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A Survey on Wireless Body Area Network Challenges and Energy Management Issue

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Abstract:
Advances in wireless communication technologies, Such as wearable and implantable biosensors, along with recent developments in the embedded computing area are enabling the design, development, and implementation of body area networks. This class of networks is paving the way for the deployment of innovative healthcare monitoring applications. In the past few years, much of the research in the area of body area networks has focused on issues related to wireless sensor designs, sensor miniaturization, low-power sensor circuitry, signal processing, and communications protocols. In this paper, we present an overview of body area networks, and a discussion of BAN communications types and their related issues.BAN face many difficulties related to requirements in terms of delay, power. This paper provides a survey of body area networks, its working, challenges, Applications.

Keywords: Wireless Body Area Networks (BAN), Wireless Sensor Networks (WSN), Challenges, Energy Efficiency, Energy Scavenging and Harvesting, Applications

1.INTRODUCTION

The field of computer science is constantly evolving to process larger data sets and maintain higher levels of connectivity. At same time, advances in miniaturization allow for increased mobility and accessibility. A Body Area Network (BAN) is defined formally as a system of devices in close proximity to a person's body that cooperate for the benefit of the user. A WBAN is based on IEEE 802.15.6, allowing near field communication up to one-meter range from the human body. A body area network (BAN), also referred to as a wireless body area network (WBAN) or a body sensor network (BSN), is a wireless network of wearable computing devices. A Wireless Body Area Network (WBAN) allows the integration of intelligent, miniaturized, low-power sensor nodes in, on, or around a human body to monitor body functions and the surrounding environment. A Wireless Body Area Network (WBAN) typically consists of a collection of low-power, miniaturised, invasive or non-invasive, lightweight devices with wireless communication capabilities that operate in the proximity of a human body. These devices can be placed in, on, or around the body, and are often wireless sensor nodes that can monitor the human body functions and characteristics from the surrounding environment [1]. Furthermore, the measurements can be recorded over a longer period of time, improving the quality of the measured data. In order to realize communication between these devices, techniques from Wireless Sensor Networks (WSNs) and ad hoc networks could be used. When referring to a WBAN where each node comprises a biosensor or a medical device with sensing unit, some researchers use the name Body Area Sensor Network (BASN) or in short Body Sensor Network (BSN) instead of WBAN. However, because of the typical properties of a WBAN, current protocols designed for these networks are not always well suited to support a WBAN [7]. The following illustrates the differences between a Wireless Sensor Network and a Wireless Body Area Network:

–The devices used have limited energy resources available as they have a very small form factor. Furthermore, for most devices it is impossible to recharge or change the batteries although a long lifetime of the device is wanted (up to several years or even decades for implanted devices). Hence, the energy resources and consequently the computational power and available memory of such devices will be limited.
–All devices are equally important and devices are only added when they are needed for an application (i.e. no redundant devices are available).
–The propagation of the waves takes place in or on a loss medium, the human body. As a result, the waves are attenuated considerably before they reach the receiver.
–The devices are located on the human body that can be in motion. WBANs should therefore be robust against frequent changes in the network topology. –And finally the devices are often very heterogeneous, may have very different demands or may require different resources of the network in terms of data rates, power consumption and reliability.
There are several advantages introduced by using wireless BANs which include:

–**Flexibility**: Non-invasive sensors can be used to automatically monitor physiological readings, which can be forwarded to nearby devices, such as a cell phone, a wrist watch, a headset, a PDA, a laptop, or a robot, based on the application needs.

– **Effectiveness and efficiency**: the signals that body sensors provide can be effectively processed to obtain reliable and accurate physiological estimations. In addition, their ultra-low power consumption makes their batteries long-lasting due to their ultralow power consumption.

– **Cost-effective**: With the increasing demand of body sensors in the consumer electronics market, more sensors will be mass-produced at a relatively low cost, especially in gaming and medical environments[2].

2. WBAN ARCHITECTURE

The general architecture of the WBAN network has three tiers: Intra-WBAN, inter-WBAN and beyond-WBAN (Figure 1).

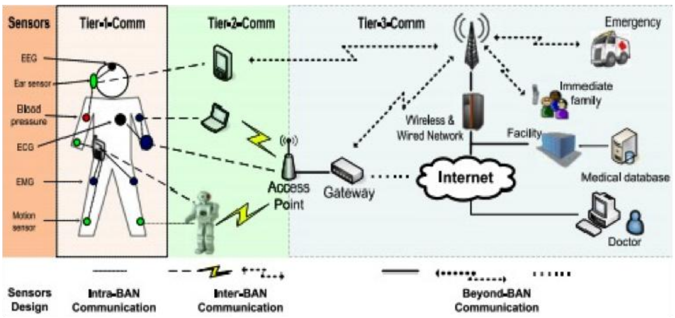

Figure.1. A three-tier architecture for WBANs

The intra-WBAN refers to two types of communications: Those between body sensors and those between sensors and a portable Personal Server or Device (PS/PD), also called Body Control Unit (BCU), Body Gateway or Central Node. The sensors can be on, near or within the body, and they are of two types. Some of them only respond and collect data on physical stimuli and then process and report this information wirelessly to the portable PD. Some others called actuators perform medicine administration based on the information received from other sensors in the same network, or through interaction with the user. The PD is the one that gathers all the information acquired by sensors and actuators. Once this information is collected by the PD, it has to be communicated through one or more access points (AP) to other networks that are easily reachable (e.g., Internet or cellular networks): This is the inter-WBAN communication. The communication standards deployed include Bluetooth/Bluetooth Low Energy, Zig Bee, UWB, cellular and WLAN [2]. A gateway device makes the connection with the beyond-WBAN communication network, thus increasing the coverage range and allowing authorized health-care personnel to access remotely the patient's medical information through Internet or cellular networks. The major design areas relevant for the WBAN architecture are: 1. Sensors, power and radio hardware components, concerning sensors design, location and positioning of nodes, Signal processing, data storage and feedback control, power Source, dynamic control and energy conservation, energy harvesting technologies, and antenna design. 2. Network stack for radio and wireless transmissions, channel modelling, interfaces with other wireless transmission standards, interference, efficient MAC protocols, and cross-layer approaches. 3. Localization and mobility, concerning mobility awareness protocols, location and positioning of nodes. 4. Security and privacy is about secure data collection, processing and storage, security and integrity of data transmission, and invasion of privacy. 5. Certification and standardization takes care of dependability and QoS issues, service-oriented architecture (SOA), interoperability, certification and regulatory processes [13].

3. TYPES OF NODES USED IN WBAN

An independent device in a WBAN is defined as node which exhibits communication capability. Nodes can be categorized into three different groups based on their functionality, implementation and role in the network [4].The classification of nodes in WBANs based on functionality is as follows:

***Personal Device (PD)* –** It collects all the information received from sensors and actuators and handles interaction with other users. The PD then informs the user through an external gateway, display/LEDs on the device or an actuator. This device may also be referred to as body gateway, sink, Body Control Unit (BCU) or PDA in some applications.

***Sensor* –** Sensors measure certain parameters in one's body either internally or externally. The nodes collect and reply to record on physical stimuli, process necessary data and provide wireless response to information. These sensors are physiological sensors, ambient sensors or bio-kinetics. Some existing types of these sensors could be used in one's wrist watch, mobile, or earphone and consequently, allow wireless monitoring of a person anywhere, anytime and with anybody. A list of various types of commercially available sensors used in WBANs is as follows: EMG, EEG, ECG, Temperature, Humidity, Blood pressure, Blood glucose.

***Actuator* –** The actuator interacts with the user upon receiving data from the sensors. Its role is to provide feedback in the network by acting on sensor data.

***Implant Node* –** This type of node is planted in the human body, either immediately below the skin or inside the body tissue.

***Body Surface Node* –** These types of nodes are either placed on the surface of the human body or 2cm away from it.

***External Node* –** These types of nodes are not in contact with the human body and rather a few centimeters to 5 meters away from the human body.

The classification of nodes in WBANs based on their *role* in the network is as follows:

***Coordinator* –** The coordinator node is like sort of gateway to the outside world, another WBAN, a trust center or an access coordinator. The coordinator of a WBAN is the PDA, through which all other nodes communicate.

***End Nodes* –** The end nodes in WBANs are limited to performing their embedded application. But, they are not able to relaying messages from other nodes.

***Relay* –** The intermediate nodes are called relays. They have got parent node, possess a child node and relay messages. In essence if a node is at an extremity (e.g. a foot), any data sent is required to be relayed by other nodes before reaching the PDA. The relay nodes may also be capable of sensing data.

4. CHALLENGES FACED BY WBAN

(i). Extreme energy efficiency: To deliver the levels of comfort and unobtrusiveness required for widespread adoption, WBAN sensor nodes must be small and have batteries that last on the order of days to years, depending on the application.The size requirement obviously limits the size of the batteries that will power the nodes (energy scavenging is another option, but the amount of power available from such techniques is relatively small), so WBAN nodes must be extremely frugal in their energy usage.

(ii). Unique characteristics of the wireless channel: The behaviour of the wireless channel around the human body poses a unique set of challenges to reliable communication. The first of these challenges is severe attenuation of the wireless signal between the sensor and the hub that can occur (attenuation of over 100 dB has been observed) and may push the received signal power below the level required for reliable communication [3]. This level is referred to as the receiver's *sensitivity* and is typically limited in BAN nodes due to their relatively small antennas and simple energy-efficient designs.

(iii). Managing interference: The nodes in a WBAN can be centrally coordinated by the hub, thus allowing a large number of devices to coexist in a single network without having them interfere with each other. Things become more complicated when multiple people wearing WBANs come into range of each other. In this case coordination may become impossible. The difficulty comes from the peoples' actions, which are unpredictable from a network's viewpoint, and can result in networks moving into and out of range of each other [3].

(iv). Security: The use of wireless technology, especially to deliver health care, also brings with it a host of concerns about security and privacy. The security mechanism of the system is responsible for providing the following security services on specified biomedical data when requested to do so by the applications. Data Encryption—the data is encrypted so that it is not disclosed whilst in transit. Data encryption service provides confidentiality against eavesdropping attacks [12].

(v). Interoperability and Quality of Service: If the IEEE 802.15.6 technology can be merged with other technologies like RFID and WSNs, more intelligent E-healthcare applications can be maintained. This extends the capability of the existing e-healthcare systems and will provide better services in future. Also, a BAN deployed on one human body may be used to provide different applications with different requirements in data rates, frequency, reliability and power usage. Hence, BANs would require ensuring consistence data transfer amongst the different wireless technologies being used to be scalable, promote information exchange, interact plug and play devices, provide uninterrupted connectivity and ensure efficient migration across networks. Also, the devices in a BAN themselves may have different frequency, data rate and power requirements.

5. ENERGY EFFICIENCY

Energy-aware management is critical in order to increase the lifespan of sensor nodes. Energy consumption can be divided into three domains: sensing, (wireless) communication and data processing. A lot of research has been done to obtain a long-lived WBAN, where low power hardware is a fundamental requirement [9]. The wireless communication is likely to be the most power consuming. The power available in the nodes is often restricted. The size of the battery used to store the needed energy is in most cases the largest contributor to the sensor device in terms of both dimensions and weight. Batteries are, as a consequence, kept small and energy consumption of the devices needs to be reduced. In some applications, a WBAN's sensor/actuator node should operate while supporting a battery life time of months or even years without intervention. For example, a pacemaker or a glucose monitor would require a lifetime lasting more than 5 years. Especially for implanted devices, the lifetime is crucial. The need for replacement or recharging induces a cost and convenience penalty which is undesirable not only for implanted devices, but also for larger ones. The lifetime of a node for a given battery capacity can be enhanced by scavenging energy during the operation of the system. If the scavenged energy is larger than the average consumed energy, such systems could run eternally [7]. However, energy scavenging will only deliver small amounts of energy. A combination of lower energy consumption and energy scavenging is the optimal solution for achieving autonomous Wireless Body Area Networks. For a WBAN, energy scavenging from on-body sources such as body heat and body vibration seems very well suited. The energy is a very crucial parameter in the WBAN systems. For instance, in invasive sensor nodes it is impossible to change the battery very frequently as it is very difficult to access the node. For non invasive nodes, if the system demands high battery consumption then it deters continuous monitoring and thus defeats the purpose. Again at transceiver part sending and routing contributes to maximum power consumption. If each node in the network transmit it the data directly to the sink node or base station, the energy consumed by the communication will be high. Thus Energy usage depends essentially on two things: Architecture of Sensor node and Network requirements. Architecture of the Sensor node is as depicted [15].

5.1 ENERGY SCAVANGING AND ENERGY HARVESTING IN WBAN

Limited battery energy constraints can be overcome if the battery is recharged using energy scavenging and harvesting techniques. Much research has been proposed in order to develop an energy harvesting wireless sensor network, which seems to overcome the stringent power constraint problems. Recent research has enabled wireless sensor nodes to harvest energy from surrounding environments. An adaptive duty cycling algorithm that allows energy harvesting sensor nodes to autonomously adjust the duty cycle according to the energy availability in the environment is proposed in [9]. For a WBAN, energy scavenging from on-body sources such as body heat and body vibration seems very well suited. The most promising solution to energy problem is energy harvesting and preferably harvesting from the host environment. Energy harvesters use specialized devices to convert the energy which is present in the surrounding environment in the form of light, heat and vibrations etc. into electric energy. It eliminates the problem of replacing or charging the battery at frequent intervals unlike traditional battery sources and provides power to body nodes without the need of replacement at frequent intervals. Moreover this energy is a clean energy, free from pollution and easily available in human environment.

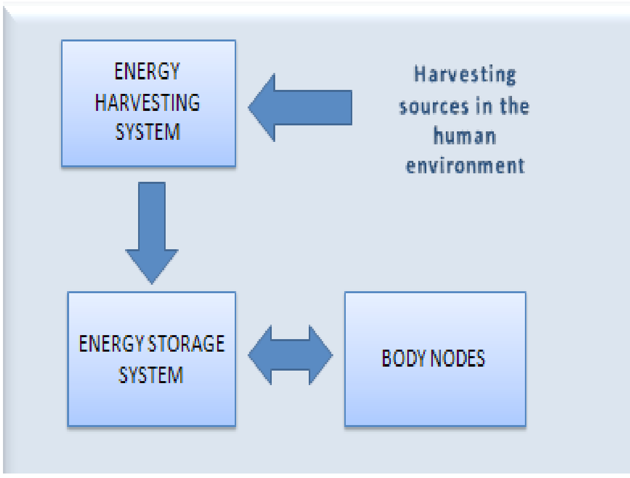

Figure. 2. Energy harvesting in human environment.

Energy harvesters introduce new factors in network that are availability of energy, its collection and utilization in intelligent way. When energy is extracted from human environment, the energy harvesters provide limited power as compared to the batteries. To ensure the availability of harvested power at required time it motivates us to store energy with capacitors or/and batteries, so that the harvested energy/power can be utilized efficiently and effectively. When the battery charging is below a specific level to perform its operation, the body nodes become inactive and it completely interrupts all tasks inside the network. To resume the operation of body nodes in network the battery needs to achieve acceptable power level and meanwhile the node is suspended from operation. From above, we can conclude that for the smooth operation of body nodes, the intelligent exploitation of collected energy is an important factor. This has lead to the introduction of energy neutral operation, which is a state in which energy consumed is always less than the harvested energy in the network [8].

6. WBAN APPLICATIONS

The ability to deploy a finite number of wireless sensor nodes on the human body leads to the opportunity of developing a large number of applications in several fields.

i) Healthcare*:* At a first glance this is the most promising field of application for a WBAN. Several non-intrusive sensors deployed inside or on the human body allow the patients and the doctors to sample continuous waveform of biomedical signals in a remote and continued fashion. Events that require prompt assistance like heart attack and epileptic seizure can be detected and even foreseen thanks to the continuous monitoring of the heart and brain activity, respectively [1]. The use of WBANs is expected to augment health care systems to enable more effective management and detection of illnesses, and reactionto crisis rather than just wellness [4].

ii) Sport and Entertainment: A real-time log of vital parameters like blood pressure, heart beat; blood oximetry and posture can improve fitness and sport experiences. In this way users can gather information concerning their sport activity and use them to prevent injuries and to plan future training to improve their performance. WBANs bring more realism in the user experience in the field of entertainment. Motion capturing techniques make possible to track the position of different parts of the body by means of a network of gyroscopes and accelerometers wirelessly connected to a central node and worn by the user. The real-time information about the motion allows the user to use his body as a controller in videogames. Moreover, film industry takes advantage of motion capture along with post production techniques to realize highly realistic digital movies where actors play the role of non-human subjects [1].

iii) Military and Defence: Network-Enabled Capability (NEC) is the name of the long term program aimed to achieve enhanced military effect through the use of information systems. New capabilities added by a WBAN will enhance the performance, at both individual and squad level, of soldiers engaged in military operations. At individual level, a set of sensors can monitor vital parameters and provide information about the surrounding environment in order to avoid threats, while information taken at squad level will make the commander able to better coordinate the squad actions and tasks. Spatial localization techniques and communication between different WBANs (inter-WBAN communications) play an important role in this field, as well as security in order to prevent sensitive information from being caught by the enemies [1].

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