A Review of Emerging Low Power Networks in Internet of Medical Things (IoMT)

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Abstract. The future IoT healthcare insurance business model will focus on a strategic view and implementation. It is not only restricted to implementing trend technologies. It should take into consideration the value propositions, financial propositions, and the partner chains. Low-power wide-area technologies (LPWA) could be regarded as the result of endeavors either to raise the range of WLANs and low-power wireless personal area networks (LoWPANs) or to minimize the cost and energy consumption of cellular networks. As the preferred infrastructure for Internet of Medical Things (IoMT) applications, LPWA technologies are highly suggested. The major goal of the LPWA technology is IoT applications that run on affordable low-battery devices and necessarily involve over a large geographic and reasonable data price. This paper reviews the most recent technological developments and the issues they provide. This article explores the significance of interoperability among various LPWA technologies and provides recommendations for selecting the most appropriate LPWA solutions for a variety of IoMT. Finally, problems facing LPWA in IoMT are discussed, and research directions are proposed.

Keywords: LPWA · IoMT · Low power wide area network · Internet of Medical Things · Short Range Wireless Technologies · Long Range Wireless Technologies

1 Introduction

At the beginning of 2020, the novel Corona Virus (COVID-19) pandemic spreads rapidly into various countries around the world. The emergence of Internet of Medical Things (IoMT) plays a core role in the development of health and clinical facts systems will restructure the current business models of healthcare insurance indicator of several nations. The future IoT healthcare insurance business model will focus on a strategic view and implementation. It is not only restricted to implementing trend technologies. It should take into consideration the value propositions, financial propositions, and the partner chains. The new market strategy should have special features to adapt to the acceleration of changes. These features include running to customer-centric and support the relationship with them. Empowering long-term premiums to support and protect

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people healthy and leveraging a new trend in technologies to provide a suitable lifestyle, which ensures well-being and health reversal.

Traditionally, IoT applications could be worked over short-range wireless networks, e.g., Bluetooth; wireless local area networks (WLANs), e.g., IEEE 802.11 (Wi-Fi); wireless home automation, e.g., ZigBee and Z-Wave, and cellular networks, e.g., the global system for mobile communications (GSM) and long-term evolution (LTE). According to the remote monitoring systems, wearable biosensors are utilized either invasive or non-invasive for gathering all necessary biomedical signals and forwarding real-time processed data to the doctors and the patients' dedicated interface. Low-power wide area technologies (LPWA) could be regarded as the result of endeavors either to raise the range of WLANs and low-power wireless personal area networks (LoWPANs) or to minimize the cost and energy consumption of cellular networks [1].

The IoMT has been served all the medical fields, including define recognition, essential signs monitoring, remote monitoring, medical drugs, waste, and equipment monitoring.

Devices through IoMT based wireless could be systematically gathered data and shared with other platforms to manage the environment around us without the need for human intervention. Low-power wireless, in particular IEEE 802.15.4, will therefore continue to play an important role in the future of IoMT as mentioned in Fig. 1.

This review offers researchers with a comprehensive overview of the challenges highlighted in a single article. Thus, it is an interesting and current review for anyone engaged in LPWA networks.

After this section, the paper is structured as follows: Enabling technologies of short-range and long-range wireless in IoMT in Sects. 2 and 3 respectively. In Sect. 4, the development LPWA in IoMT. Section 5 challenges with LPWAs are listed, along with suggestions for future research. The paper is concluded in Sect. 6.

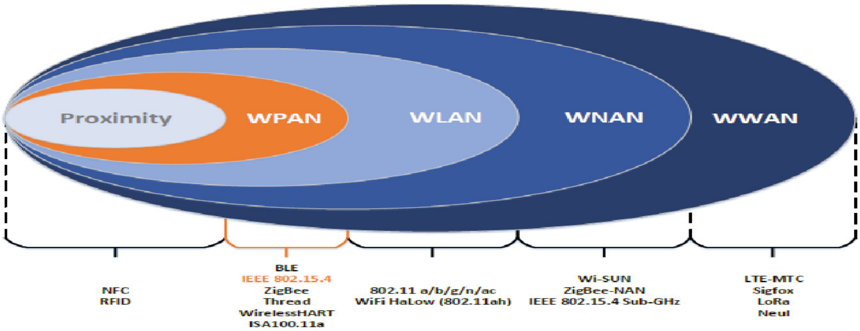

Fig. 1. Wireless communication technologies in IoT applications [1]

2 Short Range Wireless Technologies in IoMT

The short-range communication technologies are utilized for exchange data up to 100 m. There are a number of short-range wireless technologies in IoMT with various features and performances such as Bluetooth, Bluetooth low power (BLE), ZigBee, WiFi, and Light Fidelity (Li-Fi). The BLE and Bluetooth are utilized to transfer the information among peripherals [2]. The short-range communication technologies are specifically useful in the body area networks (BANs) [3]. The technical features and applications of these systems in the domain of IoMT are investigated in the sections below:

2.1 Zigbee

ZigBee is a specification designed wireless technology for offering as long as battery lifetime, a low data rate, and a secure networking [4]. It is a simple network for installing and configuring, which is supported various network topologies (mesh network protocol) and a huge number of nodes. In addition to the capacity, its equipment could be operated for a few years before the battery requires to be changed, which makes it one of the technologies utilized in different medical applications in wireless body area network (WBAN). ZigBee is a secure networking that providing three levels of security mode to avoid the information from being replaced or accessed through attackers [5]. With a range of 100 m, ZigBee can operate at 2.4 GHz, 915 MHz, and 868 MHz frequency bands with a data rate of 250 Kbps, 40 Kbps, and 20 Kbps for each of the operating frequencies respectively. With the utilization of WBAN, ZigBee is targeted healthcare applications that need frequent measurements and text-based transmission of data with low power. It could be utilized for the body temperature monitoring, the pulse monitoring, and others [5]. The limitations of ZigBee are low data rate, capacity, and interference. ZigBee is insignificant for some WBAN healthcare applications which are required high data rate and it is difficult to connect up to 255 devices within a maximum of 100m it in hospitals [4]. Furthermore, interference in 2.4 GHz band is another downside for many wireless systems where can operate.

2.2 Bluetooth

Portable devices can be communicated through using wireless technologies standard called Bluetooth. Bluetooth is a specification designed for short-range wireless technologies standard, where several Bluetooth devices form a short-range personal network known as a piconet [6]. A piconet can contain a device that can work as a master and can establish up to 7 devices known as slaves. The slave device can be only connected with a master device, but cannot establish with other slave devices directly. It can transmit small data packages over multiple1 MHz channels of bandwidth and utilized short-range radio frequency (RF) from 2.402 to 2.480 GHz ISM bands. Bluetooth is primarily utilized for communication wireless devices distributed in a small area (a maximum of 100 m coverage range). The maximum possible data rate of Bluetooth is 3 Mbps and the time required for communication setup and data transmit is about 100 ms. Multiple radios are allowed a various number of applications such as streaming of audio between a smart phone (Android, iPhone) and speaker, managing healthcare devices from a tablet, or swapping messages among nodes [4].

2.3 BLE

BLE is played a critical role in wireless communication in wearable healthcare ecosystem. it is designed for ultra-low energy, high data transmission rate, strong signal strength, miniaturized size, reliable and secure operations of continuous data streaming applications. It supports over 40 channels using a robust frequency hopping spread spectrum (FHSS) to deliver ranges of data rate between 125 kbps and 2 Mbps, power levels from 1 mW to 100 mW, and security options [4]. The best option for short-range communications in healthcare was found to be Bluetooth Low Energy [7].

2.4 WiFi

WiFi (also called IEEE 802.11) is another short-range technology that allows interconnection among wireless devices within distance limitations. WiFi is utilized radio waves to send data within 100m range, and its utilized for closed environments such as houses and small companies. Smart devices have been communicated and exchanged data through WiFi without a router. It can support 5 GHz and 2.4 GHz in the ISM band. Moreover, there are another type of IEEE 802.11 like 802.11a/b/e/g/h/i/k/n/p/r/ac/ad/ax standards. The main features that have been observed to 802.11ac are to enhance the performance and speed and preferable control the interference. It can achieve these advantages through applying more channel bounding and MIMO and denser modulation [4]. WiFi has benefits over ZigBee and Bluetooth in terms of the data rate and coverage area. The new generations of WiFi are authorizing nodes to interconnect at too high data rates as mentioned in [4].

2.5 Li-Fi

The enormous utilization of the wireless spectrum has many downsides such as the interference and the reduction of radio frequency radiations. One of the revolutionary solutions to dominate these problems is Li-Fi for indoor utilization and for high-speed data network. Li-Fi is short-range technology that utilizes visible light for communication instead of existing Radio Frequency (RF) technology. Li-Fi is supported transmission of data through the illumination of Light Emitting Diodes (LEDs) and a photodetector to examine the signals. Li-Fi is the resolution as it is cheap, much more impressive and it is considered a healthy environment compare to Wi-Fi. Li-Fi has used a light spectrum with wavelengths from infrared (IR) to ultraviolet (UV) containing the visible light (VL) spectrum alternatively of radio waves for relocating of data. From the medical point of view, LED might be made available in homes and hospitals, which can bring the LiFi applicable for WBAN healthcare applications. Moreover, Li-Fi is provided high secure and private connection, low interference, and high bandwidth [69]. These advantages can assist to protect the privacy of the patient while ensuring reliable communication. By contrast, the downside of the utilize of LiFi is due to the requirements for a light source. This limitation is prevented cross-wall communications and imposed the communication to be short-range.

2.6 NFC

Near Field Communication (NFC) is another short-range half duplex wireless technology mode that can allow two-way interaction between two NFC-enabled devices, which can assist contactless transactions and provide an easy way to communicate devices with a single touch. NFC technology is allowed exchange of data among devices within the10 cm range [8]. The advantages of the NFC-based healthcare devices are its small size and nonvolatile memory. It can operate on radio frequency for data access is 13.56 MHz and data which can be transmit at 106.212 or 424 Kbps.

Nowadays different wearable health-related devices are available, such as heart monitors, biosensors, body temperature, etc., which can be helped to send this critical data in real-time. The doctor is tapping his/her reading device at the tag and obtaining the data. Thus, through utilizing NFC, Electronic Health Records (EHR) could be applied, which helps at simplifying the process of including healthcare records and prescriptions. With the assist of NFC tags, the patient's EHR can synchronize and save the real-time data sent by the sensors. Similarly, each patient's record and doctor's prescriptions for the day can be updated.

The NFC devices can afford ways to accelerate the processes in hospitals: the doctors equipped with NFC-enabled smartphones, computers can check all the information about a patient in a moment, without any problems of data being conflicting. NFC-based healthcare is provided not only automation, precision and efficiency in healthcare as well as it is economically feasible in developing countries. There are three types of NFC devices includes Type A, Type B, and FeliCa. These types operated in two modes, namely an initiator (or active mode) and a target (or passive mode). The NFC tag device is a passive device that can include data that is stored some information in it with a unique identification number, but cannot fetch the data included in the other devices [8]. Despite this issue, the active devices can transmit and receive data from other devices. The main benefit of NFC over Bluetooth is that the time required to set up communication among two NFC-enabled devices at once is one-tenth of a second. NFC-based healthcare is slower in speed than Bluetooth and consumes lesser power [8].

2.7 WirelessHART

WirelessHART (Highway Addressable Remote Transducer) is another open-standard wireless sensor networking technology for process automation, which is developed by ISA, the ISA100.11a. It has been operated in the 2.4 GHz ISM radio band with a 128-bit AES encrypted secure networking technology through leveraging IEEE 802.15.4 compatible Direct-sequence spread spectrum (DSSS) radios with channel hopping on a packet-by-packet basis [9]. The protocol of WirelessHART is deployed Time Division Multiple Access (TDMA) as MAC protocol integrated through precise time synchronization between devices. The network of WirelessHART is organized as a multi-hop mesh network, which means each device could be relayed packets from neighbors in order to achieve multi-hop communication, which can be ensured reliable message delivery leveraging the variant paths available in terms of failures. Both unicast and multicast traffic are supported. WirelessHART was designed with a particular focus on field devices communications to support closed-loop supervisory and regulatory applications because of its high sufficient communication among multiple field devices and efficient routing capabilities in order to guarantee multi-channel frequency hopping [10]. Despite this, external applications could be also utilized as the gateway in order to schedule traffic for field devices. WirelessHART in IoT healthcare sensor networks (IoT-HSNs) control application could be utilized for Parkinson's disease (PD) patients that involve a bio-actuator injection system for this medicine as suggested by measurement and supervisory system [10].

2.8 Infrared

The infrared technology is presented by the Infrared Data Association (IrDA) that utilizes infrared light for short-range wireless technology and mobile object technologies [11]. IrDA is consisted instruction for wireless infrared communication protocols with specifications detailed providing a half-duplex, asynchronous system, and serial communication link up to a few meters, with transmission rates between 2400 bits/s to 115,200 kbits/s. The IrDA protocol stack is divided into three layers: the physical layer, the link access (IrLAP) layer, and the link management layer (IrLMP) layer. The IrLAP protocol is described a basic link-level connection between a pair of devices and is specified the High-level Data Link Control (HDLC) standard for managing access to infrared medium [11]. Thermometers and medical cameras can make use of IrDA's temperature sensing capabilities. High-speed imaging of a body and local temperature measurement with increased precision are both possible with the infrared-based thermal imaging application [12, 13].

3 Long Range Wireless Technologies in IoMT

With long-range communication technologies, the main needs of IoT applications are long range coverage, high capacity, low data rates, low energy consumption, low-cost end devices [1]. It is utilized for transmission of the health-related data up to kilometers relying on the range of the implemented technology such as WiMAX 50 km, LoRa 25 km, LoRaWAN 15–45 km, SigFox [14] 50 km, EC-GSM 100 km. The LPWAN technologies can be divided into two classes: licensed radio spectrum, unlicensed radio spectrum. The licensed radio spectrum includes NB-IoT, LTE-M, EC-GSM-IoT, and Thingstream. The unlicensed radio spectrum can be included SigFox, RPMA, NWAVE, Telensa, Weightless, LoRa, NB-fi, helium, MIOTY, hiber, sata4M2M, CTP. There are other technologies are not classified in LPWAN technologies but has similar features such as WiFi-SUN, WiFi-Halow, Jupiler Mesh, and DASH7.

3.1 LoRa

LoRa is one of the most promising widely adopted LPWAN technologies that originated by Semtech [14]. LoRa is a physical-layer technology for long-range, low-power wireless communication systems. It had become more robust wireless solutions for data collection to interference and long-range coverage (more than 10 km) can offer the possibility by utilizing Mary frequency-shift keying (FSK) modulation (symmetric for uplink (UL) and downlink (DL)) and chirp spread spectrum (CSS) modulation, a technique when the signal is modulated through chirp pulses [15]. It has four vigorous parameters that usually control the performance of LoRa including the transmit power, Spreading Factor (SF), Code Rate (CR), and the Bandwidth (BW).

Using the 868 MHz ISM band within a maximum SF as well as transmit power of 14 dBm, the authors of [16] show that LoRa can travel more than 15 km on land and over 30 km on water.

LoRaWAN protocol provides an architecture for medium access control that developing for battery-based end devices. The end devices allow connecting to the concentrator in a basic star topology. The connection in end devices allows one or more gateways through utilizing single-hop LoRa or FSK communication, whilst the gateways and network servers are connected through standard IP connections [4].

LoRa runs on the sub-1 GHz spectrum, the frequencies of LoRa utilized in European Union in the range of 868 MHz, while in Asia in the range of 433 MHz and in the Americas in the range of 915 MHz [17]. These frequency bands are unlicensed, which can offer the LoRa adoption very straightforward for IoMT applications.

3.2 Sigfox

Sigfox is one of the LPWAN technology originated by Ludovic Le Moan and Christophe Fourtet in 2010 and it set rolling the first global 0G network that used to connect billions of things that broadcasting data without launching or preserving the network. It's a substitutional network operator that offers end to end solutions technology for different IoT application connectivity. It's used the Ultra-Narrow-Band (UNB) carrier and operates in the 200 kHz band of the ISM band. The UNB band gives ultra-communication range for 1–50 km and decreases the noise level as it used a Binary Phase Shift Keying modulation (BPSK) and because of its managed by one operator no roaming needs to be involved for operating that technology in different countries [18]. Sigfox technology offers a low data bit rate to transfer 100 kHz with a data rate of 100 bps. Because its work on the ISM band it's restricted with the limitation of the band and must respect the duty cycle regulation. Sigfox security features including messages singed with a private key, encryption and scrambling methods, limits to transmit 140 transmissions of 12 bytes payload UL and 8 bytes payload for and DL per day per device. Due to the restricted number and the small size of messages that can be sent per day utilizing the low power consumption. Sigfox technology is pushing the heavy processing to the base station which gives in result affordable devices and drastically extends the battery life of the devices [4].

3.3 Wi-Fi HaLow

IEEE 802.11a is the Wi-Fi Alliance technology that has especially IEEE launched for IoT in 2010, also referred to as Wi-Fi HaLow, which was officially released in 2017. There are no commercially available chips yet. The core members of Wi-Fi Alliance consist of some of the world's largest chip manufacturers, including Broadcom, Qualcomm, Mediatek, and Intel. There should be no issues for future IoT chips to be accommodated in Wi-Fi HaLow technology. It is very important for Wi-Fi Alliance to complete promotion before the IoT market boosting [19].

Wi-Fi HaLow is employed multiple-input multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM), which can support ultra-high data rates, multiple bandwidths, and streams in terms to increase the data rate up to 347 Mbps based on the application [20]. The frequency band of the Wi-Fi HaLow application is adapted to be available sub 1 GHz, with more than 6,000 users access, ultra-low power consumption, strong penetration through obstacles, long-range connectivity, and reliable data throughput.

3.4 NB-IoT

3GPP developed and standardized a new LPWA solution named NB-IoT. While NB-IoT does have a definition in LTE Release 13 [21], it is generally viewed as a separate technology. To alleviate the pressure on devices' resources, NB-IoT uses a lower data rate (maximum of 158.5 kbps on the UL and 106 kbps on the DL [22]). Due of this, it cannot support LTE capabilities like carrier aggregation, dual connectivity, or channel quality measures. Healthcare applications can benefit from NB-IoT because of its low cost, low power consumption, and extensive indoor coverage [23].

3.5 DASH7

Another well-defined LPWAN standard is the DASH7 Alliance Protocol (D7AP). D7AP is an open-source international standard, which is provided technical specifications on RFID tags and sensor nodes for Wireless Sensor and Actuator Network protocol (WSAN). It can operate in the Sub-1 GHz bands according to the ISO/IEC 18000-7 standard and identify by DASH7 Alliance. The ISO/IEC 18000-7 is an open standard which is defined the parameters of the ISM band air interface for wireless communications at 433 MHz. The 433 MHz frequency generates D7A with long propagation coverage and better deployment. A full OSI stack (7 OSI layers) known as D7A protocol (D7AP) is specified [29]. This stack supports a high level of functionality applied for active RFID and WSAN. It provides a quite long-range (up to 2 km), tag-to-tag communication, less delay especially for moving nodes, extended battery lifetime for connecting the objects, and a fairly high data rate (up to 167 kbps). The less frequency of DASH7 can bring a high propagation with penetration capability on multi-floored buildings, thus can operate with less power consumption.

D7A builds around the concept of BLAST network technology, and the features of D7A are:

- Bursty: refers to sending short transfer of data in response to an event or operation and sporadic sequences of data.
- Light: Specifies small packet size limited to 256 bytes per transaction.
- Asynchronous: Communication is a transfer of command and response approach between gateways (GWs) and End-devices (EDs) without periodic synchronization.
- Stealth: EDs communicate towards pre-paired the GWs and hence the devices no need any periodic discovery beacons for the ability to respond in communication.

- Transitive: D7A Supports mobility which allows ED to move freely within various GWs coverages and, at the same time, does not lose connectivity.

In this section, the DASH7 Alliance protocol communication is illustrated along with the various layers belonging to mobility in terms to explain the role of each one in the communication. In the uplink, EDs make utilize of Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol to access the channel and transmit data in the PHY layer. In the downlink, EDs utilize the transmission, reception, scan automation, and multiple access processes in the data link layer (DLL). DASH7 provides Gaussian Frequency Shift Keying (GFSK) modulation scheme and adapts for either a star, tree, or node-to-node network topology. The gateways have the functionality of receiving data and processing it, whereas the endpoints are simpler devices, containing sensors that monitor the needed data and information. The endpoint is designed to be in a sleep mode, which enables low energy consumption and allows for periodically receiving and sending data to the gateways.

The architecture of D7AP is similar to LoRa, which is supported three classes of devices: EDs, gateways, and sub-controllers as shown in Fig. 2. An ED is the least power-demanding platform consisting of sensors and actuators with a transceiver. It can be collected data and transmitted to a gateway when required in asynchrony mode. This platform is redesigned in terms to operate less power consumption and sleeping most of the time. It does not contain all D7AP features, and it utilizes a periodic wake-up mechanism to listen to the possible incoming packets. The sub-controller device is similar to an ED and can use as a relay for packets between an ED and a gateway. However, all D7AP functionalities can be deployed on the sub-controller device. The gateway can be also deployed to all D7AP functionalities and can be always in receiving mode until sending. It received information from an ED, processed them, and transmitted them to the IP-Network or forwarded them to another DASH7 network. The network service can be shared the same functionalities as the network service in LoRaWAN, it can be aggregated the received data, delete duplicates when is required, and select

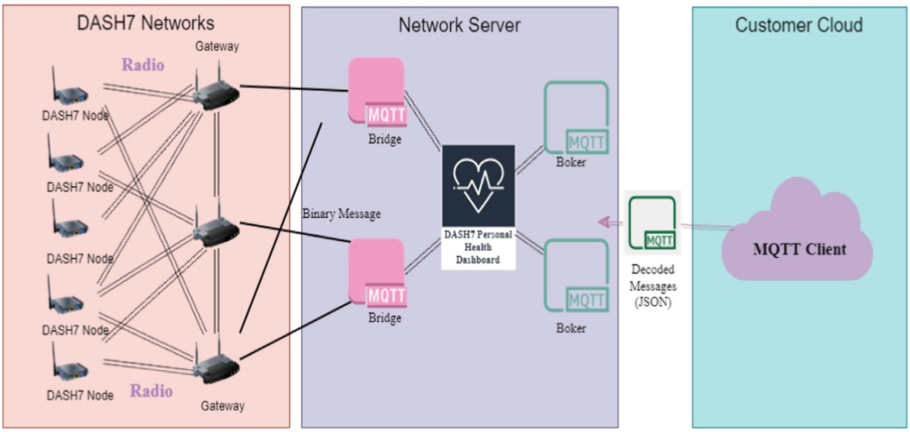

Fig. 2. DASH7 architecture in IoMT.

the nearest gateway for an ED in the downlink. Finally, the customer cloud such as a temperature sensor can be programmed or coded executing at the edge of the network. It receives the information and updates or configures the ED. DASH7 has high reliability in the domain of the healthcare environment compared to Wi-Fi, Bluetooth, and ZigBee as it is not suffering from interference issues whilst acquiring the advantages of less power with high connectivity coverage at low cost [24].

3.6 eMTC

The enhanced machine-type communication (eMTC) technology is typed of the long-term evolution technology. The goal of eMTC technology is to enhance the reliability of packets, low-cost design, less complexity, and security [25]. The eMTC is redesigned based on the 3rd Generation Partnership Project (3GPP) standards in terms to recognize a low power and expand the existing service coverage. The eMTC network is considered a multi-carrier network that can spread radio resources in the frequency domain and in the time domain through implementing respectively a frequency-division duplex (FDD) mechanism, a single carrier (SC-FDMA) mechanism, a TDD mechanism and an orthogonal frequency-division multiple access (OFDMA) mechanism for uplink and downlink health packet transmissions. In the eMTC, the radio access network protocol is utilized universal terrestrial radio access network (E-UTRAN). Moreover, the eMTC MAC protocol is implemented scheduling methods to schedule health packet transmissions in order to guarantee the transmission of the health packet successfully in the context of the WBAN-enabled IoT to achieve a better performance in terms of throughput and a spectrum efficient health packet transmission.

3.7 RPMA Technology

Ingenu proposed the Random Phase Multiple Access (RPMA) [26] LPWA technology (formerly On-Ramp). Unlike LoRa and SigFox, RPMA leverages the global 2.4 GHz ISM band to create a global LPWA. RPMA uses DSSS modulation, which doesn't limit duty cycle or frame duration in the 2.4 GHz ISM band. RPMA provides international availability, better spectrum usage, and higher transmission power (and coverage) than LPWA technologies operating in regional sub-GHz ISM bands, such as LoRa and SigFox.

4 Development LPWA in IoMT

Connected health could be introduced more significant challenges among the quality of healthcare for rural areas within the physical world and better communication to care providers and the section of urban areas with different connectivity challenges. [27] has been addressed these issues by using user scenarios and proposed LoRa based framework for identifying these problems. The authors focused on the lifetime of battery-powered IoT devices for long-term, affordable IoT devices for long-term operation, providing significant information about the providers' health or wellbeing.

The primary goal of this study [28] is to focus on the implementation of the synergies between state-of-the-art communication and AI techniques under smart wearable devices; thus, preparing the development of rightful innovative services and wearable ecosystems. The experimental study is proposed in which the performance of long-range connectivity provided wearable devices helping LPWAN communications and TinyML-based computation is analyzed. Furthermore, the limitation of resource-constrained units such as wearable devices for operating intelligent mechanisms is analyzed. A new architecture [29] proposed a health IoT architecture using LoRa technology. it represented the improvement and progress of current medical infrastructure of IoT. The authors in [30] presented technology and system that utilizes viable, low cost, and low power consumption with data processing, which can assist through LoRa communication technologies and ESP32-based MCU. The aim of the proposed system is to control sensors that discover and predict dangers that will happen for elderly people. This article concluded that the prototype can be enhanced the user's life quality, specifically for those who lived in remote rural areas.

The work in [31] demonstrates the advantages and disadvantages of current communication systems and technologies, suggesting new IoT platforms in the medical area, devoted to home and hospital care services, which is built on LoRa technology.

In [32] has been proposed a proof of concept for monitoring and supporting elderly people using the LoRaWAN communication technologies, the Things Network, and ESP32-based MCU. It has been focused on providing real-time data. The LoRa gateway is configured and connected to The Things Network, receiving the periodically transmitted data from the LoRa nodes. The LoRa nodes are segmented into two distinct types personal LoRa nodes and residential LoRa nodes. This article showed that it is possible to deploy sensor networks to control the elderly using the LoRa gateway and other low-cost technologies. [33] has been proposed an advanced framework with integrated AI that combines Edge computing and Fog computing, LoRa, and IoT-based technologies to build a five-layer system, namely, sensor layer, edge layer, fog layer, cloud layer, and the application layer. The proposed framework could inherit the advantages of these technologies to improve and support health monitoring tasks such as fall detection system or electrocardiogram (ECG) monitoring and satisfy both requirements of high data rate-applications and Lora duty cycle regulation.

5 Challenges and Future Research Directions

In this section, we'll talk about the problems and restrictions of the currently available LPWA for IoMT, as well as the ways in which future research might attempt to address those problems.

5.1 Real Time Communication

Real-time measurements of patients should have been collected by health care systems using the appropriate sensors, then transmitted to medical centers where they should be analyzed and classified according to the complexity of situations require urgent medical assistance. There are a variety of licensed and unlicensed choices accessible for this application. LoRaWAN, RPMA, or NB-IoT can all be utilized for two-way real-time medical control, which requires a minimum of 28.8 kbps. However, there are times when even doctors who can see their patients remotely need to meet with them via video chat. Thus, RPMA and NB-IoT can provide real-time video-based monitoring of health issues, much to how smart home applications can monitor a home's security and temperature. Finally, with the exception of SigFox, all other technologies under consideration are appropriate for use in medical periodic reports and event-driven alerts. Implemented systems for telemedicine should naturally be energy efficient and support numerous devices across a wide range. With 53,547+ versus 40,000 nodes and a 15 km against 5 km coverage, respectively, LoRaWAN and NB-IoT are the right solution in terms of network throughput and range. When looking at available long-range communications solutions, NB-IoT was proven to be the dominant solution for healthcare [7]. For healthcare, it is suggested to use both short-range and long-range M2M communications. The central node of the WBAN and sensors would be connected with technologies such as Bluetooth and ZigBee, while the WBAN would be connected to the provider's base station with a suitable LPWA technology [7]. Even though a system like this is good since it can use short-range M2M architectures, it is highly improbable to have low power use, be scalable, or be less complex and difficult.

5.2 Radiation Absorption in Human Bodies

Exposure to radiofrequency radiation may be harmful to humans, especially to more delicate bodily systems. For example, 15 min of exposure to infrared radiation at an absorption rate of 8 W/Kg in the head or chest might trigger serious damage to the eyes [34]. Even though the highest exposure rate accepted in Europe is 2 W/kg and the highest exposure rate permitted in the US is 1.6 W/kg. Therefore, lowering the rate of radiation exposure is one of the primary problems in WBAN [35]. As a result, sensors must keep their power efficiency high and their power absorption low [36] to reduce the amount of energy collected by the human body to minimize the number of energy received by the human body. Because of this, WBAN devices should require less maintenance and have a lower minimum transmit power requirement. With their low transmission power and short duty cycles, LPWAN technologies offer a potential answer in this context.

5.3 LPWAN Protocols

The LPWAN is a promising technology with a long range and low power consumption, but more work needs to be done on the LPWAN protocols before they can be used to serve e-health applications. Many medical applications necessitate the immediate or on-demand transmission of data. These types of data transfers are not permitted by LPWAN protocols such as LoRaWAN, which are designed primarily for uplink data transfers. However, because many of these protocols do not allow mobile devices can communicate with each other [37], these protocols must also deal with problems that emerge when patients move.

6 Conclusion

The best LPWA technology in IoT-based healthcare depends on the application. Each application's needs determine its technology. Various connectivity solutions must be implemented in order to interface and interconnect IoT devices within a major healthcare application. The administrator must develop an architecture for an overlay that may include edge computing at the hospital facility; cloud computing resources for connectivity to remote devices, and local connectivity through Bluetooth from an IoT technology device to a smartphone that acts as a relay. The level of heterogeneity of the wireless technologies that are integrated into such an architecture will influence the ultimate complexity of the architecture to its maximum capacity. DASH7 has high reliability in the domain of the healthcare environment compared to Wi-Fi, Bluetooth, and ZigBee. Healthcare applications can benefit from NB-IoT because of its low cost, low power consumption, and extensive indoor coverage. The eMTC technology can achieve a better performance in terms of throughput and a spectrum-efficient health packet transmission in the context of the WBAN-enabled IoT.

References

1. Baddeley, M.: Software Defined Networking for the Industrial Internet of Things (2020)
2. Vidakis, K., Mavrogiorgou, A., Kiourtis, A., Kyriazis, D.: A comparative study of shortrange wireless communication technologies for health information exchange. In: 2020 International conference on electrical, communication, and computer engineering (ICECCE), Istanbul, Turkey (2020)
3. Ahad, A., Tahir, M., Yau, K.L.A.: 5G-based smart healthcare network: architecture, taxonomy, challenges and future research directions. IEEE Access **7**, 100747–100762 (2019)
4. Qadir, Q.M., Rashid, T.A., Al-Salihi, N.K., Ismael, B., Kist, A.A., Zhang, Z.: Low power wide area networks: a survey of enabling technologies, applications and interoperability needs. IEEE Access **6**, 77454–77473 (2018)
5. Chung, Y.-F., Liu, C.-H.: Design of a wireless sensor network platform for tele-homecare. Sensors **13**(12), 17156–17175 (2013)
6. Negra, R., Jemili, I., Belghith, A.: Wireless body area networks: applications and technologies. Procedia Comput. Sci. **83**, 1274–1281 (2016)
7. Baker, S.B., Xiang, W., Atkinson, I.: Internet of things for smart healthcare: technologies, challenges, and opportunities. IEEE Access **5**, 26521–26544 (2017)
8. Patil, V., Varma, N., Vinchurkar, S., Patil, B.: NFC based health monitoring and controlling system. In: 2014 IEEE Global Conference on Wireless Computing & Networking (GCWCN) (2014)
9. Maass, A.I., Neši´c, D., Postoyan, R., Dower, P.M., Varma, V.S.: Emulation-based stabilisation of networked control systems over WirelessHART. In: Proceedings of the 2017 IEEE 56th Annual Conference on Decision and Control (CDC), Melbourne, Australia (2017)
10. Devan, P.A.M., Hussin, F.A., Ibrahim, R., Bingi, K., Khanday, F.A.: A survey on the application of wirelessHART for industrial process monitoring and control. Sensors **21**(15), 4951 (2021)
11. Williams, S.: IrDA: past, present and future. IEEE Pers. Commun. **7**(1), 11–19 (2000)
12. Rozlosnik, A.: Potential contribution of the Infrared Industry in the future of IoT/IIoT. In: Proceedings of the 14th Quantitative InfraRed Thermography Conference, Berlin, Germany (2018)

13. Baker, B.C.: Wireless Communication Using the IrDA Standard Protocol. Microchip Technology (2008)
14. Semtech. http://www.semtech.com/
15. Liao, C.-H., Zhu, G., Kuwabara, D., Suzuki, M., Morikawa, H.: Multi-hop LoRa networks enabled by concurrent transmission. IEEE Access **5**, 21430–22144 (2017)
16. Petajajarvi, J., Mikhaylov, K., Roivainen, A., Hanninen, T., Pettissalo, M.: On the coverage of LPWANs: Range evaluation and channel attenuation model for LoRa technology. In: Proc. 14th Int. Conf. ITS Telecommun. (ITST) (2015)
17. Zorbas, D., Papadopoulos, G.Z., Maille, P., Montavont, N., Douligeris, C.: Improving LoRa network capacity using multiple spreading factor configurations. In: 2018 25th International Conference on Telecommunications, ICT (2018)
18. Foubert, B., Mitton, N.: Long-range wireless radio technologies: a survey. Future Internet **12**(1), 13 (2020)
19. Qiao, L., Zheng, Z., Cui, W., Wang, L.: A survey on Wi-Fi HaLow technology for internet of things. In: 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2) (2018)
20. Shin, J.O., Chan, A., Kung, H., Tarokh, V.: Design of an OFDM cooperative space-time diversity system. IEEE Trans. Vehicular Technol. **56**(4) (2007)
21. Meredith, J.M.: Evolved Universal Terrestrial Radio Access (E-UTRA); NB-IOT; Technical Report for BS and UE radio transmission and reception (2017)
22. Hoglund, et al.: Overview of 3GPP release 14 enhanced NB-IoT. IEEE Network **31**(6), 16–22 (2017)
23. Tengshe, R.R., Sahoo, A.: NB-IoT for healthcare. In: Principles and Applications of Narrowband Internet of Things (NBIoT), pp. 127–152. IGI Global (2021)
24. Yearp, A., Newell, D., Davies, P.,Wade, R., Sahandi, R.: Wireless remote patient monitoring system: effects of interference. In: 2016 10th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS) (2016)
25. Ali, W.H., Uysal, M.: Next generation M2M cellular networks: challenges and practical considerations. IEEE Commun. Mag. **53**(9), 18–24 (2015)
26. rpma (2022). https://www.ingenu.com/technology/rpma/
27. Dimitrievski, A., et al.: Rural Healthcare IoT Architecture Based on Low-Energy LoRa. Int. J. Environ. Res. Public Health (2021)
28. Sanchez-Iborra, R.: LPWAN and embedded machine learning as enablers for the next generation of wearable devices. Sensors **21**(15) (2021)
29. Subramanian, P.M., Rajeswari, A.: LoRa-based infrastructure for medical IoT system. In: Rao, Y.V.D., Amarnath, C., Regalla, S.P., Javed, A., Singh, K.K. (eds.) Advances in Industrial Machines and Mechanisms. LNME, pp. 331–337. Springer, Singapore (2021). https://doi.org/10.1007/978-981-16-1769-0_30
30. Lousado, J.P., Pires, I.M., Zdravevski, E., Antunes, S,: Monitoring the health and residence conditions of elderly people, using LoRa and the things network. Electronics **10**(14) (2021)
31. Drăgulinescu, A.M.C., Manea, A.F., Fratu, O., et al.: LoRa-based medical IoT system architecture and testbed. Wireless Pers. Commun. (2020) (2020)
32. Lousado, J.P., Antunes, S.: Monitoring and support for elderly people using LoRa communication technologies: IoT concepts and applications. Future Internet **12**(11) (2020)
33. Queralta, J.P., Gia, T.N., Tenhunen, H., Westerlund, T.: Edge-AI in LoRa-based health monitoring: fall detection system with fog computing and LSTM recurrent neural networks. In: 42nd International Conference on Telecommunications and Signal Processing (TSP) (2019)
34. Ahmed, G., et al.: Rigorous analysis and evaluation of Specific Absorption Rate (SAR) for mobile multimedia healthcare. IEEE Access **6**, 29602–29610 (2018)
35. Foster, K.R.: Thermal and nonthermal mechanisms of interaction of radio-frequency energy with biological systems. IEEE Trans. Plasma Sci. **28**(1), 15–23 (2000)

36. Fernandez, M., Espinosa, H.G., Guerra, D., Peña, I., Thiel, D.V., Arrinda, A.: RF energy absorption in human bodies due to wearable antennas in the 2.4 GHz frequency band. Bioelectromagnetics **41**(1), 73–79 (2020)
37. Ayoub, W., Samhat, A.E., Nouvel, F., Mroue, M., Pre´votet, J.-C.: Internet of mobile things: overview of lorawan,dash7, and nb-iot in lpwans standards and supported mobility. IEEE Commun. Surv. Tutorials **21**(2), 1561–1581 (2018)