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Research Paper

TECHNOLOGIES AND APPLICATIONS OF WIRELESS BODY AREA NETWORK: A REVIEW

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Recent advances in micro electronics, physiological sensors, low-power integrated circuits and wireless communication has allowed the realisation of Wireless Body Area Networks (WBAN), which are used for health monitoring, athletic guidance, monitoring traffic, crops, infrastructure etc. The body area networks (BAN) are low power, miniaturized, inexpensive, large scale multifunctional network. It allows continuous health monitoring of a person with real-time updates of medical records through the Internet. As a result, it decreases cost and regular visits to the doctor and also saving the human life's when unpredictable health condition occurs. This paper review the key aspects of WBAN, its architecture, standard technologies, challenging issues and applications in medical and non medical fields.

Keywords: Wireless Body Area Network (WBAN), Zigbee, Bluetooth, Channel Models

INTRODUCTION

Now-a-days the health conditions are unpredictable and also with ageing of the population, existing medical resources cannot satisfy future healthcare demands of seniors and patients. Resources are limited and it is impossible for many people to afford long-term hospital stays due to economic restrictions, work, and other reasons. As a result, wireless monitoring medical systems will become part of mobile healthcare centres with real-time monitoring of health conditions by the technology of Wireless body Area network (Zhang *et al*., 2005). In WBAN, a number of intelligent physiological sensors can be integrated into a wearable wireless body area network, which can be used for detection of health conditions of the people. The implanted sensors in the human body will collect various physiological changes in order to monitor the patient's health status irrespective of their location. The information

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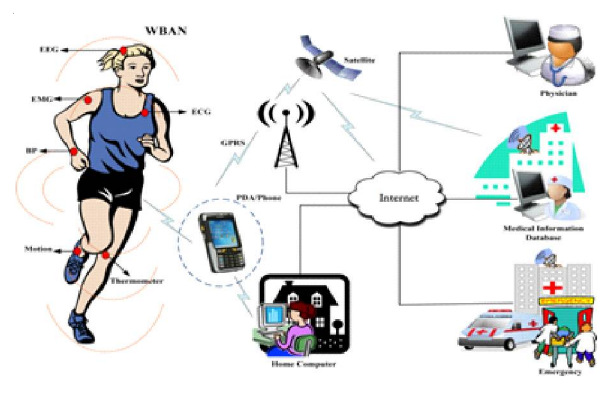
will be transmitted to an external processing unit without any connection between them (Wireless). This device will instantly transmit all information in real time to the doctors throughout the world. If an emergency is detected, the physicians will immediately inform the patient through the computer system by sending appropriate messages or alarms (www.lifewire.com/introduction-to-body-area-networks-817364).

Generally, there are two types of devices: sensors and actuators. The sensors are used to measure certain parameters of the human body, either externally or internally. Examples are measuring the heartbeat, body temperature or recording a prolonged electrocardiogram (ECG) etc. The actuators (or actors) on the other hand do some specific actions according to the data they receive from the sensors or through interaction with the user. E.g., an actuator equipped with a built-in reservoir and pump administers, injects the correct dose of insulin to the diabetic people based on the glucose level measurements. Interaction with the user or other persons is usually handled by a personal device called PDA or a smart phone which acts as a mediator for data of wireless devices (Kiran Pooja Ahlawat, 2015).

WBAN ARCHITECTURE

Figure 1 shows the secure 3-level WBAN architecture for medical and non-medical applications. Level1 contains in body and on-body BAN Nodes or sensors (BNs) such as Electrocardiogram (ECG) – used to monitor electrical activity of heart, Oxygen saturation sensor (SpO2) –used to measure the level of oxygen and Electromyography (EMG) – used to monitor muscle activity (Chen *et al*., 2011).

Figure 1: Architecture of WBAN



The wireless network nodes can be implemented as tiny patches or incorporated in clothes or shoes. These network nodes continuously collect the raw information and process it, store them locally, and send them to the personal server (Emil Jovanov *et al*., 2005). The wireless sensor nodes are of minimal weight, miniature form-factor, low-power operation to permit prolonged continuous monitoring, seamless integration into a WBAN, standard-based interface protocols, and patient-specific calibration, tuning, and customization **(**Emil Jovanov *et al*., 2005).The information between devices propagates in the form of waves. The propagation frequency of different nodes is different and is divided into various channel models.

Channel Models for WBAN

In WBAN systems, information from devices which are close to or inside the human body propagates as Electromagnetic waves. These waves experience some losses caused by energy absorption, reflection, diffraction and shadowing by body tissues and body posture. So, the human body will not become an ideal medium for the propagation of radio waves (Sai Sanath Kumar *et al.*, 2016). The various channel models for WBAN are:

- Implant node: This is the node placed just below the skin of a human body to propagate further deeper into the body tissues.
- Body Surface node: This is the node placed on the surface of the human skin or at most 2 centimetres away.
- External node (Gateway Node): This is the node placed away from the body that is not in contact with human skin.

These are some scenarios for which the devices are operating. These scenarios along with their description and frequency bands are listed in Table 1 and are determined based on the location of the communicating nodes (*i. e.,* implant, body surface and external). The scenarios are grouped into classes that can be represented by the Channel Models (CM).

Level 2 contains a BAN Network Coordinator (BNC) that gathers patient's vital information in the form of electromagnetic waves from the nodes which contains a small transmitting antenna. The BNC transfer the collected information to our personal computers or to the nearest base station. The base station antenna transmits this information either to the physician or to the database station where the medical information is stored or alerting the ambulance through a satellite (Kiran, Pooja Ahlawat, 2015).

Level 3 contains a number of remote base-stations. When the information is received by physician, he will check the present conditions of the person. If the received information contains critical condition of a person then the details of the person is verified and his current location is tracked. Then an instruction is given to the ambulance by ringing an emergency alarm there by admitting the person in the hospital and certain treatment is provided (Kiran, Pooja Ahlawat, 2015).

STANDARDS OF WBAN

There are certain standards available for the communicating the BANs. They are RFID, Zigbee, Bluetooth, wireless personal area network, wireless local area networks, MICS,

Table1: List of Channel Models in WBAN [7]

Scenario	Description	Frequency Band	Channel Models
S1	Implant to Implant	402-405 MHz	CM1
S2	Implant to Body surface	402-405 MHz	CM2
S3	Implant to external	402-405 MHz	CM2
S4	Body surface to Body surface (LOS)	13. 5, 50, 400, 600, 900 MHz 2. 4, 3. 1-10. 6GHz	CM3
S5	Body surface to Body surface (NLOS)	13. 5, 50, 400, 600, 900 MHz 2. 4, 3. 1-10. 6GHz	CM3
S6	Body surface to external (LOS)	900 MHz 2. 4, 3. 1-10.6 GHz	CM4
S7	Body surface to external (NLOS)	900 MHz 2. 4, 3. 1-10. 6 GHz	CM4

etc. Minute chips, which are usually as a part of wearable gadgets, depending on these standards. The description of some of the standards is as follows:

Bluetooth

Bluetooth technology has the biggest coverage on the market. Bluetooth doesn't focus on the topic of low power consumption, which is most important in WBAN applications. Bluetooth transmitter has a transmit power of 1mW, where WBAN solution can use much lower powers ~100uW than the Bluetooth. This innovation was considered as a short distance wireless communication standard broadly used for concerning a diversity of hand-held gadgets to bear information and voice applications (Luis Filipe *et al*., 2015). Bluetooth devices operates in 2.4 Giga Hertz ISM band, making use of frequency hopping technique amongst 79 MHz channels at a supposed speed of about 1600 hops/sec to trim down interference (Saarika *et al*., 2016).

Zigbee

Zigbee/IEEE 802.15.4 targets low-data-rate and low-power-consumption applications. Basically, the Zigbee Alliance has been working on solutions for smart energy, and home, building, and industrial automation. The Zigbee Health Care public application profile completed their research and submitted their flexible framework that meets Health Alliance requirements for remote health and fitness monitoring (Huasong Cao *et al.*, 2009). It handles complicated communication in low power communication gadgets such as nodes with collision avoidance schemes. It consumes a lesser amount of power of about 60mW and provides a low information rate of 250 kbps (Saarika *et al*., 2016).

UWB

According to the Federal Communications Commission (FCC), UWB refers to any radio technology having a transmission bandwidth exceeding the lesser of 500 MHz or 20 percent of the arithmetic centre frequency. FCC also provides license-free use of UWB in the 3.1–10.6 GHz band to have a relatively low power spectral density emission. This leads to the suitability of UWB applications in short-range and indoor environments, and environments sensitive to RF emissions (e.g., in a hospital) (Huasong Cao *et al.*, 2009).

MICS

MICS is a short range standard. It collects signals from different sensors on the body in a multi-hop arrangement. MICS has low power radiation and thus more suitable for the sensors in ubiquitous health care monitoring (http://fiji.eecs.harvard.edu/CodeBlue).

Bluetooth 3.0 + High Speed

Bluetooth technology was designed as a replacement of RS232 cables, and later evolved to become a widely accepted wireless alternative standard for connecting a variety of personal devices. It is different from others in supporting audio and data traffic streams. This is probably why Bluetooth headsets are seen everywhere. The newly adopted standard was Bluetooth 3.0 + HS which introduces the 802.11 protocol adaptation layer (PAL) into the protocol stack, and increases data rate support from 3 Mb/s to 24 Mb/s, supporting applications like transferring bulk data files. Together with its Low Energy extension, Bluetooth accommodates applications with different data rate, power consumption, and network coverage requirements (Saarika *et al*., 2016).

Sensium

It provides on-body health monitoring applications that makes use of ultra-low power consumption. Sensium creates wireless links to smart phones, thus offering health monitoring applications at a reasonable cost (Wong *et al*., 2009).

Challenges of WBAN

BAN technology is still emerging and there are a lot of problems left to solve. Not considering ethical issues like privacy, there are still plenty of technical challenges that we must overcome before BAN will become an effective solution. The BAN draft submissions have defined solutions for a lot of the basic wireless network protocols, but there is still a large amount of ambiguities and researches must be done to effectively propagate a signal in and around the human body.

Security

There must require a Considerable effort to make WBAN transmission secure and accurate. The patient's database must make secure and should not mingled with another person's database. The data must be received from a dedicated WBAN system. Although security is a high priority in most networks, little study has been done in this area for WBANs. As WBANs are resource constrained in terms of power, memory, communication rate and computational capability, security solutions proposed for other networks may not be applicable to WBANs (Mohsen *et al*., 2015).

Signal and Path Performance

The signal and path loss inside the human body is drastically different than the rules. The rules governing signal and path loss remains the same. Researchers have been able to model a system without signal loss throughout the human body; however the more interesting research involves using the human body as a transmission medium for electrical signals. Marc Wegmueller et al. have attempted to model the conductivity and permittivity of signals sent from one area of the body to another (Erik Karulf, 2008).

Interoperability

WBAN systems would have to ensure seamless data transfer between devices across standards such as Bluetooth, Zigbee etc. to promote information exchange, plug and play device interaction. Further, the systems must be scalable, ensure efficient migration across networks and offer uninterrupted connectivity.

Sensor validation

Pervasive sensing devices are subject to inherent communication and hardware constraints including unreliable wired/wireless network links, interference and limited power reserves. This may result in erroneous datasets being transmitted back to the end user. It is of the utmost importance especially within a healthcare domain that all sensor readings are validated. This helps to reduce false alarm generation and to identify possible weaknesses within the hardware and software design (Donoghue *et al.*, 2006).

Usability

Given the close proximity of users with the BAN technology, the demands on usability are exceptionally high. Zheng et al. noted a usability problem with systems such as Lifeguard and AMON; the technology placed artificial restrictions on the user, which made adoption more difficult. Zheng's group decided to use advances in textile manufacturing to sensing wearable shirts that would actively monitor the wearer (Erik Karulf, xxxx).

System Devices

The sensors used in WBAN would have to be low on complexity, small in form factor, light in weight, power efficient, easy to use and reconfigurable. Further, the storage devices need to facilitate remote storage and viewing of patient data as well as access to external processing and analysis tools via the Internet.

Invasion of Privacy

People might consider the WBAN technology as a potential threat to freedom, if the applications go beyond "secure" medical usage. Social acceptance would be key to this technology finding a wider application.

Data Consistency

Data residing on multiple mobile devices and wireless patient nodes need to be collected and analysed in a seamless fashion. Within body area networks, vital patient datasets may be fragmented over a number of nodes and across a number of networked PCs or Laptops. If a medical practitioner2 s mobile device does not contain all known information then it is unable to take care of patient (Donoghue *et al.*, 2006).

Interference

The wireless link used for body sensors should reduce the interference and increase the coexistence of sensor node devices with other network devices available in the environment. This is especially important for large scale implementation of WBAN systems (Mehmet R Yuce, 2010).

Data Management

As BANs generate large volumes of data, the need to manage and maintain these datasets is of utmost importance (John O' Donoghue and John Herbert, 2012).

Besides, we also have some more challenges like cost, constant monitoring, constrained deployment, consistent performance. The last challenge that BAN technology faces is actually a problem of Human-Computer Interaction (HCI) and how to make this technology usable (Erik Karulf, xxxx).

APPLICATIONS OF WBAN

WBAN applications can be divided into medical and nonmedical applications.

Medical Applications

Cardiovascular Diseases: A WBAN is a key technology to prevent the occurrence of sudden heart attacks, monitors episodic events or any other abnormal condition and can be used for ambulatory health monitoring (Lo and Yang, 2005).

Cancer Detection: Cancer remains one of the biggest threats to the human life. According to National Centre for Health Statistics, about 9 million people had cancer diagnosis in 1999 and this number increases every year. A set of miniaturised sensors capable of monitoring cancer cells can be seamlessly integrated in WBAN. This allows physician to diagnose tumours (http://www. cdc.gov/nchs/Default. htm).

Asthma: A WBAN can help millions of patients suffering from asthma by monitoring allergic agents in the air and by providing real-time feedback to the physician. Chu et al proposed a GPS-based device that monitors environmental factors and triggers an alarm in case of detecting information allergic to the patient (Chu *et al.*, 2006)

Non Medical Applications

Lifestyle and Sports: BANs enable new services and functions for wireless body centric networks including wearable entertainment system (e.g., music entertainment), navigation support in the car or while walking, museum or city guide, heart rate and performance monitoring in sports, infant monitoring, wireless cash card (e.g., display of recent transactions and checking of balance, etc) (Ragesh and Baskaran, 2012).

Military Applications: The opportunities for using BANs in the military are numerous. Some of the military applications for BANs include monitoring health, location, temperature and hydration levels. A battle dress uniform integrated with a BAN may become a wearable electronic network that connects devices such as life support sensors, cameras, RF and personal PDAs, health monitoring GPS, and transports data to and from the soldier's wearable computer. The network could perform functions such as chemical detection, identification to prevent casualties from friendly fire and monitoring of a soldier's physiological condition. Calling for support, his radio sends and receives signals with an antenna blended into his uniform. As a result, BANs provide new opportunities for battlefield lethality and survivability (Ragesh and Baskaran, 2012).

WBAN for animals: Wireless Body Area Network is an extremely useful device. It is deployed for the analysis of various contagious diseases in human beings and animals. Initially, animals health is to be protected which gives us food in the form of milk, eggs, meat, eggs etc. The reason behind this is that human and animals are interdependent on each another which is a symbiotic connection. The applications of WBAN are tabulated in Table1.

Table 2: WBAN Applications [23]

Application Type	Sensor Node	Date Rate	Duty Cycle (per device) %per time	Power Consumption	QOS (Sensitiveto Latency	Privacy
In-body Applications	Glucose Sensor	Few kbps	<1%	Extremely Low	Yes	High
	Pacemaker	Few kbps	<1%	Low	Yes	High
	Endoscope Capsule	>2Mbps	<50%	Low	Yes	Medium
On-body Medical Applications	ECG	3 Kbps	<10%	Low	Yes	High
	SpO2	32 bps	<1%	Low	Yes	High
	Blood Pressure	<10 bps <	<1%	High	Yes	High
On-body Non-Medical Applications	Music for Headsets	1.4 Mbps	High	Relatively High	Yes	Low
	Forgotten Things Monitor	256 Kbps	Medium	Low	No	Low
	Social Networking	<200 Kbps	<1%	Low	No	High

CONCLUSION

Wireless Body Area Networks are a very useful technology which offers a wide range of uses not only to patients but also to the whole society by continuous monitoring. Thus WBANs ensure in improving the quality of life. In this paper, we review on wireless body area network architecture, its standards, challenges and applications.

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