An Overview of Wireless Body Area Networks for Remote Monitoring Systems.

By Trevor LeDoyt, ECE '17

Abstract

The increasing age of the population and the rising costs of healthcare are motivating the use of Wireless Body Area Networks (WBANs) as a means for low cost mobile medical monitoring devices. The use of biosensors in a WBAN remote monitoring system allows health care professionals to remotely monitor their patient's physical & physiological parameters. This method of monitoring will allow patients healthy enough to return home and free up hospitals and healthcare staff to handle urgent matters. Typical patients that will benefit from a remote health monitoring system are: elderly patients, postoperative patients, and patients with disabilities. Remote monitoring systems can be used to track a patient's vitals, provide feedback directly to a patient or healthcare professional, and trigger alarms in the event of an emergency. The purpose of this research paper is to provide a general overview of WBAN technologies used specifically for remote health monitoring systems. This paper will focus on three areas that are critical to the progress of wireless body area networks: power consumption, communication protocols, and security.

Introduction

Wearable devices have been used to assist health care patients for decades. In fact, the portable hearing aid, developed in the 1930's, is one of the earliest wearable devices invented. The hearing aid revolutionized the healthcare industry by providing patients suffering from hearing loss with a portable hearing amplifier. Since that time, advancements in energy storage, semiconductors and wireless technology have compelled researchers to explore the additional possibilities that portable medical systems can achieve. Traditional Body Area Networks use wires to transmit signals between network sensors. WBAN, as the name suggests, do not use wires to transmit the biosensor signals, which greatly improves the comfort and mobility of a patient [3]. Using WBAN for health monitoring systems allows health care professionals to monitor their patients remotely outside of the hospital environment. Remotely monitoring patients promotes accessibility and affordability in healthcare, tackling one of the biggest concerns of the aging population. But before it is adopted by the healthcare industry, WBAN technology must overcome several technological obstacles.

Key Considerations

Over the past few years, remote monitoring has gained a lot of attention. Current commercially available devices including FITBIT and JAWBONE allow users to monitor their vitals and track their health and fitness progress. Although these devices provide services and functionality like those needed in the health care industry, the current wireless technology has several drawbacks that prevent it from being a viable remote monitoring solution.

First, current commercially available personal monitoring systems like the ones mentioned above typically have a battery life that lasts only several days. Hospital patients will require systems that provide continuous monitoring, therefore, the batteries will need to last several months or longer.

Second, since these personal wearable devices have become increasingly popular, there have been reports of them interfering with other remote monitoring devices. This is a major concern, because developing a global remote monitoring system will only lead to an increase in the number of devices operating in close proximity of

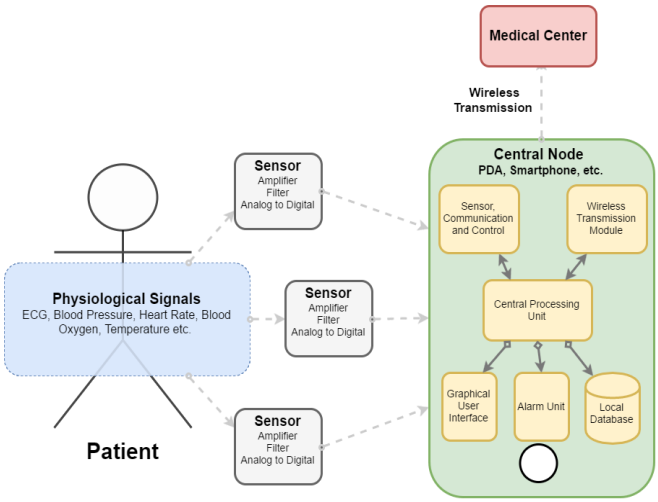
one another. Future wearable devices will need to be free of interference.

Third, commercially available devices have been vulnerable to hacking since their release. Hacking a remote monitoring device used for healthcare may allow unauthorized users access to a patient's medical history, vitals, or other personal information, so it is necessary that these systems be secure from unauthorized users.

Although the current personal wearables suffer from issues preventing their use in healthcare, new wireless technology, such as intra-body channel communication, which transmits data over the surface of the body may resolve many of those issues.

Architecture

The architecture of a remote health monitoring system can vary greatly depending on its specific purpose. The goal here is to provide a general overview of a typical health monitoring system. A typical WBAN remote monitoring system uses miniature biosensors attached to or implanted on the body of the patient to measure physiological signals. These biosensors communicate wirelessly with a central node located on or near the patient. The central node processes the signals and makes decisions based on the information received. Here the device can update the patient via a graphic user interface (GUI), notify the doctor of progress or even sound an alarm.



Architecture of Typical Wireless Body Area Network

Power

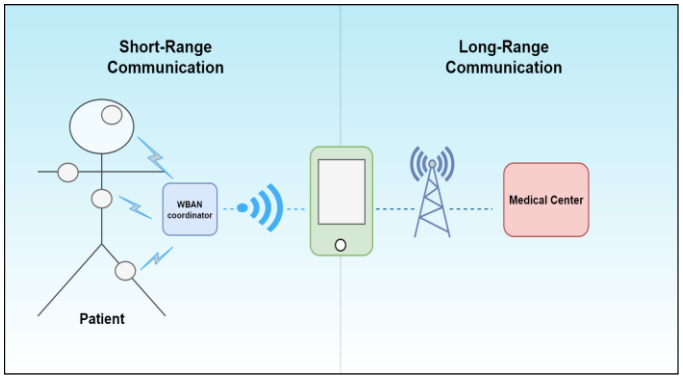
Managing energy storage and power consumption in a WBAN is a difficult task. A remote monitoring system must maintain adequate power due to the critical nature of the services provided by the device. If the system loses power, even momentarily, it can put a person at serious risk. The mobility requirements of a remote monitoring system are what make managing power consumption such a difficult task. The size and weight of the batteries must be kept small enough to avoid restricting a patient, but large enough to provide a long operating life. To resolve this issue, researchers look for creative ways to reduce the power consumed by the device and recharge the batteries. One way designers and researchers do this is harvesting energy from the environment, such as energy from sunlight [14]. The problem with this approach, is it is unpredictable and the efficiency depends on the user's environment. A patient outdoors can receive one thousand times more power than a patient indoors for the same time duration [14]. Another method of energy harvesting uses magnetic generation which relies on a patient's activity, such as walking, to generate electrical power. This method suffers from the same inconsistencies as other environmental sources or energy. Some researchers found a more reliable source using fabric made from piezoelectric nanowires to convert the vibrational or frictional energy from breathing or heartbeats into electrical energy [14].

Currently the best way to reduce the overall power consumption in a WBAN system is by choosing a good wireless communication system. The wireless communication system is often the largest consumer of power in WBAN [13]. For example, a mobile ECG monitor requires 35 mA/h to transmit, process and analyze data from sensor nodes to a computer, more than 50% of this energy is used for transmission [2]. The next section discusses the different types of communication protocols used by WBANs along with their energy usage.

Communication Protocols

Communication in a remote monitoring system can be divided into two types. The first type is the short-range body area network (BAN) communication which takes place nearest to the body, this includes the communication between the biosensors and the central

node. This form of communication can be accomplished using wired, textile or short range wireless communication. The second type of communication is long range communication, which is used to communicate between the patients local remote monitoring device and the health care provider or remote monitoring station. Since most power constraints are limited to the patient's body area network, this paper will only focus on short-range communication.



Short-range and Long-range communication

The following Radio Frequency (RF) and non-RF protocols are some of the more common protocols available to a BAN system. As you will see, each protocol comes with its pros and cons. Typically deciding on a protocol involves choosing the one that best fits a specific task.

Bluetooth

Bluetooth is a high bandwidth, low cost and low-power RF standard which operates in the 2.4 GHZ spectrum. To reduce interference, it uses frequency hopping over 79 channels with a range of 10 meters (approximately 30 feet). Bluetooth has a high data rate of 1-3 Mbps, but has a high-power consumption and is vulnerable to attacks [7]. Bluetooth uses approximately 100mW when operating and is one of the largest consumers of power of the wireless communication standards mentioned here. The high-power consumption and vulnerability issues make Bluetooth less than ideal for a remote health monitoring system.

Bluetooth Low Energy (BLE)

BLE is a low energy protocol designed to send small packets of data and use only a small fraction of power compared to the original Bluetooth [12]. BLE uses only 50mW of power while operating, but is considered vulnerable like the original Bluetooth.

ZigBee

ZigBee is a low energy, low-cost and low data-rate solution. The low power consumption of ZigBee allows it to operate on a single battery for multiple months to multiple years depending on the application. For message authentication, guarantee integrity and privacy ZigBee uses a 128-bit advanced encryption standard (AES) algorithm that can adequately protect BAN transmissions [7]. ZigBee is a may be a good solution for a remote health monitoring because of its low transmission power consumption [6] [12] and available encryption.

Security

Security and patient confidentiality are two important factors in the design of a WBAN. Due to the nature of the data transmitted using M-WBAN technology, all information transmitted between sensors and external sources should be subject to the following security requirements: data confidentiality, data authenticity, data integrity and data freshness [9]. Data confidentiality means that the data only available to those with authorization. Data authenticity means that the transmitted data is actually from the stated sender, which can be achieved by using a Message Authentication Code (MAC). Data integrity means that the data has not been tampered with. This can be confirmed by inspecting the encrypted MAC.

Intra-Body Channel (IBC)

In late 2011, IEEE developed the 802.15.6 standard to address medical device applications. This standard was designed to address the power, security and interference issues associated with wireless medical remote monitoring [8][12]. One of the protocols introduced in this standard was Intra-Body Channel communication.

Intra-Body Channel, sometimes referred to as Human Body Channel Communication (HBC), is a relatively newer form of WBAN communication that addresses the power consumption, communication and security issues surrounding WBAN, IBC uses the human body as the transmission medium. Transmission over the body is accomplished using one of the two following methods: Capacitive Coupling or Galvanic Coupling. For information on Galvanic Coupling see [Ryan] and for information on Capacitive Coupling [Arlo]. IBC is capable of using less than 1mW of power and transmitting over 100kbps [13], which make it an

excellent choice for a remote health monitoring. Another benefit to using IBC is it requires direct surface contact with the patient wearing the sensors, therefore it is more secure and less prone to interference than the other RF methods [13].

Conclusion

The future of global healthcare will rely on a safe and reliable means for remote healthcare monitoring. Research has proven that BANs fulfill many of the requirements needed for a successful remote monitoring, however, before they become a viable solution, they will need to overcome their power, communication, and security issues. New wireless technology, such as intra-body communication may be the solution needed to move remote health monitoring into the healthcare industry.

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