Internet of Medical Things

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ABSTRACT

The "Internet of Medical Things" (IoMT) is the network of interconnected, smart medical devices, sensors, and other healthcare technologies that collect and exchange health data for improved patient care, diagnosis, and treatment. IoMT is said to build upon the concept of the Internet of Things (IoT), applying it to the health sector. This has to do with embedding electronics and sensors into medical devices and wearables, allowing them to communicate and share data over a network. IoMT with its attendant benefits is faced with challenges and limitations, but also has a lot of future prospects for humanity. The paper examines the pros and cons of Internet of Medical Things and its future prospects for man.

KEYWORDS: *Internet of Medical Things (IoMT), smart medical devices, sensors, Internet of Things (IoT), wearables, software platforms, smart health objects (SHOs), communication protocols, robotics, healthcare*

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INTRODUCTION

The Internet of Health Things (IoHT), also known as the Internet of Medical Things (IoMT), is a subset of IoT focused on healthcare applications. It involves interconnected devices and software platforms that collect, transmit, and analyze patient data to enhance healthcare delivery, reduce costs, and improve outcomes. According to Gubbi et al., they posited that, "The IoHT connects patients, caregivers, and healthcare providers through networked medical devices and health monitoring systems" [1]. The IoHT/IoMT is the use of "smart health objects" (SHOs) like medical devices that collect data, such as medical sensors, wearables, and connected medical equipment, and home monitoring systems, offering real-time insights and supporting proactive healthcare. IoT is used to collect health-related data from individuals, as well as computing devices, mobile phones, smart bands and wearables, digital medications, implantable surgical devices, or other portable devices, which can measure health data and connect to the internet [2, 3], as shown in Figures 1 and 2.

THE HISTORY AND EVOLUTION OF IoMT

The late 1960s: The origins of the IoT and IoMT can be traced back to the late 1960s with the development of ARPANET, which was a precursor to the modern internet, and the exploration of connecting computers and systems. Examples of interconnected electronic devices exist as far back as the early 19th century, with the invention of the telegraph which was able to transmit information by coded signal over distance, the origins of the IoT date to the late 1960s. Prominent group of researchers at that time began to explore ways to connect computers and systems, which led to ARPANET, the network created by the Advanced Research Projects Agency (ARPA) of the US Defense Department; a forerunner of today's Internet.

Late 1970s: Businesses, governments and consumers in the late 1970s started exploring ways to connect personal computers (PCs) and other machines to one another.

The 1990s: By the 1990s Local Area Networks (LANs) provided an effective and widely used way to communicate and share documents, data, and other information across a group on PCs in real time. In the mid-1990s, the internet extended those capabilities globally, while researchers and technologists began to explore ways humans and machines could better connect, paving the way for the development of the IoT and its applications in various sectors, including healthcare [4].

The Internet of Medical Things (IoMT) is a relatively new concept which evolved from the Internet of Things (IoT) technology. This concept gained traction in the early 2000s, with the development of smart sensors, devices, and communication protocols. With the advancement in IoT technology, it naturally extended into the healthcare sector, giving rise to the Internet of Medical Things (IoMT).

Emergence of connected devices 2000-2010: The rise of wireless networks and smartphones facilitated the development of health-related apps and wearable devices like **Fitbit** (2007). Furthermore, implantable devices such as pacemakers with wireless data transmission began to be explored for real-time monitoring.

During 2010-2015: During this period, hospitals started adopting RFID and wireless monitoring systems to track equipment and patients. Remote patient monitoring (RPM) became more prevalent with tools to track chronic diseases like diabetes and hypertension, reducing the need for frequent hospital visits. It was also in the 2010s that the IoMT started gaining momentum, with the introduction of wearable devices, smart medical sensors, and telemedicine platforms.

From 2015-2020 (Growth and integration): There was the proliferation of IoMT devices including smart inhalers, connected insulin pumps, and AI-based diagnostic tools. Cloud computing and big data analytics enhanced real-time data collection and predictive modeling, as shown in Figures 3 and 4. However, cybersecurity and data privacy became a major concern. The internet of Medical Things (IoMT) gained popularity with researchers and industry experts exploring its applications in healthcare.

Acceleration during COVID-19 (2020-2022): The adoption of telehealth and remote patient monitoring was significantly accelerated during the pandemic. IoMT was critical in reducing in-person hospital visits and managing patients remotely. As a result, devices such as pulse oximeters, connected thermometers, and wearable ECG monitors saw a sharp rise.

Current trends (2023 – Present): This has to do with the integration of AI, 5G, and edge computing, enabling faster and more intelligent decision-making. IoMT continues to evolve with the advancements in artificial intelligence, machine learning, robotics, and data analytics, which are enabling more sophisticated healthcare solutions [5, 6]. Robots are improving our daily lives in the workplace, revolutionizing healthcare and patient care, companions and assistants at home, in public safety and emergency response (i. e. protecting lives), and in agriculture and environmental protection (i. e. sustainable solutions) [7-9].

IoMT AND SMART e-HEALTHCARE

IoMT and enabling wireless technologies: IoT systems consist of sensors and devices connected via a network of cloud ecosystems over high-speed connectivity between each module, as shown in Figures 5 and 6. The raw data collected at these devices/sensors is sent directly to the vast storage offered by cloud services. This data is further cleaned and then analyzed to gain further insights into it. This requires additional software, tools, and applications which will further assist in visualization, analysis, processing, and management of the data. Currently, the use of 5G/6G or beyond is prevalent in IoMT due to their high bandwidth and ultra-low latency benefits [10].

Smart e-healthcare: Smart hospitals are hospitals that are built on intelligent automated and optimized modules (maybe based on AI/ML) on the ICT infrastructure to improve patient care procedures and to add new capabilities. Some of the applications of smart hospitals are telemedicine, telehealth, and as well as remote robot surgery. Telemedicine is the provision of clinical care at a distance, while telehealth is the provision of a non-clinical care at a distance. In remote robot surgery, medical robots perform surgery through instruction from the doctor sitting far away.

IoMT ARCHITECTURE

The architecture of IoMTs consists of three layers which are: Things layer, Fog layer, and Cloud layer. In this architecture, the health experts can directly communicate through the router between the Thing layer and Fog layer, through the local processing servers at the fog layer.

1. The Things layer consists of patient monitoring devices, sensors, actuators, medical records, pharmacy controls, nutrition regimen generator, etc. The layer is directly in contact with the users of the ecosystem. This data from elements such as wearables, patient-monitoring data, remote care data is collected at this layer, the devices used must be secured to ensure the integrity in the data collected.

2. The Fog layer operates between the cloud and the things layer, which consists of local servers and gateway devices for a sparsely distributed fog networking framework.
3. The Cloud layer consists of data storage and computation resources for the data to be analyzed and derive decision-making systems based on it. The cloud also offers a vast reach to incorporate huge medical and healthcare systems to handle their day-to-day operations with ease. This layer consists of cloud resources where the data generated from the medical infrastructure will be stored and analytical work could be performed as deemed necessary in the future.

EMERGING TECHNOLOGIES IN IoMTs

This has to do with technologies such as blockchain, PUF, AI, and SDN and their roles in IoMT.

Blockchain Technology: The Blockchain is a decentralized ledger recording transactions of computing nodes in the network. IoMT has raised growth in distributed computing markets and blockchain offers a solution to many issues arising in the security of participating entities in the healthcare system built around it, as shown in Figure 7. The blockchain is said to contain blocks or nodes that are connected over a network where the information exchanged between any of the nodes in networking is recorded and can further be used for cross-references. The blocks contain the information from previous blocks which helps in identifying the exact source of miscreants in the network, such that blocks not identified in the network are discarded, proving that blockchain can be considered for use as a trusting strategy in information exchange systems like IoMT [11, 12].

Physically Unclonable Function (PUF) Devices: PUF devices generate a unique fingerprint for the vulnerable elements in the IoMT ecosystem, as shown in Figure 8. These unique fingerprints/signatures arise from the variation in the fabrication of these devices. The fingerprints are used for secrete key generation (cryptography keys) to secure the devices and their data in the IoMT ecosystem where the end devices (sensors) are at risk of hardware tampering attacks [13]. The PUF devices reside in the “thing layer” which plays an important role in the authentication of IoMT devices in the ecosystem.

AI IN IoMT: Some of the IoMT applications include AI, Machine Learning (ML) and Natural Language Processing (NLP) in e-healthcare. Precision medicine requires advanced diagnostics and tailored regimes with quick delivery time, for which AI is well suited for by providing real-time solutions in determining new pathways for the treatment of certain conditions based on historic and real-time data. AI-based solutions can be used for various features in the healthcare ecosystem, such as the use of AI techniques for the creation of classifiers like automatic capturing of patient information, scheduling patient appointments, determining lab tests, treatment plans, medications, surgical treatment, and so on [14].

SDN IN IoMT: The network part in IoMT is divided into two parts which are: data plane, and control plane. The data plane forwards traffic towards its destination, and while the control plane performs the necessary tasks that allow the data plane to make forwarding decisions. Software-Defined Networking (SDN) provides a standard way to communicate between the data plane and control plane. Some of the examples of SDN protocols are the OpenFlow, OpenvSwitch Database Management protocol, and OpenFlow Configuration protocol (OF-CONFIG) [15]. Patient monitoring systems have also improved the response from healthcare experts as well.

RELATED WORKS

The use of sensors for the collection of data from parameters like temperature, ECG, blood pressure, pulse, and heartbeat has transformed the accuracy of the data and has eventually led to patients getting better service than before [16].

CHALLENGES FACING IoMT

Some of the challenges confronting IoMT are as follows [17-19]:

1. Data privacy and security: Since IoMT devices store and transmit sensitive patient data, making them vulnerable to cyberattacks, data breaches, and privacy violations, there is the need to ensure protection against breaches.
2. Interoperability: The devices from different manufacturers must communicate seamlessly in order to avoid data silos and fragmented healthcare records.
3. Regulation and compliance: There is the need to adhere to healthcare regulations such as HIPAA or GDPR.
4. Data management: Handling and analyzing vast amounts of data requires robust infrastructure and AI algorithms.
5. Technological challenges: IoMT devices require efficient energy management solutions, as well as reliable and secure network connectivity essential for IoMT devices to communicate and transmit data. Additionally, it must be scalable to accommodate a growing number of devices and users.

6. Lack of standardization: The absence of common standards and communication protocols across different IoMT devices and systems creates interoperability issues..
7. Data integrity and accuracy: Ensuring the reliability and accuracy of data collected by IoMT devices is crucial, and errors in data handling can have serious consequences.
8. Device diversity: The wide variety of IoMT devices, each with unique capabilities and functionalities, adds to the complexity of managing and integrating them.
9. Ethical concerns: The issues related to data ownership, consent, and the potential for misuse of IoMT data raise ethical considerations.
10. Resource constraints: The effective implementation and utilization of IoMT technologies could be hindered by inadequate training and resources for healthcare professionals.
11. Technical issues and downtime: Frequent technical issues and system downtimes can disrupt IoMT operations and impact patient care.
12. Staffing shortages: Insufficient staffing levels can make it difficult to manage and maintain IoMT systems effectively.

FUTURE PROSPECTS

The IoMT market is expected to continue its rapid growth, which is driven by the advancements in AI, 5G, and miniaturization of sensors. Predictive analytics, powered by data from IoMT devices, will play a significant role in preventive care and population health management [20-22].

CONCLUSION

The transformation of the healthcare sector by the Internet of Medical Things is now more connected, data-driven, and patient-centered. However, while there are some challenges, the potential benefits of IoMT far outweigh the risks, thereby making it a cornerstone of modern and future healthcare systems. IoMT has the potential to revolutionize healthcare by enabling personalized medicine, remote monitoring, and improved patient outcomes. By its ability to connect medical devices, sensors, and healthcare systems, IoMT can help reduce healthcare costs, improve patient engagement, and as well enhance the overall quality of care.

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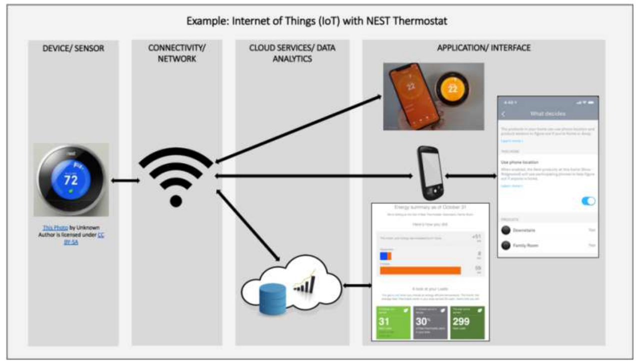

Figure 1. Internet of Things

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Figure 2. mHealth

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Figure 3. Health information on the Internet

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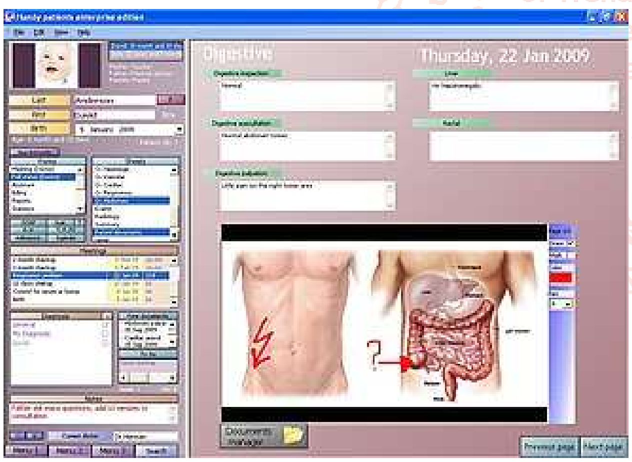

Figure 4. Electronic health record

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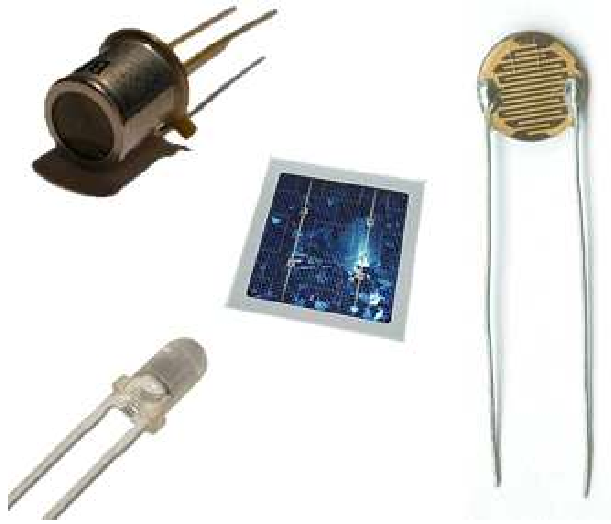

Figure 5. Sensors

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Figure 6. Robotic sensors

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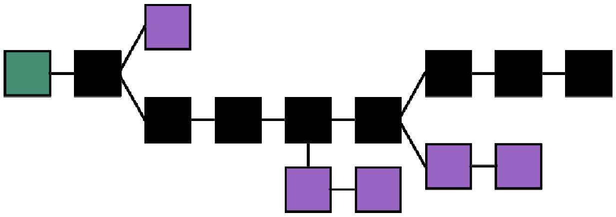

Figure 7. Blockchain

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Figure 8. Physical unclonable function

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