



HAL
open science

A Holistic Analysis of Medical Internet of Things (MIoT)

Nikhat Akhtar, Saima Rahman, Halima Sadia, Yusuf Perwej

► **To cite this version:**

Nikhat Akhtar, Saima Rahman, Halima Sadia, Yusuf Perwej. A Holistic Analysis of Medical Internet of Things (MIoT). *Journal of Information and Computational Science*, 2021, 11 (4), pp.209-222. hal-03226578

HAL Id: hal-03226578

<https://hal.science/hal-03226578>

Submitted on 20 May 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A Holistic Analysis of Medical Internet of Things (MIoT)

¹Nikhat Akhtar, ²Saima Rahman, ³Halima Sadia, ⁴Yusuf Perwej

¹Research Scholar (Ph.D), Department of Computer Science & Engineering, Babu Banarasi Das University, Lucknow

²Assistant Professor, Department of Computer Science & Engineering, Integral University, Lucknow

³Assistant Professor, Department of Computer Science & Engineering, Integral University, Lucknow

⁴Associate Professor, Department of Computer Science & Engineering, India

¹dr.nikhatakhtar@gmail.com, ²nasir.saima@gmail.com, ³halima@iul.ac.in, ⁴yusufperwej@gmail.com

Abstract — Traditional healthcare systems are confronted with new problems as the number of patients continues to rise. To solve this problem and improve the healthcare domain's accuracy, reliability, performance, and effectiveness. Since its introduction, the Medical Internet of Things, also known as (MIoT), has become increasingly important in improving the health, protection, and treatment of billions of people. The Medical Internet of Things (MIoT) is a network of linked healthcare software and hardware devices that forms the medical IT systems. MIoT devices are linked to cloud systems, which store and analyze the data they collect. MIoT tools are rapidly transforming healthcare delivery due to their ability to capture, interpret, and distribute health data. By linking patients to their physicians and allowing the transfer of medical data over a secure network, it can reduce unnecessary hospital visits and the strain on healthcare systems. The MIoT has the potential to decrease device interruption through remote provision from the provider healthcare perspective. The MIoT is also expected to provide real-time healthcare services via the internet and smart devices like Smartphone's, wearable medical devices, and embedded medical devices. Moreover, the MIoT can properly detect optimum times for replacing supplies for several devices for their continuous and smooth operation. In this paper, we present a comprehensive literature review of recent contributions focused on the Medical Internet of Things (MIoT). Medical Internet of Things-based healthcare services are expected to improve the user's quality of life, lower prices, and expand their expertise.

Index Terms — *Medical Internet of Things (MIoT), Cloud Computing, Internet of Things (IoT), Wearable Sensors, Perception Layer, Application Layer, Healthcare.*

1. Introduction

The Internet of Things (IoT), a modern concept, has broad applications in a variety of fields, including healthcare [1]. Internet of Things (IoT) systems typically has a complex architecture that connects different types of devices to provide a specific service to the end user [2]. The Internet of Things (IoT) is a framework in which everyday objects can be fitted with detecting, measuring, networking, and processing capabilities, allowing them to connect with other devices and provide services to achieve a specific purpose through the Internet [3]. IoT devices were deployed in several medical domains, especially with the excessive use of medical wireless sensors, [4] devices, Unmanned Aerial Vehicles (UAVs), and robots. The Medical Internet of Things (MIoT) shares many of the same requirements as the conventional Internet of Things (IoT), especially in terms of managing a large number of devices, dependable communication, and system heterogeneity and interoperability [5]. The Medical Internet of Things (MIoT) is a healthcare system comprised of smart medical devices and software applications. The MIoT is capable of providing remote medical diagnosis and timely health services through the internet. Medical IoT, also known as healthcare IoT, refers to an increasing range of IoT applications in the medical field [6]. Sensors and software for remote healthcare tracking, telemedicine consultation, and distribution, for example, are among the IoT devices and

applications created specifically for healthcare needs and settings.

Today's internet-connected devices are being developed to increase efficiencies, reduce healthcare costs [7], and boost patient results. Organizations are exploiting the ability of I Medical Internet of Things technology as computing resources and wireless capabilities increase. One of the fastest-growing segments of the IoT market is healthcare products. In reality, by 2026, the size of this industry, which is also known as the Medical Internet of Things (MIoT), is expected to hit \$176 billion. According to a recent Deloitte survey, there are currently over 500,000 medical technologies available. The Medical Internet of Things (MIoT) is the interconnection of a variety of personal medical devices, as well as devices and health-care providers such as hospitals, medical researchers, and private businesses [8]. The Medical Internet of Things (MIoT) has gotten a lot of attention recently because of its many benefits, including making it easier to handle diseases and medications [9], enhancing care practices and the patient experience, and lowering costs. MIoT has now been accepted by about 70% of healthcare organizations [10]. In reality, the healthcare industry accounts for one-third of all IoT devices [11].

The Medical Internet of Things (MIoT) is helping people all over the world improve their health and access to medical services. Medical IoT also uses AI and machine learning [12] to support life-changing changes to conventional medical equipment, such as the smart inhaler for asthma sufferers. In reality, in the sense of body area networks, medical sensors and actuators are used as wearable devices. Rather than holding patients in hospitals, these systems can continuously track their health in real time while still providing them with greater physical versatility and mobility. Medical robots, on the other hand, can be used as surgical robots as well as hospital robots [13], which are capable of conducting small procedures with precision. They can also perform medical tasks like cardiopulmonary resuscitation (CPR) [14]. The Medical Internet of Things (MIoT) blends conventional medical system reliability and protection with traditional Internet of Things (IoT) dynamicity, genericity, and scalability capabilities [15]. It has the potential to address the issue of ageing and chronic diseases by managing a large number of devices for a large number of patients. Furthermore, the Medical Internet of Things (MIoT) addresses additional issues such as patient mobility [16]. Many services have been provided by the Medical Internet of Things (MIoT) technology, including improving healthcare services, disease management, data collection, patient experience, and low-cost services.

The remainder of this paper is structured in the following manner. In section II, the relevant work is discussed. In sections III and IV, we discuss the Medical Internet of Things (MIoT) and the Medical Internet of Things (MIoT) layer. The communications in the Medical Internet of Things are presented in section V. We present amalgamate wearable medical sensors in MIoT in section VI. We provide technical necessity for medical internet of things applications in sections VII. We are discussing MIoT use cases in medical sector in sections VIII. We are widely discussing advantage of MIoT in sections IX. In section X, we present challenges of MIoT. Section XI brings this paper to a close.

2. Related Work

This section presents a comparison of different approaches, design context discussed with the using of Medical Internet of Things. The Medical Internet of Things (MIoT) is a network of interconnected nodes in the healthcare sector, each of which is made up of a set of linked IoT devices, clinical systems, and wearable sensors. It improves the patient's care efficiency as well as medical response times [17]. Hu et al. [18] introduced a scheme based on cloud computing using IoT sensors which is related to the digital signature, time stamp mechanism and the asymmetric technology to monitor the other personal information. This scheme is very efficient in providing medical services and utilizing less medical resources. Yusuf Perwej and colleagues explore the technical aspects of Internet of Things security briefly. Because when only two instruments were combined in the field of medical care, security was a major concern [19]. A generic survey on medical big data analysis was conducted in to sort big data issues and challenges of adopting IoMT solutions [20]. Williams and Woodward identified general issues that contribute to a potentially insecure MIoT environment, such

as consolidated reporting, context expertise, governance, regulations, resilience measures, standards, and technical controls [21]. Rodrigues et al. [22] reviewed technological advances made so far which can be used in MIoT and then analyzed the challenges to be overcome. Li et al. [23] describe a wireless sensor network health monitoring and alarm device that tracks, stores, and analyses body health data in order to send alerts when suspicious behaviour is detected. Ullah et al. [24] presented a new semantic model for patients' e-health based on existing technologies, which are used to deploy IoT in the field of medical and smart health care. Roman et al. [25] consists of an early wearable prototype for health monitoring that measures body temperature, heart rate, and fall detection to show these data on a Liquid Cristal Display (LCD) screen and send notifications to the caregiver using a Global System for mobile communications (GSM) module. Turabieh et al. [26] introduced a dynamic L-RNN [27] from artificial intelligence [28] to recover missing data from MIoT applications to guarantee high quality of services to the end users.

Chandel et al. [29] propose the use of sensors embedded in commercial mobile devices for continuously monitoring healthcare or fitness on elderly, due to their attractive form factor and low power consumption. Joyia et al. [30] identified several problems in the MIoT, where software implementation remains difficult. We agree that our work is a significant step toward addressing these issues. By tracking vitals such as blood pressure, sugar levels, and irregular cellular development, Rohokale et al. [31] proposed a healthcare monitoring system for rural citizens.

3. Medical Internet of Things (MIoT)

The Internet of Things (IoT) is a concept that refers to platforms of interconnected web-enabled devices and medical technologies that use sensors, processors, software, and hardware to capture, send, analyze, and manage data. The Medical Internet of Things (MIoT) is a subcategory of the Internet of Things that is revolutionizing the healthcare industry. IoT sensor-based devices [5] allow for integration with mobile technologies, which are referred to as Medical Internet of Things (MIoT). As the data collected by these devices is combined with electronic health record (EHR) systems, which capture crucial data that is used to support clinical decision making, a new dimension is opened, and several possibilities and uses emerge through which this technology can play a pivotal role in transforming current healthcare systems, making them more effective and resilient.

Patients, medical personnel, and visitors can all be tracked using MIoT-based technology, further enhancing the idea of smart hospitals. Real-time patient tracking, advanced diagnostics, robotic surgery, and other medical IoT applications will all help improve patient outcomes. The scenarios that MIoT brings about include the location awareness, proximity inferencing, movement detection, and environmental sensing functionality. Medical findings data can now be gathered and shared in unprecedented ways, saving time and money [32] and promoting future promises. Medical IoT is also critical in the increasingly dispersed nature of health and healthcare, as telemedicine and related

technological advances eliminate the need for office visits. The Medical Internet of Things (MIoT) is driving a healthcare revolution [16]. Patients and customers profit from the use of interconnected web-enabled technologies. Via enhanced automation, protection, and other technological gains,

medical IoT provides new opportunities for healthcare providers to enhance patient care and manage the inherent complexity of the healthcare market.

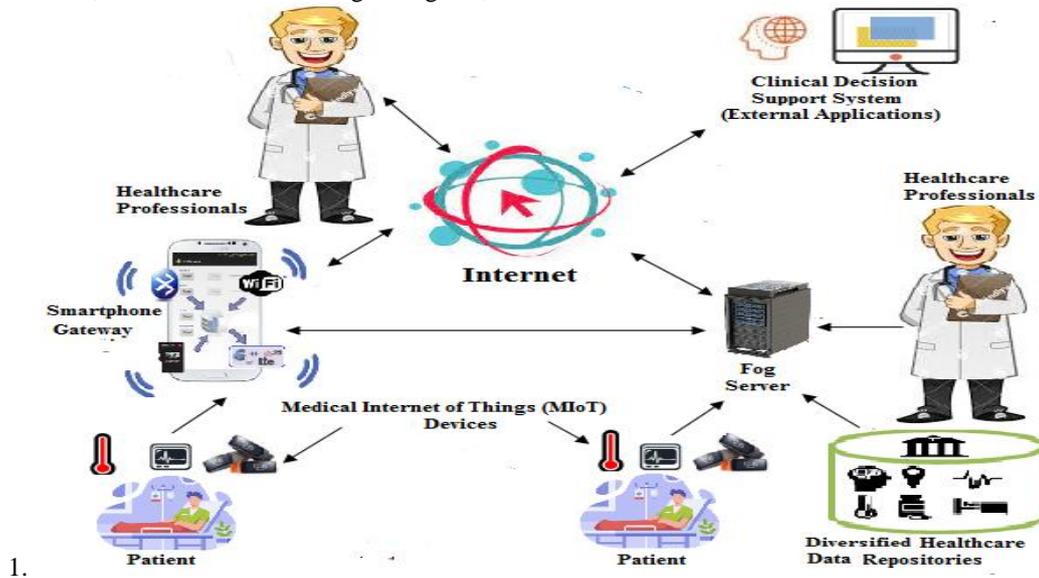


Fig. 1. The Medical Internet of Things (MIoT)

4. Medical Internet of Things (MIoT) Layers

The aim of the MIoT is to collect real-time health data from patients and store it in network facilities linked to the Internet. Doctors use m-health data to monitor, diagnose, and treat their patients. In addition, integrating mobile health devices into the client environment allows for real-time prediction of [33] various health anomalies. As shown in figure 2, the IoT architecture in health care delivery is made up of five basic layers, the first perception layer, second sensing layer, third network layer, fourth business layer, and fifth application layer.

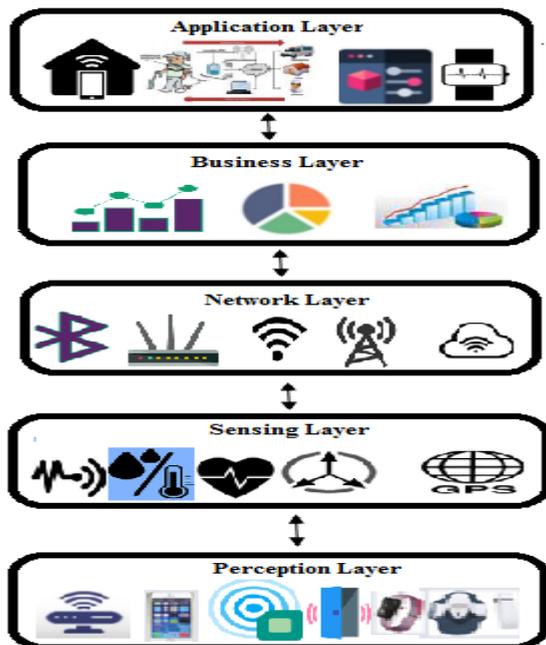


Fig. 2. Medical Internet of Things (MIoT) Layer

4.1 Sensing Layer

A lot of data is used by mobile health applications. To store, send, and receive data, the devices are connected to IoT servers. The following are some of the most important features of medical health devices, Low power consumption, IP powered and wireless networking, and lightweight and easy-to-wear [34]. The aim of connected devices is to aid in the tracking, diagnosis, and treatment of sick person's while maintaining low power, low cost, physical size, and ease of use. Since these devices are designed to operate for long periods of time while still providing as much battery life as possible, low power consumption is expected.

4.2 Perception Layer

This layer has main responsibility in data collection (i.e. heart rate, pressure, temperature, etc.) using sensors in the physical layer, after that, the collected data [35] is being transferred to the network layer. The perception layer's main role is to gather healthcare data from a number of sensors. The Internet of Things is built on the basis of perception and recognition technologies. As an example, in the patient care systems, a lot of sensors are connected to the sick person's body to make sure that there is a monitoring to the sick person's condition and provide help when its needed. Radio frequency identification (RFID), infrared sensors, cameras, GPS, medical sensors, and smart device sensors are examples of sensors that can detect changes in the environment. These sensors provide comprehensive perception through object recognition, location recognition, and geographic recognition, as well as the ability to convert this data to digital signals for easier network transmission. The IEEE 802.15.4 standard [36] is used to base or introduce the majority of perception layer protocols. The IEEE 802.15.4 is a low-complexity, low-cost, and low-power-consumption

standard. It facilitates wireless communication with a low data rate and is primarily targeted at low-cost, low-spectrum IoT smartphones. IEEE 802.15.4 describes the specifications for the physical (PHY) and the MAC layers, for various types of devices (fixed, portable or moving devices), having very limited battery consumption requirements or even having no battery at all.

4.3 Network Layer

The arrangement of various network elements is referred to as MIoT topology. The network layer, which is made up of wired and wireless systems as well as middleware, processes and transmits the information gathered by the perception layer with the help of technical platforms. From the perspective of service providers, the most important aspect in developing IoT [37] topology is to define related behaviours and functions in medical services. The architecture is a blueprint for describing the physical elements, organisation, and operation of an IoT healthcare network. It can be thought of as a complete mesh networking device with Internet access. RFID, wireless sensor networks, Bluetooth, ZigBee, low-power Wi-Fi, and the global infrastructure for mobile communications are examples of short-range networking technologies. Since such network devices transmit privacy-sensitive data in healthcare, network security is a major concern [38]. Trust management, confidentiality, integrity, authentication, and protection from denial of service attacks are all issues that network layer security must address in IoMT. The IEEE 802.15 standard [39] is used for the majority of the protocols in this layer. At this layer, the most popular protocols for IoMT are Wi-Fi and ZigBee. Bluetooth is still used, though less often, due to its inability to reach vast areas such as hospitals.

4.4 Business Layer

This layer's primary duty is to manage the medical provider's business logic as well as to help the business lifecycle (i.e., controlling, monitoring, and adjusting) business procedures. Any device's performance is determined not only by the technology used in it, but also by how it is distributed to its users. These activities are handled by the device's business layer. It entails creating flowcharts, graphs, analyzing data, and determining how the device can be enhanced, among other things. The business layer describes an application's intended behavior and serves as a device manager [40]. It has responsibilities to manage and control applications, business and profits models of IoT. This layer is also in control of the user's privacy. It can also decide how knowledge can be produced, processed, and modified.

4.5 Application Layer

The medical data is transmitted to medical-specific software applications for further processing after it has been transferred by the previous layers. The application layer is in charge of converting this data into a format that end devices and medical servers can understand [41]. The application layer incorporates medical information tools to include customised medical services and meet the needs of end users, based on the target population's current condition and service demand. The application layer interprets and applies data and

is in charge of providing the user with application-specific services. Artificial intelligence is one of the most promising medical applications provided by IoT. Image analysis, text recognition with natural language processing, drug activity design, and gene mutation expression prediction are only a few of the scientific applications of artificial intelligence [42]. AI has the capability to read available EMR data, including medical history, physical, laboratory, imaging, and medications, and contextualize these data to generate treatment and diagnosis decisions and possibilities. IoT-based health care and deep machine learning [12] will help doctors see what they can't see and have new and improved diagnostic capabilities. Artificial intelligence and deep learning can also optimize disease management, can provide big data and analysis generated from medical Health apps and IoT devices, and are starting to see adoption in health care [43]. The application layer protocols might not always be medical-specific since they were designed for general-purpose applications. COAP, MQTT [44], and HTTP Restful are the most widely used general-purpose application layer protocols in healthcare systems.

5. Communication in Medical Internet of Things (MIoT)

Communication is a skill that is undervalued, especially in medicine. Although our world has become increasingly linked as a result of the ever-increasing number of new devices, applications, and infrastructure; many doctor-patient interactions remain woefully outdated. Often physicians exaggerate their ability to interact with patients who are ill. The comparison of different communication protocols used in MIoT is summarised in table 1. According to a survey of doctor-patient relationships, 76 percent of surgeons believe their patients are fully happy with their contact. These issues can be addressed with real-time apps, which can greatly enhance coordination between patients, physicians, and the entire healthcare team. Any company will benefit from real-time data with a well-thought-out implementation strategy. Five different forms of communication networks are used to transmit real-time data between medical devices. Body Area Networks, Neighbourhood Area Networks, RedTacton, Home Area Networks, and Wide Area Networks are examples of these groups.

5.1 Body Area Network (BAN)

Body area networks (BANs) are a hot topic in research and development because they have the potential to revolutionize healthcare delivery and monitoring. The network usually covers the entire human body, with nodes linked through a wireless communication channel [45]. These nodes are arranged in a star or multi-hop topology, depending on the implementation. BANs consists of sensors and actuators around the human body in order to monitor human organs or to deliver either impulses or medicine on the body or inside the body, also known as implant medical devices like pacemakers, or capsule endoscopes with a wireless communication link to an access point or hub shown in figure 3. The benefit is that the patient does not have to stay in bed and can walk about easily in the room or even leave the hospital for a short time. This increases the patient's quality of

Table 1. The Comparison of Different Communication Protocols used in MIIoT

Technologies	Layer	Security	Data Rate	Topology	Range	Frequency (Band)	Power Consumption	Drawbacks
RFID	Perception	Encryption (AES, DES)	106–424 Kbps	Star, Ring	20 cm	13.56 MHz	Very Low	No authorization
Bluetooth	Perception-Network	Secure pairing 128-AES encryption	1, 2, 3 Mbps	Star, Point-to-point	80–115 m	2.4 GHz	Low	Blue jacking, Bluesnarfing
LoRa WAN	Network	Authentication, Encryption	300 Bps - 37.5 kbps	End-to-End	3–4 km	sub GHz	Low	Low bandwidth
ZWave	Perception-Network	Encryption	40 kbps	Mesh network	30 m	sub GHz	Low	Coverage is limited
WiFi	Network	Authentication, Authorization	0.1–54 Mbps	Star	80 m	2.4 GHz, 5 GHz	Medium	Eavesdropping
6LoWPAN	Network	Authentication, Integrity	50 kbps	Mesh topology	10–100 m	2.4 GHz	Low	Less Secure
NFC	Perception-Network	Authentication	106–424 Kbps	Point-to-point	20 cm	13.56 MHz	Very Low	Hacking
ZigBee	Perception-Network	encryption, Integrity	250 kbps	Mesh	10 - 100 m	2.4 GHz	Low	Fixed key
UWB	Perception	Passive keyless entry	53–480 Mbps	Peer to peer, multi-hop	10 m	3.1–10.6 GHz	Very Low	Need large frequency range
IrDA(Infrared)	Perception-Network	Line-of-sight and very low bit error rate	14.4 Kbps	Point-to-point	1 m	850–900 nm	Low	Data transfer is very less
WSN	Network	Encryption, Authentication	80 -250 kb/s	Star, Tree, Ring	20 - 100 m	2.45 GHz	Low	DOS attack
5G Network	Physical layer	Authentication, Authorization	5-10 Gbps	Star	1,000 feet	28 GHz - 39 GHz	Medium	Distributed DoS, Inter cell Interference

life while also lowering healthcare costs. In addition, data collected over a longer period and in the natural environment of the patient, offers more useful information, allowing for a more accurate and sometimes even faster diagnosis.

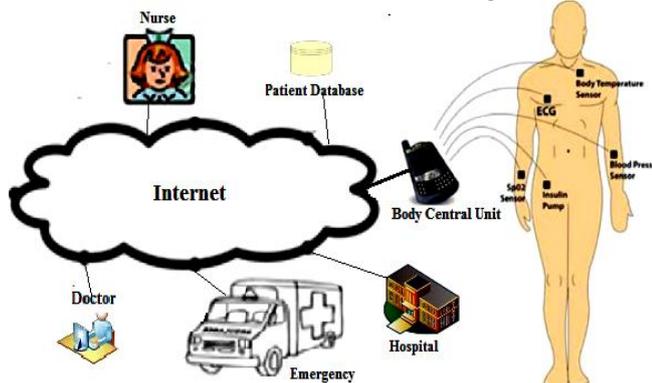


Fig. 3. Body Area Network (BAN)

5.2 Neighbourhood Area Network (NAN)

A neighbourhood area network (NAN) is a subset of Wi-Fi hotspots and wireless local area networks (WLAN), all of which enable users to connect to the Internet easily and cheaply. A NAN is usually set up by a single person to represent a family or a group of neighbors [46]. A NAN consists of one or more persons putting up an 802.11 access point (AP), such as an Apple Airport or an Intel 2011, to cover a small geographic area. The coverage can be up to 1 kilometer in radius if the AP owner is using an omni-directional antenna. Neighbors participating in the NAN would use a directional antenna pointed back at the AP. NANs, on the other hand, offer a much wider radius of Internet connection. Therefore, commercialization of NANs is an effective way to speed up the extension of neighborhood Wi-Fi networks.

5.3 RedTacton

The RedTacton is a technology that uses the surface of the human body as a high speed and safe network transmission

path shown in figure 4. The RedTacton is a Human Area Networking technology that transmits data at high speeds using the surface of the human body [47]. Technically, it is completely distinct from wireless and infrared technologies as it uses the minute electric field emitted on the surface of human body as medium for transmitting the data. The RedTacton device is designed for monitoring the patient’s health conditions without disturbing the patient who is in critical care units. It helps the doctor to monitor the live data of the patient at the time of visit and to direct the nurse or their assistant to monitor and look over the patient.

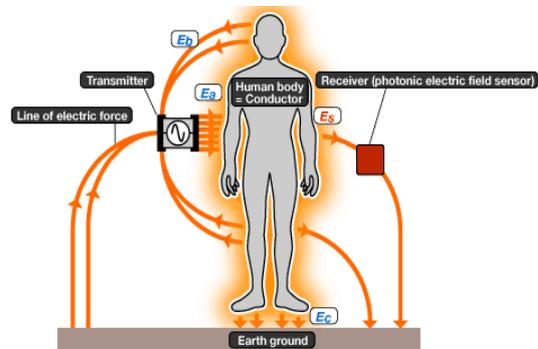


Fig. 4. The RedTacton Model

5.4 Home Area Network (HAN)

A home area network (HAN) collects sensor data from a number of devices in the home and sends control information to these devices to help control energy usage. A controller is used in HAN to manage contact and transfer the collected data to an available Access Point (AP) in the patient's home [48]. There are various HAN topologies, depending on the way the devices are interconnected and the role taken by controllers in the information transmission. The different type of technologies used in HAN technologies like ZigBee, Wi-Fi, Ethernet, Z-Wave, HomePlug, Bluetooth [49], Wireless M-Bus, Wavenis etc.

5.5 Wide Area Network (WAN)

A WAN is a network that connects smaller metropolitan and campus networks in different locations into a single, distributed network using various links such as private lines, Multiprotocol Label Switching (MPLS), virtual private networks (VPNs), wireless (cellular), and the Internet. A Wide Area Network (WAN) represents the communication from a mobile Base Station or from an access point to the mobile/Internet (remote) medical infrastructure [50]. WANs allow them to carry out their essential daily functions without delay. In case of emergencies, a WAN ensures real-time data transmission to emergency response teams.

6. Amalgamate Wearable Medical Sensors in Medical Internet of Things (MIoT)

In today's world, where time is valuable, people, especially the working class, spend the majority of their days juggling multiple tasks and neglecting their health and fitness. Even a simple clinic visit with a doctor will necessitate multiple tests for diagnosis, medication, and care, all of which can take a long time [51]. As a result, many people just visit a doctor when they have a serious illness. As a result, many people are looking for an alternative, such as a body-worn system that not only constantly monitors the user's health in real time but also provides timely insights on different health parameters to both the user and his or her physician.

The primary function of Physiologic Monitoring Devices is to track and, in certain cases, relay signals from the patient's body to other medical systems [52]. Usually, they consist of tiny wireless modules, health sensors, which gather

information such as blood pressure, blood glucose, temperature, pulse oximetry or motion. These devices can be broadly divided into two categories [53], wearable devices (e.g., sleep apnea system) and indigestible devices. The systems mentioned above may use a plethora of IoMT communication protocols, including WiFi, Bluetooth [49], ZigBee and 6LoWPAN. ZigBee is a standards-based wireless mesh network used widely in smart city, medical, and asset tracking. The variety of treatment methods and of medical occasions is intentionally focused on various health monitoring WBAN-based systems. 6LoWPAN came to exist from the idea that the Internet Protocol could and should be applied even to the smallest devices, and that low-power devices with limited processing capabilities should be able to participate in the Medical Internet of Things. Any medical data cannot be transmitted directly to the MIoT network's gateway.

As a result, a coordinator is required to read the unique signals, convert them to data, and then send them to the IoMT network [54]. For example, an oxygen saturation device works as follows, a finger sensor sends data to an oxymeter module which forwards data to a node for processing and data are finally collected by the IoMT network [55]. Body temperature and pulse sensors can receive and transmit data with Bluetooth [49]. A typical architecture of IoMT monitoring devices involves sensors connected directly to the human body. In custom solutions such as, Arduino modules are used to gather medical data from the sensors [56].

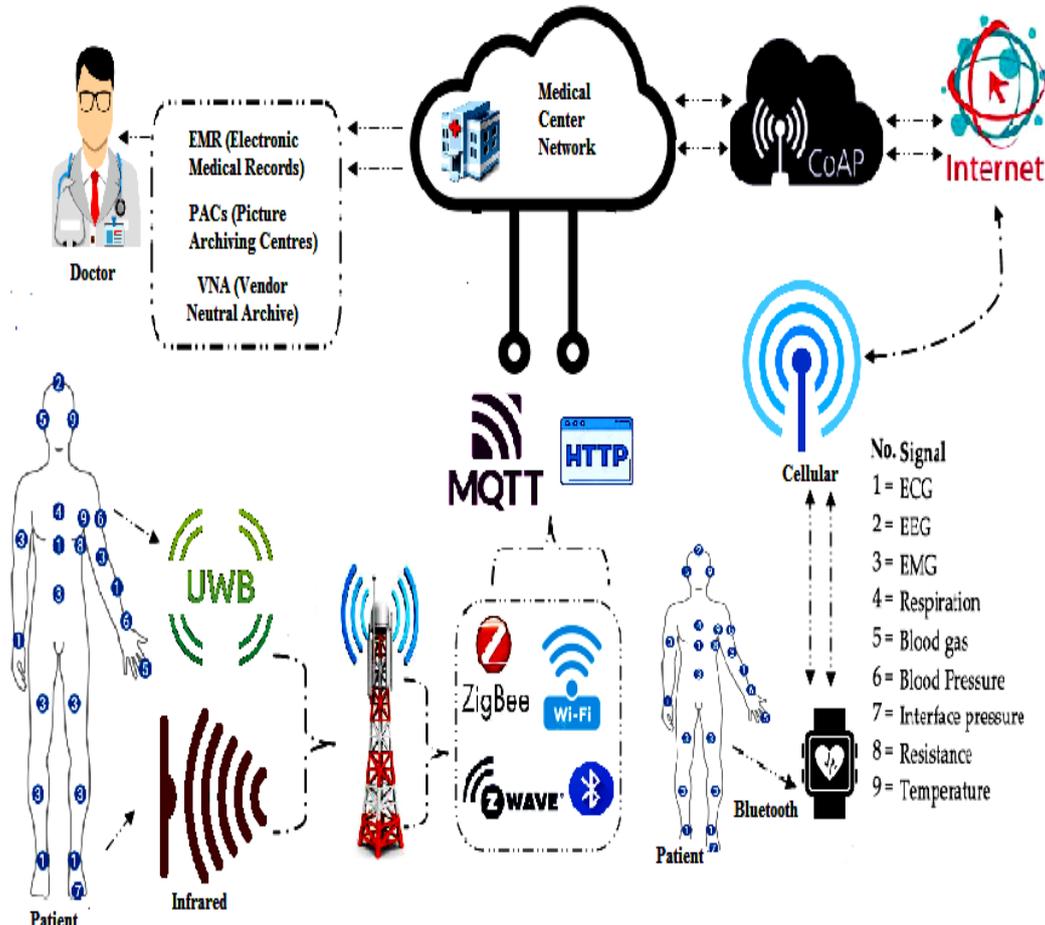


Fig. 5. Amalgamate Wearable Medical Sensors in MIoT

Figure 5 depicts contact between different monitoring devices, such as wearable sensors and ingestible. At the awareness layer (e.g., infrared or UWB), the sensors gather information about the patient's body and send it to an aggregator using network layer protocols (e.g., Z-Wave, Bluetooth or ZigBee, Wi-Fi). The data is then transmitted to the medical centre Network through a coordinator. The above activities can be carried out using protocols such as Wi-Fi and ZigBee. For certain medical applications, data is sent to the doctor through an end computer [57] or even outside the

Medical centre for remote monitoring. At the application layer, MQTT or plain HTTP can be used for these scenarios. MQTT is a machine-to-machine (M2M) Medical Internet of Things (MIoT) connectivity protocol. It was created as a lightweight messaging transport that publishes and subscribes. A patient is outside the Medical Centre and is wearing a smart watch that communicates with the body sensors via Bluetooth [49] and sends medical data to the Medical Centre network via the cellular network.

Table 2. The Medical Care Wearable Sensors Devices are used in MIoT

Vital Signs	Sensor Feature	Specific Aim	Inside	Outside	Connectivity	Strengthness	Weakness
Libre	CGM	Semi-invasive and General Health	Yes	Yes	Cloud Based	Ambulatory Glucose Profile (AGP) provides a snapshot of a patient's glucose levels over a typical day.	This model received from the submitter lacks transparency, making it difficult to gain a firm understanding of the factors that determine a cohort's progress through the model.
BP., PR., TEMP F.D.	ICs (LM35)	Primary Health care Center	Yes		Bluetooth,	Seamless integration with smart-phones.	Large size, Not totally wireless, No algorithm for multiple parameter assessment.
Sweat, TEMP.	Single chip IC	General Health	Yes	Yes	Bluetooth	Miniaturized, Seamless connectivity via Bluetooth.	Requires complex algorithm and data library for useful interpretation of biomarkers
Dexcom	CGM	Semi-invasive ,General Health	Yes	Yes	Internet	Easy, pain-free insertion, self-retracting needle that's free of a plunger system and water-resistant.	Can't restart if your sensor fails before the 10 days and isn't compatible with all smartphones
BP, HR., TEMP.,	Zephyr BT, Omron BP monitor, GP Temp monitor	Cardiac Patients	Yes	Yes	Bluetooth, GPRS/GSM	Web interface, Mobile interface wearable system, Critical alert algorithm, GPS location trigger algorithm.	Web interface, Mobile interface wearable system, Critical alert algorithm, GPS location trigger algorithm.
HR	Smartphone camera	General Health	Yes	Yes	Bluetooth, Internet.	Availability, easy to use.	Not a complete system for real time health monitoring. Requires integration with other systems.
Ziopatch	ECG	Cardiac monitoring	Yes		Internet	Zio Patch using Artificial Intelligence to Catch Irregular Heartbeats	Patient may experience skin irritation.
ECG	Fiber Electrodes,	General Health	Yes	Yes	Bluetooth, Internet.	Intelligent Transmission algorithm, Power efficiency, washable vest, Seamless connectivity to medical server and tablet device.	Requires complex algorithm for other physiological parameter extraction, external power source, No ECG recognition algorithm, No data protection algorithm.
HRV	Smartphone Camera	General Health	Yes	Yes	Bluetooth, Internet.	Availability, easy to use.	Not a complete system for real time health monitoring. Requires integration with other systems
Sweat	Trade secrete	Diabetic, Hypoglycemic patient	Yes	Yes	Bluetooth	Wrist Wearable device, Seamless connectivity to Android smart phone, Emergency routing, SOS button.	No autonomous SOS algorithm only during excess precipitation (cold sweat) and manual button press, No additional functionality.
ECG, BP, TEMP., SpO2	Bluetooth, GSM/GPRS, Internet	General Health	Yes	Yes	Bluetooth, Internet.	Intelligent data analysis algorithm, Intelligent Transmission algorithm, Power efficiency, Seamless connection with PDA to remote Medical server.	Large size, No Data fusion algorithm for pattern recognition, No data protection algorithm.
TEMP HR BP R		Heardh diseases and diabetes	Yes	Yes	ZigBee, Bluetooth, WIFI, 3G	Data security algorithm, User interface integrated with PDA, access to clinic server, trend analysis algorithm, early warning algorithm.	Require user to physically answer question
Sweat, TEMP	Ion detection sensor array.	General Health	Yes	Yes	Bluetooth	Portable, stress detection algorithm, efficient power consumption.	Integration into full Telemedical device is required.
TEMP HR, ECG	ICs (LM35, LM358, AD624)	General Health	Yes	Yes	IEEE 802.1 Wireless Protocol, GSM	IC sensors, mobile computing entity and display, and remote monitoring entity.	Remote display of ECG signal are absent, no intelligent algorithm for critical condition warnings.
Preventice	Accel, ECG	Cardiac monitoring and General Health	Yes	Yes	Mobile App Connectivity	Preventice helps healthcare professionals diagnose, treat and improve the health of a million+ at-risk patients by reducing costs.	None
BP, HR, SpO2, BG, TEMP,	Accu-Check BG meter, Nonin Onyx II	General Health in Older Adults	Yes		Bluetooth, Infrared, 3G	Real time monitoring of bio data, intelligent fuzzy logic for pattern recognition, warning algorithm for critical conditions.	Large size, No geo location service algorithm, No data protection algorithm.
TEMP BP, HR, R	Simulation	General Health	Yes		ZigBee	Algorithm for efficient transmission of medical data wirelessly Using ZigBee technology.	No real life implementation with real sensors and patients.
HR	Zephyr HxM	Elderly, Heart Diseases	Yes	Yes	Bluetooth	Mobile and Smartphone integration, Medical cloud connectivity, Energy estimation algorithm, stress algorithm for critical alert.	Algorithm requires user's manual input, not fully autonomous and Simulation technique was used for system test.
Oura Ring	Accel, Gyro, PPG HR, skin temp.	General Health	Yes	Yes	All Android Devices	The Oura ring keeps me very aware of trends in my key health markers, like HRV and resting heart rate.	It also doesn't properly track the high-intensity interval training I do because it only takes periodic heart-rate measurements during the day.

Under the influence of medical wearable's, the conventional "patient-doctor" paradigm is experiencing major changes. Many procedures are automated by sensors and computers, which speed up diagnosis and care while also allowing people to keep track of their own health. Wearable devices linked to the Internet of Things are causing a healthy amount of disruption in medical practice, ushering in a new age in digital medicine. In recent times, our results for telemedical medical care services as applied to wearable sensors devices are summarized in table 2. Wearable devices in healthcare enable doctors to give each patient their full attention without devoting a lot of time to them [58]. Wireless data transfer and alerting systems send alerts to the hospital or your personal physician, allowing preventive action to be taken right away in the event of concerning symptoms. Finally, wearable's aid in the prevention or monitoring of illnesses, provide real-time input and assistance in recovery, alert patients to take medications, and aid in the compliance with a treatment plan.

7. Technical Necessity for Medical Internet of Things (MIoT) Applications

Since the systems built to date have had to rely on the current Internet infrastructure, the technological capabilities required to support consumer health applications on the Internet are modest [59]. We'll talk about the technical requirements for consumer health apps in terms of bandwidth, latency, availability, protection, and degree of access in this section.

7.1 Bandwidth

The bandwidth requirements of medical applications differ greatly. On the user side, retrieving information from health-related Web pages requires little bandwidth, but the potentially large number of requests made of any given site could increase the aggregate bandwidth requirement [60] on the information provider's side. Access to patient health records could demand somewhat greater bandwidth than is typically available today or significantly greater if records include enhanced content, such as medical images or videotapes of telemedicine consultations.

7.2 Ubiquity

Widespread Internet access is critical to the success of consumer medical applications. As previously stated, many user applications currently only need moderate bandwidth and latency, so standard modem Internet connectivity at 24 to 64 kilobits per second (kbps) may be sufficient. Additional bandwidth could be needed if online access to Medical records and downloading of educational videos become more popular and widespread and if online health records grow to include not just text but medical images and perhaps even videos.

7.3 Latency

In general, applications that benefit the consumer medical sector do not necessitate instantaneous information transmission, so the Internet's latency requirements are not large.

Timeliness is a problem in some patient-monitoring systems, but delays of a few seconds will not endanger a patient's health. Latency could become more of an issue if online medical records became the norm and care provider organizations needed timely access to them for purposes of treating patients.

7.4 Security

Many applications in the consumer medical sector necessitate a high degree of protection. While accessing health information from customer Web pages is usually not a problem, access to online medical records necessitates confidentiality because such records include personal information. Data from remote patient monitoring devices also require security to prevent corruption (intentional or unintentional) during transit across the network or after storage. Security requirements will grow as consumers use the Internet to store, retrieve, and update their personal health records.

7.5 Availability

The need for network availability varies greatly across consumer medical applications. For the dissemination of health information to customers and e-mail communications between patients and providers, the Internet is now sufficiently open.

8. MIoT Use Cases in Medical Sector

There have been a slew of new inventions that have sparked interest in the medical field. From treating chronic diseases on one end of the spectrum to disease prevention on the other, the MIoT plays a significant role in a wide variety of medical applications. We're going over some MIoT use cases right now.

8.1 Remote Sick Person Monitoring System

One of the best MIoT medical sector applications is a remote sick person monitoring device, which is commonly used around the world. A MIoT-based remote sick person monitoring system is an extension of medical systems that allows for remote monitoring of a sick person's vitals.

8.2 Drug Storage

RFID technology will automate the entire chain of storage, usage, and inspection, reducing necessary working hours and streamlining previously paper-based processes. It can help avoid stock shortages and make drug recalls easier. It may also aid in the avoidance of misunderstanding caused by identical drug names, dosage amounts, and dosage types.

8.3 Robotics and Medical Sector Automation

In the medical sector, robotics and medical sector automation are strong MIoT applications [61]. Learning robots can complete tasks on their own with the assistance of the machine. Statistical pattern recognition, parametric and

non-parametric algorithms, neural networks, recommender systems, and other technologies are used in robotics and medical sector automation systems [62][63]. Robotics and medical sector automation in the MIIoT based healthcare industry allows multiple robots to be interconnected. The IIoT platform offers distinctive facilities by interconnecting objects or people and transferring those data between the two robots without a human to a computer or human interaction.

8.4 Newborn Anti-Kidnapping System

At a large general hospital's obstetrics and gynaecology department or a women and children's hospital, combining mother and child identification management, and infant security management will prevent unsupervised access by outsiders. In particular, every newborn should receive an RFID anklet that uniquely identifies the baby and has a unique correspondence with the mother's information. If the family has the correct baby, the RFID anklet only needs to get checked by a nurse or other staff member.

8.5 Smart Medical Center

Smart medical centre are medical facilities that use MIIoT applications to monitor the health of sick person, saline levels, blood pressure, and control vitals from a distant position. Smart hospitals operate mainly on IIoT applications that can monitor the sick person and generate an alarm if the condition of the patient is deteriorating. Smart medical centre use MIIoT applications, cloud computing, machine learning, and artificial intelligence. A MIIoT medical centre app development company can especially build IIoT applications for smart medical centre based on their requirements.

8.6 Alarm System

The system will immediately call for assistance in the event of a sick person's distress due to real-time monitoring and recording of hospital medical equipment and sick people. It would also help to discourage sick people from leaving the hospital on their own, as well as protect temperature-sensitive medications and laboratory samples from harm or theft.

8.7 Medical Center Information Management System

Medical centre information and management systems built on the Internet of Things offer a single source of information about a patient's medical history. MIIoT applications use actuators and sensors to gather data and link physical and analogue devices through the internet. Medical staff analyses the data, which is processed in medical centre information and management systems. The elements of MIIoT based medical centre information and management systems do not only limit the sick person's health history. But, also support supplementary systems such as financial & commercial systems, communication & networking systems, department management systems, medical documentation.

8.8 Medical Wearable's

Care teams will gather various data points about the sick person's sleep habits, movement, heart rate, temperature, so on using MIIoT devices in the form of wearable's. These

wearable's will provide nurses and sick people with real-time details. Consider the case of a heart patient who has an abnormally high heart rate. The wearable will immediately transmit the signal to the nursing staff and allow them to provide immediate and timely assistance to the sick person.

8.9 Tracking Staff, Inventory in Medical Sector

In a medical facility, IIoT monitoring is the method of keeping track of the hospital's physical properties, including personnel. Indoor GPS is a term used to describe the use of IIoT monitoring in medical settings. RFID tags [65] are widely used in IIoT to track and control medical sector properties. IIoT medical sector applications enable tracking in medical sector units, rooms, beds, and even shelf-level tracking for true workflow automation.

9. Advantage of Medical Internet of Things (MIIoT)

IIoMT also helps to monitor, inform and notify not only sick person's but also healthcare providers with actual data to identify issues before they become critical, thus allowing for earlier prevention. However, MIIoT isn't meant to replace current healthcare professionals; rather, it's meant to provide them with data gathered from sensors to help them make better diagnoses and treatment plans, as well as to cut down on inefficiencies and duplication in the current medical system. The benefits to introducing MIIoT are vast, and certainly there are even more benefits to be discovered as we continue to grow our expertise in this space as an industry.

9.1 Ameliorate Sick Person Engagement

MIIoT technology also aids the sick person in self-monitoring and gathering appropriate data; for example, a smart thermometer can track and collect data right from the sick person's home, as well as telemedicine.

9.2 Blockchain used in MIIoT

A private Blockchain based system for medical data management has been proposed in [66]. It uses Ethereum smart contracts to control data access permissions between entities such as patients, hospitals, physicians, research organisations, and others [67]. Permissions, record ownership metadata, and data integrity are all smart representations of medical information in the smart contract. The medical record data are stored in external server (off-chain) and a cryptographic hash of the record is kept on the Blockchain ensuring data integrity [68]. The proposed system eliminates mining for simplification.

9.3 Identify Sick Person Needs and Provide Tailored Assistance

MIIoT provides the facility to check symptoms in a customised way. As an example, if a patient has diabetes but does not want to measure his heartbeat, MIIoT gadgets can be customised to do that.

9.4 Better Sick Person Experience

MIoT hospitals are being adopted by the healthcare industry to improve the patient experience. Remote control is possible with IoT-connected medical centre apps, which make physical spaces smarter and more integrated. The overall quality of procedures, clinical activities, and resource management enhance the patient's experience.

9.5 Helpful for Neuro Technology

Brainwaves and mood-enhancing neuro signals can be read by MIoT instruments. As a result, doctors will use them to track and monitor the mental health of patients from afar. Wearables with MIoT capabilities can track and transmit an ill infant's temperature and sleep patterns, allowing doctors to respond appropriately.

9.6 Fight against COVID-19

In the current pandemic, MIoT will assist medical centre staff in providing medical services to sick people who may be quarantined. It helps healthcare professionals to use a range of resources to access customized knowledge about their ill patients. These tools enable them to track devices, sensors, perform remote patient monitoring, prescribe medicines, provide connected assistance, make online diagnoses, and eventually help manage their sick person's health more efficiently.

9.7 Reduced Errors

MIoT medical centre applications make it easier for doctors to practise, avoid, and diagnose medicine. Smart medical centre applications using MIoT help to minimise mistakes by providing real-time data and the ability to analyse previous treatments and diagnoses of a sick person. Moreover, constant automated monitoring and enhanced study of the sick person's condition leads to proper treatment without the possibility of error.

9.8 Objective Reporting

We no longer have to depend exclusively on subjective sick person assessments of "how they are feeling" because the devices can record and report on actual behaviour at the level of the nervous system; now, we have an objective measure of disease development and sick person therapy effectiveness as recorded by the devices.

9.9 Geriatric Care Devices

MIoT devices that provide compassionate treatment for the elderly are another advantage of MIoT for medical centres. MIoT devices and sensors are a growing market that helps the elderly stay independent for longer.

9.10 Local Activity Recording

The device's recording capabilities allow us to capture data that we've never had access to before. This information would greatly enhance our understanding of how these chronic

diseases function. And, if we have a greater understanding of the disease, we will certainly improve our disease prevention and treatment strategies.

9.11 Ameliorate Disease Management

By offering ubiquitous control systems that can be used for disease management, the MIoT medical centre application helps to eliminate the need for a health care professional. In addition, readily available sensors and gateways analyse data [69] and wirelessly relay it to medical professionals, expanding the reach of disease management systems.

9.12 Precision Medicine

Improved therapy with less unwanted side effects is made possible by delivering targeted stimulation that is tailored for that person. When you take a pill, it is generally metabolised in some way and then spread systemically across the body, regardless of the intended target.

10. Challenges of MIoT

For MIoT technologies to work properly, it is necessary to collect relevant data. As a matter of fact, as for IoT technologies in general, MIoT does not work [70] properly without the correct data. This is unsurprising given that one of the key advantages of this technology is that it aids in decision-making. The ability to capture, process, and use data from MIoT medical devices is needed. Not only does this necessitate the installation of a beacon to collect data, but it also necessitates the installation of a It must also be converted into facts that medical professionals can use to make decisions. A critical success factor for any MIoT technology is security. This applies to more than just patient safety, which is important. Medical data is extremely sensitive, so users must have confidence that their information is safe. This fosters confidence, which is a crucial quality that MIoT devices must help to ensure. Benefits are accompanied by challenges. The challenges of MIoT are discussed in this segment.

10.1 Security

In general, the Internet of Things entails dealing with massive quantities of data streaming from sensors. When it comes to IoT in medical devices, this data is often highly sensitive, including information about a sick person's condition and location, treatment specifics, and so on. A sensor node's processing capacity [71] is woefully inadequate. As a result, conventional security and encryption technology are ineffective in these situations. Therefore, we must design an encryption algorithm suitable to the capabilities of a sensor node and it requires particular attention to proper security and practices to address possible cyber attacks in place.

10.2 Connectivity

Any MIoT system that is supposed to handle real-time data indefinitely needs reliable, uninterrupted connectivity [72]. The cost of a shortage is much higher in IoMT than, say, in a

smart home device. As a result, medical device hardware and software design needs special attention and should resolve the issue of connectivity.

10.3 Interoperability of data

Data collected from the various MIIoT devices is of no use if it cannot be collated and computed to give meaningful and clinically relevant results. To utilize the potential benefits of MIIoT to the fullest, it is imperative that all MIIoT devices are interoperable with one another and allow for relaying of the data to everyone using the technology including the providers and the payers.

10.4 Data Completeness and Data Compression

Nodes in the MIIoT will occasionally be required to monitor for 24 hours a day, collecting a massive amount of data that must be stored using a compression algorithm to reduce storage and transmission volume [73]. Traditional data compression algorithms, on the other hand, are prohibitively expensive for sensor nodes. Additionally, compression algorithms are unable to lose the original data. Otherwise, the system could misdiagnose the sick person's condition.

10.5 High Infrastructure Costs

Although the long-term goal of MIIoT is to lower overall healthcare costs, the costs of developing the Healthcare IT infrastructure are massive. The initial investment is high due to the cost of hardware, dedicated MIIoT IT infrastructure, cloud computing, and developing a consumer-facing app. Although the potential return on investments is a definitive, the high infrastructure costs serve as an obstacle to MIIoT.

10.6 Standardization problem

The number of vendors and manufacturers of medical devices, all looking to achieve scalability and reduce the time to market of their product, standardization of [74] the MIIoT devices becomes an issue. Lack of standardization affects interoperability of medical devices reducing the overall effectiveness of MIIoT.

11. Conclusion

Current advancements in wearable and embedded health tracking technology have the ability to drastically alter the future of healthcare facilities by allowing patient monitoring to be done anywhere. The Internet of Medical Things (IoMT) is a network of sensors, wearable devices, medical devices, and clinical systems that are all linked together. It enables a variety of healthcare applications to lower healthcare costs, provide prompt emergency responses, and improve medical treatment quality. The internet of medical stuff can function like a health butler; people can ask the butler for something, which is human-machine communication; the machine can send something, usually data, to another machine, and another machine can respond to it, which is machine-machine communication and the machine can send something, usually

data, to another machine, which is machine-machine communication. The MIIoT platform must also provide data exchange frameworks for third-party applications. In this paper, we are holistic analysis of Medical Internet of Things. We have also discussed some of the Medical Internet of Things (MIIoT) layer, and architectures of MIIoT along with their applications, advantage of MIIoT and the future research challenges. Patients can be empowered by MIIoT-based platforms because they become self-aware of their health status. MIIoT is transforming the healthcare industry by allowing seamless medical data communication and providing tailored and personalized medicine.

Reference

- [1] Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M., "Internet of Things (IoT): A vision, architectural elements and future directions", *Future Gener. Comput. Syst.*, 29, pp. 1645–1660, 2013
- [2] Yusuf Perwej, Mahmoud Ahmed AbouGhaly, Bedine Kerim and Hani Ali Mahmoud Harb. "An Extended Review on Internet of Things (IoT) and its Promising Applications", *fCommunications on Applied Electronics (CAE)*, New York, USA, Volume 9, Number 26, Pages 8 – 22, February 2019, DOI: 10.5120/cae2019652812
- [3] E. Park, Y. Cho, J. Han, and S., "Comprehensive approaches to user acceptance of Internet of Things in a smart home environment," *IEEE Internet Things J.*, vol. 4, no. 6, pp. 2342 - 2350, Dec. 2017
- [4] Yusuf Perwej, Majzoob K. Omer, Osama E. Sheta, Hani Ali M. Harb, Mohamed S. Adrees, "The Future of Internet of Things (IoT) and Its Empowering Technology" , *International Journal of Engineering Science and Computing (IJESC)*, Volume 9, Issue No.3, Pages 20192 – 20203, March 2019
- [5] Islam, S.M.R., Kwak, D., Kabir, M.H., Hossain, M., Kwak, K.: The Internet of Things for health care: a comprehensive survey. *IEEE Access* 3, 678–708, 2015
- [6] Akyildiz, I. F., Pierobon, M., Balasubramaniam, S., & Koucheryavy, Y. "The internet of Bio-Nano things", *IEEE Comm. Magazine*, 53(3), pp. 32 – 40, 2015
- [7] Firoj Parwej, Nikhat Akhtar, Yusuf Perwej, "An Empirical Analysis of Web of Things (WoT)", *International Journal of Advanced Research in Computer Science*, Volume 10, No. 3, Pages 32-40, 2019, DOI: 10.26483/ijarcs.v10i3.6434
- [8] Tathagata Adhikary, Amrita Deb Jana, Arindam Chakrabarty, and Saikat Kumar Jana. "The internet of things (iot) augmentation in healthcare: An application analytics", In *International Conference on Intelligent Computing and Communication Technologies*, pages 576– 583. Springer, 2019
- [9] Ekaterina Balandina, Sergey Balandin, Yevgeni Koucheryavy, and Dmitry Mourmstev. Iot use cases in healthcare and tourism. In *Business Informatics (CBI)*, 2015 IEEE 17th Conference on, volume 2, pages 37–44. IEEE, 2015
- [10] HIPAA Journal. 87% of Healthcare Organizations Will Adopt Internet of Things Technology by 2019. Accessed: Nov. 20, 2017
- [11] Intel. A Guide to the Internet of Things Infographic. Accessed: Oct. 13, 2017

- [12] Yusuf Perwej, "An Evaluation of Deep Learning Miniature Concerning in Soft Computing", International Journal of Advanced Research in Computer and Communication Engineering, Volume 4, Issue 2, Pages 10 - 16, 2015, DOI: 10.17148/IJARCC.2015.4203
- [13] Ryan A Beasley. Medical robots: current systems and research directions. Journal of Robotics, 2012
- [14] Jacob Rosen and Blake Hannaford. Doc at a distance. IEEE spectrum, 43(10):34–39, 2006
- [15] Yusuf Perwej, Kashiful Haq, Firoj Parwej, M. M. Mohamed Hassan, "Internet of Things (IoT) and its Application Domains", for published in the International Journal of Computer Applications, Vol. 182, No.49, Pp 36- 49, April 2019, DOI: 10.5120/ijca2019918763
- [16] Mavroggiorgou, Argyro et al. "Internet of Medical Things (IoMT): Acquiring and Transforming Data into HL7 FHIR Through 5G Network Slicing." Emerging Science Journal 3.2 (2019): 64. Web
- [17] Osei-Bonsu, William, Aviel Stein, and Michael Boswell. "The Current Ethical and Regulatory Status of the Internet of Medical Things (IoMT) And The Need of a New IoMT Law." The Journal of Healthcare Ethics & Administration 4.2, 2018
- [18] C.-T. Li, C.-C. Lee, and C.-Y. Weng, "A secure cloud-assisted wireless body area network in mobile emergency medical care system," Journal of Medical Systems, vol.40, no.5, pp.1–15, 2016
- [19] Yusuf Perwej, Firoj Parwej, Mumdouh Mirghani Mohamed Hassan, Nikhat Akhtar, "The Internet-of-Things (IoT) Security: A Technological Perspective and Review", International Journal of Scientific Research in Computer Science Engineering and Information Technology (IJSRCSEIT), Volume 5, Issue 1, Pages 462-482, February 2019, DOI: 10.32628/CSEIT195193
- [20] Anna Challoner and Gheorghe H Popescu. Intelligent sensing technology, smart healthcare services, and internet of medical things-based diagnosis. American Journal of Medical Research, 6(1):13–18, 2019
- [21] P. A. Williams and A. J. Woodward, "Cybersecurity vulnerabilities in medical devices: A complex environment and multifaceted problem," Med. Devices, Evidence Res., vol. 8, pp. 305-316, Jul. 2015
- [22] J. J. P. C. Rodrigues, D. B. De R. Segundo, H. A. J. et al., "Enabling technologies for the internet of health things," IEEE Access, vol. 6, pp. 13129–13141, 2018
- [23] Li, H.; Yang, C.; He, Z.; Imran, M.A.; Ahmad, W. Health Activities Monitoring and Warning System for Geriatric Daily Living in Extra Care Homes; IEEE: Piscataway, NJ, USA, 2019; pp. 386–391
- [24] K. Ullah, M. A. Shah, and S. Zhang, "Effective ways to use internet of things in the field of medical and smart health care," in Proceedings of the 2016 International Conference on Intelligent Systems Engineering (ICISE), pp. 372–379, Islamabad,
- [25] Roman Richard, A.A.; Sadman, M.F.; Mim, U.H.; Rahman, I.; Rahman Zishan, M.S. Health Monitoring System for Elderly and Disabled People; IEEE: Piscataway, NJ, USA, 2019; pp. 677–681
- [26] H. Turabieh, A. Abu Salem, and N. Abu-El-Rub, "Dynamic L-RNN recovery of missing data in IoMT applications," Future Generation Computer Systems, vol. 89, pp. 575–583, 2018
- [27] Yusuf Perwej, "Recurrent Neural Network Method in Arabic Words Recognition System", International Journal of Computer Science and Telecommunications (IJCST), which is published by Sysbase Solution (Ltd), UK, London, (<http://www.ijcst.org>), ISSN 2047-3338, Volume 3, Issue 11, Pages 43-48, November 2012
- [28] Yusuf Perwej, Firoj Parwej, "A Neuroplasticity (Brain Plasticity) Approach to Use in Artificial Neural Network", the International Journal of Scientific & Engineering Research (IJSER), France, ISSN 2229 – 5518, Volume 3, Issue 6, Pages 1- 9, June 2012 DOI: 10.13140/2.1.1693.2808
- [29] Chandel, V.; Sinharay, A.; Ahmed, N.; Ghose, A. Exploiting IMU Sensors for IOT Enabled Health Monitoring; ACM Press: New York, NY, USA, pp. 21–22, 2016
- [30] G. J. Joyia, R. M. Liaqat, A. Farooq, and S. Rehman, "Internet of medical things (IoMT): applications, benefits and future challenges in healthcare domain," Journal of Comm., vol. 12, no. 4, pp. 240–247, 2017
- [31] V. M. Rohokale, N. R. Prasad, and R. Prasad, "A cooperative Internet of Things (IoT) for rural healthcare monitoring and control," Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE), 2011
- [32] Yusuf Perwej, Faiyaz Ahamad, Mohammad Zunnun Khan, Nikhat Akhtar, "An Empirical Study on the Current State of Internet of Multimedia Things (IoMT)", International Journal of Engineering Research in Computer Science and Engineering (IJERCSE), ISSN (Online) 2394-2320, Volume 8, Issue 3, Pages 25 - 42, March 2021 DOI: 10.1617/vol8/iss3/pid85026
- [33] L.Mineti, I.Patrono, A.Vilei, "Evolution of wireless sensor networks towards the Internet of Things: A survey", in Proc. SoftCOM, Sept.2011.
- [34] A.J.Jara, M.A.Zamora, A.F.Skarmeta, "Knowledge acquisition and management architecture for mobile and personal health environment based on the Internet of Things", in Proc. Int. Conf. TrustCom, pp.1811-18, 2012
- [35] Yusuf Perwej, "An Experiential Study of the Big Data", International Transaction of Electrical and Computer Engineers System (ITECES), USA, Science and Education Publishing, Volume 4, No. 1, Pages 14-25, March 2017 DOI: 10.12691/iteces-4-1-3
- [36] IEEE 802 Working Group. IEEE Standard for Local and Metropolitan Area Networks–Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs); IEEE Std 802, 4, 2011
- [37] Nikhat Akhtar, Yusuf Perwej, "The Internet of Nano Things (IoNT) Existing State and Future Prospects", GSC Advanced Research and Reviews (GSCARR), Volume 5, Issue 2, Pages 131-150, 2020, DOI: 10.30574/gscarr.2020.5.2.0110
- [38] Fuentes, M.R.; Huq, N. Securing Connected Hospitals by Trend Micro. 2018. Available online: <https://documents.trendmicro.com/assets/rpt/rpt-securing-connected-hospitals.pdf>
- [39] Poongodi, T.; Rathee, A.; Indrakumari, R.; Suresh, P. IoT Sensing Capabilities: Sensor Deployment and Node Discovery, Wearable Sensors, Wireless Body Area Network (WBAN), Data Acquisition. In Principles of Internet of Things (IoT) Ecosystem: Insight Paradigm; Peng, S.L., Pal, S., Huang, L., Eds.; Springer

- International Publishing: Cham, Switzerland, 2020; pp. 127–151.
- [40] Business Logic Attack. Available online: <http://whatis.techtarget.com/definition/business-logic-attack>
- [41] Ahmadi, H.; Arji, G.; Shahmoradi, L.; Safdari, R.; Nilashi, M.; Alizadeh, M. The application of internet of things in healthcare: A systematic literature review and classification. *Univ. Access Inf. Soc.*, 18, 837–869, 2019
- [42] Miller DD, Brown EW. Artificial intelligence in medical practice: the question to the answer? *Am J Med*, vol. 131(2), pp. 129-133, 2018
- [43] Tobore I, Li J, Yuhang L, Al-Handarish Y, Kandwal A, Nie Z, et al. Deep learning intervention for health care challenges: some biomedical domain considerations. *JMIR Mhealth Uhealth*, 2;7(8), 2019
- [44] Su, C.R.; Hajiyev, J.; Fu, C.J.; Kao, K.C.; Chang, C.H.; Chang, C.T. A novel framework for a remote patient monitoring (RPM) system with abnormality detection. *Health Policy Technol.*, vol. 8, pp. 157–170, 2019
- [45] D.P. Tobon, T.H. Falk, M. Maier, "Context awareness in WBANs: a survey on medical and non-medical applications", *Wireless Communications, IEEE*, 20 (4), pp. 30-37, 2013
- [46] F. Ye, Y. Qian, L. He and R. Q. Hu, "Energy efficient self-sustaining wireless neighborhood area network design for smart grid", *IEEE Trans. Smart Grid*, vol. 6, no. 1, pp. 220-229, 2015
- [47] Yusuf Perwej, "A Literature Review of the Human Body as a Communication Medium using RedTacton", *Communications on Applied Electronics (CAE), Foundation of Computer Science FCS, USA*, Vol. 9, No.4, PP 7 – 17, 2016, DOI: 10.5120/cae2016652161
- [48] Klaus Doppler, Mika Rinne, Carl Wijting, Cássio B Ribeiro, and Klaus Hugl. Device-to-device communication as an underlay to lte-advanced networks. *IEEE Communications Magazine*, 47(12), 2009
- [49] Yusuf Perwej, Kashiful Haq, U. Jaleel, S. Saxena, "Some Drastic Improvements Found in the Analysis of Routing Protocol for the Bluetooth Technology Using Scatternet", *Special Issue on the International Conference on Computing, Communications and Information Technology Applications (CCITA-2010), Ubiquitous Computing and Communication Journal (UBICC), Seoul, South Korea*, ISSN Online: 1992-8424, ISSN Print: 1994-4608, Volume CCITA-2010, Number 5, Pages 86-95, 2010
- [50] K. E. Nolan, W. Guibene and M. Y. Kelly, "An evaluation of low power wide area network technologies for the Internet of Things", *Proc. IEEE Int. Wireless Commun. Mobile Comput.*, pp. 439-444, 2016
- [51] Xu S, Zhang Y, Jia L, Mathewson KE, Jang KI, Kim J, et al. Soft microfluidic assemblies of sensors, circuits, and radios for the skin. *Science*, vol. 344, pp. 70-74, 2014
- [52] Haghi, M.; Thurow, K.; Stoll, R. Wearable devices in medical internet of things: Scientific research and commercially available devices. *Healthc. Inform. Res.* 2017, 23, 4–15
- [53] Dang, L.M.; Piran, M.J.; Han, D.; Min, K.; Moon, H. A Survey on Internet of Things and Cloud Computing for Healthcare. *Electronics*, 8, 768, 2019
- [54] Yusuf Perwej, Faiyaz Ahamad, Mohammad Zunnun Khan, Nikhat Akhtar, "An Empirical Study on the Current State of Internet of Multimedia Things (IoMT)", *International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)*, Volume 8, Issue 3, Pages 25 - 42, March 2021, DOI: 10.1617/vol8/iss3/pid85026
- [55] Adiputra, R.; Hadiyoso, S. Hariyani, Y. "Internet of Things: Low Cost and Wearable SpO2 Device for Health Monitoring" *Int. J. Electr. Comput. Eng.*, 8, 939, 2018
- [56] Hussain, S.R.; Mehnaz, S.; Nirjon, S.; Bertino, E. Secure Seamless Bluetooth Low Energy Connection Migration for Unmodified IoT Devices. *IEEE Trans. Mob. Comput.*, 17, 927–944, 2018
- [57] Yusuf Perwej, S. A. Hannan, Firoj Parwej, Nikhat Akhtar, "A Posteriori Perusal of Mobile Computing", *International Journal of Computer Applications Technology and Research, ATS (Association of Technology and Science)*, Vol. 3, Issue 9, pp. 569 - 578, 2014, DOI: 10.7753/IJCATR0309.1008
- [58] S. Seneviratne, Y. Hu, T. Nguyen, G. Lan, S. Khalifa, K. Thilakarathna, et al., "A survey of wearable devices and challenges", *IEEE Communications Surveys & Tutorials*, vol. 19, no. 4, pp. 2573-2620, 2017
- [59] Nikhat Akhtar, Firoj Parwej, Yusuf Perwej, "A Perusal of Big Data Classification and Hadoop Technology", *International Transaction of Electrical and Computer Engineers System (ITECES), USA*, Volume 4, No. 1, Pages 26-38, May 2017, DOI: 10.12691/iteces-4-1-4
- [60] Ekarin Suethanuwong, "Scheduling time-triggered traffic in TTEthernet systems", *Emerging Technologies & Factory Automation (ETFA) 2012 IEEE 17th Conference*, 17 - 21 Sept. 2012
- [61] K. Cleary and C. Nguyen, "State of the art in surgical robotics: Clinical applications and technology challenges", *Comput. Aided Surgery*, vol. 6, pp. 312-328, 2001
- [62] Nikhat Akhtar, Devendera Agarwal, "A Literature Review of Empirical Studies of Recommendation Systems", *International Journal of Applied Information Systems (IJ AIS)*, ISSN : 2249-0868, Foundation of Computer Science FCS, New York, USA, Volume 10, No.2, Pages 6 – 14, December 2015, DOI: 10.5120/ijais2015451467
- [63] Nikhat Akhtar, Devendera Agarwal, "An Efficient Mining for Recommendation System for Academics", *International Journal of Recent Technology and Engineering (IJRTE)*, ISSN 2277-3878 (online), SCOPUS, Volume-8, Issue-5, Pages 1619-1626, January 2020, DOI: 10.35940/ijrte.E5924.018520
- [64] Thomas Martin, Emil Jovanov and Dejan Raskovic, "Issues in Wearable Computing for Medical Monitoring Applications: A Case Study of a Wearable ECG Monitoring Device", *IEEE*, pp. 43-48, 2000
- [65] T. Dimitriou, "A Secure and Efficient RFID Protocol that Could make Big Brother (partially) Obsolete," in *Proceedings IEEE PerCom*, 2006
- [66] Yusuf Perwej, "A Pervasive Review of Blockchain Technology and Its Potential Applications", *Open Science Journal of Electrical and Electronic Engineering (OSJEEE)*, New York, USA, Volume 5, No. 4, Pages 30 - 43, October, 2018
- [67] Khatoon, A.: A Blockchain-based smart contract system for healthcare management. *Electronics* 9, 94, 2020

- [68] Yusuf Perwej, Nikhat Akhtar, Firoj Parwej, "A Technological Perspective of Blockchain Security", *International Journal of Recent Scientific Research (IJRSR)*, ISSN: 0976-3031, Volume 9, Issue 11, (A), Pages 29472 – 29493, November 2018, DOI: 10.24327/ijrsr.2018.0911.2869
- [69] Ashraf Darwish and Aboul Ella Hassanien, "Wearable and Implantable Wireless Sensor Network Solutions for Healthcare Monitoring", *Sensors*, vol. 11, pp. 5561-5595, 2011
- [70] Thad Starner, *The Challenges of Wearable Computing: PART 1*, IEEE, pp. 44-52, 2001
- [71] J. Lin, W. Yu, N. Zhang, X. Yang, H. Zhang and W. Zhao, "A survey of Internet of Things: architecture enabling technologies security and privacy and applications", *IEEE Internet of Things Journal*, vol. 4, no. 5, pp. 1125-1142, 2017
- [72] Yusuf Perwej, Bedine Kerim, Mohamed Sirelkhtem Adrees, Osama E. Sheta, "An Empirical Exploration of the Yarn in Big Data", *International Journal of Applied Information Systems (IJ AIS)*, Foundation of Computer Science FCS, New York, USA, Volume 12, No.9, Pages 19-29, 2017, DOI: 10.5120/ijais2017451730
- [73] A. Gatouillat, Y. Badr, B. Massot and E. Sejdić, "Internet of medical things: A review of recent contributions dealing with cyber-physical systems in medicine", *IEEE Internet Things J.*, vol. 5, pp. 3810-3822, Oct. 2018
- [74] G. J. Joyia, R. M. Liaqat, A. Farooq and S. Rehman, "Internet of medical things (IOMT): applications benefits and future challenges in healthcare domain", *JCM*, 2017