

A Review of State-of-the-Art on Wireless Body Area Networks

Fatemeh Rismanian Yazdi

Department of Computer
Engineering, Tehran North Branch,
Islamic Azad University, Tehran,
Iran

Mehdi Hosseinzadeh

Department of Computer
Engineering, Iran University of
Medical Science, Tehran, Iran

Sam Jabbehdari

Department of Computer
Engineering, Tehran North Branch,
Islamic Azad University, Tehran,
Iran

Abstract—During the last few years, Wireless Body Area Networks (WBANs) have emerged into many application domains, such as medicine, sport, entertainments, military, and monitoring. This emerging networking technology can be used for e-health monitoring. In this paper, we review the literature and investigate the challenges in the development architecture of WBANs. Then, we classified the challenges of WBANs that need to be addressed for their development. Moreover, we investigate the various diseases and healthcare systems and current state-of-the-art of applications and mainly focus on the remote monitoring for elderly and chronically diseases patients. Finally, relevant research issues and future development are discussed.

Keywords—Wireless body area networks; review; challenges; applications; architecture; radio technologies; telemedicine

I. INTRODUCTION

As time goes on, communication technologies have started the gap toward a pervasive world. Because of, MP3 players and mobile phones are portable devices; people normally carry these devices around their bodies. In 1995, Zimmerman examined how these electronic devices operate near or inside the human body. He used the term PAN, personal wireless network as a communication channel for communication within the body. Later, around 2001, PAN term has been changed to encompass communications and implantable use of devices around or inside the body to the physical network BAN [1]. Body sensor networks are called, BSN. The Physical wireless network is a mono-purpose wireless sensor network that combines different wireless networks and devices to able remote monitoring. BAN devices may be embedded in the body or may be mounted on the body or in a fixed position on the wearable technology or may be placed in mobile devices that people can carry in different situations, in clothing, pocket, hand or different bags [2]. Gateway devices are used to connect wearable devices to the Internet through the human body. As a result, medical professionals can use online patient data from the patient's own Internet access [3].

One of the WBANs applications is the medical environment in which the situation of a large number of patients should be controlled permanently or in real-time. To create WBANs, several tiny wireless sensors are in strategic areas in or around the patient's body. Currently, wireless monitoring of physiological signals is one of the basic needs to deploy complete WSNs in health systems. The main purpose of the WABNs is to provide biological feedback

information and consistently control the body's health parameters such as body temperature, blood glucose, heart rate, body movement, electrocardiogram (ECG), electroencephalogram (EEG), electromyography (EMG), galvanic skin response (GSR), photoplethysmography (PPG), and arterial blood pressure and heart with a simple and efficient way. Because of health care costs are increasing and the world population ageing, human health monitoring is one of the important issues [4], [5].

The rest of the paper is structured around the following sections: different architecture of WBANs and characteristics of communication and the position of WBANs presented in Section 2. In Section 3, medical and non-medical application and different device of WBANs are evaluated. Design challenges and requirements and open issue are discussed in Section 4. Communication standard and radio technologies present in Section 5. Telemedicine and diverse disease that monitor by WBANs are discussed in Section 6. Finally, conclusion and future direction are provided in the last section.

II. WBANS ARCHITECTURE

WBANs were classified with intelligent nodes based on implementing within the body as follows: In the body or implantable sensors - these nodes implanted in the patient's body, inside the body tissue or underneath the skin. On the body or wearable sensors - these nodes placed the surface of the patient body or two centimeters away from it [6]. Placed it around the body or surface sensors - these nodes are external of the body rather than five meters away from a patient's body [7].

These nodes are continually monitoring patient vital information and usually utilize wireless communication to join a master node. The first, master node accumulates data from all the other nodes in the network and then directs the information to the medical devices. According to the received data and patient's specifications, the medical team can do proper medical practice. Moreover, this system can provide records of vital sign of the patient. In general, these sensors measured the precise parameter of the patient and the actor sensor action based on the information gained from sensors.

In another classification, the sensors in each WBANs are divided into two categories based on the kind of signal measurements [7]. The first type is gathering with variable

signal continuous which needs to real-time signal processing such as, electrocardiograms graph [8] sensors and accelerometer [9]. The second type is a collection of discrete variable time signal that they are not immediately for instance, Pressure sensors [10], and respiratory tract sensor [11]. In Table 1, the summary of the general characteristics of WBANs is provided [2].

These nodes can have diverse topologies including the star, mesh, and tree topologies. Nevertheless, the most standard topology is the star in which node in the center of the star being placed at a location and the other nodes are connected to a central master node. Based on the application, sometimes various nodes connect to a central master node to merge the process and transfer information. Some of the parts of the human body movements are pondering the relative to each other and this process should be considered until deploying nodes in the body. In Fig. 1 explains an example of nodes based on the human body. Nodes to transmit sound and images must be cautiously established with attention to sensitive nerve in the head. In addition, the sensitivity of the SAR (Specific Absorption Rate) eye should be regarded. The nodes located in the torso and head towards each other will not move very much. Nevertheless, the nodes located in boundaries for example legs, arms, torso and head may move toward each other more [12].

In Table 2 is explained possible communication between nodes in the body [13]. These nodes have very low processing power and are able to produce energy for the whole body in the body and on the body. Nevertheless, these nodes in close proximity to or inside the human body and thus position SAR can be a slightly larger, if all power is available for a small volume of data. Thus, localization of SAR in the body must be at least [14].

TABLE I. GENERAL CHARACTERISTICS OF WBANS

Attribute	Value
Network size	Max 100 devices
Network density	2-4 Nets/m ²
Network Setup time	<1 Sec/device
Power consumption	<1 m W/Mbps
Startup time	<100 ns
Latency (end to end)	10 ms
Distance	2 meter stander 5meter special case

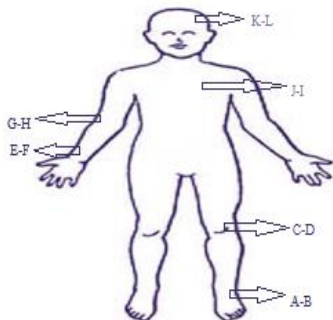


Fig. 1. Description node links on the body.

TABLE II. DISTRIBUTED WBANSON BODY

Link	Description
A-B	Through the ankle
C-D	Through the thigh
E-F	Through the hand
G-H	Through the wrist
I-J	Torso, front to back
K-L	Left ear to right ear

Another architecture for WBANs in medical and non-medical application are designed. According to demand, it can be used in the emergency event or normal traffic. Upon demand to attain special information, traffic is started by master node and is the maximum goal for diagnostic recommendations. These are divided in two interconnected (in case of operation) and discrete (when information is required from time to time). Emergency traffic management is started by starting node when more than a predefined threshold exists and must be replaced in less than a second. This kind of traffic is not created at regular intervals and is quite unpredictable [14].

Normal traffic data is requested in a normal condition with no critical time for events. This consists of the general health of patients and their treatments for many diseases; for example, gastrointestinal, neurological disorders, cancer, rehabilitation, disability, heart diseases and more. Normal data are gathered, and the master node does the processing. Depending on the application requirements, the master node may include a raiser radio circuit to transfer of critical life emergency and an additional circuit to connect multiple physical layers. More master nodes are connected to critical telemedicine and medical server for the appropriate recommendations [15].

WBANs in many ways are similar to the wireless network, but the differences between the two can be seen. Scalability in WBANs limited in the human body, but in WSN can monitor the environment in the wide area covered. Node density also is numerous in WBANs while in WSNs is few and limits. Security and privacy level and authentication of a node and real-time communication among most important issue in WBANs while in WSNs no attention to support them. Usually in the WBANs nodes perform multi-tasks, but in WSNs is purpose single.

In addition, data rate, mobility, network topology, node size between two networks is diverse result in different architect to design and implementation. Most importantly, energy source and high reliability and low delay are very critical for WBANs because data mostly consist of medical information and can be as a life threat for patients [16], [17]. Thus, WBANs have several advantages rather than WSNs such as flexibility, effectiveness and cost-effective. Table 3 shows the differences between wireless body area networks and wireless sensor networks.

TABLE III. DIFFERENCES BETWEEN WIRELESS BODY AREA NETWORKS AND WIRELESS SENSOR NETWORKS

Issues	Wireless Body Area Network	Wireless Sensor Network
Node Size	Small is essential	Small is preferred, but not important
Scale	Human body (centimeters/ m)	Monitored Environment (meters/ km)
Node Tasks	Node performs multiple tasks	Node performs a special task
Network Topology	More variable because of body movement	Very likely to be fixed or static
Node Number	Fewer, limited in space	Many redundant nodes for wide area coverage
Energy-Scavenging Source	Most likely motion and thermal	Most likely solar and wind power
Node Lifetime	Several years/months, smaller battery capacity	Several years/months
Node Replacement	Replacement of implanted nodes difficult	easily
Power Demand	Likely to be lower, energy supply more difficult	Likely to be large, energy supply easier
Wireless Technology	IEEE 802.15.6	Bluetooth, ZigBee, GPRS, WLAN
Result Accuracy	Through node accuracy and robustness	Through node redundancy
Security Level	High	Low
Biocompatibility	A must for implants and some external sensors	Not a consideration in most applications

III. APPLICATION AND DIFFERENT TYPE OF DEVICES

The human body sensor network has a lot of potential for a variety of applications including remote medical diagnosis, interactive games and military applications. Table 4 lists some of the applications of the sensor in the body and on the body. Applications inside the body include the supervision and program changes for regulating heart rate and substantial heart implant in the body, the limb movement, and restoration of bladder function control. Medical applications in the body sensors include monitoring of ECG, blood pressure, temperature, and respiration. On-body sensors communicate between a gateway device and sensors. In addition, the body of non-medical applications includes monitoring of forgotten things, creating social networks and assesses soldier's battle. Some of the human body sensor network applications are discussed below [13], [15].

According to the type of application, data rate information and ranging from transferring data are different. Data can also be sent in similarly stream and the higher rates posted during the guarantee of the correct data is received from health-care professionals in term of bit error rate (BER) for the number of lost packets [17]; for medical devices, the reliability is based on the speed of the data. Low data rate can be a high BER (10^{-4}) while devices with higher data rates require a lower BER

(10^{-10}) can be gained [16]. Energy consumption is critical issue in the design for improving the lifetime of battery WBANs. Energy is used for sensing, communication, and processing data. Usually, the available energy for nodes is limited. Energy consumption based on utilities, shape, and position and the rate of transfer data is different. Generally, providing Qos in management of medical applications, especially in healthcare application is important [16].

Additional demands have increased fast exponential cost of health care and medical interventions for innovative solutions for remote health monitoring as a body sensor network [12]. The result in WBANs extends a wide area in medical application.

In medical application for healthcare is prevention, diagnosis, treatment of diseases and other physical and mental of people activities. Also, for animal healthcare with different sensors such as accelerometer, GPS, Bluetooth, temperature, humidity, wind sensor monitoring for realizing the disease, for example, respiratory, gastrointestinal, metabolic [18], [19] that prevent of these disease could be helpful for massive financial losses in the animal agriculture industry. Medical application has many classifications for monitoring general healthcare, disability assistance, infant healthcare, pregnant women, elderly monitoring. In neonatal monitor the smart jacket or wrist band with wearable sensors and smart textile. In [20] author has suggested design of continuing vital health monitoring. There are different sensors, such as ECG with conductive textiles and phototherapy with skin sensors and temperature sensor, pulse rate sensors.

Also, the system consists of special hardware, namely, microphone to record voice, memory and processors for analyzing information and Bluetooth for transferring information. In [21] the author suggested a wrist band for the baby named Kims. Wrist sensor monitors vital parameters of infant and processing information for early detection of infectious diseases and treatments. Wristband consist of various types of sensors for the instance microphone for record audio signals and then with processing signal recognize health sings for example cry, sneeze, vomit and cough. Then processing with coding scheme and compare with original signs for awareness of disease to beginning the treatment.

In non-medical application can be classified in entertainment such as interactive games, dance lessons, microphones, shopping and cameras and advanced computer and so on [22], [23] and training the sports for instance golf, football, and cricket where athletes sensors connected to the body and move them to record and review their training and monitoring and self-assessment and better adjustment to professional athletes plan and rehabilitation and motion capture [24]. Smartphone and wearable watches are being connected to BANs for gaining physiological parameters, for example heart rate, acceleration, gait length by distance measurement, pace, burned calories and elapsed time.

Military and security applications consisting of the camera, biometric sensors, GPS are supported by body sensor networks, particularly for the control and monitor the battlefield where the sensors are located with soldiers, move to track, monitor their health, and detect the existence of toxic

substances in the air and that life-threatening people [13]. Sleep disorders are the significant issue in daily lives. Thus, sleep monitoring attracted many researchers in these years. Moreover, it is widely used in varied medical application and implant sensors, for example cardiovascular diseases, diabetes, cancer and remote control sensors such as telemedicine system, patient monitoring. New BANs applications suggested in [25] for example, identify frostbites, assist blind swimmers that support the special disease. Fig. 3 summarizes categories of WBANs application.

A taxonomy of the device represents for monitoring patients as follow: Node wireless sensor is a device that collects and responses to physical stimuli and makes the process on data report data for wireless sensor. This device includes hardware components, such as sensors, processing unit, a processor, memory and a transmitter or receiver [26]. A Wireless Driving node is a device that the data received from the sensor or through user interaction works. The sensor actuator components consist of hardware drivers (medical hardware, for instance a drug-delivery system) a processing unit, processor, memory and a receiver or transmitter [2].

Wireless personal devices (PD) is a device that all information gained by the sensors and actuators to gather user information through an external gate driver or a page Show - LEDS on it. The components of this device consist of a processing unit, processor, memory and a transmitter and receiver [16]. This device is called Body Control Unit (BCU), body gateway or sink. In some design, a Personal Digital Assistant (PDA) or smart phone is used [27]. Many diver's kinds of sensors and actuators are used in WBANs. The significant target of all these devices can be found in health applications. The number of nodes in WBANs depends on the abilities and the nature of the network. Usually, the number of nodes is in the range of 20-50 [28], [29]. There are challenging issues in the design and implementation of WBANs. Following are mentioned some of the issues.

IV. WBANS DESIGN CHALLENGES AND OPEN ISSUE

In this section, we present the main challenges of WBANs. There are numerous challenges such as reliability, security, size, latency, privacy, availability, capacity constraints, confidentiality, data speed, bandwidth, mobility, the quality of service requirements, transmission range, and so on [30]. Proficient communication is as ease of deployment and scalable, reliable (in data measurement, data communication, data analysis), user-friendliness, fast, fault-tolerant, low power of data communications [31], [32].

So that gain operational efficiencies, body wireless network implementations must ponder that significant issues depend on the proper coverage area in most of the human body. Small coverage area causes to body temperature and change location, and movement of nodes. So, the implementation of the network is vital aspect [33]. Moreover, exist major challenges between BANs and applications. For example, increased attenuation for communicating application, data rate, power consumption, trade-off between processing and communication, storage energy harvesting. In summary, we classified power efficient mechanism for BANs

applications in scheduled contention, lower power listening, and TDMA based mechanisms.

Some challenging issues exist in the Wearable Health Monitoring System (WHMS) for example, battery technologies and energy scavenging, sensor miniaturization and efficiency design, security and validation of information, standardization and cooperation between different communication levels.

The most critical limitation is the energy source for gathering, processing, and transfer data for extending the lifetime of the network. Hence, to widespread the lifespan of the network, particular implanted nodes is necessary. Therefore, especially focused should be given to network lifetime when selecting or implementing communication protocols for WBANs such as routing and so on [34]. In this regard, routing algorithms are designed respect to energy challenge that can be classified into ten categories including: Thermal-Aware, Cluster and Tree-Based, Medium Access Control, Cross-Layer, Opportunistic, Restriction of Location and Number of Relays, Mobility-Aware, Link-Aware, QoS-Aware, Hybrid protocol. The classification of the body area network application is shown in Fig. 2 [35].

The patient needs to be capable of moving easily. For instance, motions of the hands, walking, sleeping, running, twisting, up to and down stairs, etc. this category named "Mobility-aware" [36], [37]. Protocols that investigate the location and placement and relay of nodes are the category of "location restriction and number of relays" [38], [39]. This category uses multi-hop for data transferring, that cause reduces energy consume. Also, determine location cause to increasing packet delivery rate and reduce packet drops.

Some protocols deal with the link status between the transmitter and the receiver for exchange information, including packet delivery ratio, HELLO message and signal strength. This category named "Link-aware" [40], [41]. Any protocol in this category that considers the link status for direct impact on various factors, include energy consumption, delay, reliability. Another category is links between the source and destination with cluster and tree for data transmission is "cluster and tree based" protocols [42]. This category is efficient in improving WBANs by using tree-based methods for allocating nodes and also gathering data, that cause reduce energy consumption. Next classification composed of multiple layers, containing network layer and transport layer, to improve WBANs. In other words, improve the efficiency and interaction between the protocols and two or more layers of the protocol stack.

This category named "Cross-layer" [43]. Also, another category related to the communication channel is "opportunistic" protocols [43]. This category discusses on how sensor nodes achievement of the communication channel. "Medium Access Control" is another category that focuses on energy consumption and cost. According to access the communication channel MAC protocols have been divided into two subcategories of scheduled and random protocols [44], [45].

The movements of the body may effect on topology networking capabilities, communications, or signal reception. However, the most significant restriction of energy is its source in which the body sensor network node is equipped with a small battery. The Sensors node in WBANs perform different activities, such as sensing, processing, analyzing which radiation absorption and heating effects on the human body; also because, if excessive heat will damage body tissues. So, mechanisms need to be supplied to impede the temperature rise in the nodes; for example, limited or traffic controls algorithms. This class named "thermal-aware" [46], [47]. For instance, the Thermal Aware Routing Algorithm (TARA) that routes data away from high temperature areas [47]. Packets are receding from the heated zone and rerouted via alternate paths. The disadvantage of TARA is from low network lifetime and low reliability into account and high ratio of dropped packets. The development and smarter of TARA is Least Total Route Temperature (LTRT) [48] that the node temperatures are modified on to graph weighs and minimum temperate routes are acquired. But LTRT suffers that a node needs to know the temperature of all nodes in the network.

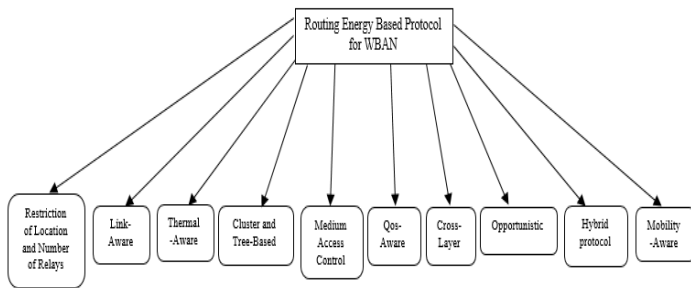


Fig. 2. Classification of routing protocols in body area networks with respect to energy

Energy efficiency requirements in MAC protocols have been evaluated in [49]. The method is proposed [50] to reduce power consumption by data aggregation mechanism. The energy-efficient and reliable protocol have been proposed in [51]. The protocol for patient monitoring has been presented in [52] that investigated location and position. Relay nodes placement schemes for minimizing energy consumption proposed in [53]. All of these protocols are the category of "Qos-Aware".

The last category is mixture of other categories called "Hybrid protocol". The protocol can be the mixture of two or more category for instance, link status and MAC. Fig. 2 shows classification of routing protocols in WBANs based on the consumed energy. Table 5 summarizes the examples of routing protocols with respect to energy in WBANs.

Cloud computing is a new method that able to sorting, processing, delivering, securing, analyzing, and distributing data streams [58] that relay on signal characteristics and the rate of data production and the sensing parameters. The algorithm processing can provide additional information for monitoring, emotion detection, activity recognition, skin prevention. Cloud computing in WBANs has some challenges such as, data management (collected and store data in a specific time and space and locations), data processing, data analysis (modeling and analysis tools for different applications), communication interface between the cloud and BAN resources, and stream data management for collecting and cleaning and aggregating and transferring and storing data. Also, aggregation and real-time processing of large scale data information.

Scalability is other challenges of WBANs communications [59]. Moreover, flexible system should be able to handling and configure it self-automatically. Therefore, self-organization and self-maintenance and self-management should be supported. Providing quality of service is another issue that related to the WBANs, where service is the appropriate service depends on their application and the nature of transport sensitive data [60]. For instance, when the WBANs implemented to monitor and support the patient's health care status, the information must be transfer real-time. Delays in the transfer of significant or critical alarms may be disastrous [61]-[63].

Another significant factor of WBANs applications is security of information. For instance, data confidentiality (transmit information private and encryption the information), data authenticity (verify the data is being sent from the trust center and not a false adversary), data integrity (verify when data is transmitted in an insecure) and data freshness (guarantees data in transmission). The security and the privacy of the collected personal medical data for protection should be encrypted to protect the patient privacy.

WBANs nodes should ensure integrity, high accuracy, confidentiality, and authenticity of data downloaded [64]-[66]. A privacy enhanced authentication scheme for the medical information system is proposed in [67], however, in [68] by Kumari et al. proposed scheme for verifying the attack, online password guessing attack and imitation attack. The digital signature is investigating in [69] to ensure the security of information that can ensure confidentiality of information. False alarms or Adding false data may lead to misleading results on patient safety. Result in a life threatening for the patient. Thus, security in WBANs should be established in various layers and levels for instance the physical layer and the network layer. Nonetheless, security upstairs may increase the energy consumption and influence the network lifetime [70], [71].

TABLE IV. APPLICATION AND USAGE OF WBANS

Application Type	Sensor Node	Type of sensor	Bandwidth (Hz)	Accuracy (bits)	Data Rate	Duty Cycle % per time	Power Consumption	QoS	Privacy
In-Body Application	Glucose sensor	Strip-base	0-50	16	Few Kbps	< 1%	Extremely low	Yes	High
	Pacemaker	accelerometer	0-500	12	Few Kbps	< 1%	low	Yes	High
	Endoscope Capsule	a pill and contains a tiny camera	--	--	> 2 Mbps	< 50%	low	Yes	Medium
On-Body Medical Application	ECG	Skin/chest electrodes	100-1000	12	3 Kbps	< 10%	Low	Yes	High
	EMG	Skin electrodes	0-10000	16	320Kbps	--	--	--	--
	Temperature	Temperature probe or skin patch	0-1	8	120bps	--	--	--	--
	SpO2	Pulse Oximeter	--	--	32 Kbps	< 1%	low	Yes	High
	Blood Pressure	Arm cuff based monitor	0-1	8	< 10 bps	< 1%	High	Yes	Medium
On-Body Non-Medical Application	Music for Headsets	sound	--	--	1.4 Mbps	High	Relatively High	Yes	Low
	Forgotten Things Monitor	monitor	--	--	256 Kbps	Medium	Low	No	Low
	Social Networking	Mixed sensor	--	--	<200 Kbps	< 1%	Low	No	High

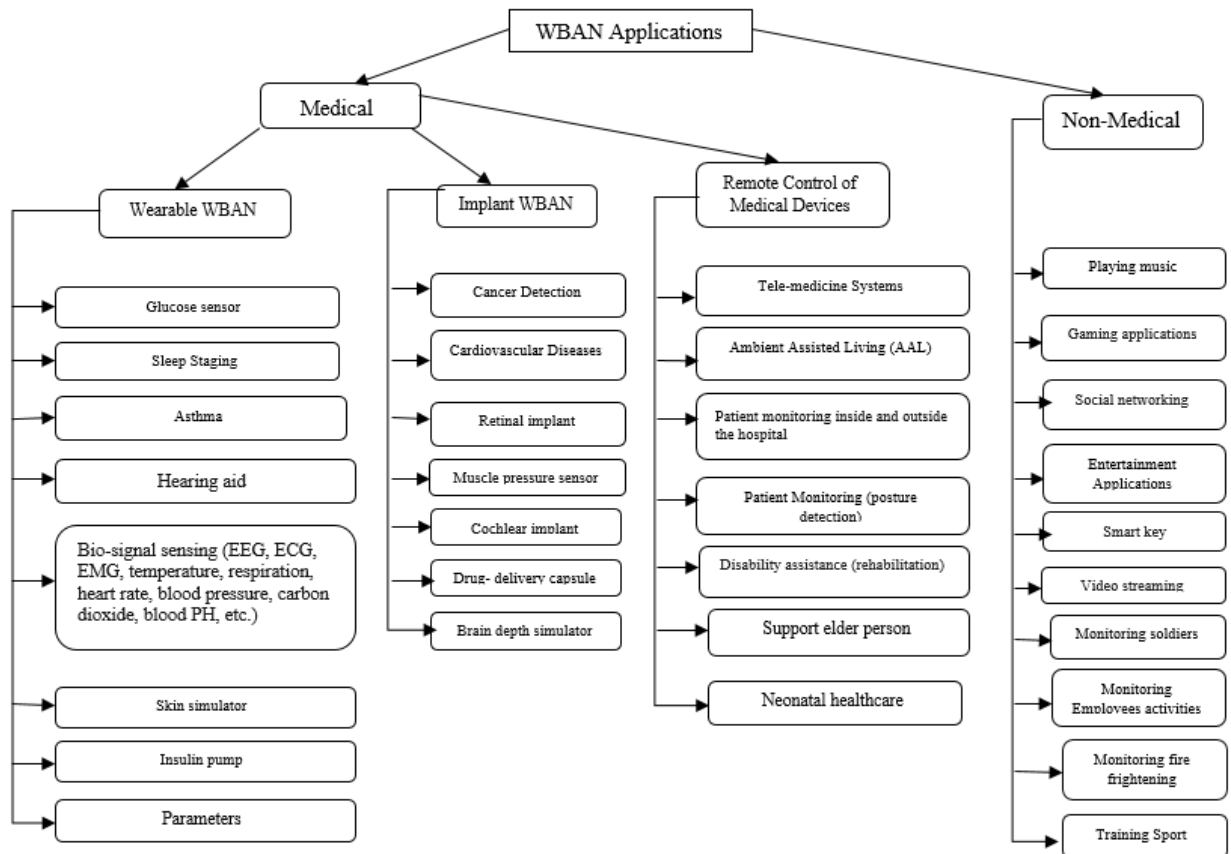


Fig. 3. Application for Wbans.

TABLE V. SUMMARIZE THE EXAMPLES OF ROUTING PROTOCOLS WITH RESPECT TO ENERGY IN WBANS

Type of protocols	Protocol	Author	Date[] Ref []	Advantage	Disadvantage	+Simulator	Energy Consumption	Goal
Mobility-Aware								
	IM-SIMPLE	Javaid, N., et al.	2014 [36]	stability period: Good network lifetime: Good throughput: Good energy consumption: Good Throughput Good Stability: Good Life Time: Intermediate	packet drop: high	-	Good	Reducing energy consumption
	EERS	Liang, L., Ge, et al.	2014 [37]	network lifetime: Very Good energy consumption: Low delay: Low	Overhead: high	Lab Room	Low	Achieving higher reliability and energy efficiency
Restriction and number of relay								
	REEC	Sandhu MM, et al.	[38] 2014	stability period: Good network lifetime: Good throughput: Good Residual energy: Good	—	--	Good	Reliable energy-efficient critical data routing
	EAWD	Elias J	[54] 2014	energy consumed: Low does not need to install additional relays	—	3D electrom	Low	increase the network lifetime
	Braem, et al.	Braem B, et al.	[39] 2007	network lifetime: Good	There is not the possibility of the continuous use of relays, so the cooperation technique has been proposed instead.	--	Good	Energy efficiency of communication despite path loss
Link-Aware								
	IM-Simple	Javaid, N., et al.	[36] 2014	stability period: Good network lifetime: Good throughput: Good energy consumption: Good	packet drop: high	---	Good	Reducing energy consumption
	AMR	Ortiz AM, et al.	[55] 2012	network lifetime: Good, packet delivery rate: increased data loss: decreased residual energy: high	Requires additional packet switching between nodes	---		Adaptive multi-hop tree-based routing; improving network performance
	EERS	Liang, L., Ge, et al.	[56] 2014	network lifetime: high energy consumption: low delay: low	overhead : high	Lab room		Achieving Higher reliability and energy efficiency
	CO-LAEEBA	Ahmed, S., et al.	[41] 2015	stability period: Very Good network lifetime: Very Good throughput: Very Good residual energy: Good path loss: Good	--	---		Providing a link-aware and energy-efficient protocol
Thermal-Aware								
	IA-MAC	Ahmad A, et al.	2014 [46]	energy consumption: Low Cost: Low network lifetime: Good packet loss rate: low Packet delivery ratio: Intermediate Number of packet drops: Good	packet transmission: low cycle count: low	--	Good	Improving medium access control; achieving adaptive sleep/wakeup mechanism
	LTRT	Takahashi D, et al.	[48] 2007	temperature rise: Low Delay: Low	Packet delivery rate: High	Java	Low	Reducing the temperature rise

				average hop count: low				of the implanted sensor nodes in the human body
	TSHR	Ahourai F, et al.	[57] 2009	temperature rise: Low Delay: Intermediate packet drop: zero network lifetime: long	packet delivery: high	C++	Low	Efficient thermal-aware routing
	TARA	Tang Q, Tummala N, et al.	[47] 2005	Temperature rise: High Temperature: balance	packet delay: high network lifetime: short	Matlab	Low	Avoiding hotspots during packet transmission
Cross-Layer								
	COMR	Abbasi UF, et al.	[43] 2014	network lifetime: Good delay: Good energy consumption: Good	packet delivery ratio: decrease	Omnet++	Good	Improving reliability by a cross-layer opportunistic method
Cluster and Tree-Based								
	RTT	Chebbu H, et al.	[42] 2012	Reliability: high	a large number of relays	Channel sounder	Good	Reliable data transfer
Medium Access Control								
	BODY MAC	Fang G, et al.	[44] 2009	bandwidth allocation: Good delay: decreases power consumption: Good	--	OPEN-ZB TOOLSET	Good	Presenting a MAC protocol for energy efficiency
	MED MAC	Timmons NF, et al.	[45] 2009	power efficiency: Good overhead: no synchronization	---	OPNET	Good	Presenting a medical MAC protocol for energy-efficient and adaptable channel access
Opportunistic								
	COMR	Abbasi UF, et al.	[43] 2014	network lifetime: Good delay: Good energy consumption: Good	packet delivery ratio: decrease	Omnet++	Good	Improving reliability by a cross-layer opportunistic method

V. RADIO TECHNOLOGIES OF WBANS

The general standard used in Body Wireless Communication is IEEE 802.15.1 (Bluetooth) and 802.15.4 (Zigbee), a primitively section of the 802.15 operate in a wireless personal area network (WPAN). Bluetooth is a short-range communication system that replaces the cables for electronic devices. Two categories of basic rate (BR) configuration consist of Enhanced Data Rate (EDR), and Low Energy (LE). Then, proposed Zigbee for a special case of sensor networks that extensively adopted to perform WBANs.

IEEE Standard Association recommendation the IEEE 802.15 task groups 6 for low power devices and operated on, in or around the human body for different applications in WBANs. Generally, the characteristics of the physical layer are classified in RF communication (Radio Frequency), movement of the body, None-RF communication [72]. This layer is responsible for archiving some tasks such as, active and reactive of the radio transceiver. The choice of this layer depends on usage and aspect of the application, on medical or non-medical, implantable sensor, wearable sensor, surrounding sensors. Monitoring critical signs, for example heart rate, body position, blood pressure, and oxygen saturation are now performed through small sensors [73].

These lightweight and intelligent devices are able to measure physical events, processing and wireless transmission. Wireless sensor particles are placed intra-body or implanted on the body and extend or extra-body of the smallest in a short distance of wireless networks surround the human body is done by using an RF transmission technology [74].

In late 2011, the standard of wireless network protocols was approved. The standard has explained three physical layers, Ultra Wideband (UWB), Narrow band (NB), Human-Body Communication (HBC) [75]. All of them extract to the conclusion that propagate physical layer operations based on radio frequency, whereas human body communication based on non-radio frequency. Numerous researchers have been scrutinizing inside the human body by narrowband radio signals and ultra wide band in the path lose [72].

Multiple frequency bands use monitoring operation of the physical narrowband with 402-405 MHz frequency in implantable devices. Three various bands of frequency (863-956 MHz) are for coverage wearable applications, and from 2360 to 2400 MHz they are for medical applications. Moreover, UWB PHY operates at higher frequency regions, particularly the low (3-5 GHz) and high (6-10 GHz) bands with a channel bandwidth of 499.2 MHz [76]. HBC is

classified in two-body communications channel (BCC) or internal body communications (IBC) [77]. IBC can reuse frequency in the following desirable features, security, and energy [78]. Since NB is lower frequencies, so numerous numbers of healthcare applications are matched.

Table 6 summarizes the characteristics of the body communication channel and internal body communications [72], [79]. HBC has some advantages such as, intrinsic security, saving, energy consumption compared to UWB. Molecular communication use molecules as messages transferred between a sender and a receiver by using nanotechnology for Nano medicine application and alternative of ultrasonic communications [80].

Generally, IBC communication within the body can be categories into two sets based on how the electrical signals are transmitted, Capacitive coupling (electrical field) and the galvanic pair (waveguide) [74]. In both kinds of the sender and receiver, two pairs of electrodes are needed. In the coupling capacitor, only one of the electrodes of the deliver and the receiver is connected to the body, while the other electrode (ground electrode) is floating. In the galvanic pair method, both the sender and the receiver electrode are connected to the human body [78].

Capacitive theory with communication within the body by coupling capacitor engender is attached from human body to the around environment. The signal is created between transmitter and receiver channel by creating a loop through the surrounding. The transmitter signal electrode genders the electric field in the human body. The electrical signal is controlled by an electrical potential and acts as a conductor with the earth and return path in the body [79]. On the other hand, a galvanic couple of pairs of alternating current is achieved in the human body, which is controlled by the AC current in the body as a deliberation line [77]. Using various electrical signals between the electrodes of the transmitter in the galvanic coupling with communications inside the body, main release of the two signal transmitter electrode and a weak signal in the receiver occurs by two electrodes [74]. Generally, ion content in the human body carries information by galvanic coupling method. Table 7 summarizes the capacitive coupling method and compares galvanic coupling [72].

TABLE VI. COMPARISON BETWEEN IBC AND RF

	IBC	RF (NB, UWB)
Communication Medium	Human Body	Air
Frequency Band	Centered at 21 MHz ($f_{BW} = 5.25$ MHz)	Different bands (402 M-10 GHz)
Data Rate	less than 2 Mb/s	less than 13Mb/s
Transmission Range	less than 2 m	10 m
Signal Attenuation	Low	High(Body Shadowing)
On-Body Antenna	No	Yes
Energy Efficiency	High	Low

TABLE VII. COMPARE BETWEEN TWO METHODS OF COMMUNICATION IN WBANS

Galvanic Coupling	Capacitive Coupling
Quality of signal influenced by dielectrics of human tissue.	Quality of signal influenced by the environment around the body.
Lower transmission data rate.	Higher transmission data rate.
Must be connect with body tissue .	Dose not require connect with the human body tissue.
Location base, exact distance and orientation along the body.	Interference the surrounding devices
Modeled by a waveguide.	Modeled by a perfect conductor.
Ground is not require as a refrence.	Ground is require as a refrence.
Domain of signal is the body tissue.	Domain of signal is the environment.

VI. PATIENT MONITORING AND TELEMEDICINE SYSTEMS

Monitoring human activity with WBANs classification are: Remote monitoring (elderly, baby, staff, etc.), security (soldiers), training (sport), emergency situation (rescue, firefighters), safety (elderly, personal safety, etc.) [25].

The recent innovation in telecommunications and information technology provide clinical health care system at a distance. This system improves health care quality and helps the barriers of distance, special in rural communities that they are inaccessible. Developments in the mobile application, to health care system professionals in various locations, permit the patient to share information and discuss issues of helping them to be used in the same place. A telemedicine system through mobile technology can significantly reduce the overall cost and it can save time [81]. The incidence of disease such as kidney problems, Alzheimer's disease, Parkinson disease, anxiety disorder, and infant death syndrome, assistance to the disable people can be reduced by providing health care [82].

Disable people, for example paraplegic diseases used for monitoring the position of the legs and nerves and simulate the positioned of the muscles. BANs for disability people classified in way finding for blind persons, monitoring elderly people, activity monitoring, posture detection, rehabilitation. This kind of device can direct involvement for disabling the person, such as electric wheelchair or control the function invention, for instance fall detection system. In [83] suggested the architecture for fall and accident detection that consist of a gyroscope and accelerometer and a magnetometer that placed on the hip and the user's leg and on the upper torso. The result depicts that this system can investigate and reduce the fall detection and accident in 85/6%.

In chronic diseases that usually take more than three months. The diseases kill 17 million people a year, which can be reduced or prevented by a strategy of suitable health care system. Common chronic diseases exist, for example, asthma cancer, diabetes, and viral diseases such as hepatitis C. In the following, some of the disease can support and monitor, the vital sign of patients are explained.

Diabetes includes a metabolic disease in which blood glucose in the long term is more than one level. Diabetes is resulting not enough insulin production in the pancreas. In the early stages of diabetes, people may have no symptoms. Many people are identified random in a test or during screening. Increasing blood sugar, diabetes symptoms become apparent. Frequent urination, Polydipsia, overeating, weight loss, despite increased appetite; fatigue and blurred vision are common early symptoms of diabetes. Many patients diagnosed with diabetes or have diabetes for several years. Worldwide, more than 246 million people endure from diabetes [13]. A number that is expected to reach 438 million in 2030 to about 7.8 percent of the population accounts for young people. Conclusion monitoring and proper dosage reduce the risk of fainting. By using WBANs to automatic, monitoring diabetes, as soon as high or low level of glucose, a signal can be transferred to the system and alter the patient for doing proper actions.

Cardio Vascular Disease (CVD) is the leading death in the world and includes almost 30% of all deaths globally. Based on the World Health Organization, 17.5 million people worldwide each year die from heart attack or stroke [12]. Most of these deaths could be avoided with suitable medical health care. This is an instance to show the need for constant monitoring of wireless networks and their usefulness in the body.

Numerous of people suffer diabetes or cardiovascular diseases, and percent of population aged 60 years and elderly population will grow in the future that is predicted to prompt to 1200 million people in year 2025. These disease rapid epidemics show many potential customers and the absence of the medical center and staff and nursing homes for older people are observed. WBANs continuously monitor the vital physiological parameters of the body [84]. Therefore, there is no need the patient stays in hospital for a long time and do not spend lots of money for health care. For instance, the place of a wireless sensor network used to monitor a patient's medical body is explained in Fig. 4 [16].

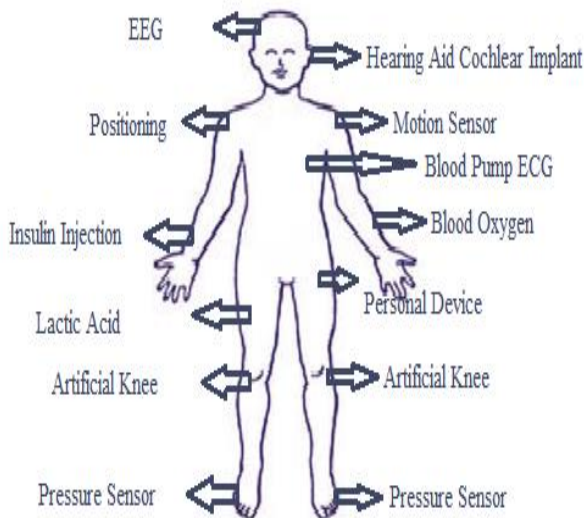


Fig. 4. Example of patients monitoring in WBANs

Different sensors installed on clothes that connect with the body or even under the human skin of a person to measure temperature, control the blood pressure, heart rate, ECG, EEG, respiration rate, SPO2 and after measuring the device; the patient can get medications from the system [16]. Accelerometer sensors are used to monitor and distinguish body posture that placed on some strategically location on the human body. The WBANs has a critical role in real-time monitoring of healthcare. Any wearable sensors monitor a special physiological sign. These drugs can be predetermined and is delivered by an external source or instant after the sensor notice a problem [85].

Cancer is one of the biggest ventures to human life. A series of partial sensors that are able to monitor cancer cells in the human body sensor integrated network and this allows doctors to detect tumors without biopsy. It is estimated that by the National Center for Health Statistics, 2020 with an increase of 50 percent, cancer deaths reach to 15 million.

The epileptic is seizures due to abnormal activity of nerve cells in the brain cortex. Brain imaging and blood tests may diagnose the disease. Epilepsy often confirmed by electroencephalogram (EEG) and imaging. Electroencephalogram (EEG) can help show brain activity increased risk of seizures. In the diagnosis of epilepsy, EEG may help distinguish the kind of seizure or already syndrome. Diagnostic imaging by CT scan and MRI after a febrile convulsion to detect structural problems in and around the brain is recommended [86].

WBANs can also be used to prepare assistance to people who are not acting well. To illustrate, paraplegic patients can be equipped with sensors to determine the position of the legs, or the sensor is connected to the nerve and creates to restore the ability to move. An additional example is the help for the vision. The artificial retina includes a matrix of miniature sensors, which can be implanted in the human eye. Artificial retina chips deliver electrical pulses to the brain and nervous system. The input can be gained locally by light sensor or by an external camera in a pair of sensitive glasses. Therefore, help patients that limited or no eye to see [87].

Body sensor networks for monitoring patients with asthma and allergy factors in the air and provide feedback in real-time to help a doctor [13]. Location-based system was designed, which diagnosed oversees environmental factors and allergy diagnosis in patients [88]. Approximately 300 million people in worldwide suffer from asthma and 250000 people death every year death.

There are other survey studies in the literature [30], [89], [90]. This overview currently explains thousands of opportunities where wireless sensor networks are suitable for body. The significant characteristic of all these programs is that the wireless sensor network is used to improve the quality of the user's life.

VII. CONCLUSION

The accelerating health care cost and high demand for medical services call for innovative solutions to ensure fast and cost-effective medical monitoring cause for evolution in health care systems. Becoming mature, enough in wireless

communication radio technologies led to emerge WBANs. This network consists of miniature electronics and low-power sensors that attached or implanted on body for transferring information of monitoring patient health in all-day and anywhere. With the current technological evolution, these networks have various usages in different scope not only in medicine, but also in entertainment, fight, travel, industry, game, sport and so on. Thus, recently researchers focused on issues related to improve communication and applications.

We believe that, using WBANs can cause patient no longer stays in the hospital and attains easier communication with doctors and gain online medical consultation and save time and cost for care. These technologies can regard the next step in improving personal health care systems. In soon, wearable BANs could be used for virtual social interactions: all data can be swapped through BANs when meeting each other or share in social networks. This information can gather processing and management by ad-hoc mobile sensors and different applications in events and analysis information for preventing disasters and prevention medical emergency.

In this survey, we have reviewed the current research on WBANs. In order to find and investigate the most relevant research articles in this area. First, we present some fundamental mechanism and concept in WBANs and review challenges and numerous WBANs applications. Then, we highlighted to need to be addressed to make WBANs for a wide range of applications for researchers and developers.

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