delivery. According to World Health Organization [59], “telemedicine is the provision health services by healthcare practitioners using information and communication technologies in sharing valid information on diagnosis, treatment and disease prevention and injury, research and evaluation where distance is barrier and to enhance continuous education of medical professionals with the objective of protecting the health of

* Corresponding author: Uzondu C. Dike

individuals and communities at large ([3]and [7])". Therefore, the innovation of telemedicine is a proficient tool in improving and providing healthcare access to the remote areas. The integration of the telemedicine with Internet of Things (IoT) became prominent and attracting attention as demand for healthcare solutions grows with advancement of technology in health industry [45]. This has allowed for effective healthcare service delivery by enabling an unprecedented scale of real-time monitoring of patients, data processing and evaluation. For instance, the limitations of the traditional healthcare system were seen during the COVID-19 pandemic and other global health crises which emphasized the important of alternative remote healthcare solutions as component of Internet of Things (IoT) [17].

On the other hand, Internet of Things is the interconnectivity of devices embedded with sensors, software with other technologies to interact and exchange information with other system devices over the internet ([3]and [7]). Applicable in the healthcare professional are devices likes health monitoring system that collect and transmit data of patient in real-time. Cloud-based solutions perform calculations and make storage capability necessary to process a large amount of data and difficult computations needs of effective telemedicine solutions [45].

The combining effect of telemedicine with Cloud-based internet of things (IoT) system provides a new dimension of healthcare service provision with efficient and proactive care [3]. Example, Internet of Things (IoT) equipment can monitor a vital sign in patient and transfer information to the cloud server where it is process in real-time [46]. Hence, it enables healthcare providers to detect abnormal situations such as potential health issues which is about occur and make decision with timely interventions. The integration allows for real-time health service, such integration offers the potential to enhance healthcare delivery by enabling real-time monitoring, data analysis, and patient management on an unprecedented scale [55]. However, the challenges associated with effectively merging telemedicine with Cloud-Based IoT systems remain substantial, necessitating further exploration and development. Hence, this study aims to examine how Cloud-Based Internet of Things can enhance telemedicine services, providing a comprehensive patient monitoring, real-time data processing and remote diagnose capabilities

1.1. Statement of Problem

The remote medical consultations and patients monitoring has become widely embrace with the evolution of healthcare technology which has made telemedicine a concept that is crucial in medical profession [44]. However, the connection of the concepts of Cloud-Based Internet of Things (IoT) system with telemedicine has not been widely explore which in essence is limiting the effectiveness of real-time health service delivery.

Consequently, the advantages of combing the Cloud-Based Internet of Things (IoT) with telemedicine has not been deployed to help eliminate the obstacle face by healthcare providers such as privacy and data security, compatibility and conformity issues, and real-time healthcare service delivery which prevent has been impeding the success of full telemedicine deployment ([19]; [30]). For instance, ensuring that during that data is secured from unauthorized users and cyberattack during process of transferring sensitive patients' information through a computer device and cloud networks is one of the major challenges confronting telemedicine solutions [2].

Again, the problem of standardizations in various Internet of Things (IoT) instrument and telemedicine channels resulted in interoperability consequences, rendering difficulties in integrating different systems with ease [8]. Therefore, inconsistency and accuracy of an appropriate patient care services is hindered. There is a problem of scalability as demands for healthcare services grows in response to the global health crisis such as the outbreak of COVID-19 pandemic which raised the needs for scalability of telemedicine solution to contain the increasing amount of data and patients' interactions [21]. The ineffectiveness and inadequate level of scalability effort in the current system reduces the quality of healthcare services provided.

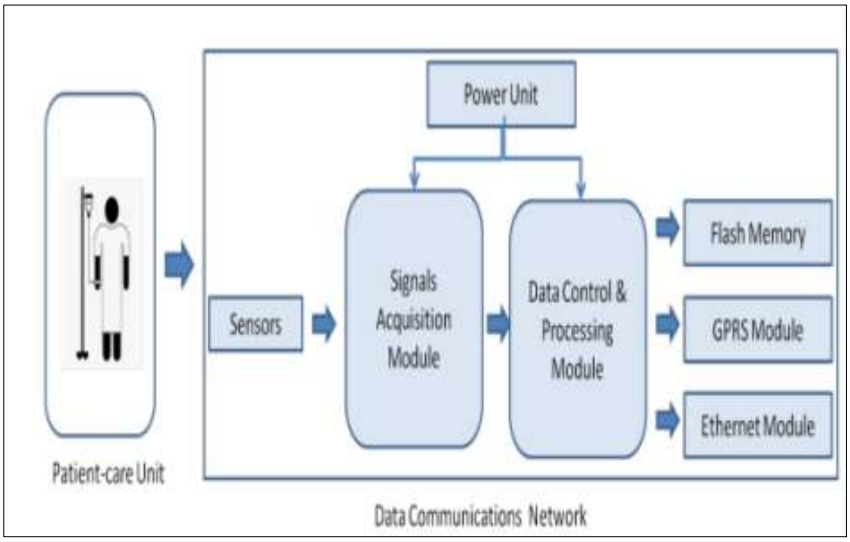
Further, deficit in infrastructure is a militated factor against the progress of real-time processing of data delaying the process of decision making which is crucial in health service delivery [1]. It is important to note that the real time online healthcare service delivery requires accurate monitoring and on-time intervention. Hence, the challenges confronting the process must be given attention to enable the advantages of telemedicine integrating with Cloud-Based Internet of Things to be realized and prevent the fragmented care currently experience globally, so that healthcare professionals will be more efficient in attaining the goal of promoting healthcare accessibility through technology advancement [13].

Against the foregoing, this study attempts to examine how Cloud-Based Internet of Things can enhance telemedicine services, providing a comprehensive patient monitoring, real-time data processing and remote diagnose capabilities.

2. Literature review

2.1. Overview of Telemedicine

Telemedicine is an advancement of technology in medical field has brought about the dynamic of healthcare service provision where diagnosis, consultation and monitoring of patients are done remotely. It refers to the remote provision of healthcare services through communication technology, allowing patients to obtain care irrespective of their geographical location [31]. This concept enables physicians to conduct virtual consultations with patients making use of live videoss, captured images or emails, while obtaining information pertinent to the patient's condition [37]. The emergence of telemedicine has been driven by technology innovations, while the notion has been in existence for decades. It was originally utilised to deliver healthcare in rural regions with a shortage of medical experts [37]. Telemedicine has progressively developed to include multiple facets of healthcare delivery, ranging from consultations to real-time monitoring [33]. Over the years, the growth in development of cloud computing and rendering healthcare service has triggered new ways in the delivery of medical services especially in the evolvement of telemedicine [40].



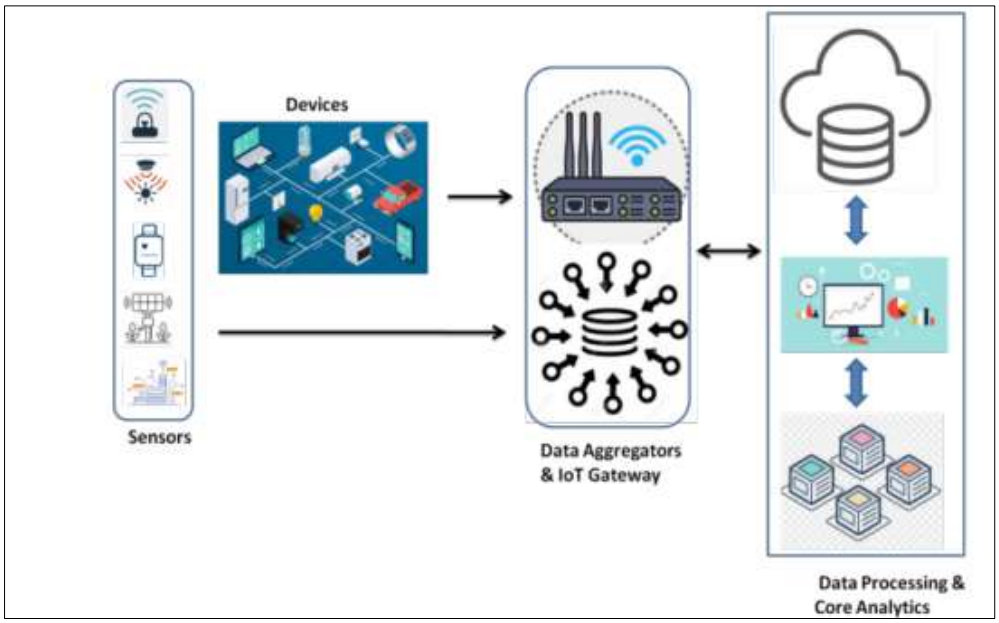
Source: Jaya et al. (2023)

Figure 1 Conceptual Model of Telemedicine

2.2. Role of IoT in Telemedicine

Internet of Things is the interconnectivity of devices embedded with sensors, software with other technologies to interact and exchange information with other system devices over the internet. Applicable in the healthcare professional are devices likes health monitoring system that collect and transmit data of patient in real-time. Cloud-based solutions perform calculations and make storage capability necessary to process a large amount of data and difficult computations needs of effective telemedicine solutions. The nexus of internet of things (IoT) and telemedicine has become necessary to provide new solutions to overcome distance barriers and enabling the needed assistance to improve efficiency of health service delivery.

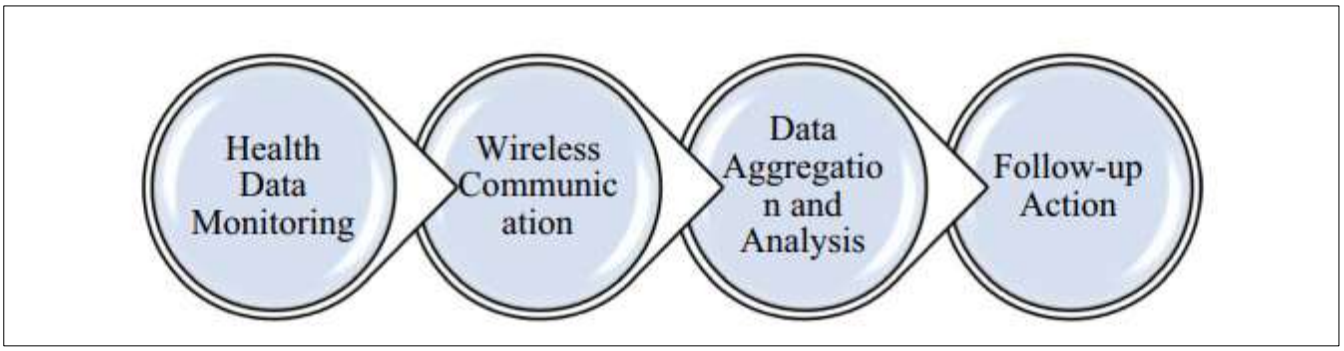
According to World Health Organization [59], “telemedicine is the provision health services by healthcare practitioners using information and communication technologies in sharing valid information on diagnosis, treatment and disease prevention and injury, research and evaluation where distance is barrier and to enhance continuous education of medical professionals with the objective of protecting the health of individuals and communities at large”. Therefore, the innovation of telemedicine is a proficient tool in improving and providing healthcare access to the remote areas.



Source: Jaya et al. (2023)

Figure 2 Concept of Internet of Things

The integration of the telemedicine with Internet of Things (IoT) became prominent and attracting attention as demand for healthcare solutions grows with advancement of technology in health industry. This has allowed for effective healthcare service delivery by enabling an unprecedented scale of real-time monitoring of patients, data processing and evaluation. For instance, the limitations of the traditional healthcare system were seen during the COVID-19 pandemic and other global health crises which emphasized the important of alternative remote healthcare solutions as component of Internet of Things (IoT). The COVID-19 pandemic pushed the spread of telemedicine globally, driving healthcare systems to rely more on digital platforms to avoid the hazards of in-person consultations. For example, in Latin America, the pandemic signaled a dramatic movement toward telemedicine, overcoming the limits of traditional healthcare systems [33]. Similarly, in the United States, telemedicine grew swiftly in response to legislative relaxations and technology improvements during the pandemic [23].



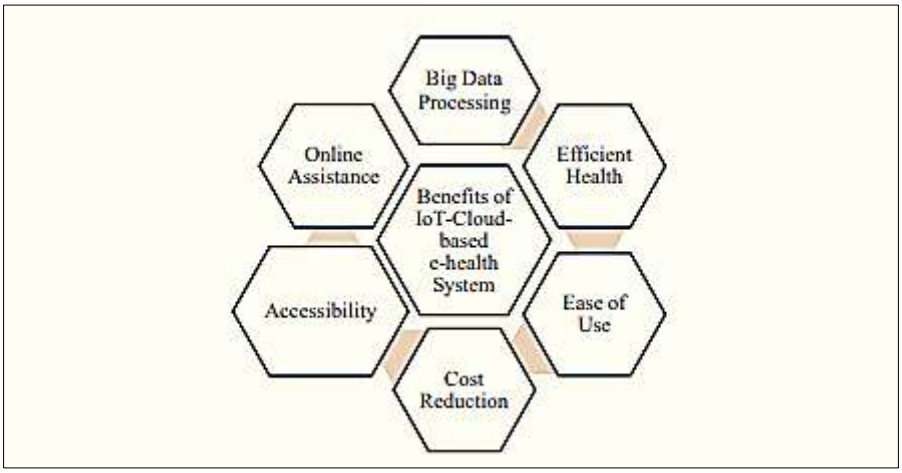
Source: Darbandi et al. (2022)

Figure 3 Steps of Medical-Internet of Things

2.3. Cloud-Based IoT Data Warehousing

Cloud-Based IoT refers to the integration between the Internet of Things and cloud computing. The concept has been an emerging technology as they have been seen as entities capable of complementing each other's abilities. This concept involves the synergism between man, machines, objects, devices, applications and software, communicating with each other with the help of the internet. The combining effect of telemedicine with Cloud-based internet of things (IoT) system provides a new dimension of healthcare service provision with efficient and proactive care. Example, Internet of Things (IoT) equipment can monitor a vital sign in patient and transfer information to the cloud server where it is process in real-time. Hence, it enables healthcare providers to detect abnormal situations such as potential health issues which is about occur and make decision with timely interventions. The integration allows for real-time health service.

Such integration offers the potential to enhance healthcare delivery by enabling real-time monitoring, data analysis, and patient management on an unprecedented scale. These mean easy accessibility to better health with reduced cost in terms of time and money and faster tracking of health improvement for future reference. However, the challenges associated with effectively merging telemedicine with Cloud-Based IoT systems remain substantial, necessitating further exploration and development.



Source: Butpheng et al. (2020)

Figure 4 The Benefits of Internet of Things (Iot)-Cloud-Based in Health Systems

2.4. Definitions and Fundamental Components

2.4.1. IoT (Internet of Things)

The Internet of Things (IoT) refers to a system of interrelated devices, sensors, software, and other technologies that connect and share data via the internet. These "things" can vary from everyday household objects like smart refrigerators and wearables to industrial gear and healthcare gadgets. The key aspect of IoT is its ability to gather, share, and analyze data in real-time, enabling the automation of processes and improving decision-making efficiency ([3]; [10]; [9]).

The Internet of things (IoT) began in 1959 but the greatest progress in this subject was noticed in the recent 8–10 years. Telemedicine has been employed in the treatment of cardiac disorders, injuries, and diabetes [36]. The key benefit of IoT is that it is necessary to access information and it helps to avoid an emergency. People are more than willing to monitor and control their health at home due to their hectic lifestyles. Internet of things (IoT) devices is aimed for remote monitoring in the healthcare sector, to keep the patient safe and healthy, and to empower the medical practitioner to offer timely care to the patients [19]. It has boosted patient satisfaction as inter actions with doctors have become easier and more efficient. ([9]; [12]). Furthermore, remote monitoring of patient's health helps to reduce the trips to the hospital and keep track of patient health records. IoT also has a big impact on reducing healthcare expenses and increasing treatment outcomes ([11]; [16]).

2.4.2. Fundamental Components of IoT

Sensors and Actuators: These are physical devices embedded in objects that collect data from the environment. Sensors assess various factors such as temperature, humidity, and motion, whereas actuators conduct particular actions in reaction to incoming data, such as setting a thermostat ([4]; [19]).

Connectivity: The acquired data from sensors is communicated over networks like Wi-Fi, Bluetooth, 4G/5G, or Zigbee to cloud platforms or other devices for further processing ([7]; [19]) Connectivity facilitates seamless communication between devices and systems.

Data Processing: Once the data is transferred, it needs to be analysed to provide useful insights. This is often done on cloud platforms where huge amounts of data are examined and stored. Advanced data analytics and artificial intelligence (AI) are commonly applied at this stage to boost automation and predictive capabilities ([10]; [19]).

User Interface: The processed data is made visible to users through dashboards, applications, or automated reports, allowing them to engage with and operate their IoT devices remotely ([9]; [19]).

2.4.3. Cloud Computing

Cloud computing is important to the operation of IoT, as it provides scalable resources for data storage, processing, and management. This integration of IoT with cloud computing enables for real-time monitoring, predictive analytics, and seamless scalability of IoT services, which is particularly valuable in areas like healthcare, manufacturing, and smart cities ([11; [19]).

Role of Cloud Computing in IoT

Cloud computing plays a vital role in the architecture and functionality of the Internet of Things (IoT). It provides the infrastructure necessary for the storing, processing, and administration of massive amounts of data created by IoT devices ([19]; Harris, 2023). The real-time processing capability of cloud platforms allows IoT devices to undertake complicated activities without the need for expensive and high-performance hardware at the user end ([3]; [32])

One of the key advantages of cloud computing in IoT is scalability. Cloud platforms such as Amazon Web Services (AWS), Microsoft Azure, and Google Cloud offer scalable resources, ensuring that IoT systems can accept enormous datasets and a growing number of devices without performance degradation ([4]). This flexibility is particularly significant in healthcare and telemedicine, where IoT applications generally require real-time data processing and uninterrupted services ([7]; [34]).

Another crucial issue is data storage and accessibility. Cloud-based IoT offers centralized storage, where the data collected from sensors and devices is transported to the cloud for analysis. This allows healthcare providers and organizations to access and share patient data across different locations, promoting more efficient remote monitoring and collaboration among medical teams ([10]; [47]).

Additionally, cloud platforms give enhanced analytics and artificial intelligence (AI) capabilities. By integrating AI and machine learning, cloud computing boosts IoT applications by enabling predictive analytics, pattern recognition, and data-driven insights, which are crucial for early diagnosis, decision-making, and individualised treatment plans ([38]; [56]).

Cloud security measures, including encryption and access control, further strengthen the protection of sensitive IoT data, guaranteeing compliance with healthcare standards such as the Health Insurance Portability and Accountability Act (HIPAA) in the U.S. ([11]; [54])

Furthermore, cloud-based computing provides simplicity of usage and cost savings. IoT-cloud-based e-Health systems are easily embraced by consumers as they only demand clicks on wearable devices, basic input interactions using smartphone applications or simply wearing sensors and allowing the systems to collect data automatically ([11]; [29]; [35]). IoT-cloud-based e-Health systems can integrate multiple technologies to promote efficiency, cut waste and drive down costs. Moreover, they may scale up or down fast based on demand and they allow health systems to pay-as-they use ([7]; [25], [28]; [32]). Increased Physician Involvement: in IoT-cloud-based e-Health systems physicians can get patient health data in real-time and remotely. This enables them to monitor more patients wearing sensors, enhance outcomes and even engage in telemedicine under specific situations ([3]; [14]; [28]; [34]; [37]).

Another crucial factor is Accessibility and availability and efficient health resources management. In IoT-cloud-based e-Health systems patients, caregivers and healthcare professionals can access e-Health data or services anytime, anywhere by using cloud computing servers or web servers ([3]; [10]; [14]; [29]; Rasool *et al.*, 2023). IoT-cloud-based e-Health systems guarantee patients have access to personal data so they can learn about their health state. They also allow clinicians to monitor patient health effectively and efficiently and govern the allocation and use of health resources precisely ([3]; [14]; [28])

Fundamentals of Cloud-Based IoT

Cloud-based Internet of Things (IoT) solutions are crucial to current digital health and telemedicine. These systems provide efficient data collecting, storage, real-time processing, and scalability, making them vital for remote healthcare and patient monitoring. The integration of IoT with cloud computing boosts the performance and usefulness of telemedicine systems, giving better flexibility and resource optimization ([20]; [27]and [33]).

- Data Collection and Storage

In cloud-based IoT systems, data gathering is primarily performed by sensors and devices that monitor various characteristics such as heart rate, blood pressure, or environmental variables. These sensors are embedded in wearable gadgets, home health monitoring equipment, or other IoT-enabled solutions. The data generated by these devices is continuously transferred to cloud storage via secure internet connections ([27]and [32]).

Cloud storage plays a key role in storing enormous amounts of unstructured data in real time. Unlike traditional data storage methods, cloud-based storage systems can scale easily to meet growing datasets. Cloud platforms like AWS, Microsoft Azure, and Google Cloud provide safe, redundant storage solutions that ensure data is available to healthcare practitioners and researchers at any time ([4]; [24][27]). Cloud systems also offer automated backups and disaster recovery, boosting the reliability and security of sensitive patient information ([9]; [11], [12]).

- Real-Time Data Processing

Real-time data processing is one of the main advantages of integrating IoT with cloud computing. Once the data is acquired by IoT devices and stored in the cloud, cloud-based systems can rapidly evaluate and process the data to deliver actionable insights. For instance, real-time data analytics enable healthcare providers to recognise anomalies, such as irregular heartbeats or abnormal glucose levels, and intervene swiftly [[10] and [29]].

Cloud-based IoT systems employ advanced analytics techniques, including artificial intelligence (AI) and machine learning (ML), to enhance decision-making and deliver predictive analytics. For example, an AI-powered cloud system can find trends in patient data and predict possible health hazards, allowing healthcare professionals to give preventive care [[10] and [12]]. This real-time processing not only saves the time between diagnosis and treatment but also enhances the overall quality of care.

- Scalability and Flexibility

Scalability and flexibility are significant features of cloud-based IoT systems. In healthcare, where patient data volumes are continuously expanding, cloud platforms offer the required capabilities to manage massive datasets without performance deterioration ([9]; [14] and [23]). Cloud providers offer on-demand scaling, which allows healthcare organisations to expand or reduce their processing power and storage capacity as needed, avoiding the need for costly infrastructure upgrades.

This scalability also extends to the amount of IoT devices linked to the network. As healthcare providers integrate more devices, such as new wearables or home monitoring systems, cloud platforms can readily accommodate the added load. Furthermore, the versatility of cloud-based IoT systems allows them to adapt to varied healthcare settings, from small clinics to huge hospitals, making them highly versatile in different medical situations ([23] and [25]).

Cloud platforms also offer multi-device and multi-platform integration, ensuring that healthcare providers can monitor patients remotely across numerous devices, enhancing the accessibility and delivery of healthcare services.

2.5. Advantages of Integration

The integration of cloud-based IoT with telemedicine delivers several benefits, boosting healthcare delivery through improved patient outcomes, operational efficiency, and the scalability of services. These developments not only make healthcare more accessible but also enhance the long-term viability of telemedicine in varied healthcare settings ([16]; [49], [51]).

2.5.1. Improved Patient Outcomes

- Early Detection and Intervention

Cloud-based IoT solutions offer continuous patient monitoring, enabling the early discovery of health problems. Wearable technologies and sensors track vital indicators in real-time, while advanced algorithms examine the data to identify potential dangers ([3]; [52]and [54]). For example, individuals with cardiac issues may receive real-time alerts if aberrant rhythms are identified, allowing for quick medical action. Early identification lessens the risk of complications and reduces hospitalizations, thus improving long-term patient outcomes.

- Enhanced Patient Engagement and Compliance

Integrating IoT with telemedicine promotes patient involvement by delivering real-time feedback and individualised health information. Patients can monitor their own vital signs using connected gadgets and smartphone apps, establishing a sense of ownership over their health ([54],[58]). Additionally, individualised reminders for medication adherence, food, or physical exercise, provided via telemedicine platforms, promote compliance with treatment programs. Studies have demonstrated that more patient engagement leads to better health outcomes and enhanced quality of life ([7]; [9]; [14] and [19]).

2.5.2. Operational Efficiency

- Streamlined Workflows

Cloud-based IoT solutions simplify operational workflows by automating common tasks such as data collecting, reporting, and scheduling. Healthcare providers can access patient data in real-time through connected dashboards, minimising the time spent on administrative activities and focusing more on patient care ([58] and [59]). Automation of diagnostic data transmission from wearables or home monitoring devices to the healthcare practitioner also removes human data entry, minimising errors and enhancing accuracy [42].

- Cost Savings Through Reduced Hospital Visits

By providing continuous remote monitoring, cloud-based IoT minimises the need for in-person visits, cutting healthcare expenses for both patients and providers [[9]; [12]; [23]]. Telemedicine technologies allow for early interventions and remote diagnostics, eliminating unnecessary hospital stays and emergency department visits. For chronic illness care, this results in significant cost savings, since patients can be followed remotely and treated proactively before issues emerge ([57]; and [59]). Additionally, the reduced demand for physical infrastructure helps healthcare firms' lower operational expenses.

2.5.3. Scalability and Accessibility

- Broader Reach of Telemedicine Services

Cloud-based IoT boosts the scalability of telemedicine services by allowing healthcare providers to extend their reach beyond geographical borders. This is particularly advantageous for rural and underdeveloped areas where access to healthcare is limited. With telemedicine platforms integrated into IoT systems, healthcare professionals may monitor and treat a bigger number of patients remotely without needing to expand physical facilities. This broadens access to healthcare services, making it easier for patients to receive timely care ([43]; [49]and [61]).

- Adaptability to Various Healthcare Settings

The versatility of cloud-based IoT allows it to be easily adapted to varied healthcare environments, from small clinics to huge hospitals. Healthcare practitioners can tailor IoT solutions depending on their specific needs, enabling easy interaction with existing telemedicine platforms and electronic health records ([43]; [49]and [61]). This versatility supports a wide range of healthcare applications, including primary care, mental health services, chronic illness management, and post-operative follow-up, making it a versatile solution across many medical sectors. ([32]and [35]).

Table 1 Summary of Literature Review

Author	Description of the Study	Limitation of the Study	Adopted Method	Conclusion
Islam *et al.* (2023)	The study presents an Integrated Scalable Framework for Cloud and IoT Based Green Healthcare Systems. It focuses on utilizing IoT devices and cloud infrastructure to facilitate remote patient monitoring, enhance healthcare service delivery and promote energy efficiency in healthcare systems. The framework aims to reduce costs and improve inter-system compatibility while addressing the challenges of data availability particularly in developing countries.	The study acknowledges limitations in the use of smart devices with in-built sensors instead of individual, single-purpose sensors. This choice affected the precision of the experiments and the accuracy of the data collected. The authors suggest that using dedicated sensors would have improved the demonstration of wireless technologies and communication protocols, as well as simplified energy efficiency calculations.	The research employs a combination of literature review, system architecture design, implementation, simulation, and optimization techniques to evaluate the proposed framework. It also includes experimental data to analyze the energy efficiency of the system and discusses potential enhancements for greener operations.	The researcher presented an integrated framework for green healthcare and use cutting-edge technology to make an interactive user interface and also ensure the system's scalability and performance ratio with interface designed and developed for patients and doctors, where patients can send their healthcare data using wearable sensors, and doctors can receive those data in real-time.
Lakshimi *et al.* (2021)	The study discusses a cloud-based Internet of Things (IoT) healthcare system for remote patient monitoring, particularly in the context of COVID-19. It highlights the use of wearable sensors to monitor vital health parameters and the integration of various IoT devices for data collection and analysis	This study only focused on proposing cloud-based IoT healthcare sensors to formulate patient monitoring remotely and do not strengthen research study with primary and secondary data which could be used to support the model built.	The proposed system utilizes wearable sensors, a lightweight IoT hub, mobile applications and machine learning tools for data classification and analysis.	Patient physiologic data such as heart rate, breathing, elevated temperature, and stress levels are measured using sensors and can be sent via a Wi-Fi device to the cloud. This healthcare practitioner will analyse medical data to ensure effective therapy. The video function may be incorporated into future face-to-face consultations between doctors and patients.
Darbandi *et al.* (2022)	This study explores the integration of cloud computing with the Internet of Things (IoT) to enhance the treatment and management of the COVID-19 pandemic. It emphasizes the role of IoT in healthcare systems for early detection,	This study only focused on the use of literature review to analyze the impact of IoT in managing COVID-19. Hence, analysing periods before COVID-19 will help to differentiate better the impact of IoT on COVID-19	This study employs a literature-based research approach, analyzing existing articles related to IoT and its impact on managing COVID-19.	The findings indicated that the utilisation of IoT technologies, including drones and robots, has proven effective in minimising patient interaction and detecting illness signs. Furthermore, they demonstrated that IoT wearable devices and the cloud platform for storing patient information

	prevention, and patient care during the pandemic			have facilitated physicians in monitoring the patient's status.
Butpheng *et al.* (2020)	This study reviews research from 2017 to 2020, focusing on the integration of IoT devices and cloud computing in e-Health systems. It examines various perspectives related to security and privacy within these systems.	The study highlights that the adoption of IoT in healthcare, especially in developing countries, is still in its early stages, indicating a need for further research	The study employs a systematic literature review to analyze existing frameworks and identify key limitations in the healthcare sector regarding privacy by design.	The Internet possesses the capacity to safeguard consumers against detriment and enable them to engage comprehensively in informed health-related decision-making. Primarily, greater degrees of e-Health integration reduce the likelihood of encountering inaccurate material online. The researcher submitted that the integration of IoT-based e-Health systems with intelligent technologies like cloud computing, which provide advanced aims and applications, is a potential future trend.
Sreelekshmi *et al.* (2023)	This research explores the integration of Artificial Intelligence (AI) within Internet of Things (IoT) frameworks in healthcare, focusing on enhancing patient care, diagnosis, and treatment through technological advancements.	The methodology adopted which focused only on literature review is limited in scope and deep insight as using other relevant secondary data sources will strengthen the research findings.	The study employed a comprehensive literature review, case studies, and statistical analysis to identify trends and validate hypotheses regarding AI's impact on IoT healthcare systems	The submitted that AI is capable of enhancing IoT-based healthcare systems, facilitating the development of more personalised, efficient and accessible healthcare solutions.
Auwal (2023)	This research investigates the integration of Internet of Things (IoT) devices in telemedicine, focusing on their role in remote patient monitoring and data transmission. It aims to explore the benefits, challenges and user satisfaction associated with IoT-powered telemedicine solutions.	This study is limited to using a qualitative research approach which could limit the scope of the study	A qualitative research approach was employed, utilizing in-depth interviews and content analysis to gather insights from healthcare practitioners and patients engaged with IoT-powered telemedicine	The analysis of this study reveals that IoT-enabled remote patient monitoring substantially improves patient care by enabling prompt interventions and decreasing hospital admissions, thereby enhancing healthcare outcomes and underscoring the efficacy of IoT-powered remote patient monitoring concerning healthcare results.
Kumar and Ganesh (2024)	The study explores the transformative impact of the Internet of Things (IoT) and cloud computing on	The study primarily focuses on the technological benefits of IoT and cloud computing in telemedicine without	The study employs a literature review approach, analyzing existing case studies and research findings related to IoT and cloud computing in	The convergence of IoT and cloud-based telemedicine applications has significantly changed healthcare delivery and access. The integration of these technologies has

	telemedicine. It discusses how these technologies facilitate continuous remote monitoring, real-time data collection, and improved patient engagement, ultimately leading to better healthcare outcomes	extensively addressing socio-economic factors such as implementation costs for healthcare providers or accessibility challenges for patients in low-income regions. This study also lacks a detailed investigation of long-term outcomes and user experiences with these methods.	telemedicine to draw conclusions about their effectiveness and challenges.	empowered healthcare providers with real-time data insights and improved patient care. However, it emphasizes the need for robust security measures and interoperability among devices and platforms to address existing challenges.
Haleem (2021)	The study discusses the applications of biosensors in the medical field, focusing on their design, operation, and implementation for biomolecular analysis. It highlights the significance of biosensors in diagnosing diseases, including their role in personalized medicine, particularly in the context of COVID-19	The study may have limitations related to the scope of biosensor applications, potential biases in the selection of studies reviewed, and the rapid evolution of technology that may not be fully captured in the analysis.	The authors conducted a literature review to gather and synthesize existing research on biosensors and their applications in healthcare, particularly during the COVID-19 pandemic.	The study concludes that biosensors have significant potential in the medical field, offering rapid, accurate, and cost-effective diagnostic solutions. The authors emphasize the need for further research and development to enhance the capabilities and accessibility of biosensor technologies.
Lakshmi (2021)	This study focuses on the development of a cloud-based IoT healthcare system designed for remote patient monitoring. It emphasizes the integration of wearable sensors and cloud technology to facilitate real-time health monitoring and data analysis. The system aims to enhance patient care by allowing healthcare professionals to monitor patients remotely, thus improving the efficiency of healthcare delivery and reducing complications	The study acknowledges potential limitations related to self-diagnosis by patients, which can be hazardous. It emphasizes the importance of having healthcare professionals monitor sensor data to ensure accurate diagnoses and timely interventions. Additionally, the reliance on technology may pose challenges in terms of data security and privacy, although measures are mentioned to protect patient information	The methodology involves a three-stage architecture consisting of data processing model which handles the processing of incoming data from sensors. The Sensor Module which collects health data from patients using various sensors and the data analysis in which the collected data to provide insights and alerts to healthcare providers	The study concludes that the proposed healthcare monitoring system can significantly improve patient care by enabling remote monitoring and timely interventions. It highlights the potential for integrating various sensors and devices into a compact unit, making it easier for patients to carry and use. The system's design aims to enhance the quality of healthcare services, especially in light of challenges posed by situations like the COVID-19 pandemic

	associated with delayed treatment			
Yu and Zhou (2021)	This study explores the architecture and implementation technologies of health IoT, focusing on integrating various communication technologies to enhance user experience. It covers aspects such as cloud fusion health IoT architecture, multimodal information acquisition, and emotional perception in health IoT	This study focused on modeling a cloud based IoT and not necessarily strengthen findings with primary data to get better insights.	The study employs a combination of theoretical exploration and practical implementation. It utilizes cloud computing, wireless communication, and physiological signal sensors to create a health monitoring system. Additionally, it incorporates machine learning techniques, such as migration learning and continuous conditional random fields, for emotion data labeling and classification	The research concludes that the proposed cloud convergence health IoT architecture significantly optimizes user experience and enhances the connection between health IoT applications and users. It emphasizes the importance of integrating various technologies to improve health monitoring and emotional interaction

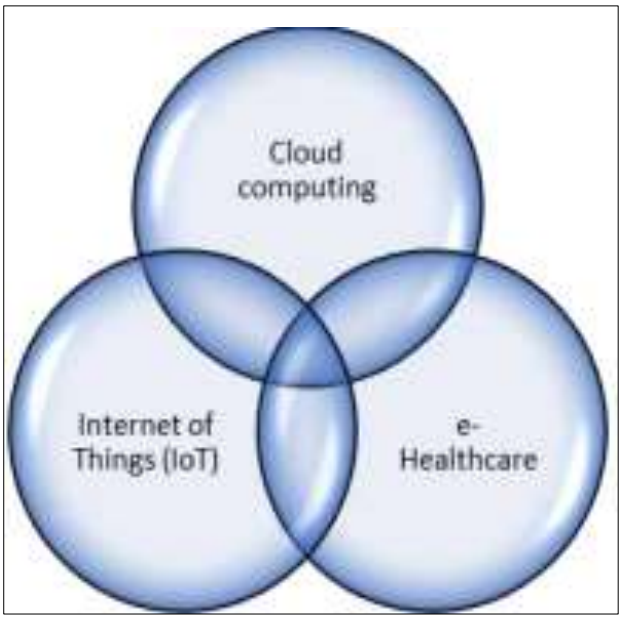


Figure 5 IoT-Telemedicine Model

Source: Butpheng et al. (2020)

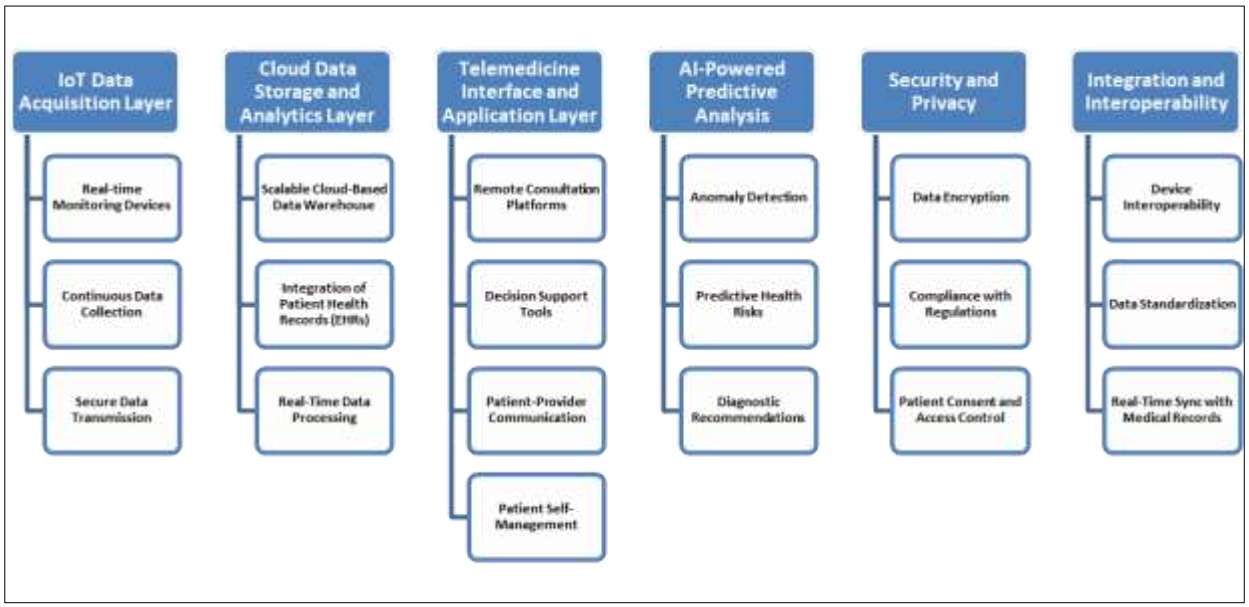


Figure 6 Telemedicine Integration with Cloud-Based IoT Model

Source: Authors' Computation, 2024

The figure 7 above reveals the major constituent of The Telemedicine Integration with Cloud-Based IoT Model, which are integrated to enable holistic patients' monitoring, data processing and distant diagnosis [27]. These four considerations may be viewed as constituting the layers of the conceived model: Each of the layers improves the applicability and efficiency of telemedicine by integrating IoT devices, cloud and AI analytics. The detailed explanation about how these layers work into a typical telemedicine system in accordance to the analytical assertiveness of the proposed model is explained below;

IoT Data Acquisition Layer: This layer is the foundation of the model, responsible for collecting real-time data from patients through various IoT-enabled devices such as wearable sensors, home-based monitors, and other smart health devices [9]. These devices continuously track vital signs like heart rate, blood pressure, glucose levels, and more. This

data is transmitted securely via encrypted, low-latency communication protocols to the cloud, ensuring that healthcare providers receive accurate and up-to-date patient information.

Cloud Data Storage and Analytics Layer: Once data is collected, Data collected is stored in a scalable cloud-based data warehouse that can hold enormous amount of health information data [14]. The adoption of EHRs guarantees that current developments are supported by historical information obtained from patients. But in this layer, some details involve artificial intelligence analytics. It takes the data to work with algorithms for health predictions, any abnormalities such as heart rates or blood sugar levels are identified. Data processing is also real-time on the cloud infrastructure for passing tangible feedback from the system to the healthcare providers and patients (Ramesh *et al.*, 2021).

Telemedicine Interface and Application Layer: In this layer, care providers and consumers of the health services communicate directly with the telemedicine system [27]. Tele-consultations services include video consults, messages, and apps so that patients can meet with their healthcare providers without going to the clinic. For improved and actionable decision-making, many technologies leveraging the concept of AI provide diagnostic suggestions and read alerts from databases in real-time or archived. There also constant interaction between the patient and the service provider which allows the modification of the treatment plans because of new information. Moreover, patients are engaged in their care by having the self-management tools available where one can view one's information, track a health plan's progress, and receive caregiver instructions.

AI-Powered Predictive Analysis: AI is used in this model to support analytic processing of real time and historical data for the purpose of making predictions [27]. Identify possible abnormalities, including minute manifestations of arrhythmia or other life-threatening illness signs, as well as predict health risks including heart attacks. These all-artificial intelligent based suggestions assist the healthcare providers by providing diagnostic advice, which can be crucial during telemedicine consultation sessions to timely intervene effectively [5].

Security and Privacy: Since health information is highly sensitive, there are two primary requirements, namely security and privacy [9]. To enhance security of the patient's information, the model uses encrypted mechanism throughout to secure the data in transit and at rest. The design also ensures that the app conforms to health care data protection laws including the HIPAA and the GDPR ([15]and [53]). Had patient consent and all the access control mechanisms will ensure that no person will have a full control of the data belonging to another person hence his/her privacy will always be protected.

Integration and Interoperability: To make its functioning possible it is going to be necessary to integrate and interact with multiple IoT health devices [27]. This layer provides compatibility in the essential devices hence an effective processing and analysis of data from various types of sensors. Rules of converting and sharing health data include HL7 or FHIR to standardize health data for convenient use in different platforms. The system also has a synchronization mechanism that enables, instant updating of the patient records in the EHRs after changes or updates in the health status of the patient have been noted [50].

3. Research Methodology

3.1. Research Design

The qualitative approach is used to underpin the study and the design of the research is more exploratory in kind. Since the area of interest, IoT and cloud computing in telemedicine is still relatively unexplored, this research opts for a systematic literature review to capture existing data regarding the field. Thematic analysis is then used alongside review of existing literature to make categorizations thus enabling the formulation of new conceptual model.

3.2. Systematic Literature Review (SLR)

A systematic literature review was favored for the data gathering process because of its systematic and orderly nature. The SLR method is used to find suitable literature, its quality, and to extract the findings. In the present review, there was a major emphasis on IoT, cloud computing, and telemedicine, and all the articles included were published between 2021 and 2024 to catch the most recent technological developments. The following steps were taken during the SLR process:

Defining Research Questions: The research questions attempt to examine how Cloud-Based Internet of Things can enhance telemedicine services, providing a comprehensive patient monitoring, real-time data processing and remote diagnose capabilities.

Database Selection: Studies used in this paper were obtained from prominent research databases including but not limited to PubMed, IEEE Xplore, Science Direct, and Google Scholar. The search involved some of the specialized publishing areas in IoT, cloud computing, telemedicine, and advanced healthcare technologies.

Inclusion and Exclusion Criteria: The research papers were included if they are related IoT, cloud technologies, and telemedicine applications for healthcare, data warehouse, patient monitoring and security aspects. Such publications were excluded from this review if they were not located within the healthcare domain or if they were not based on empirical evidence.

Data Extraction: Data including research aims and methods, results and constraints were obtained and synthesized for analysis. The following themes were called out—time filter, security, analytics, and compatibility.

3.3. Thematic Analysis

After that, a thematic analysis was carried out in order to incorporate and analyses the data obtained during the SLR. Thematic analysis is a technique for applying an organizing structure to qualitative data, by locating patterns (themes) within such data. It has the advantage of the handling of large amount of qualitative data, which was crucial for comparing cross sectional studies with the aim of discovering the emergent themes.

The thematic analysis was conducted in the following stages:

- Familiarization with Data: The data gathered from the literature review were analyzed in detail to identify the general trends and challenges.
- Generating Initial Codes: The selected key terms and the ideas related to them were labeled with codes. Some of the codes include RPM, AI diagnosis, data security, and communication.
- Searching for Themes: The codes were grouped into broader themes. The primary themes identified were IoT for real-time patient monitoring; Cloud-based data warehousing and analytics; AI-driven predictive analysis; Telemedicine applications and interfaces and Security and privacy concerns in healthcare
- Reviewing Themes: The identified themes were then analyzed to make certain that they supported the objectives of the given research. Some themes were either merged together or rephrased for better understanding.
- Defining and Naming Themes: Both the themes were conceptualised relative to their functionality within the telemedicine design paradigm. The last themes was then used to build the proposed Telemedicine Integration with Cloud-Based IoT Model.

3.4. Model Development

To design a framework, positive research findings from the literature review and the thematic analysis were employed to create a conceptual model of telemedicine incorporating IoT and cloud computing. The model is designed to address key gaps in telemedicine by leveraging the following features:

- IoT Data Acquisition Layer: Smartwatches and health fitness trackers gather health information in real-time.
- Cloud Data Storage and Analytics: A cloud capable solution for the management and analysis of patient information that includes EHR.
- AI-Powered Predictive Analysis: Features include decision support systems that allow the identification of potentially deadly diseases at their early stage and risk assessment.
- Telemedicine Interface: There is a clear concept of features that include web-based consultations, secure messaging, and access to patient's records.
- Security and Privacy Layer: Full encryption and legal requirements procedures make sure that particular patient's information is well protected from the outside world.

3.5. Data Collection Process

The present research did not entail collection of primacy data but was conducted using secondary data that entails the collection of information from existing published literature. This approach offered a sound framework for analyzing

how resources used in existing frameworks can be adapted for the enhancement of telemedicine. The choice of data sources was influenced by the relevance, reliability and the timeliness of the information that was used.

4. Discussion of Results

This section provides a thematic analysis of the reviewed literature on the integration of Internet of Things (IoT), cloud computing, biosensors, and Artificial Intelligence (AI) in the healthcare industry. To perform the analysis, this paper synthesizes the results of several studies that examine the effects, the possible drawbacks, trajectory of development, and outcomes of the technologies in question. The thematic analysis allows for giving a transparent picture of the key patterns, research contributions, and limitations of previous empirical studies, as well as considering the possibilities and challenges of developing the IoT-based healthcare system today.

4.1. IoT and Cloud Computing in Healthcare

The integration of IoT and cloud computing in healthcare has emerged as a major theme across several studies. It helps the real-time accumulation of patient data to the monitoring of patients away from the respective healthcare facilities and enhancement of health services. The empirical studies of Kumar and Ganesh (2024) and Lakshmi (2021), emphasize the transformative impact of IoT and cloud computing on telemedicine. They include technologies that allow a constant watch on the patient's symptoms to avert severe complications or worse and death. Kumar and Ganesh (2024) identified the role of IoT and cloud computing in providing real-time data insights that enhance patient care. This study indicates that there are various technological benefits of the linkage of these systems including; patient involvement and constant supervision. However, limitations in comparing its socio-economic approach to the existing conventional methods of evaluating sustainable development in terms of implementation costs and access in poor areas where identified. Similarly, Lakshmi (2021) identified some advantages of wearable sensors as well as Cloud technology with reference to remote healthcare services while the study also reveals the possibility of some weaknesses such as patient self-diagnosis and patient's privacy.

Hence, based on the above study's empirical findings, IoT and cloud computing significantly improve healthcare service delivery by providing real-time access to patient data and facilitating remote monitoring. However, how to solve issues of security, privacy and means of access across different socio–economic backgrounds.

4.2. The Role of Biosensors in Healthcare

Another major theme in the literature is the application of biosensors in healthcare for real-time patient monitoring and diagnostics. Haleem (2021) explores the design and functionality of biosensors, particularly during the COVID-19 pandemic, highlighting their role in biomolecular analysis and disease diagnosis. This study emphasizes the importance of biosensors in offering rapid, accurate and cost-effective diagnostic solutions, positioning them as critical tools in personalized medicine. However, Haleem (2021) identified several limitations based on the lacked comprehensiveness of biosensor applications and bias while selecting studies. Hence, it could be argued that the growing rate of innovations in biosensor technologies is likely to have not been adequately addressed in the evaluation. Nonetheless, biosensors are consistently portrayed as pivotal in enhancing the precision of healthcare delivery, particularly for chronic disease management and pandemic response.

4.3. AI and Iot in Healthcare

Also, integration of artificial intelligence (AI) within Internet of Things (IoT) context is also a recurring theme especially in studies exploring the potential for personalized, efficient, and accessible healthcare. The empirical study by Sreelekshmi et al. (2023) show how advanced IoT systems supported by AI produce positive impacts on improving patient diagnosis, subsequent treatment plans and subsequent care regimes. This study submitted that due to AI's characteristics of handling an immense amount of information and recognizing connections, healthcare can see enhancements in a short period of time as well as disease treatments will then be much more effective and patient-specific. Hence, this study demonstrates that the application of AI in IoT environments improves the reliability of IoT-based healthcare systems and the final outcome of the treatment.

4.4. Clinical Telemedicine and Remote Patient Monitoring

Patient monitoring including telemedicine also emerged as one of the major themes of many of the reviewed studies. Studies conducted by While Kumar and Ganesh (2024) and Auwal (2023) evaluated how IoT and cloud systems influence remote patient monitoring in telemedicine. Such research also indicates that technologies, developed with the use of IoT in telemedicine solutions enables healthcare workers timely track patient status without personally attending to the patient and eliminating the need for hospitalization.

According to Auwal (2023), the usage of IoT to monitor patients at remote areas enhances health care since there will be quicker and less hospitalization. This study also found that patients are highly satisfied with these systems because they offer easier ways of accessing their needed health care services. While Kumar and Ganesh (2024) also emphasise on technological advantages of telemedicine, the current issues were identified to be the security question and the problem of the interconnection in devices. These empirical studies emphasize that though the use of telemedicine is only growing, concerns associated with data protection, privacy, and population inequality remain important to fully unlock its potential.

4.5. Iot-Based Health Care Systems Challenges and Limitations

This research has also revealed different mobile IoT applications and challenges and limitations of the IoT-based healthcare system. The study conducted by Butpheng et al. (2020) identified perpetual security and privacy problem with IoT-based healthcare applications and services, especially in developing countries. The findings of this study show that patient data privacy is an issue that requires stronger privacy by designing mechanisms to protect patients's data and secure the healthcare systems. Similarly, the study conducted by Lakshmi (2021) and Kumar and Ganesh (2024) highlighted the need to address the privacy and security of data, especially when such data involves patient information in cloud-based systems. These studies urge for better cryptography and authentication mechanisms to safeguard patients' information and improve the dependability of IoT healthcare technology. Moreso, another identified challenge is the applicability and compatibility of IoT devices as identified in Kumar and Ganesh (2024) study which pointed out the need for the devices to interact with each other and the healthcare platforms for efficient healthcare functioning. However, without this, the challenges of integrating new technologies into an existing system which will limit the efficacy of IoT solutions.

5. Policy Implication

This research work has examined the possibility of improving healthcare through the application of cloud-based IoT with telemedicine. The proposed Telemedicine Integration with Cloud-Based IoT Model offers solutions for patient monitoring through real-time data acquisition, vast cloud storage for data, data analysis through an AI algorithm and secure communication. Integrating these innovative technologies, the model is expected to enhance future trends in healthcare concerning patients' treatment outcomes, easy access to healthcare services and managed care. The integration of IoT devices assists in checking the whole different change in human health since it allows the healthcare provider to monitor the signs of the patient constantly. Also, cloud-based warehousing is helpful when it comes to holding, managing, and analyzing large amounts of healthcare data. This process is complemented by other AI-based solutions that analyse health risks, detect abnormalities and provide HealthCare specialists with diagnostic recommendations. This model not only educates and empowers the healthcare providers, it also provides self-management tools and tools for patients to take control of their individual health status. The thematic analysis of the reviewed literature highlights the transformative potential of IoT, cloud computing, biosensors and AI in healthcare. Such products facilitate continuous patient observation, advance the quality of care and raise diagnostic precision. However, this study fully appreciates the contrast that critical issues like data security, patients's privacy and system connectivity were also considered. Healthcare rules and regulations must be followed and patient records kept safe using encryption and using authorised access protocols to achieve this. Therefore, cloud-based IoT adoption in telemedicine is a development of track in the healthcare sector, which means a move toward enhancing unique and easy-to-access treatment.

However, while issues like security and how to extend the model to include all the potential stakeholders are present in the model, the model sets out the conceptual framework for smart, patient- and provider-centred healthcare delivery in the future. Hence, this study contributes to the extant literature by proposing a framework that may help in future developments of telemedicine as well as integration of IoT technologies.

6. Conclusion

In this study, efforts have been made to discuss the integration of cloud-based IoT with telemedicine and come up with a model that can improve the healthcare services through real-time data acquisition, secure cloud storage, integration of BIG data AI analysis and patient-provider interface which provides solution to some of the prevalent problems in the health care system which include, patient Health monitoring, data analytical for diagnostics or health management, and tele-services. Therefore, despite limitations like data security and privacy issues, the proposed model provides a conceptual foundation for future healthcare systems efficient for patients and providers. Hence, this study provides a significant contribution to the creation of a conceptual framework for smart healthcare technologies to help society receive more effective, affordable and customized medical assistance.

Compliance with ethical standards

Disclosure of conflict of interest

This study ensures that the data gathering procedure adheres to ethical standards relevant to the research, in compliance with the ethical criteria for secondary data sources. This was accomplished by appropriately making references to the data sources. Also, ensuring ethical practices in the deployment of the health model is crucial to maintaining trust and integrity in healthcare delivery. The ethical considerations in this case ensures acknowledging the authors in which the model ideas were adapted and also, deeper ethical consideration while applying the model was primarily focusing on ensuring patient privacy, data security and informed consent when integrating cloud-based IoT in telemedicine.

Reference

[1] Achieng, M.S. (2021) "Healthcare information systems implementation for public healthcare service delivery in resource-constrained environments: a critical realist perspective (Doctoral dissertation, Cape Peninsula University of Technology).

[2] AlOsail, D., Amino, N. and Mohammad, N. (2021) "Security issues and solutions in e-health and telemedicine". In Computer Networks, Big Data and IoT: Proceedings of ICCBI 2020 (pp. 305-318). Springer Singapore.

[3] Albahri, A.S., Alwan, J.K., Taha, Z.K., Ismail, S.F., Hamid, R.A., Zaidan, A.A., Albahri, O.S., Zaidan, B.B., Alamoodi, A.H. and Alsalem, M.A. (2021) "IoT-based telemedicine for disease prevention and health promotion: State-of-the-Art". Journal of Network and Computer Applications, 173, p.102873.

[4] Ali, S.A., Arif, T.B. and Maab, H. (2020) "Global interest in telehealth during COVID-19 pandemic: an analysis of Google Trends™". Cureus. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7567313/ (Accessed: 20 September 2024).

[5] Amjad, A., Kordel, P. and Fernandes, G., 2023. A review on innovation in healthcare sector (telehealth) through artificial intelligence. Sustainability, 15(8), p.6655.

[6] Auwal, A.M., 2023. IoT integration in telemedicine: investigating the role of Internet of Things devices in facilitating remote patient monitoring and data transmission. Research Square. DOI: https://doi.org/10.21203/rs.3.rs-3419693/v1.

[7] Bokolo, A.J. (2021) "Application of telemedicine and eHealth technology for clinical services in response to COVID-19 pandemic". Health and Technology, 11(4), pp.599-610. Available at: https://link.springer.com/article/10.1007/s12553-020-00516-4 (Accessed: 20 September 2024).

[8] Bhuiyan, M.N., Rahman, M.M., Billah, M.M. and Saha, D. (2021) "Internet of things (IoT): A review of its enabling technologies in healthcare applications, standards protocols, security, and market opportunities". IEEE Internet of Things Journal, 8(13), pp.10474-10498.

[9] Butpheng, C., Yeh, K.H. and Xiong, H. (2020) "Security and Privacy in IoT-Cloud-Based e-Health Systems—A Comprehensive Review", *Journal Title*. Available at: [URL] (Accessed: 22 September 2024).

[10] Brown, A. and Green, R. (2020) "The role of encryption in healthcare data protection". International Journal of Information Management, 52, pp.102-112.

[11] Carter, J. and Lewis, H. (2021) "Ethical considerations in telemedicine". Journal of Medical Ethics, 47(6), pp.390-395.

[12] Cui, X, (2016) "The internet of things". In: Ethical Ripples of Creativity and Innovation, Palgrave Macmillan, London, UK, pp.61–68.

[13] Dang, L.M., Piran, M.J., Han, D., Min, K. and Moon, H. (2019) "A survey on internet of things and cloud computing for healthcare". Electronics, 8(7), p.768.

[14] Darbandi, M., Alrasheedi, A.F., Alnowibet, K.A., Javaheri, D. and Mehbodniya, A. (2022) "Integration of cloud computing with the Internet of things for the treatment and management of the COVID-19 pandemic", *Information Systems and e-Business Management*. Available at: https://doi.org/10.1007/s10257-022-00580-5 (Accessed: 22 September 2024).

[15] Determann, L., 2019. Healthy data protection. Mich. Tech. L. Rev., 26, p.229.

[16] European Commission, (2020) “General Data Protection Regulation (GDPR) Compliance Guidelines”.

[17] Filip, R., Gheorghita Puscaselu, R., Anchidin-Norocel, L., Dimian, M. and Savage, W.K. (2022) “Global challenges to public health care systems during the COVID-19 pandemic: a review of pandemic measures and problems”. Journal of personalized medicine, 12(8), p.1295.

[18] Garcia, L. (2021) “Interoperability challenges in telemedicine”. Journal of Healthcare Engineering, Article ID 543827.

[19] Garai, Á., Péntek, I. and Adamkó, A. (2019) “Revolutionizing healthcare with IoT and cognitive, cloud-based telemedicine”. Acta Polytechnica Hungarica, 16(2), pp.163-181.

[20] Gelogo, H.J. Hwang, and H.-K. Kim, (2015) “Internet of things (IoT) framework for u-healthcare system”. International Journal of Smart Home, 9(11), pp.323–330.

[21] Haddad, T.C., Blegen, R.N., Prigge, J.E., Cox, D.L., Anthony, G.S., Leak, M.A., Channer, D.D., Underwood, P.Y., Williams, R.D., Hofschulte, R.D. and Christopherson, L.A. (2021) “A scalable framework for telehealth: the Mayo Clinic Center for Connected Care response to the COVID-19 pandemic”. Telemedicine Reports, 2(1), pp.78-87.

[22] Haleem, A., Javaid, M., Singh, R.P. and Suman, R. (2021) 'Biosensors applications in medical field: a brief review', Sensors International, 2, pp. 100100. doi: 10.1016/j.sintl.2021.100117.

[23] Hameed, K., Mushtaq, Z., Bajwa, I.S. and Rashid, T. (2021) “Integration of 5G and blockchain technologies in smart telemedicine using IoT”. Journal of Healthcare Engineering, [online] Available at: https://doi.org/10.1155/2021/1234567 (Accessed: 22 September 2024).

[24] Harris, N. (2023) “Effective patient education strategies”. BMC Health Services Research, 23(1), pp.34-45.

[25] Ijaz, M., Li, G., Lin, L., Cheikhrouhou, O. and Hamam, H. (2022) “Computing Based on the Internet of Things for Provision of Healthcare Services at Home”, *Journal Title*. Available at: [URL] (Accessed: 22 September 2024).

[26] Islam, M.N., Raiyan, K.R., Mitra, S., Mannan, M.R., Tasnim, T., Putul, A.O. and Mandol, A.B., 2023. Predictis: an IoT and machine learning-based system to predict risk level of cardio-vascular diseases. BMC Health Services Research, 23(1), p.171.

[27] Jaya Lakshmi, M., Ghonge, M. and Obaid, A.J. (2023) “Cloud based IoT Smart Healthcare System for Remote Patient Monitoring”, *EAI Endorsed Transactions on Pervasive Health and Technology*.

[28] Johnson, M., 2021. Training healthcare providers for telehealth. American Journal of Nursing, 121(4), pp.36-45.

[29] Johnson, P. (2022) “Barriers to telemedicine adoption in diverse populations”. Journal of Telemedicine and Telecare, 28(4), pp.210-218.

[30] Kumar, M.S. and Ganesh, D. (2024) “Improving Telemedicine through IoT and Cloud Computing: Opportunities and Challenges”. Advances in Engineering and Intelligence Systems, 3(03), pp.123-135.

[31] Kichloo, A., Albosta, M., Dettloff, K. (2020) “Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA”. Family Medicine and Community Health, 8(3). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7437610/ (Accessed: 20 September 2024).

[32] Lakshmi, G.J., Ghonge, M. and Obaid, A.J. (2021) “Cloud based IoT smart healthcare system for remote patient monitoring”. EAI Endorsed Transactions on Pervasive Health and Technology, 7(28), pp. e4-e4

[33] Medvedeva, E.I. and Aleksandrova, O.A. (2022) “Telemedicine in modern conditions: the attitude of society and the vector of development”. Sotsialnye i Sotsialnye Peremeny. Available at: http://library.vscc.ac.ru/Files/articles/1671023192_200222_eng.pdf (Accessed: 20 September 2024).

[34] McGraw, D. (2021) “Privacy and the challenge of telehealth”. Journal of Telemedicine and Telecare, 27(3), pp.145-150.

[35] McCarthy, C. (2023) “Artificial intelligence in healthcare: current applications and future directions”. Health Affairs, 42(2), pp.226-234.

[36] Nieblas, B., Okoye, K. and Carrión, B. (2022) “Impact and future of telemedicine amidst the COVID-19 pandemic: a systematic review of the state-of-the-art in Latin America”. Ciência and Saúde Coletiva. Available at: https://www.scielosp.org/article/csc/2022.v27n8/3013-3030/ (Accessed: 20 September 2024).

[37] Patel, S. (2022) “Impact of network reliability on telehealth”. Telemedicine and e-Health, 28(1), pp.15-22.

[38] Patel, S.Y., Mehrotra, A., Huskamp, H.A. (2021) "Trends in outpatient care delivery and telemedicine during the COVID-19 pandemic in the US". JAMA Internal Medicine, 181(3), pp.463-465. Available at: https://jamanetwork.com/journals/jamainternalmedicine/article-abstract/2773059 (Accessed: 20 September 2024).

[39] Paul, A. and Jeyaraj, R. (2019) "Internet of Things: A primer". Human Behavior and Emerging Technologies, 1(1), pp.37-47.

[40] Premchand, P., Prasad, Y.V.D. and Gopi, C. (2024) "Cloud powered telemedicine for enhanced remote monitoring and virtual consultations". Research In Engineering Management and Science (IJPREMS) 04, (1),151-157.

[41] Ramesh, J., Aburukba, R. and Sagahyroon, A., 2021. A remote healthcare monitoring framework for diabetes prediction using machine learning. Healthcare Technology Letters, 8(3), pp.45-57.

[42] Rasool, S., Tariq, A. and Hayat, Y. (2023) "Maximizing Efficiency in Telemedicine: An IoT-Based Artificial Intelligence Optimization Framework for Health Analysis". *European Journal of Science, Innovation and Technology*, 3(6), Available at: www.ejsit-journal.com (Accessed: 22 September 2024).

[43] Robinson, T., 2020. Telemedicine's impact on healthcare costs. American Journal of Managed Care, 26(9), pp.347-353.

[44] Sageena, G., Sharma, M. and Kapur, A. (2021) "Evolution of smart healthcare: Telemedicine during COVID-19 pandemic". Journal of The Institution of Engineers (India): Series B, pp.1-6.

[45] Sharma, L., Garg, P.K. and Khatri, S.K. (2019) "Smart E-healthcare with internet of things: current trends, challenges, solutions, and technologies". In From visual surveillance to internet of things (pp. 215-234). Chapman and Hall/CRC.

[46] Shu, M., Tang, M., Yang, M. and Wei, N. (2017) "The vital signs real-time monitoring system based on Internet of things". In 2017 4th International Conference on Information Science and Control Engineering (ICISCE) (pp. 747-751). IEEE.

[47] Smith, J. (2022) "Data integrity in telemedicine". Healthcare Technology Letters, 9(2), pp.30-35.

[48] Sreelekshmi, B., Abraham Azhikakathu, T., Uthaman, M., Aparna, M., Chippy, T. and Krishna, N., 2023. Artificial intelligence in IoT-based healthcare system enhancements. TuijinJishu/Journal of Propulsion Technology, 44(5), p.3173.

[49] Stradolini, F., Tamburrano, N., Modoux, T., Tuoheti, A., Demarchi, D. and Carrara, S. (2018) "IoT for telemedicine practices enabled by an Android™ application with cloud system integration". In: 2018 IEEE International Symposium on Circuits and Systems (ISCAS). IEEE, pp.1-5.

[50] Tanwar, S., Parekh, K. and Evans, R., 2020. Blockchain-based electronic healthcare record system for healthcare 4.0 applications. Journal of Information Security and Applications, 50, p.102407.

[51] Terrell, E.A., Aftab, S., Babitz, A., Butler, L. (2021) "The evolution of telehealth from pre-COVID-19 pandemic through a hybrid virtual care delivery model: A pediatric hospital's journey". International Journal of Pediatrics. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9098127/ (Accessed: 20 September 2024).

[52] Thompson, H. (2023) "Improving data transmission in telemedicine". Healthcare Informatics Research, 29(1), pp.44-50.

[53] Tzanou, M., 2023. Health Data Privacy Under the GDPR. TAYLOR FRANCIS Limited.

[54] Wahezi, S.E., Kohan, L.R., Spektor, B. (2021) "Telemedicine and current clinical practice trends in the COVID-19 pandemic". Best Practice and Research Clinical Anaesthesiology, 35(3), pp.289-296. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7667401/ (Accessed: 20 September 2024).

[55] Wang, Y., Kung, L., Wang, W.Y.C. and Cegielski, C.G. (2018) "An integrated big data analytics-enabled transformation model: Application to health care". Information and Management, 55(1), pp.64-79.

[56] White, T. (2020) "Continuous education in telemedicine". Medical Education Online, 25(1), Article 1750001.

[57] Williams, R. (2022) "Framework for evaluating telemedicine interventions". BMC Health Services Research, 22(1), Article 88.

[58] World Health Organization and International Telecommunication Union, (2022) "WHO-ITU global standard for accessibility of telehealth services". Geneva: Available at: https://www.who.int/publications/i/item/9789240050464 (Accessed: 20 September 2024).

[59] World Health Organization, (2021) "Global strategy on digital health 2020-2025". Available at: https://www.who.int/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf (Accessed: 20 September 2024).

[60] Yu, H. and Zhou, Z., 2021. Optimization of IoT-based artificial intelligence assisted telemedicine health analysis system. IEEE Access, 9, pp.85034-85048.

[61] Zhou, L., 2021. Wearable devices and their role in telemedicine. Journal of Medical Internet Research, 23(5), e24515