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Study and Analysis of Scientific Scopes, Issues and Challenges towards Developing a Righteous Wireless Body Area Network

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Abstract*—The escalating applies of wireless networks and the constant tininess *of electrical devices have empowered the development of Wireless Body Area Network (WBAN). In this network various sensors are attached on clothing or on the body or even implanted under the skin. This network enables medical doctor to distantly monitor essential signs and organs of patients and provide real time opinions for medical diagnosis. The numerous new, realistic and ground-breaking applications of WBAN facilitate to advance health care and the quality of life. By means of a WBAN, the patient experiences a superior and greater physical mobility and is no longer constrained to reside in the hospital. The amalgamation of low-power, miniaturized, lightweight sensors nodes lead to the development of a proactive and unobtrusive Wireless Body Area Network (WBAN). A WBAN presents a long term health monitoring of a patient devoid of any restriction on his/her normal daily life activities. It is the easiest and fastest way to monitor patient's health status effectively. Although WBAN is the efficient way to diagnose patients existing condition but the challenges related to developing an effective WBAN is not studied and analyzed significantly. The effectiveness of the WBAN strongly depends on controlling the energy consumption of sensor nodes. To achieve energy efficiency, low duty cycle MAC protocols are used. In this paper, we discuss about the basic idea and key components of WBAN, basic difference between wireless sensor networks (WSN) and WBAN, technical challenges, and its importance, quality of service (QoS) and security, analysis of MAC features, various applications, different sensors; physiological signals, their frequency; different data rate, latency of WBANs, issues related to energy or power efficiency, and existing WBAN technologies.Finally, the open research issues and challenges are also pointed out.

***Index Terms*—WBAN, WSN, MAC, QoS, Energy efficiency**

I. INTRODUCTION

The elderly people in various countries and their poverty are unable to manage the rising expenses of health care which is the vital point to prompt beginning of novel technology motivated improvement to existing health care applications. Small and intelligent medical devices namely sensors are the recent advances in electronics which can be used on, around, in or implanted in the human body. These devices need to send their data to an external medical server where it can be analyzed and stored. Wired connection for transferring this data occupies a high cost for operation and preservation where the wireless technology enables an easier application which is cost efficient [1]. This also helps the patient to feel better physical mobility and is no longer constrained to reside in a health care clinic. This is the next step in enhancing the personal health care where e-health is defined as the health care practice supported by electronic processes and communication which is more mobile and is referred to as m-health [2]. In order to completely utilize the profits of wireless technology in telemedicine, e-health and m-health, a wireless on-body network or a Wireless Body Area Network (WBAN) appeared around 2001 by Van Dam et al. [3] and several researchers found the same interest in this new research area [4]-[8]. Using a wireless Body Area Network the results of patient's health measurements can be recorded over a longer period of time, improving the quality of the measured data [9]. The tiny and intelligent devices like sensors are used externally or internally to measure certain parameters of the human body, examples include measuring the heartbeat, body temperature or recording a prolonged electrocardiogram (ECG). On the other hand actuators are used for some specific actions according to the data they receive from the sensors or through interaction with the user. In order to establish communication between devices like sensors, actuators, receiver, transceivers the researchers might be used the current techniques like Wireless Sensor Networks (WSNs) and ad hoc networks and current protocols. But these are not well suited for WBAN because of its typical, tiny properties. The major challenges of WBAN are differentiated with those of in WSN are illustrated in Table I.

Technical properties and major issues of WBAN technology are illustrated in Table II which is used by the IEEE [10]. In this research paper we present a detail analysis of the issues, scopes, and challenges in Wireless Body Area Networks. Our objective is to make available and endow with a better understanding of the current research issues in this up-and-coming meadow. The remainder of this paper is organized as follows. Section 2, the patient monitoring and WBAN applications are discussed in Section 3 the key components of WBAN is discussed in Section 4 physiological signals. Section 5 power efficient WBAN systems is discussed, in Section 6 MAC features are analyzed towards developing an energy efficient WBAN, in Section 7 QoS issues and reliability are explained, in Section 8 available wireless technology and WBAN described, and in Section 9 open research issues are mentioned and finally we conclude the paper in conclusion section.

Table I: Differences between WSN and WBAN

Challenges	WSN	WBAN
Scale	Monitored environment (m/km)	As large as human body parts (millimetres/ centimetres),

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		Human body (cm/m)
Node number	Many redundant nodes for wide area coverage	Fewer, more accurate sensors nodes required (limited by space)
Nodes' Result accuracy	Through node redundancy	Through node accuracy and robustness
Node tasks	Node performs a dedicated task	Single sensors, each performs multiple tasks
Node size	Small is preferred, but not important	Pervasive monitoring, small is essential
Network topology	Very likely to be fixed and static	More variable due to body movement
Data rates	Homogeneous	Heterogeneous WBAN may occur in a more periodic manner and stable data rate.
Latency	Nodes can be physically unreachable after deployment. It may be necessary to maximize battery life-time in WSN at the expense of higher latency.	Replacement of batteries in WBAN nodes is much easier done when energy conservation is definitely beneficial.
Node replacement/ Access	Performed easily, nodes even disposable	Replacement of implanted nodes difficult
Node lifetime	Several years/months	Several years/months, smaller battery capacity
Power supply	Accessible and likely to be replaced more easily and frequently	Inaccessible and difficult to replace in an implantable setting
Power demand	Likely to be large, energy supply easier	Likely to be lower, energy supply more difficult
Energy scavenging source	Most likely solar and wind power	Most likely motion (vibration) and thermal (body heat)
Biocompatibility	Not a consideration in most applications	A must for implants and some external sensors
Security level	Lower	Higher, to protect patient's information
Context awareness		Very important because body physiology is very sensitive to context change
Impact of data loss	Likely to be compensated by redundant nodes	More significant, may require additional measures to ensure QoS and real-time data delivery
Wireless technology	Bluetooth, Zigbee, GPRS, WLAN,…	Low power wireless technology required, with signal detection more challenging
Mobility	WSN nodes are usually considered stationary.	WBAN users may move around. WBAN nodes share the same mobility pattern.
Authenticity of nodes installed on correct place	No need	Needs to install sensors on correct place and correct person
Real time communication	Not required in all the cases	Need grantee of accuracy and on time delivery of message
Architecture	Wires nodes communicate in WiFi are ad-hoc mode fashion	Sensors, actuators, and central unit communicate through PDA

Table II: IEEE specification for WBAN technology

Distance/ operating space	2 m standard and 5 m special use; in, on, and around the body
Network Density	2-4 nets/m2
Network Size	Max : 100 devices/network, modest < 64 devices per BAN
Target lifetime	Up to 5 year for implants Up to 1 week for wearable Ultra-long for implants Long for wearable
Target frequency bands	MedRadio, ISM, WMTS, UWB Global Unlicensed and Medical bands
Power Consumption	~1mW/ Mbps, support for several power management and consumption scheme
Peak power consumption	Between 0.001–0.1mW in stand-by mode up to 30mW in fully active mode Scalable
Network Throughput	100 Mbps Max
Data rate	From sub kb/s up to 10 Mb/s Scalable
MAC	Low power listening, wake up, turn-around and synchronization Scalable, reliable, versatile, self-forming
Topology	Self-forming, distributed with multi-hop support Star, Mesh or Tree
Device Duty cycle, Very Low, Low, and High duty cycle modes	From 0.001% up to 100% Adaptive, Scalable Allows device driven degradation of services

Startup Time	< 100 µs or < 10 % of Tx slot
Latency	10 ms
Network setup time	< 1 sec (Per device setup time excludes network initialization)
Coexistence	Simultaneous co-located operation of up to 10 independent BANs
QoS support and differentiation	• BER: from 10–10 to 10–3 • P2P latency: from 10ms – 250ms • Reservation and prioritization Real-time waveform data, periodic parametric data, episodic data and emergency alarms
Future proof	Upgradeable, scalable, backwards compatible, effective sleep mode, peer to peer, point to multi point communication , QoS and guaranteed bandwidth, high privacy and security
Fault tolerance	Ability to isolate and recover from failures. Self healing capability; No single point of failure
Dynamic Environment	Seamless operation of multiple nodes moving in and out of range of each other; Body shadowing (twisting, turning, running), Attenuation
Security	Authentication, Authorization, Privacy, Confidentiality, Encryption, Message integrity; Many levels, long term, short term, light weight
Safety/Biocompatibility	Meet regulatory requirements. e.g., FDA, SAR and HIPPA; No harmful effects of long term continuous use
Ergonomic consideration	Non-invasive, unobtrusive, small size, weight and form-factor Size, shape, weight and form factor restricted by location and organ
Reprogramming, Calibration, Customization	Ability to reprogram, recalibrate, tune and configure devices wirelessly; Personalized, integrated, configurable and context aware services
Antenna Pattern	Omni Directional, small, and flexible

II. Patients' Monitoring And WBAN Applications

Patients continuous monitoring is vital and the usefulness of WBAN regarding this issue is easily understandable. The researchers from many medical disciplines have already presented that the main cause of death in the world is Cardio Vascular Disease (CVD), representing 30% of all global deaths. According to the World Health Organization, world-wide about 17.5 million people die of heart attacks or strokes each year; in 2015, almost 20 million people will die from CVD. These deaths can often be prevented with proper health care [11]. Worldwide, more than 246 million people suffer from diabetes, a number that is expected to rise to 380 million by 2025 [12]. Frequent monitoring enables proper dosing and reduces the risk of fainting and in later life blindness, loss of circulation and other complications [12]. Applications of WBAN can categorized depending on the domain of application. The major WBAN applications for medical treatment, healthcare and diagnosis are illustrated in the Table III mentioned bellow.

Table III: Applications of WBAN

Field of Applications/Diseases	Functions of WBAN
Cardiovascular Disease (CVD): 30% of all global deaths17.5 million Deaths per Year, 2015, expected 20 million patients [13]	The corresponding medical staff can do treatment preparation in advance as they receive vital information regarding heart rate and irregularities of the heart
Paraplegic: 2 million people worldwide, live with a spinal cord injury (SCI). Each year 11,000 new injuries are reported. Every 49 minutes a new injury occurs [14]	Interaction between the data from the sensors and the actuators makes it possible to restore the ability to move [15]
Broken teeth & building crowns and bridges	To reduce errors and improve productivity in the development of dental prosthetics
Cancer: 12.7 million cancer cases and 7.6 million cancer deaths are estimated to have occurred in 2008 [16]	Sensor can be placed in the suspect locations and doctor can start treatment as soon as a cancer cell detected.
Alzheimer, depression, Hypertension: More than 65 year old citizen. 357 million in 1990 Expected 761 million in 2025	Wireless sensor network can help homebound and elderly people who often feel lonely and depressed by detecting any abnormal situation and alerting neighbors, family or the nearest hospital.
Diabetes: Worldwide, more than 246 million people, expected to rise to 380 million by 2025 [17]	If the sensor monitors a sudden drop of glucose, a signal can be sent to the actuator in order to start the injection of insulin. Consequently, the patient will experience fewer nuisances from his disease [18]
Asthma: 300 million people worldwide, 250,000 annual deaths [19]	Sensor nodes that can sense the allergic agents in the air and report the status continuously to the physician and/or to the patient himself [20]
Defective Tooth positions treatments [21]	For observing the patient's dental retainer usage.
Epileptic Seizures Strike: Early Warning 275,000 deaths from stroke each year [22]	The portable unit "Mobi" is designed to detect abnormal brain activity that happens before a seizure. When the signs of electrical trouble are picked up the device will

	transmit a warning to a receiver and the patient could then take steps to set down or tell someone.
Pain treatment	Actuator is a spinal cord Stimulator implanted in the body for long-term pain relief.
Visually impaired: 285 million people are visually impaired, worldwide: 39 million are blind and 246 have low vision [23]	An artificial retina, consisting of a matrix of micro sensors, can be implanted into the eye beneath the surface of the retina. The artificial retina translates the electrical impulses into neurological signals. The input can be obtained locally from light sensitive sensors or by an external camera mounted on a pair of glasses
High Blood pressure: High blood pressure contributes to more than 12.7 million strokes worldwide. [22]	If the sensor monitors a change in blood pressure more than threshold value, a signal can be sent to the actuator in order to start the injection medicine. Consequently, there are lesser chance of strokes
Parkinson's disease: An estimated seven to 10 million people worldwide are living with Parkinson's disease [24], [25]	estimate the severity of tremor, bradykinesia, and dyskinesia from accelerometer data and performed a thorough assessment [26]
Renal failure 2008, 2 million people with end-stage kidney disease due to diabetes in United States [17]	Can provide portable, noninvasive fall risk assessment in end stage renal disease patients on hemodialysis
Post operative monitoring	the patient will no longer need to stay in bed, but will be able to move around freely

III. THE KEY COMPONENTS OF WBAN

Towards bridging the physical world and electronic systems of WBAN the researchers, academicians, industrial personnel must use sensors as the central and key component. The frequency and amplitude range of human physiological signals are comparatively low; thus, a low sampling frequency and low data transmission rate would be sufficient. However, what kind of and how many sensors a WBAN system employs depend largely on the application scenario and the system infrastructure. To better monitor a human's vital signals, behavior, and surrounding environment, a wide range of commercially available sensors can be deployed, such as accelerometer and gyroscope, ECG, electromyography (EMG), and electroencephalography (EEG) electrodes, pulse oximetry, respiration, carbon dioxide (CO_2), blood pressure, blood sugar, humidity, and temperature sensors etc [27].These will help to measure the physiological data characteristics, as shown in Table IV**.** It also notices the wide variation in data rate, bit error rate (BER), delay tolerance, duty cycle, and lifetime, which requires scalable solutions with quality of service (QoS) provisions.

Table IV: Sensors' characteristics used in WBAN

Sensors	How it works	Data rate(kbps), Bit error rate (BER), Setup time, Duty cycle, Desired battery lifetime, P2P latency
Accelerometer	Measures the acceleration relative to freefall in three axes	High, <10 kbps up to 12 nodes, $<10^{-10}$, <3s, <1%, >1 week, < 250 ms
Gyroscope	Measures the orientation based on the principles of angular momentum	High, <10 kbps up to 12 nodes, $<10^{-10}$, <3s, <1%, >1 week, < 250 ms
ECG	Measures potential difference across electrodes put on corresponding parts of the body	High, 6.0, $<10^{-10}$, <3s, <10%, >1 week, < 250 ms
EMG	Measures potential difference across electrodes put on corresponding parts of the body	High, 1.536 Mbps for up to 6 nodes,$<10^{-10}$, <3s, <10%, >1 week, < 250 ms
EEG	Measures potential difference across electrodes put on corresponding parts of the body	High, 3.6, $<10^{-10}$, <3s, <10%, >1 week, < 250 ms
Pulse Oximetry	Measures ratio of changing absorbance of the red and infrared light passing from one side to the other of a thin part of the body's anatomy	Low, $<10^{-10}$, <3s, <1%, >1 week, < 250 ms
Respiration	Uses two electrodes, cathode and anode covered by a thin membrane to measure the oxygen dissolved in a liquid	Low, 0.24; $<10^{-10}$, <3s, <1%, >1 week, < 250 ms
Carbon dioxide	Uses the infrared light and measures the	Low, $<10^{-10}$, <3s, <1%, >1 week, < 250 ms

	absorption of the gas presented	
Blood pressure	Measures the systolic pressure (peak pressure) and diastolic pressure (minimum pressure)	Low, 0.05, <10 kbps up to 12 nodes, $<10^{-10}$, <3s, <1%, >1 week, < 250 ms
Blood sugar	Traditionally analyzes drops of blood from a finger tip recently, uses non-invasive method including a near infrared spectroscopy, ultrasound, optical measurement at the eye, and the use of breath analysis	Low, $<10^{-10}$, <3s, <1%, >1 week, < 250 ms
Humidity	Measures the conductivity changes of the level of humidity	Very low
Temperature	Uses a silicon integrated circuit to detect the temperature changes by measuring the resistance	Very low, 0.0024-0,05; $<10^{-10}$, <3s, <1%, >1 week, < 250 ms
Drug delivery		<16
Deep brain simulations		<320, $<10^{-3}$, <3s, <50%,>3 years, < 250 ms
Hearing Aid		70, $<10^{-10}$, <3s, <10%, >40 hours, < 250 ms
Capsule Endoscope		500, $<10^{-10}$, <3s, <50%, >24 hours, < 250 ms
Drug Dosage		<0.5, $<10^{-10}$, <3s, <1%, >24 hours, < 250 ms
Audio		1 Mbps for 3 nodes, $<10^{-5}$, <3s, <50%, >24 hours, < 100 ms
Video/ Medical Imaging		<10 Mb/s for 2 node, $<10^{-3}$, <3s, <50%, >12 hours, < 100 ms

IV. PHYSIOLOGICAL SIGNALS

Physiological signals are the raw data that we must send and receive through wireless technology like sensors as shown in Table V. Most physiological signals are low frequency in nature and occupy a small information bandwidth. At such low frequencies and low amplitudes, some problems inherent to circuits need additional attention [27].

Table V: Physiological signal and its parameters

Physiological Signal	Signal frequency range/ Bandwidth (Hz)	Range of parameter
ECG signal	0.01-250	0.5-4 mV
Respiratory rate	0.1-10	2-50 breaths/min
Blood pressure (BP)	0-50	10-400 mg/Hg
Blood flow	0-20	1-300 ml/s
Blood pH	0-2	6.8-7.8 pH
EEG	0.5-60	3µV-300µV
Body temperature	0-0.1	32-40 ^{0}C
EMG (Electro myogram)	10-5000	10µV-15mV
GSR (Galvanic Skin Reflex)	0.03-20	30µV-3mV
Cardiac rate	0.4-5	
Oximetry	0-30	
Arterial pressure	0-60	
Nerve potentials	Max 10,000	0.01-3 mV

V. POWER EFFICIENT WBAN SYSTEM

Several attributes need to be considered for the design of an energy-efficient MAC protocol for a WBAN. The prime attribute is energy efficiency. WBAN devices, being operated by a battery require stringent restriction on the use of energy resources. To achieve this goal, design of energy-aware communication protocol is required. Energy-efficiency can be increased by minimizing the energy wastes identified below. However, WBANs are intended to support life saving critical applications. Hence reliability, safety and security are considered important metrics besides energy efficiency. The QoS is also an important factor of a good MAC protocol. Other parameters of importance include scalability, adaptability to changes in network topology, throughput, jitter, latency and bandwidth utilization. Throughput, jitter and latency requirements depend on the nature of the application. In case of medical applications, latency should be less than 125ms for QoS packet, whereas in case of consumer electronics (CE) applications, jitter and latency should be less than 50ms and 250ms, respectively [28].

Almost all the devices in wireless sensor networks are battery operated therefore, power challenge is present in almost every area of application of wireless sensor networks, but limitation of a smart sensor implanted on a person still poses even further challenge. In a full active mode a node can't operate more than a month because a typical alkaline battery provides about 50 watt-hours of energy [29]. Any commercial applications have to guarantee that all the devices will work for at least a year without any maintenance / replacement. For example heart pacemaker's devices. The developers have to design better scheduling algorithms and power management schemes to deal with these power issues. Critical parameters in the design of a power efficient WBAN system are described in Table VI.

Table VI: Parameters in the design of power efficient WBAN and their functions

Parameter	Functions
Average bandwidth	Influences the active communication time of wireless controllers and therefore the duty cycle of the system
Maximum required Bandwidth	Critical for bursts of urgent messages, and affects the maximum latency for data transmissions
Active power	Determines the type, size and weight of the battery, as well as the battery life.
Standby power	Determines the maximum battery life, as a function of the system duty cycle
Startup time	Represents the overhead and determines the efficiency of individual transmissions
Communication Setup	Protocol-related timing parameter that represents time necessary to (re)establish a connection between nodes or a node and a gateway
Standards based communication technology	Influences the system interoperability and application development time
Protocol stack size and processing requirements	Determine characteristics of the wireless sensor Platform

VI. ANALYSIS THE MAC FEATURES TOWARDS DEVELOPING EFFICIENT WBAN

The main schemes of media access control (MAC) protocols for WBANs are grouped into contention-based or random access and contention free or scheduled based protocols. Contention-based MAC such as Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) protocols nodes competes for the channel to transmit data. Nodes have to perform CCA before transmission of data. If the channel is busy, the node defers its transmission till it becomes idle. The Time Division Multiple Access (TDMA) is a scheduled based multiple access technique where transmission of packets are managed in the form of time frames and time slot. A time slot can be seen as a dedicated transmission resource used to carry data with minimum or no overhead. In a TDMA, the channels are divided into fixed/variable time slots which are assigned to a particular sensor node that transmit during its slot period. However, other scheduled based MAC like Code Division Multiple Access (CDMA) and Frequency Division Multiple Access (FDMA) protocols are not suitable in the context of sensor networks, since the sensors are often constrained in terms of limited frequency bands and computation capability. CSMA based MAC protocols such as S-MAC [30], T-MAC [31], B-MAC [32] and WiseMAC [33] have not proved to be energy efficient for WBANs. TDMA based contention-free MAC protocols such as PACT [34], LEACH [35], FLAMA [36] and HEED [37] are unable to satisfy the stringent requirements of WBAN. Other MAC protocols such as Preamble-based TDMA [38], Heartbeat Driven MAC (H-MAC) [39], Reservation-based Dynamic TDMA (DTDMA) [40], Distributed Queuing Body Area Network (DQBAN) [41], [42] and [43] have also been investigated for WBAN in recent literature. A comparison between TDMA and CSMA protocols are summarized in Table VII as reported in literatures.

Table VII: Comparison between TDMA and CSMA/CA (Key features of WBAN MAC Protocols)

Performance parameters (MAC Features)	Scheduled MAC:TDMA	Random Access MAC:CSMA/CS
Power consumption, energy efficiency	Low	High
Traffic handling capability	High	Low
Bandwidth utilization	Maximum	Low
Network Scalability	Poor	Good
Effect of packet failure, Delay/Loss	Fixed/Latency	Variable/Low
Transmission efficiency	High	Very Low
Time Synchronization	Required/Essential	Not applicable

VII. QUALITY OF SERVICE ISSUES AND RELIABILITY

According to [44], [45], [46] proper quality of service (QoS) handling is an important part in the framework of risk management of medical applications. A crucial issue is the reliability of the transmission in order to guarantee that the monitored data is received correctly by the health care professionals. The reliability can be considered either end to-end or on a per link base. Examples of reliability include the guaranteed delivery of data (i.e. packet delivery ratio), in-order-delivery. Moreover, messages should be delivered in reasonable time. The reliability of the network directly affects the quality of patient monitoring and in a worst-case scenario; it can be fatal when a life-threatening event has gone undetected. WBAN QoS for all network layers is described in Table VIII bellow.

Table VIII: QoS issues in WBAN

Layers	QoS issues
Application Layer	It includes system lifetime, response time, data novelty, detection probability, data reliability and data resolution.
Transport Layer	It includes reliability, bandwidth, latency, and cost.
Network Layer	It includes path latency, routing maintenance, congestion probability, routing robustness and energy efficiency.
Connectivity Maintenance Layer	it includes network diameter, network capacity, average path cost, connectivity, robustness and

	connectivity maintenance
Coverage Maintenance Layer	It includes coverage percentage, coverage reliability, coverage robustness, coverage maintenance.
MAC Layer	It includes communication range, throughput, transmission reliability, and energy efficiency
Physical Layer	It includes physical capabilities impose resource

VIII. AVAILABLE WIRELESS TECHNOLOGY AND WBAN

We analyzed several wireless technologies that are available and foremost contenders in the emerging market of WBANs. Table IX summarizes the PHY characteristics of these technologies along with their merits and demerits. Note that end-to-end performance is determined by the complete protocol stack (i.e., including PHY and upper protocol layers). The names of technologies are: Bluetooth (http://www.bluetooth.com), Bluetooth Low Energy (BTLE), ZigBee (http://www.zigbee.org), ANT (http://www.thisisant.com), Sensium (http://www.toumaz.com), Zarlink (http://www.zarlink.com), BodyLAN (www.fitlinxx.com) and Z-Wave (www.zwave.com).

Table IX: Existing wireless technology for WBAN

Technology	PHY Characteristics: (Spectrum, Modulation, Channels, Data rate, Operating space, Peak Power, nJ/b, Topology, Join time)	Merit-Demerit
Bluetooth classic	2.4 GHz, GFSK, 79,1–3 Mb/s, 1–10 m on-body only, ~45mA@3.3V, 50, Scatter net, ~3 s	Established standard, widespread adoption in cell phones and laptops, health device profile defined, sufficient data rate, low cost Higher power, limited scalability, limited QoS, coexistence with ISM band technologies, limited security, on-body only
Bluetooth Low Energy	2.4 GHz, GFSK, 3,1Mb/s, 1–10 m on-body only, ~28mA @3.3V, 92, Scatter net, <100ms	Interoperable with Bluetooth, lower power than Bluetooth, leverage Bluetooth brand Compatibility requirements limit design freedom, limited scalability, limited QoS, coexistence with ISM band technologies, on-body only
ZigBee	2.4 GHz, O-QPSK,16,250 kb/s, 10–100 m on-body only, ~16.5mA @3.3V, 119, Star, Mesh; 30ms	Emerging standard, healthcare profile defined, lower power than Bluetooth, scalable, smaller memory footprint, Low data rate, limited QoS, coexistence with ISM band technologies, on-body only
ANT	2.4 GHz, GFSK, 125,1Mb/s, 10–30 m on-body only, ~22mA @3.3V, 73, Star, Tree or Mesh; Not defined	Simple protocol, low power, healthcare device profiles defined, smaller footprint Proprietary, limited throughput, limited QoS, coexistence with ISM band technologies, general-purpose design, on-body only
Sensium	868 MHz-915 MHz, BFSK, 16,50 kb/s, 1–5 m on-body only, ~3mA @3.3V, 72, Star, <3 s	Ultra-low-power, custom designed for BANs Proprietary, low data rate, limited QoS, coexistence with ISM band technologies
Zarlink ZL70101	402–405 MHz, 433–434 MHz, 2FSK/4FSK, 10 MedRadio, 2 ISM, 200–800 kb/s, 2 m on-body only, ~5mA @3.3V, 21, P2P, <2 s	Ultra-low power, Med Radio compliant, custom designed for implants Proprietary, implants only

IX. OPEN RESEARCH ISSUES

Although a lot of research and examine are going on, still a lot of open issues exist, they are:

- The propagation of electromagnetic waves in and on the body and a few models for the physical layer are proposed.
- New emerging technologies such as galvanic coupling and transformation of information via the bones offer promising results and need to be investigated more thoroughly.
- On the data link layer, more WBAN specific MAC-protocols need to be developed. A BAN needs efficient handling of resources. To maintain a high performance and smooth flow in the network, it should be as hassle-free as possible in terms of operations. Power saving and low delay are the important factors. Hence, we evidently think that a MAC protocol for BAN should consider the following design issues:
- Minimize power consumption to increase the lifetime of the nodes
- Maximize sleep time for a node

- Minimize unnecessary wakeup periods to save power
- Minimize overheads (e.g. control packets overheads) in the Network
- Minimize idle listening time
- Minimize collision and retransmission of a packet
- Minimize delay
- Efficient and quick response to emergency situations with minimum delay
- The mobility of the nodes of WBAN.
- Additional low-power features such as an adaptive duty cycle for lowering the idle listening and overhearing,
- The use of the human physiology such as heart beat to ensure time synchronization.
- Concerning the network layer, a promising research track is the combination of thermal routing with more energy efficient mechanisms.
- More efficient QoS and reliability mechanisms are needed.
- Mobility support embedded in the protocol
- Security
- Inter operability issue.

With an orderly combination of lower energy protocols and energy scavenging, the optimal solution for achieving independent Wireless Body Area Networks can be reached. For a WBAN, energy scavenging from on-body sources such as body heat and body vibration seems very well suited. The definitive objective is to produce a small and smart band aid containing all necessary technology for sensing and communication with a base station.

X. CONCLUSION

Wireless Body Area Network is a promising technology that can revolutionize next-generation healthcare and entertainment applications. WBAN brings out a new set of challenges in terms of scalability, energy efficiency, antenna design, QoS, coexistence, interference, mitigation, security, and privacy to name a few, which are highlighted in this article. We also discussed the state-of-the-art technologies and MAC standards relevant to WBANs, and their merits and demerits. WBAN standard formed by IEEE 802.15.6 Task Group also discussed. In this paper we presented a complete appraisal and outlook of several promising and potential fields of WBAN research arenas and enabling technologies, including application scenarios, sensor/actuator devices, radio systems, and interconnection of WBANs. WBAN skills, technology and tools need the blessing of key stakeholders in the medicine, healthcare, and hospital domain including the medical electronics industry, patients, physicians, caregivers, policy makers, patient advocacy groups, and payers (insurance companies) for it to become the omnipresent technology. Educators, engineers, researchers, and practitioners from manifold disciplines must come together and must struggle hard to defeat technical roadblocks in order to bring the vision of a ubiquitous healthcare network to reality.

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