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A survey on short-range WBAN communication; technical overview of several standard wireless technologies

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ABSTRACT

In a healthy environment, a WBAN system is the key component or aspect of the patient monitoring system. WBAN systems allow for easy networking with other devices and networks so that healthcare professionals can easily access critical and non-critical patient data. One of the main advantages of WBAN is the remote monitoring of patients using an Intranet or the Internet. There are two main components to the type of communication technology used in WBAN. This page shows an insight of a variety of short-range standardized wireless devices, as well as a taxonomy of short-range technologies. These are proposed as intra-BAN communication candidates for communication within and between body area network (BAN) entities. This paper also highlights the advantages and disadvantages of the WBAN perspective. Finally, a side-by-side comparison of the basic principles of using MICS frequency bands and preparatory technologies.

Keywords: WBAN, Short-range, WBAN communication

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1. Introduction

A wireless body area network (WBAN) integrates small smart electronic devices worn by people to monitor vital signs. It allows patients' continuous health monitoring via healthcare applications without imposing any constraints on their typical daily activities [1]. Data speeds can vary from a few thousand bits per second for easy information to a number of thousand bits per second for video streaming due to the robust range of applications. Additionally, data can be carried in burst, so ensures this is transmitted more quickly [2,3]. This study provides an analytical review of a number of widely used short-range wireless communication technologies, as well as a taxonomy of short-range technologies. These are provided as intra-BAN communication candidates for communication within and between body area network entities (BAN). This paper also discusses the benefits and drawbacks of the WBAN viewpoint.Finally, the fundamentals of using the MICS band are discussed, along with a comparison of potential technologies.

2. Short-range communication in WBAN

2.1. IEEE 802.15.1 (Bluetooth)

Bluetooth is a wi-fi verbal exchange science that can transport facts at speeds up to 3 Mbps over distances of up to 10 meters. Due to its large bandwidth and low latency, it has been widely adopted in the medical industry. Additionally, it supports a broad range of mobile platforms [4]. It is, however, avoided in healthcare monitoring applications because to its excessive power consumption. Furthermore, it has been demonstrated to be suitable for bandwidth-sensitive circumstances [5-7]. There are three different types of Bluetooth devices. As seen in Table 1, this is defined by their capacity to transmit at the highest possible power level and also specifies the maximum transmission range of Bluetooth radios.

Table 1. Bluetooth power classes [8]

Power Class	Maximum Output Power	Radio reach
Class 1	100mW (20 dBm)	~ 100 meters
Class 2	2.5mW (4 dBm)	~ 10 meters
Class 3	1W (0 dBm)	~ 1 meters

The Bluetooth protocol stack is depicted in Figure 1 as a tiered plan with a couple of protocols.

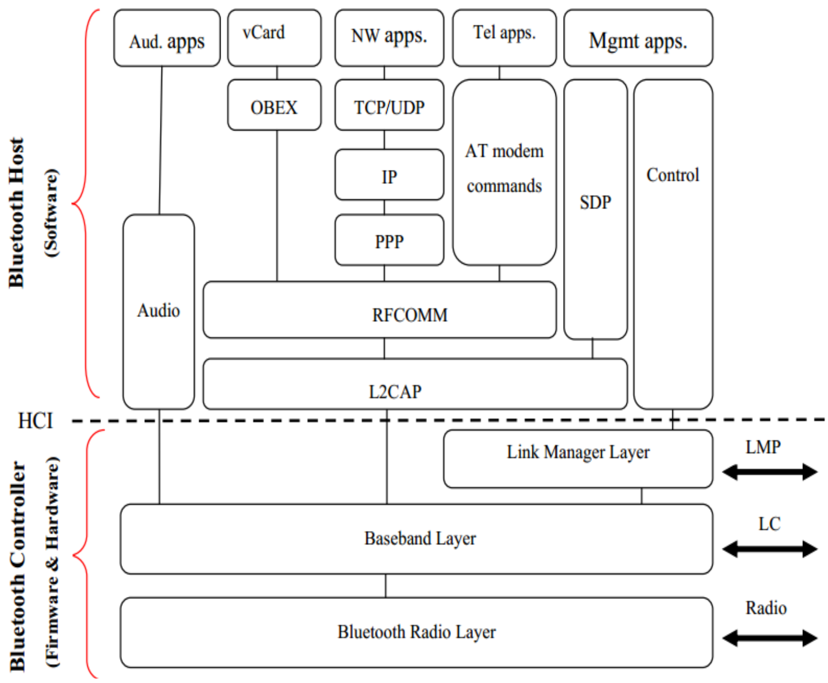

Figure 1. Bluetooth Protocol Stack [8]

Lower-layer protocols, cable substitution procedures, telephonic working programs, and procedures that have been used [8-10] can be classified into four categories:

- The Bluetooth Core System (BCS) protocol suite is comprised of the Radio Frequency (RF) protocol, the Link Control (LC) protocol, the Link Manager (LM) protocol, and the Logical Link Control and Adaptation Protocol (L2CAP). In addition, all Bluetooth applications need a service layer protocol, namely Service Discovery Protocol (SDP).
- Cable Replacement Protocol: Provides a user-friendly and dependable data stream, as well as serving as the transport layer for OBEX over Bluetooth.
- Within a Bluetooth device, the Telephony Control Protocol interprets call control signaling established from voice and data calls.

2.2. Bluetooth's limitations and flaws:

- Bluetooth devices take a lot of power and time for continuous synchronization, therefore battery life may not endure for weeks.
- Limitations in networking:
  - Networking: Automatic networking is not recommended since if a network's owner leaves, the entire network will collapse. This feature is incompatible with the needs of a network that is always changing.

- Connection setup: It takes up to five seconds to establish a connection. The lengthy query method causes data transfer and communication to be disrupted. Most crucially, if two devices are in the query state at the same time, Bluetooth requests will fail.

- Heavy and complicated protocol stack:
  - Additional expenses: The Bluetooth stack requires more processor and memory resources. It might not be the case for low-power sensor devices utilized only for BAN applications [11].

2.3. Ultra-Wideband-IEEE 802.15.3

Ultra-wideband (UWB) radio transmission is a low-power wireless signal transmission method that works over short distances and has excessive radio signal sensitivity. It has the ability to send data at extremely high speeds. This is achieved by delivering data across a far greater bandwidth than is typically available with traditional "narrowband" radio transmission systems. UWB technology provides various advantages for personal area networks (PANs). Low power consumption (1mW/Mbps) and fast data rates are only a couple of the advantages of this technology (up to 480 Mbps). Because of these qualities, UWB is an excellent choice for WBAN applications that require a large amount of bandwidth but not a large amount of power [12,13]. The ISM band at 2.4 GHz. is used in IEEE 802.15.3, the criterion name for ultra-wideband technology for personal area networks (PANs). It is meant for RF front-end and baseband processors that communicate over short distances. Its power consumption does not exceed 100 mA, which makes it small enough to be included in consumer devices. WLAN (IEEE 802.11) and Bluetooth (IEEE P802.15.3) both use a multi-carrier PHY, but UWB (IEEE P802.15.3) must decrease the consumption of power. and complexity of the system, so it adopted a single-carrier PHY method. It was possible to reach peak data rates of 11 to 55 Mbps over a range of 10 to 30 meters using the original IEEE 802.15.3 PHY in combination with multi-bit symbols and grid-coded modulation (TCM), which was far faster than the previous speed spectrum technology.

The WiMedia Alliance is responsible for two UWB-based developing standards: "WiMedia UWB" and "Wireless USB." WiMedia UWB makes use of UWB technology, which is low-power and high-speed. It can transfer data at speeds of up to 480 Mbps over short distances and up to 110 Mbps over longer distances of up to 10 meters. With little progress in the creation of UWB standards and due to high initial implementation costs as well as significant early installation and performance degradation, the success rate of UWB consumer products has been extremely low. As a result, numerous UWB providers shut down in 2008 and 2009 [14,15].

2.4. ZigBee – IEEE 802.15.4

ZigBee is a short-distance wireless technology. It has the characteristics of low cost, low power consumption and low speed. It utilizes IEEE 802.15.4 and uses the WPAN standard as its standard. ZigBee's ultimate goal is to enhance battery life, network capacity, affordability, and reliability [16,17]. ZigBee is used in a variety of applications, including smart homes, industrialization, remote control, smart tags, network sensors, medical and monitoring fields. There are two stack profiles in the ZigBee stack, which was initially released in 2007. In residential and light commercial settings, Stack profile 1 (ZigBee) is intended for use in wireless networks. Both of these devices enable comprehensive mesh networking and all ZigBee application profiles, and they have a smaller RAM and flash memory footprint. Stack Profile 2, commonly known as ZigBee Pro, on the other hand, enables multicast, many-to-one routing, and improved security through the use of a symmetric key exchange protocol (SKKE). The IEEE 802.15.4 physical layer utilizes a direct sequence spread spectrum technique to avoid potentially substantial levels of interference in the unlicensed bands in which it operates (DSSS). Depending on the frequency range, two physical layers are defined: the PHY at 868/915 MHz and the PHY at 2,450 MHz. ZigBee has a number of characteristics, some of which are shown in Table 2, including its maximum data rate and geographic coverage.

Table 2. ZigBee in different frequency bands and their characteristics [8]

Frequency band	Availability	Radio Channels	Max Data Rate	Data Modulation
868MHz	Americas	1	20kbit/s	BPSK
915MHz	Europe	10	40kbit/s	BPSK
2.4GHz	Global	16	250kbit/s	16-ary orthogonal

In compared to the other two, the 2.4GHz PHY offers faster data transfer rates, and it is also available in more locations throughout the world, as seen in the table. Therefore, it is more suitable for use in bank automation applications. 2.4 GHz ISM bands, on the other hand, have their own set of problems, including considerable physical fading and high levels of interference caused by the presence of IEEE 802.11b (WiFi), IEEE 802.15.1 (Bluetooth), and other wireless technologies in the same frequency range (band). When compared to the IEEE 802.15.4 MAC and PHY layers [18-21], The network (NWK) layer and the application (APL) layer are two new levels introduced by ZigBee. Basic communication capabilities are provided by the physical radio layer, but the Media Access Control layer (MAC layer) provides a special service, that is, it allows single-hop communication between devices. The NWK layer is in cost of routing and multi-hop capability, which is required to create a range of community topologies. The Application Support Sublayer (APS), the ZigBee Device Object (ZDO), and any ZigBee purposes produced through the person or fashion designer make up the software layer. In general, ZDO is in cost of gadget administration, whilst APS is in cost of ZDO and ZigBee software aid [22,23].

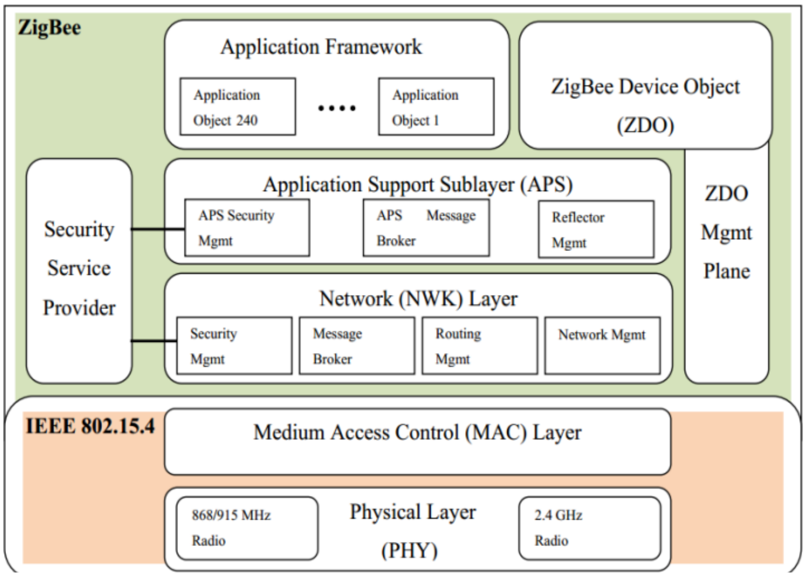

Figure 2. ZigBee protocol stack [8].

According to the IEEE.802.15.4 protocol, devices are divided into two categories. The first category is reduced function devices (RFDs), and the second category is full function devices (FFDs) (FFDs). RFDs are not coordinators, and they are included in the IEEE 802.15.4 protocol standard. Because they completely implement IEEE 802.15.4, FFD can be used as an endpoint device, coordinator, and router in a WPAN environment. There are five different types of MAC frames in the IEEE 802.15.4 MAC layer: beacons, Data Protocol Data Unit, acknowledgement, Media access control command frames, and superframes. Beacons, Data Protocol Data Unit, acknowledgement, Media access control command frames, and superframes are among the types of MAC frames supported. The request of the super-frame is determined by the facilitator [24]. The NWK of ZigBee can support some topologies, such as star, tree and mesh topologies. There are three types of ZigBee devices, each of which has a different set of network functions [25-28].

- The ZigBee Coordinator (ZC) is probably the best machine in the ZigBee network, acting as the initiator of the network and allowing additional ZigBee devices (terminal devices and router devices) to join the network. It can also send beacon frames to network devices to synchronize them with each other.
- ZigBee Routers (ZR): ZigBee Routers are devices that are used for a variety of tasks, including relaying and routing communications between devices and supporting equipment.

This type of device can send messages to their parents (the coordinator and router), but it cannot relay or route messages from other devices.

- ZigBee End Device (ZED): This type of device can pass information to its superior devices (coordinator and router). As a result, as compared to routers and coordinators, these devices consume far less memory and power than they should. This is due to the fact that they just need to pay attention to their own communications and do not need to remain up for extended amounts of time. They can, in fact, sleep as much as they like in order to preserve energy and therefore increase the battery life of their devices. The transmission range of ZigBee is 10 to 100 meters, depending on the environmental conditions and output power.

In a nutshell, ZigBee is a short-range wireless personal area network (WPAN) technology, which has the characteristics of low cost, low power consumption and low speed. ZigBee radio works in the ISM band, which is the same frequency as Bluetooth. It is possible to transmit data at speeds of 20 kbps, 40 kbps, and 250 kbps using this spectrum, which includes the frequencies 686MHz, 915MHz, and 2.4GHz. Security is also provided at the connection and network levels, as well as the application layer. It is possible to employ up to 64K (65536) nodes in a single network using a variety of different network topologies, including star, cluster tree, and mesh topologies. When it comes to MAC and PHY standards, ZigBee adheres to IEEE 802.11.4. Although ZigBee's data rates are among the lowest in the industry [29,30], this is despite the fact that the technology has been extensively tuned for power consumption.

2.5. WiFi-IEEE 802.11

The WiFi (or Wi-Fi) consortium is governed by the Wireless Local Area Network (WLAN), a powerful and fast wireless network technology is used in many homes and businesses. The IEEE 802.11 standard is supported by wireless equipment that has been WiFi-certified. Although WiFi includes all IEEE 802.11 protocols, including 802.11a, 802.11b, 802.11g, and 802.11n, we will only discuss WiFi based on IEEE 802.11b, which operates in the 2.4 GHz ISM band [31-33]. Although WiFi includes all IEEE 802.11 protocols, we will only discuss WiFi based on IEEE 802.11b for comparison purposes. When it comes to network topologies, WiFi is capable of supporting two different types:

- Access point-based topology: As shown in Figure a-3, access points (APs) allow client devices to communicate with one another.
- Peer-to-peer (ad-hoc) topology: As shown in Figure b-3, an ad hoc network is one in which devices (peer points) connect directly with one another.

WiFi makes use of the radio technology known as Direct Sequence Spread Spectrum (DSSS). Other 2.4 GHz ISM-band wireless technologies, such as 2.4 GHz ZigBee and Bluetooth [34], must be avoided in order to achieve this.

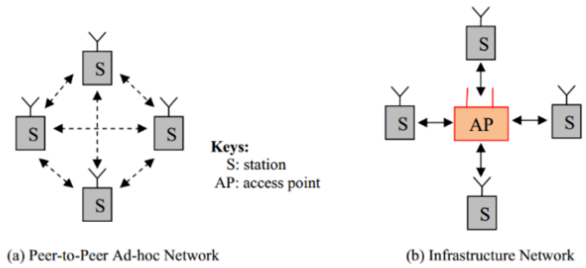

Figure 3. Two types of Wi-Fi are shown as examples [35]

WLAN networks are invulnerable due to the fact WiFi prioritizes authentication and encryption. Two frequent approaches for stopping unlawful access, eavesdropping, and snooping on WLAN networks are "suppress SSID" and "Mac tackle filtering." Two of the most ordinary encryption mechanisms provided through WiFi-compliant merchandise are Wired Equivalent Privacy (WEP) and Wi-Fi Protected Access (WPA). IEEE 802.11buses, which have a maximum transmission rate of 11 Mbit/s, use on the CSMA/CA media access technique from the original 802.11 standards to do this. In practice, 802.11b applications using UDP on the TC band at 7.1 Mbit/s can reach a maximum of 5.9 Mbit/s. Compared with the above technology, WiFi consumes less power. WiFi uses more energy and consumes more power than the above technology. Because WiFi consumes five times the power of Bluetooth, WBAN sensor devices cannot last more than a week on a single charge. WiFi also has the disadvantages of breadth and complexity of protocol stack, which necessitates the use of additional resources like as memory and processing speed. A regular WBAN sensor node may not have this capability [36-38].

WiFi is a high-power, high-speed WLAN technology that can operate in the ISM band without a license. The theoretical mbps is 802.11bps. WiFi is also known as Wi-Fi in some circles. The 11 Mbps data rate supports both ad hoc and infrastructure-based networks, in addition to link-layer security (encryption and authentication). WiFi has two drawbacks in terms of BAN: high power consumption and a hefty protocol stack [39-41].

2.6. Service for communicating with medical implants

In a multi-hop architecture, the Medical Implant Communication Service (MICS) is a short-range standard that allows signals from numerous sensors on the body to be received in real time. In WBAN communication, it is designed for use as a cipher. Considering that it has an exceptionally low radiated power, it is the ideal sensor for human care monitoring systems [42]. According to research conducted by [43], the use of technologies such as ZigBee or Bluetooth does not meet medical requirements owing to the size of the devices, the amount of power they use, and the significant interference they cause from other devices. Considering that the patient would be need to carry approximately 100 sensors, the gadget will be quite big.

A new MICS has been suggested by the Federal Communications Commission (FCC) and the European Telecommunications Standards Institute (ETSI) on behalf of the United States and other countries/regions as a consequence of this development. Using MICS frequencies of 402-405 MHz with a channel width of 300 kHz, medical equipment may interact wirelessly, allowing patients to experience greater comfort, mobility, and treatment effectiveness. The propagation characteristics of these frequencies make them suitable for transmitting radio signals within the human body. Moreover, they pose no substantial threat of interfering with other radio activities operating in the same frequency band.

In the medical field, MICS is an unlicensed, ultra-low-power mobile radio service to which data is transmitted to aid in the diagnosis and treatment of patients who have medical devices implanted in them. Medtech equipment such as pacemakers and defibrillators can be utilized in the MICS band without interfering with other users of the electromagnetic radio spectrum, according to recent research [44].

3. Performance comparison of several alternative short-range wireless technologies

This section outlines several wireless technologies currently in use. However, this does not include the use of UWB and MICS, which were previously discussed. As demonstrated in Table 3, the IEEE 802.11b WLAN technology consumes more power and needs more system resources to implement the protocol stack than the IEEE 802.11a WLAN technology. (For example, memory) This makes it an unsuitable candidate for use in BAN applications. As a result, For example, Wireless Personal Area Network (WPAN) technologies such as Bluetooth and ZigBee are actually more widely used in battery-powered body sensor networks. While Bluetooth's network capabilities are superior in many ways, ZigBee's network capabilities are quicker, more flexible, and more scalable. Standard-based security is enabled while using less energy, computing power, and system resources than previous versions of the technology.

Table 3. Description of feasibility of typical wireless BAN communication

	WiFi IEEE 802.11b	Bluetooth IEEE 802.15.1	IEEE 802.15.4			
						ZigBee
Application Focus	Web, E-mail, Video	Cable Replacement	Monitoring and Control			
Frequency band	2.4GHz	2.4GHz	2.4GHz (Global)	915MHz (US)	868MHz (EU)	
Spectrum Spreading (SS)	DSSS	Frequency Hopping (FHSS)	Direct Sequence Spread Spectrum (DSSS)			
#channels/schemes	11(US), 13(EU)	10	16	10	1	
Max Data Rate	11Mbit/s	1Mbit/s	250kbit/s	40kbit/s	20kbit/s	
Range (meters)	1 - 100	1 – 10+	1 – 100+			
Network Topology	Star, peer-to-peer	Star	Star, peer-to-peer			+ mesh
Network Size	32	8	64K			
Network join time	<3s	<10s	<<1s			
Real-time support	No	No	Guaranteed time slots			No
Protocol complexity	Medium	High	Simple			Low
System resources	1MB+	250KB+	4KB – 32 KB			
Security	Authentication, encryption	Authentication, encryption	Authentication, encryption			
Power consumption	400-700mW	200mW	60-70mW			
Battery life (days)	0.5 - 5	1 - 7	100 – 1000+			
Success metrics	Speed, Flexibility	Cost, Convenience	Reliability, Power, Cost			

The battery lifestyles of a ZigBee system can close weeks, months, or even years, relying on the application, due to the fact it is constructed on the IEEE 802.15.4 bodily and MAC standards, which have been adjusted for low electricity consumption. Furthermore, ZigBee unit is in sleep or power-off mode most of the time, decreasing electricity consumption and thereby extending battery life. As a result, amongst the options listed in Table 3, ZigBee is the fantastic conceivable answer for WBAN applications.

Conclusion

Choosing the right wavelength is also an important factor in transmitting signals without loss or damage. In this chapter, except for outlining essence of sensor. and how they work, the meaning of sensor networks used to monitor a patient's vital signs is described, as well as the several types of these systems. Connecting them to the network. The appropriate wavelength is chosen based on the state in which the system will be used to ensure that there will be no interference with other waves that may cause signal packet loss and weak reception, and this chapter presents this information in detail. The research gap section addresses the need for an effective method that can demonstrate network performance requirements over previous methods.

Acknowledgment

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