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The Development & Implementation of Wireless Body Area Networks

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Abstract : ***The increasing use of wireless networks and the constant miniaturization of electrical devices has empowered the development of Wireless Body Area Net-works . Wireless Body Area Network is a system of devices in close proximity to a person's body that cooperate for the benefit of the user where various sensors are attached on clothing or on the body or even implanted under the skin. This paper shows several uses of the BAN technology and the most obvious application of a BAN is in the medical sector, however there are also more recreational uses to BANs. Using a WBAN, the patient experiences a greater physical mobility and is no longer compelled to stay in the hospital. This paper offers a survey of the concept of Wireless Body Area Networks. As WBANs are placed on the human body and often transport private data, security is also considered. This paper will discuss the technologies surrounding BANs, as well as several common applications for BANs.***

Keywords: *Body Area Networks, Body Sensor Networks, Sensor Networks, Personal Area Networks, Healthcare Applications*

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. Body Area Networks represent the natural union between connectivity and miniaturization. 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. In particular, the network consists of several miniaturized body sensor units (BSUs) together with a single body central unit (BCU). The development of WBAN technology started around 1995 around the idea of using wireless personal area network (WPAN) technologies to implement communications on, near, and around the human body. About six years later, the term "BAN" came to refer systems where communication is entirely within, on, and in the immediate proximity of a human body. A WBAN system can use WPAN wireless technologies as gateways to reach longer ranges. . Fig.I shows the placement of sensors on human body in body area network. Different sensors measure vital body parameters. Sensors sense vital parameters like ECG, EEG, Toxins, etc. BAN technology is quite flexible and there are many potential uses for BAN technology in addition to BSNs. Some of the more common use cases for BAN technology are:

- Body Sensor Networks (BSN)
- Sports and Fitness Monitoring
- Wireless Audio
- Mobile Device Integration
- Personal Video Devices

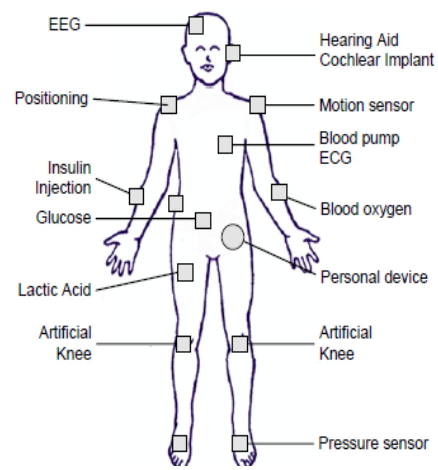

FIG. I

In several research papers, Wireless Body Area Networks are considered as a special type of a Wireless Sensor Network or a Wireless Sensor and Actuator Network (WSAN) with its own requirements1. However, traditional sensor networks do not tackle the specific challenges associated with human body monitoring. The human body consists of a complicated internal environment that responds to and interacts with its external surroundings, but is in a way separate and self contained. The human body environment not only has a smaller scale, but also requires a different type and frequency of monitoring, with different challenges than those faced by WSNs. The monitoring of medical data results in an increased demand for reliability. The ease of use of sensors placed on the body leads to a small form factor that includes the battery and antenna part, resulting in a higher need for energy efficiency. Sensor nodes can move with regard to each other, for example a sensor node placed on the wrist moves in relation to a sensor node attached to the hip. The challenges faced by WBANs are in many ways similar to WSNs, there are intrinsic differences between the two, requiring special attention. An overview of some of these differences is given in Table I . A schematic overview of the challenges in a WBAN and a comparison with WSNs and WLANs is given in Figure II.

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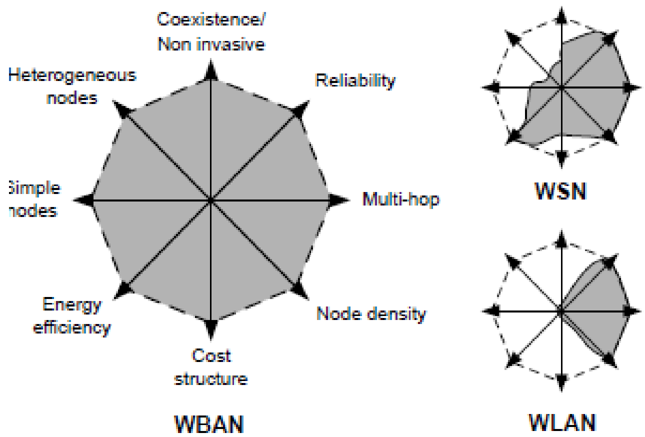

FIG II Characteristics of a WSN and WLAN

Challenges	Wireless Sensor Network	Wireless Body Area Network
Scale	Monitored environment (meters / kilometers)	Human body (centimeters / meters)
Node Number	Many redundant nodes for wide area coverage	Fewer, limited in space
Result accuracy	Through node redundancy	Through node accuracy and robustness
Node Tasks	Node performs a dedicated task	Node performs multiple tasks
Node Size	Small is preferred, but not important	Small is essential
Network Topology	Very likely to be fixed or static	More variable due to body movement
Data Rates	Most often homogeneous	Most often heterogeneous
Node Replacement	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 replaced 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 information
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 technology required

Table I. Schematic overview of differences between WSN and WLAN

Applications in Healthcare

In most cases, a WBAN will be set up in a hospital by medical staff, not by ICT-engineers. Consequently, the network should be capable of configuring and maintaining itself automatically, i.e. self-organization an self maintenance should be supported. Whenever a node is put on the body and turned on, it should be able to join the network and set up routes without any external intervention. The self-organizing aspect also includes the problem of addressing the nodes. An address can be configured at manufacturing time (e.g. the MAC- address) or at setup time by the network itself. Further, the network should be quickly reconfigurable, for adding new services. When a route fails, a backup path should be set up. The devices may be scattered over and in the whole body. The exact location of a device will depend on the application, e.g. a heart sensor obviously must be placed in the neighborhood of the heart, a temperature sensor can be placed almost anywhere. Researchers seem to disagree on the ideal body location for some sensor nodes, i.e. motion sensors, as the interpretation of the measured data is not always the same [3]. The net-work should not be regarded as a static one. The body may be in motion (e.g. walking, running, twisting etc.) which induces channel fading and shadowing effects. The nodes should have a small form factor consistent with wearable and implanted applications. This will make WBANs invisible and unobtrusive. A number of these devices can be integrated into a Wireless Body Area Network (WBAN) as shown in Figure III , which is a typical architecture for the application of WBAN to healthcare. In comparison to traditional wireless sensor and ad hoc networks, WBANs present several additional and new research challenges due to signal propagation characteristics of in and around a human body and need for safe, and dependable operation with ability to operate for long duration.

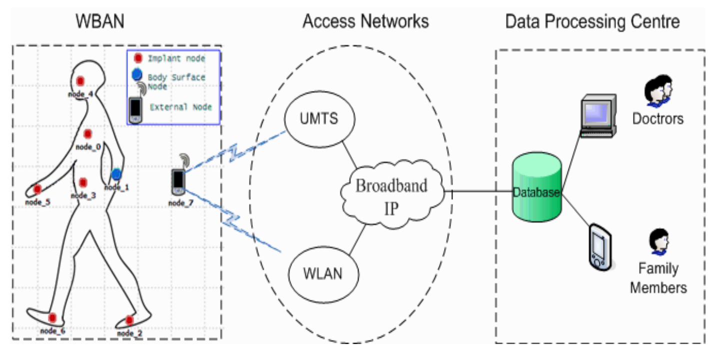

FIG III Application of WBAN to healthcare

WBAN Specific Protocols

One of the few MAC-protocols for WBANs was proposed by Lamprinos et al. [14]. They use a master-slave architecture and, to avoid idle listening, all slaves are locked in the Rx-slot of the master and go in standby at the same time. The main drawback of this protocol is that some slaves will have a low duty cycle whereas the nodes that are serviced later have a higher duty cycle. The protocol was implemented nor simulated. An adaptation of this protocol was used in [9]. This protocol divides time into frames in which only one node is allowed to transmit. The scheduling order is derived by applying the Earliest Deadline First algorithm. Omeni et al. [18] propose a MAC protocol for a star-networked WBAN that supports TDMA to reduce the probability of collision and idle listening. Each slave node is assigned a slot by the central node. When an alarm occurs at one of the nodes, the node can be assigned an extra slot for direct communication. The protocol has been evaluated on a Sensium platform. The H-MAC protocol [12] uses the human heartbeat rhythm information to perform time synchronization for TDMA. The biosensors can thus achieve time synchronization without having to turn on their radio. The algorithm is verified with real world data but assumes a certain buffer. The simulations do not show the energy gain and the protocol is designed for a star-topology WBAN only.

Conclusion

WBAN systems that monitor vital signs promise ubiquitous, yet affordable health monitoring and WBAN systems will allow a dramatic shift in the way people think about and manage their health – in the same fashion the Internet has changed the way people communicate to each other and search for information. This shift toward more proactive preventive healthcare will not only improve the quality of life, but will also reduce healthcare costs. Body area network will be highly accepted in spite of the drawbacks it may possibly have. However there are some key issues that are yet to be addressed. This technique is much more effective than any other monitoring and localization system. WBAN is expected to be a very useful technology with potential to offer a wide range of benefits to patients, medical personnel and society through continuous monitoring and early detection of possible problems. With the current technological evolution, sensors and radios will soon be applied as skin patches. Doing so, the sensors will seamlessly be integrated in a WBAN. Step by step, these evolutions will bring us closer to a fully operational WBAN that acts as an enabler for improving the Quality of Life.

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