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A Survey on Futuristic Health Care System: WBANs

Ragesh.G.K[a], Dr.K.Baskaran[b] , a*

[a]*Department of Computer Science and Engg,Government College of Technology,Coimbatore-641013,India*
[b]*Department of Computer Science and Engg,Government College of Technology,Coimbatore-641013,India*

Abstract

With the increasing use of wireless networks and miniaturization of electronic Devices has allowed the realization of Wireless Body Area Networks (WBANs). It is one of the latest technologies in health care diagnosis and management. WBAN consists of various intelligent bio sensors attached on or implanted in the body like under the skin. These sensors offer promising applications in areas such as real time health monitoring, interactive gaming and consumer electronics. WBAN does not compel the patient to stay in the hospital thereby giving much physical mobility. This paper presents an overview on the various aspects of WBAN.

Keywords: Wireless body area network; WBANs; Real time health monitoring; Bio sensors; Health care diagnosis;

1. Introduction

The growing cost of healthcare and the aging population in developed countries have introduced great challenges for governments, healthcare providers and healthcare industry. There is great interest in using emerging wireless technologies to support remote patient monitoring in an unobtrusive, reliable and cost effective manner thereby providing personalized sustainable services to patients. Wireless Body Area Networks (WBANs) is one such emerging technology that has the potential to significantly improve health care delivery, diagnostic monitoring, disease-tracking and related medical procedures. A crucial aspect of WBANs is their ability to provide highly reliable communications for medical devices, especially those implanted in the human body. Wireless Body Area Network (WBAN) consists of a number of inexpensive, lightweight, miniature sensors which could be located on the body as tiny intelligent patches, integrated in to clothing or implanted beneath the skin or embedded deeply in to the body tissues. Their main purpose is to enable doctors and other medical staff to safely monitor the health status of patients. This WBAN technology brings affordable and efficient healthcare solutions to people that will improve their quality of life. BANs have many applications in home and health care, sports, ambient systems, pervasive computing,

*Ragesh.G.K. Tel.: +91-9447539622
E-mail address:rageshwarrier@gmail.com.

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and many more areas. Strategically placed wearable or implanted wireless sensor nodes consistently monitor the patient's vital signs, such as electrocardiogram (ECG), EEG and blood pressure; or important environmental parameters like temperature and humidity. The patient related data (gathered data) from all WBANs may ultimately be sent to a centralized healthcare repository for permanent records. Physicians can remotely access this data to assess the state of health of the patient. Additionally the patient can be alerted using SMS, alarm, or reminder messages.

In this article a survey of the state of the art in Wireless Body Area Networks is presented. Aim is to provide a better understanding of the current research issues in this emerging field. The remainder of this paper is organized as follows. First, the WBAN Channel Characteristics is discussed in Section 2. Next, the standardized technologies used for WBAN communication is discussed in section 3. Section 4 deals with the necessity of security and privacy in WBAN. Section 5 deals with the Physical layer and existing protocols for MAC layer. Section 6 discusses the WBAN specific routing protocols and other protocols related to WBAN. Relation to wireless sensor networks is treated in section 7. An overview of existing projects is given in Section 8. Finally, section 9 concludes the paper.

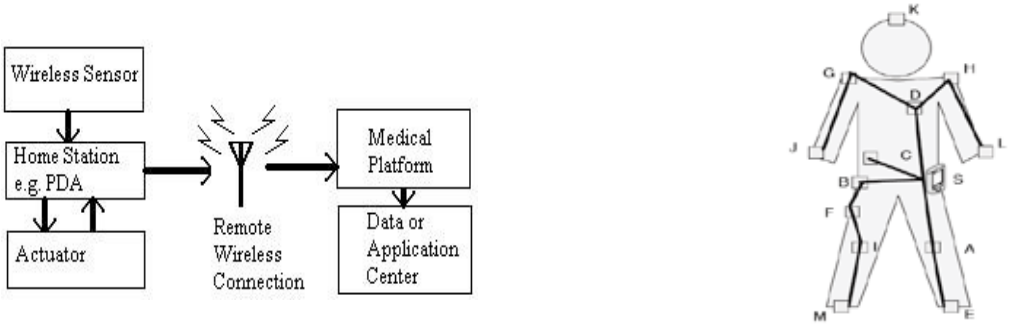

Fig. 1. (a) Data flow in a typical medical BAN; (b) Schematic representation of an example of WBAN on the human body. Sensor D measures the heart rate.

2. WBAN Channel Characteristics

The network formed by the WBAN will be located on the human body or it will be very close to it. Usually sensors are attached with a patch or it will be located on wrist band. On a channel quality perspective this has serious implications. The placement of nodes on the body as well as the path to other nodes has great impact on the channel quality. Different people will have different channel quality as the shape of the body also influences the channel. In a human body a direct line of sight path with two nodes is impossible tissues will absorb the signal and more path loss will occur. The channel quality for WBANs is the major challenge for networking as it will limit possible solutions. Because of the miniature sensor design, energy consumption will have to be very limited. As most of the energy is consumed by the radio, it should be turned off most of the time. Protocols of WBAN should cope with the poor channel quality available in the network.Inorder to reduce the energy consumption in WBAN, nodes can undergo in a sleep mode after the computation process using hibernation like technique.

2.1 Access method

Carrier Sense Multiple Access (CSMA) and Time Division Multiple Access (TDMA) are popular medium access techniques used in WBAN. In a CSMA based protocol, node will first sense the carrier i.e.; listens to the medium. If no activity is noticed, the node will start its transmission. Otherwise, it will start a back-off procedure where it will probabilistically wait for a given time. The main idea behind TDMA is to control access to a shared medium by dividing time in little segments, called slots. Nodes wishing access to the medium are assigned one or more of these slots. Although CDMA is an alternative accessing technique in WBAN, TDMA is the most preferred one as it provides slot reservation to nodes providing higher reliability than CDMA. Moreover delay guarantees are stricter in CDMA than in TDMA.

The communication in WBAN is a form of many to one communication where all traffic end up at a single point in the network. In WBAN, the traffic from sink to the nodes should not be excluded however, most of the traffic considered to flow from nodes to the sink. Control traffic probably flow from sink to the nodes but significantly smaller than the amount of data traffic from nodes to the sink. As WBAN assumed to be a connected network, nodes can either make a direct connection with the sink or it can rely on other nodes to make a contact. To simplify the analysis and to bring high energy efficiency most of the research works assume symmetric links and multi-hop topologies in WBAN, although this may not be the case in reality.

3. Technologies and Standards

A number of standardized technologies are related to WBAN research

3.1. IEEE802.15.6

The IEEE 802.15 task group 6(BAN) is developing communication standard optimized for low power devices and operation on, in or around the human body (but not limited to humans) to serve a variety of applications including medical, consumer electronics/personal entertainment and other. It can use existing ISM bands as well as frequency bands approved by national medical and/or regulatory authorities. Support for Quality of Service (QoS), extremely low power, and data rates up to 10 Mbps is required.

3.2. IEEE 802.15.4

Some researchers consider this as a MAC protocol and lots of research focuses on this protocol. However, research points out that the performance of IEEE802.15.4 is not sufficient for WBANs.The performance of this protocol in a multi hop environment is very poor.

3.3. Bluetooth

Bluetooth is a broadly available WPAN protocol and is very popular for current medical care solutions, especially because of the large range of available hardware implementations. However Bluetooth and other WPAN protocols have been designed for high data rate networks and large battery capacity which does not match the WBAN requirements. Also lowering the data rates will increase the protocol overhead.

4. Security and Privacy

It is essential to develop a comprehensive and strong security technique to protect the WBAN system from possible security threats. Data confidentiality is required to protect data from a disclosure. Eaves dropping may cause severe damage to patient related data. Hence privacy, confidentiality, authentication, data freshness, data integrity, availability and secure management are fundamental requirements. Although there are already several prototype implementations of WBANs, studies on data security and privacy issues are few and existing solutions are far from mature. Practical issues such as conflicts between security, safety and usability also need to be optimized carefully.

5. Physical and MAC layer

A lot of research has investigated to physical layer. At the beginning of WBAN research a number of authors proposed Ultra Wide Band (UWB) as a physical layer for WBANs.UWB has the advantage of low energy consumption, good co-operation with existing wireless networks and a range large enough to support the entire body. Due to standardization issues and difficulties delivering the very high speeds UWB does not progress well. As opposed to the wide bands proposed by UWB, other researchers propose the small, Industrial, Scientific and Medical (ISM) bands of the IEEE 802.15.4 andIEEE802.15.6.Current most working WBAN prototypes are based on ISM bands.

A number of WBAN specific MAC protocols exist. These can be divided in to single-hop and multi-hop protocols. The latter refers to the protocols which are optimized for multi hop topologies. The first protocols were designed based on a single hop topology. An example for this is Heart Beat driven MAC (H-MAC), which uses the heart beat to synchronize nodes. The protocol is specifically designed for WBANs; however traffic adaptations is not possible. Because of the dynamic nature, ad-hoc network protocol could also be considered as WBAN protocols. Ad hoc network protocols are based on always – on radios, which matters their application to WBAN unfeasible.

6. WBAN specific routing protocols

When considering wireless transmission around and on the body, important issues are radiation absorption and heating effects on the human body. To avoid the heat generation, five thermal aware routing protocols were proposed. To reduce tissue heating, the radio's transmission power can be limited or traffic control algorithms can be used. Researchers showed that the bio effects caused by radio frequency radiation are highly related to the incident power density, network traffic and tissue characteristics. A price-based rate allocation algorithm further shows that the bio effects can be reduced via power scheduling and traffic control algorithms. The Thermal Aware Routing Algorithm (TARA) routes data away from high temperature areas due to focusing data communications, defined as *hotspots*.

7. Relation to wireless sensor networks

In several papers, WBANs are considered to be a special type of WSN or Wireless Sensor and Actuator Network (WSAN) with its own requirements. However, traditional sensor networks do not tackle the specific challenges associated with human body monitoring. The most important difference is the need for reliable communication with each WBAN node, as opposed to the redundant character of WSN nodes. This corresponds to the typical medical application of WBANs, where only a single sensor per vital parameter is used. Moreover, the scale of WBANs is very small compared to typical large scale

deployments of WSNs. In a WBAN, up to twenty nodes are expected to be deployed on a single person, while WSN protocols are usually designed for hundreds of nodes deployed in areas with diameters of hundreds of meters. A lot of research is being done towards energy efficient routing in ad hoc networks and WSNs. However, the proposed solutions are inadequate for WBANs.

The following illustrates some main differences between Wireless Body Area Networks and Wireless Sensor Networks:

- There are no redundant devices in WBANs inspite of WSNs. All nodes in the network must be highly robust, reliable, and accurate. The lost information from one node often cannot be recovered by other nodes.
- Because of the special features of the environment in which the WBAN operates (human body) the data loss is more significant. The signals of the sensors, specially the implanted ones, are considerably attenuated because the propagation of the waves takes place in or on a very lossy medium. Proprietary mechanisms may be required to ensure the QoS and real time data interrogation capabilities. However, in WSNs the data loss may be covered by other sensors.
- The sensors which are either implanted into a tissue or attached on the surface of body must be very small in size to support unobtrusive monitoring of the patients. However, in WSNs the sensor size is not the main concern though smaller sensors are preferred. The small size of the WBAN sensors severely affects the power resources of the devices. The power supply recharge of the devices is often impossible. Thus, a long lifetime of the sensors is required.
- The sensors in a WBAN are located in or on the human body which can be in motion. This challenge for WBAN is rarely available for WSNs. Thus the WBAN must be robust against the high probable network topology changes. In addition, biological variation and complexity cause a more variable structure.

Table 1.WBAN Application-Examples

Application	Data rate
ECG (12 leads)	288kbps
ECG (6 leads)	71bps
EMG	320kbps
EEG (12 leads)	43.2kbps
Blood saturation	16bps
Temperature	120bps
Motion sensor	35kbps
Cochlear implant	100kbps
Artificial retina	50-700kbps
Audio	1Mbps
Voice	50-100kbps

Table 2.WBAN Challenges

Challenges	WBAN
Scale	As large as human body parts (millimeters/centimeters)
Node number	Fewer, more accurate sensor node required
Node size	Pervasive monitoring and the need for miniaturization
Event detection	Early adverse events detection vital; human tissue failure irreversible
Data protection	High level wireless data transfer security required to protect patient's information
Access	Implantable sensor replacement difficult and requires biodegradability
Bio Compatibility	A must for implantable and some external sensors. Likely to increase cost
Context Awareness	Very important because body physiology is very sensitive to context change
Wireless Technology	Low power wireless required, with signal detection more challenging
Data Transfer	Loss of data more significant, and may require additional measures to ensure QoS and real-time data interrogation capabilities

8.Existing WBAN projects

In the recent years a lot of work related to WBANs has appeared in the literature. The attempts are mostly focused on proposing solutions for the issues of the WBANs. Before introducing the IEEE 802.15.6 standard by the IEEE 802.15 Working Group the structure of WBANs and protocols and mechanisms of the physical layer and MAC sub layer of WBANs have been one of the most important concerns which attracted attention of many researchers. There are currently several research groups throughout the world which focus on design and implementation of a WBAN. The researchers have employed different wireless technologies in their projects in the field of wireless short-range connectivity,

such as the IEEE 802 family of WPANs, WLANs, Bluetooth and Zigbee. Due to major drawbacks of other WPAN and WLAN solutions the IEEE 802.15.4/ Zigbee system has been the most favoured approach in the existing projects before the IEEE 802.15.6 standard is introduced.

In [4] proposes a system that could perform real-time monitoring of complex conditions on streaming data from various body sensors within a Wireless Body Area Network (WBAN). The system enables personal medical applications to be developed using personal electronic devices combined together with sensors in a WBAN.

In [6] Stevan Marinkovic and Emanuel Popovici developed implemented and tested a Nano power Wake up Radio mainly intended for Wireless Body Area Networks (WBANs), but it can be also used in other types of low power wireless networks. The radio was tested for power consumption and robustness to communication interferences from a wireless device commonly found around the person carrying a WBAN.

Janani.K, V.R. and SarmaDhulipala [2] and R.M.Chandrasekaran *et al.,*[3] developed a WSN based frame work for human health monitoring in [7].In this paper the framework they proposed provides a clear understanding how WSN is used for remote monitoring of the patient's health. The paper mainly focus on the understandability of the remote patient monitoring done in hospital, the vital network parameters to be considered, scalability and power consumption.

Jae-Hoon Choi and Heung-Gyoon Ryu proposed a new QAPM (Quadrature-Amplitude-Position-Modulation) scheme for improving power efficiency in [8]. In this paper, they were analyzed existing PSSK and new propose QAPM scheme. The PSSK and QAPM scheme are extension method for increase power efficiency. And the simulation results, shows that BER performance of QAPM and PSSK better than QAM and PSK in AWGN channel. Also throughput of QAPM has better throughput characteristics in low SNR than PSK, QAM and PSSK.

In Opportunistic Routing for Body Area Network [9] provides an opportunistic scheme to exploit the body movements during the walking to increase the life time of the network. In this work they exploited the motion of the body parts to increase the lifetime of the network. To evaluate the performance of the proposed scheme, the energy consumption of the network per bit for the single hop, multi-hop using relay node and the opportunistic scheme are compared. The results shows the proposed scheme can increase the life time of the network by decreasing the energy consumption in both the sensor and relay nodes while maintaining the same BER as the other two schemes.

In Wearable ECG Monitor project [10] a wearable ubiquitous healthcare monitoring system using integrated electrocardiogram (ECG), Photoplethysmogratphy (PPG), Skin Temperature and Accelerometer etc. were designed and developed. In this design, nonintrusive healthcare system was designed based on WBAN for wide area coverage with minimum battery power to support RF transmission. In this system, WBAN, Zigbee, is used to communicate between wearable physiological signal devices and the personalized mobile system. We have developed various devices such as a wearable chest, wrist and necklace Device. The wearable ubiquitous healthcare monitoring system allows physiological data to be transmitted in wireless sensor network for Mobile network.

In [11] Mrinmoy Barua and M.S. Alam [2] and Xiaohui Liang *et al;* [3], an efficient secure data transmission scheme in WBAN is proposed with data integrity. The scheme is user-centric and the secure key is shared among all sensors in a WBAN to minimize any additional memory and processing power requirements. Security analysis and numerical results demonstrates that the scheme can minimize the mean waiting time of a real-time traffic in WBAN and provide proper security and privacy.

Xigang Huang and Hangguan Shan [2] and Xuemin (Sherman) Shen *et al*; [3] investigate the energy efficiency of cooperative communications in wireless body area network (WBAN) in [12]. Three transmission schemes had been compared in thispaper.Direct transmission, single-relay cooperation, and multi-relay cooperation. For each of them, they analyzed its outage performance and studied the problem of optimal power allocation with the constraint of targeted outage probability.

9. Conclusion

In this paper various key aspects of WBAN including Channel characteristics, access methodologies, routing protocols, WBAN challenges and existing WBAN projects are outlined. Also discussed energy requirements, security/privacy issues and issues present in various layers of WBAN. Finally some of the examples of WBAN application related to health sector are mentioned. There are many challenges that still need to be addressed, especially on high bandwidth and energy efficient communication protocols, interoperability between BANs and other wireless technologies, and the design of successful applications. Future work will be concentrating on the design of a light weight, flexible context aware mechanism which will carefully optimize security, safety and usability. We hope this article will inspire practical designs of cryptographic enforced, context aware, dependable and privacy enhanced WBANs.

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