Wireless Body Area Network Technology

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Abstract:
Wireless communication technology has advanced to new levels. Now a day the wireless technology is trending towards wearable and implantable biosensors. Recent developments in embedded computing area alongwith biosensors have enabled implementation, design and development of Body Area Networks. In this paper we present an overview of BAN technology, its communication types, its application and related issues. Currently the level of information provided and energy resources capable of powering the sensors are limiting. While the technology is still in its primitive stage it is being widely researched and once adopted, is expected to be a breakthrough invention in healthcare, leading to concepts like telemedicine and m Health becoming real.

Keywords:
WPAN; BSN(body Sensor Network); physiological sensors; carrier sense multiple access; adhoc network

1. INTRODUCTION

1.1 History

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. Through gateway devices, it is possible to connect the wearable devices on the human body to the internet. This way, medical professionals can access patient data online using the internet independent of the patient location.Recently, there has been increasing interest from researchers, system designers, and application developers on a new type of network architecture generally known as body sensor networks (BSNs) or body area networks (BANs), made feasible by novel advances on lightweight, small-size, ultra-low-power, and intelligent monitoring wearable sensors. In BANs, sensors continuously monitor human's physiological activities and actions, such as health status and motion pattern. Although many protocols and algorithms have been proposed for traditional wireless sensor networks (WSNs), they are not well suited to the unique features and application requirements of BAN.

2. The BAN Technology Concept

2.1 A Body Area Network is formally defined by IEEE 802.15 as a 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.The rapid growth in physiological sensors, low-power integrated circuits, and wireless communication has enabled a new generation of wireless sensor networks, now used for purposes such as monitoring traffic, crops, infrastructure, and health. The body area network field is an interdisciplinary area which could allow inexpensive and continuous health monitoring with real-time updates of medical records through the Internet. A number of intelligent physiological sensors can be integrated into a wearable wireless body area network, which can be used for computer-assisted rehabilitation or early detection of medical conditions. This area relies on the feasibility of implanting very small biosensors inside the human body that are comfortable and that don't impair normal activities. The implanted sensors in the human body will collect various physiological changes in order to monitor the patient's health status no matter their location. The information will be transmitted wirelessly to an external processing unit. 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.

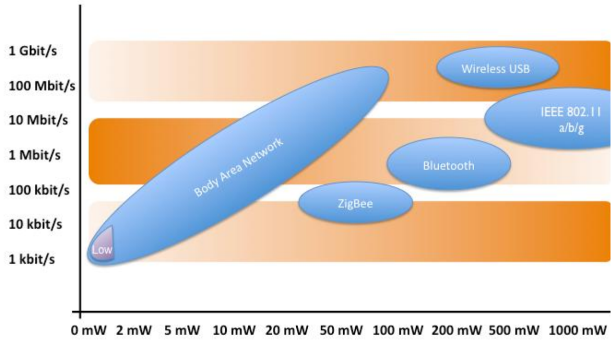

Fig 1: Data Rate vs Power

As can be seen the range of BAN devices can vary greatly in terms of bandwidth and power consumption.

2.1 Advantages of BAN technology

2.1.1 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.

2.1.2 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.

2.1.3 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 Components

A typical BAN or BSN requires vital sign monitoring sensors, motion detectors (through accelerometers) to help identify the location of the monitored individual and some form of communication, to transmit vital sign and motion readings to medical practitioners or care givers. A typical body area network kit will consist of sensors, a Processor, a transceiverand a battery. Physiological sensors, such as ECG and SpO2 sensors, have been developed. Other sensors such as a blood pressure sensor, EEG sensor and a PDA for BSN interface are under development. At the hardware level, body sensors must be small, thin, non-invasive, wireless-enabled, and must be able to operate at a very low power level. From the communications perspective, it is imperative to design appropriate medium access control (MAC) protocols to ensure higher network capacity, energy efficiency, and adequate quality of service (QoS). At the application level, innovative architectures should be implemented for the corresponding applications.

3. BAN Communication Architecture

Compared with existing technologies such as WLANs, BANs enable wireless communications in or around a human body by means sophisticated pervasive wireless computing devices. Figure 2 illustrates a general architecture of a BAN-based health monitoring system. ECG, (electroencephalography) EEG, (electromyography) EMG, motion sensors, and blood pressure sensors send data to nearby personal server (PS) devices. Then, through a Bluetooth/WLAN connection, these data are streamed remotely to a medical doctor's site for real time diagnosis,to a medical database for record keeping, orto the corresponding equipment that issues an emergencyalert.

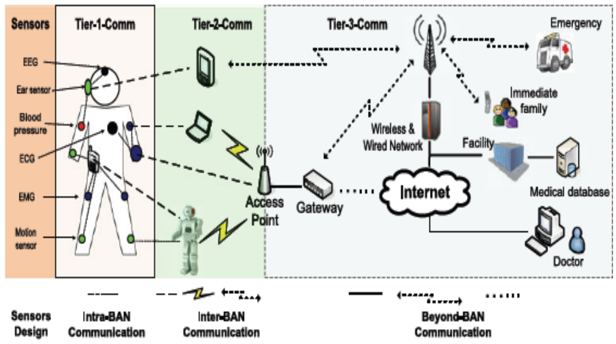

Fig 2: A three- tier architecture based on BAN communication system

The BAN communications architecture has been separated into three components: Tier-1 Comm design (i.e., intra-BAN communications), Tier-2-Comm design (i.e., inter-BAN communications), and Tier-3-Comm design (i.e., beyond-BAN communications), as shown in Fig. 2. These components cover multiple aspects that range from low-level to high-level design issues, and facilitates the creation of a component-based, efficient BAN system for a wide range of applications. By customizing each design component, e.g., cost, coverage, efficiency, bandwidth,QoS, etc., specific requirements can be achieved according to specific application contexts and market demands.

3.1 Intra-BAN communications

We introduce the term "intra-BAN communications" in reference to radio communications of about 2 meters around the human body, which can be further sub-categorized as: (1) communications between body sensors, and (2) communications between body sensors and the portable PS, as shown in shown in Fig. 2 Due to the direct relationship with body sensors and BANs, the design of intra-BAN communications is critical. Furthermore, the intrinsically battery-operated and low bit-rate features of existing body sensor devices make it a challenging issue to design an energy-efficient MAC protocol with QoS provisioning. To avoid the challenges of wirelessly interconnecting sensors and a PS, existing schemes, such as MITHril and SMART utilize cables to directly connect multiple commercially available sensors with a PS (i.e., a PDA). Alternatively, CodeBlue stipulates that sensors directly communicate with APs without a PS. compared with the previous

3.2 Inter-BAN communications

Unlike WSNs that normally operate as autonomous systems, a BAN seldom works alone. In this section, we define "inter-BAN communications" as the communications between the PS and one or more access points (APs). The APs can be deployed as part of the infrastructure, or be strategically placed in a dynamic environment for handling emergency situations. Similarly, the functionality of a tier-2-network (as shown in Fig. 2) is used to interconnect BANs with various networks that are easy to access in daily life, such as the Internet and cellular networks. We divide the paradigms of inter-BAN communications into two categories, infrastructure-based architecture (Fig. 3) and ad hoc-based architecture (Fig. 4). While the infrastructure-based architecture provides larger bandwidth with centralized control and flexibility, the ad hoc-based architecture facilitates fast deployment when encountering a dynamic environment, such as medical emergency care response, or at a disaster site (e.g., AID-N).

3.2.1 Infrastructure based architecture

Most BAN applications use infrastructure-based, inter-BAN communications that assumes an environment with limited space, e.g., a waiting room in hospital, home and office, etc. Compared to its ad-hoc networks counterpart, infrastructure-based networks offer the advantage of centralized management and security control. Due to this centralized structure, the AP also works as the database server in some applications (e.g. SMART, CareNet).

two approaches; there is a typical architecture of utilizing a star topology, whereby multiple sensors forward body signals to a PS that in turn forwards the processed physiological data to an access point (e.g.WiMoCa). As advancement to a two level BAN, in the first level, multiple wired or wireless sensors connected to a single central processor in order to reduce the amount of raw data, and save energy. After data fusion, the size of data that needs to be transmitted from the central processor to a PS is reduced. However, these solutions involve more challenges, such as advanced sensor data processing by considering the specific biomedical communications characteristics.

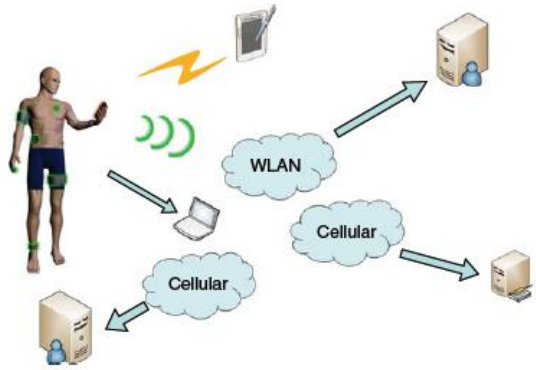

Fig. 3 Inter-BAN communication architecture: infrastructure based mode

3.2.2 Ad hoc based architecture

In the ad hoc based architecture, multiple APs are deployed to help the body sensors transmit information within medical centers. Thus, the service coverage is larger than in the infrastructure-based architecture, facilitating users to move around in a building, playground, or in an emergency rescue spot. While the coverage of a BAN is limited to about two meters, this way of interconnection extends the system to approximately one-hundred meters, which suits both in a short-term setup, and in a long-term setup (e.g., at home). Two categories of nodes exist in this architecture setup, i.e., sensor/actuator nodes in or around a human body, and router nodes around a BAN, both of which have the same radio hardware to facilitate multi-hop routing. This architecture setup is similar to that of a traditional WSN, and both of them often employ a gateway to interface with the outside world. In WSNs, however, every node functions as a sensor node and a router node. Since there is only one radio, all communications share the same bandwidth, and thus collisions can easily occur, given that the number of routers and sensor/actuator nodes is larger in certain area. Normally, an asynchronous MAC mechanism, such as carrier sense multiple access with collision avoidance (CSMA/CA) in ZigBee/IEEE 802.15.4, is used to deal with collisions.

Fig. 4 Inter-BAN communication architecture: ad hoc based mode

3.3 Beyond-BAN communication

Compared to the Tier-2-Comm's design, Tier-3-Commdesign is intended for use in metropolitan areas. Inorder to bridge the two networks for inter-BAN andbeyond-BAN communications, a gateway device, suchas a PDA can be employed to create a wireless linkbetween these two networks.As shown in Fig. 2, the beyond-BAN tier communicationscan enhance the application and coverage rangeof an E-healthare system a step further by enablingauthorized healthcare personnel (e.g., doctor or nurse)to remotely access a patient's medical information bymeans of cellular network or the Internet.A database is also an important component of the"beyond-BAN" tier. This database maintains the user's profile and medical history. According to user's servicepriority and/or doctor's availability, the doctormay access the user's information as needed. At thesame time, automated notifications can be issued tohis/her relatives based on this data via various meansof telecommunications.The design of beyond-BAN communication isapplication-specific, and should adapt to the requirementsof user-specific services. For example, if anyabnormalities are found based on the up-to-date bodysignal transmitted to the database, an alarm can benotified to the patient or the doctor through emailor short message service (SMS). If necessary, doctorsor other care-givers can communicate with patientsdirectly by video conference via the Internet. In fact, itmight be possible for the doctor to remotely diagnosea problem by relying on both video communicationswith the patient and the patient's physiological datainformation stored in the database or retrieved by aBAN worn by the patient.An ambulatory patient travelling to a location outside his/her hometown might experience a criticalsituation if a medical condition requiring immediateattention is triggered. With the help of BAN communicationsusing the architecture described above,emergency personnel could retrieve all of the necessarymedical information from the healthcare database totreat the patient based on the awareness of the existingmedical condition.

4. Challenges in BAN

Problems with the use of this technology could include:

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

4.2 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.

4.3 System and device-level security: Considerable effort would be required to make BAN transmission secure and accurate. It would have to be made sure that the patient ''secure'' data is only derived from each patient's dedicated BAN system and is not mixed up with other patient's data. Further, the data generated from WBAN should have secure and limited access.

4.4 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.

4.5 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.

4.6 Data consistency: Data residing on multiple mobile devices and wireless patient notes 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 practitioner's mobile device does not contain all known information then the quality of patient care may degrade.

4.7 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.

4.8 Data Management: As BANs generate large volumes of data, the need to manage and maintain these datasets is of utmost importance. O'Donoghue, John, and John Herbert. "Data Management within mHealth Environments: Patient Sensors, Mobile Devices, and Databases."

Besides hardware-centric challenges, the following human-centric challenges should be addressed for practical BAN development. These include:

4.9 Cost: Today's consumers expect low cost health monitoring solutions which provide high functionality. WBAN implementations will need to be cost optimized to be appealing alternatives to health conscious consumers.

4.10 Constant monitoring: Users may require different levels of monitoring, for example those at risk of cardiac ischemia may want their WBANs to function constantly, while others at risk of falls may only need WBANs to monitor them while they are walking or moving. The level of monitoring influences the amount of energy required and the life cycle of the BAN before the energy source is depleted.

4.11Constrained deployment: The WBAN needs to be wearable, lightweight and non intrusive. It should not alter or encumber the user's daily activities. The technology should ultimately be transparent to the user i.e., it should perform its monitoring tasks without the user realising it.

4.12 Consistent performance: The performance of the WBAN should be consistent. Sensor measurements should be accurate and calibrated, even when the WBAN is switched off and switched on again. The wireless links should be robust and work under various user environments.

5. Conclusion

BAN is a promising technology which can revolutionize next generation healthcare and entertainment applications. BAN brings out a new set of challenges in terms of scalability, energy efficiency, antenna design, QoS, coexistence, interference mitigation, and security and privacy to name a few, which are highlighted in this paper. We also discuss state-of-art technologies and standards which are relevant to BANs, as well as their merits and demerits. Developing a unifying BAN standard which addresses the core set of technical requirementsis the quintessential step for unleashing the fullpotential of BANs, and is currently under discussionin the IEEE 802.15.6 Task Group. In the end severalnon-technical factors would also play crucial roles inthe success of the BAN technology in mass marketing,such as affordability, legal, regulatory and ethicalissues, and user friendliness, comfort and acceptance.BAN technology needs the widespread acceptance ofkey stakeholders in the healthcare domain, includingthe medical-electronics industry, patients, caregivers,policy makers, patient advocacy groups and ordinaryconsumers for it to become a truly pervasive technology.Engineers, researchers and practitioners frommultiple disciplines must come together and strive hardto overcome technical roadblocks in order to bring thevision of ubiquitous healthcare network to reality. Wehave presented a comprehensive survey of body sensornetworks. Sensor hardware, system architecture, communicationprotocols, applications, and design issuesare discussed in detail. We have also summarized corefunctional components forBAN system design. Despiteadvances in these areas, there are many challenges thatstill need to be addressed, especially on high bandwidthand energy efficient communication protocols, interoperabilitybetween BANs and other wireless technologies,and the design of successful applications.

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