Wireless Body Area Network: Real-Time Health Monitoring System

Kalyani P. Wagh
PG Student – M.E. (DS)
Department of Electronics & Telecommunication
Sinhgad College of Engineering, Pune-41

Supriya O. Rajankar
Assistant Professor
Department of Electronics & Telecommunication
Sinhgad College of Engineering, Pune-41

ABSTRACT

Wireless Body Area Sensor Networks (WBASN) is an forthcoming technology which utilizes wireless sensor nodes to implement real-time wearable health monitoring of patients. These sensor nodes can be worn externally or implanted inside the body to monitor multiple bio-parameters (such as blood oxygen saturation, blood pressure and heart activity) of multiple patients at a central location in the hospital. It is a radio frequency based wireless networking technology. Here patients' health status can be monitored anytime and anywhere without restricting his/her mobility. Thus patient can live his/her normal daily life activities. This paper presents architecture of a wireless health monitoring system. The system consists of multiple sensor nodes which observe various body vital parameters and heart activities. Primary motivation of Body Area Network is to provide steady, timely, comfortable and proper monitoring of physical and biomedical parameters of patient continuously.

Keywords

Wireless Body Area Networks, Quality of Service, Wireless Sensor Network

1. INTRODUCTION

The concept of advancement in telecommunication system is that you can able to communicate anywhere and at anytime. This conception is also used in health sector. Wireless medical applications have been experiencing continuous developments and an improvement during recent years. Wireless Body Area Networks provide communication solutions to the healthcare systems. In traditional health monitoring, patients necessitate to go to hospital and carry out various tests [1] [4]. Then doctor will analyze the results and accordingly treatment is started. It is time consuming process as well as it is not right process for elderly persons. A BAN allows combination of intelligent, low power sensor nodes are attached or implanted on human body which monitors various body vital signs. Each node has enough capacity to process and forward information collected to the base station for the diagnosis purpose.

The main objective of this is to provide doctor with ability to remotely monitor the patient health, diagnose it and accordingly treat the patient. Any patient properly equipped with WBAN need not be physically present at the physician's place for continues observation. A WBAN can be adequate for any emergency case because it automatically sends data about patient health condition so that physician can prepare for the treatment immediately [14] [15]. Here we propose a secure and resource-aware WBAN architecture to enable real-time healthcare monitoring.

1.1 Wireless Sensor Network

A Wireless Sensor Network (WSN) is usually comprised of a large number of sensor nodes, which can cover wide geographic area. A WSN consists of a base station (gateway) that can communicate with a number of wireless sensor nodes via a radio link. Data are collected at the WSN nodes, processed, and directly transmitted to the gateway. Data transfer may be single-hop or multi-hop configuration, as shown in Figure 1. The transmitted data is then presented to the system by the gateway connection. Due to advanced microcontrollers individual sensors become smarter.

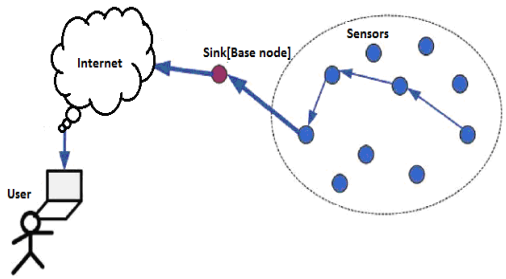

Figure 1: Wireless Sensor Network Architecture

Usages of smart microcontrollers in wireless sensor networking have opened number of opportunities in healthcare system. The idea is to place tiny wireless sensors or actuators strategically in, on or around the human body thus creating a Wireless Body Area Network (WBAN). It is a radio frequency based wireless networking technology facilitating to monitor patient's health status anytime and anywhere without restricting the patient's mobility

1.2 Wireless Body Area Network

The WBAN technology is the consequence of the existing WSN technology. In a WBAN, each medical sensor monitors different vital signs such as temperature, blood pressure, or ECG..

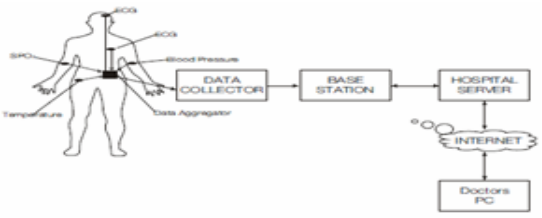

Figure 2: WBAN Architecture

Data collected by the medical sensors is transmitted to the coordinator The sensors are always activated and continuously transmit data to the coordinator. These configurations causes high energy consumption in all medical sensors and reduce seriously their operational time.

Table 1: Comparison between WSN and WBAN

Challenge	WSN	WBAN
Scale	Monitored environment	Human body
Node number	Many nodes for wide area coverage	Fewer, limited in space
Node Task	Node performs specific task	Node performs multiple task
Network Topology	Very likely to be fixed or static	Variable due to body movement
Security Level	Lower	Higher
Data Rate	Homogenous	Heterogeneous
Reliability	Low	High
Delay	Moderate	Low
Node size	Small is essential but not important	Small is essential
Power Supply	Accessible, replaced easily	Inaccessible difficult to replace

2. SYSTEM ARCHITECTURE

The WBAN architecture presented shows several key components. Different types of medical sensors can be used for monitoring various vital parameters.

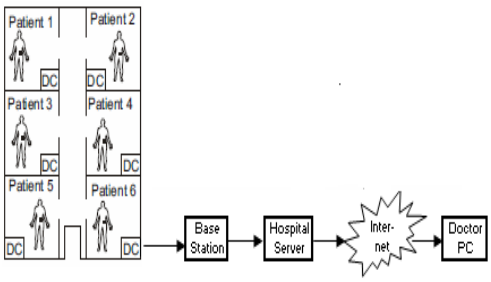

Figure 3: Proposed system for WBAN

The system is mainly consists of :

Base Layer: This layer consists of different biosensors attached to human body. The sensors collects the vital parameters, processes and sends the collected data to next layer. It consists of several components: sensor hardware, a power unit, a processor, memory and a transmitter or transceiver. There may be two types of these sensors

- *It can act as Independent node* and sends collected data to the Data collector directly

- It can be act as Aggregator which collects data

from individual node and then send the collected data to the Data collector.

The number of nodes in a WBAN is limited by nature of the network. It is expected that the number of nodes will be in the range of 20 to 50. Once medical sensors are installed, changing or recharging their batteries is uncomfortable. If the sensors are implanted inside the body then it is impractical too. In order to feel patient comfortable, the size of medical sensor should be as small as possible. Smaller size means smaller battery and therefore less energy. In this situation, energy efficient wireless medical sensors and efficient energy usage by these sensors is a very important issue.

Intermediate Data Collector/ Aggregator Layer: It collects data from individual sensor or data aggregator and sends to the base station. It may be any router. The components of an actuator are similar to the sensor's: actuator hardware a power unit, a processor, memory and a receiver or transceiver.

Base Station Layer : This layer sends all collected data wirelessly to the server A device that gathers all the information acquired by the sensors and actuators and informs the user (i.e. the patient, a nurse, a GP etc.) via an external gateway,

Server (Web based or Intranet): It stores database of all patient and also data sends by Intermediate Data Collector. Then it send this information to the doctors PC in the hospital.

2.1 System Behavior / Activities

According to the type of illness, the patient wears the specific physiological sensors to measure the vital-sign parameters. The captured data is collected by all sensors and transmitted to the data aggregator.

This data is then transmitted to the gateway by the short-range wireless communication module in the device in order to continuously monitor and record the patient's condition.

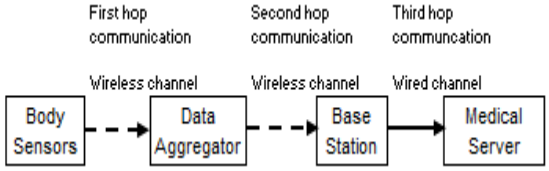

Figure 4 : Transmission path of data stream

The end to end transmission path of data stream is shown in figure 4. The transmission consists of three hops of communication : 1) the first hop communications, which

occur from body sensor to the data aggregator via wireless channels, 2) the second hop communications, which occur from the data aggregator to base station via wireless channels, 3) the third hop communications, which occur from base station to the medical server via wired channels,

Thus this network always gets connected with the gateway and transmits the vital-sign parameters to the gateway by means of multi-hop configuration. The gateway is primarily responsible for collecting and recording the patient's vital-sign data. The server which is located in the hospital, stores the data from every gateway into database. Type of sensor used in WBAN depends on user application like

An ECG sensor used to monitor heart activity

An EMG sensor used to monitor muscle activity

A blood glucose level sensor

A body temperature sensor

A SpO2 sensor for monitoring body Oxygen Level

A pulse rate sensor etc.

The purpose of the communication path is to transmit collected data from each sensor node to the PC. In this system, 2.4 GHz ISM band is used as the communication transceivers in the base layer.

2.2 Data Rates

As medical data is heterogeneous in nature, data rates will vary strongly, ranging from simple data at a few kbit/s to several Mbit/s. These are calculated by means of the sampling rate, the range and the desired accuracy of the measurements. The application data rates are not high.[6][15] The reliability of the data transmission is provided in terms of the necessary bit error rate (BER) which is used as a measure for the number of lost packets. For a medical device, the reliability depends on the data rate. Low data rate devices can deal with a high BER. While devices with a higher data rate require a lower BER. The required BER is also dependent on the criticalness of the data.

2.3 Healthcare Applications

Some of the health applications of wearable and implantable body area networks are Telemonitoring of Human Physiological Data: The physiological data collected by sensor networks may be stored for a long period of time, and can be used for medical investigations when needed.

Tracking and Monitoring Doctors and Patients inside a Hospital: Each patient has a small sensor node attached to them. Sensors vary based on their functions and each sensor node has its own specific task to perform.

Drug Administration in Hospitals: If sensor nodes can be attached to medication, the chance of getting and prescribing the wrong medication to patients can be minimized. Thus, patients will have sensor nodes that identify their allergies and required medication.

3. PHYSICAL LAYER

The WBAN standard specify multiple frequency bands (Physical layer), including ISM band as discussed above. The most widely used and currently commercially available WBAN technologies include ZigBee and Bluetooth, Ultra wide band [13] [14]. The design of physical layer protocols should meet some unique requirements for the case of WBANs, such as:

1] Seamless connectivity that needs to be maintained in dynamic environments in an attempt to realize the least possible performance degradation in terms of latency, data loss and throughput.

2] In unlicensed bands, robust protocol design is needed to mitigate interference issues as induced by surrounding devices operating at a high transmission power.

3] Power consumption should scale linearly as the data rate is increased in order to obtain a constant energy-per-bit information signal.

In physical layer, sensor mobility generates channel fading during transmission, which degrades the performance in terms of bit error rate and frame error rate.

4. MEDIA ACCESS CONTROL LAYER

MAC defines how each sensor node can efficiently share the allotted bandwidth. Primary goal of MAC protocols in WBAN is to reduce power consumption. MAC layer provides a channel access control mechanism to avoid collisions and to maximize throughput. WBAN can be developed using either a scheduled or a random MAC. It determines the packet delivery schedule and packet loss probability. Medical signals are periodic in nature. The signal rate may vary based on the physiological condition of a patient. A MAC protocol of a WBAN should be able to efficiently handle these variations [10][15]. Also, these biosensors are having very limited storage capacity so data will be transmitted without any loss and delay thus providing superior Quality of Service (QoS). Energy loss will happen due to collision, when more than one packet is transmitted at the same time. The collided packets have to be retransmitted, which consumes extra energy. The second source of energy waste is idle listening, meaning that a node listens to an idle channel to receive data. The third source is overhearing, i.e., to receive packets which contains data for other nodes. So the MAC should consider all above mentioned points.

4.1 IEEE 802.15.4

IEEE 802.15.4 is a low-power standard designed for low data rate applications. It offers three operational frequency bands: 868 MHz, 915 MHz, and 2.4 GHz bands. In the IEEE 802.15.4 protocol, there are two operation modes: *beacon enabled* and *non-beacon enabled* mode. A beacon frame is broadcasted periodically from the coordinator and it contains information, which is necessary to build the network [15].

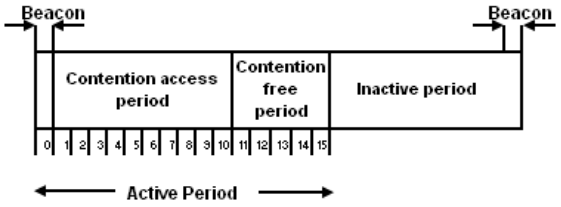

Figure 3. Super frame structure for IEEE 802.15.4

The superframe consists of both active and inactive periods. The active period contains three components: a beacon, a Contention Access Period (CAP), and a Contention Free Period (CFP). The coordinator interacts with nodes during the active period and sleeps during the inactive period [13]. There are maximum seven Guaranteed Time Slots (GTSs) in the CFP period to support time critical traffic. In a beacon enabled mode, a slotted CSMA/CA protocol is used in the CAP period while in a non beacon enabled mode, an un-slotted CSMA/CA protocol is used.

5. FEATURES OF THE EXISTING SYSTEM

A WBAN system used in health sector should have following features [13] [15]

- Sensors are tiny, so comfortable to wear
- Sensors are always on, so real time data will be accessible all the time
- Low complexity
- Exclusive medical frequency
- Low cost per unit
- Portability and unobtrusiveness
- Reconfiguration and self organization

6. DESIGN CONSIDERATIONS

Following points should be considered while designing WBAN system :

- Every sensor node in network can operate at different time. So there should be synchronization between nodes will be there.
- Any node in a system can fail at anytime for number of reason including natural issues, human-related issues or batteries exhaustion.
- How to manage the transmission delay of various types of communications in the system.
- Most of wireless network based devices are battery operated; therefore the designer should also think of about power management[4][8].
- The rate of data collection in healthcare systems
- is high. So developing effective methods of data
- processing techniques is important[2].
- 6] From patient's viewpoint the equipment should be
- small in size, light in weight and with low cost. Since the purpose of WBAN systems is to let people go about their life while accessing high-quality medical services [1][8]
- The security of the sensors and collected data is
- an important especially for sensitive applications.

7. CHALLENGES

In proposed system there exists some challenges like

- The routing link failure may happen during data transmission because of collision, node draining of energy, node busy, or other accidents. But proposed health system requires real time information and data, which means retransmission, is not possible. This motivates to design a multipath routing for WSN [13].
- The sensors are battery operated and a prolonged network lifetime is preferred. This motivates to consider energy aware routing. Similarly the mobility of the nodes may cause the existing point-to-point route invalid and an alternate route has to be chosen [12].
- In physical layer, sensor mobility generates channel fading during data transmission, which degrades the performance in terms of bit error rate (BER) and frame error rate (FER). This motivates to consider a mobility aware routing [3][6].

8. CONCLUSION

The proposed system architecture for healthcare monitoring applications is very effective, especially for older people. It provides small, inexpensive, and flexible BAN in contrast to existing wireless cardiac monitoring systems. The most significant application includes unsupervised, continuous, ambulatory health monitoring. Long term monitoring may provide detection of early signs of deterioration of patient's health and support for computer assisted rehabilitation [1] [6] [14].

The main two challenges in this system are there should be continues power supply to the body sensor nodes. Guarantee for delivery of data stream to the destination means Quality of service.

9. REFERENCES

[1] C. Otto, A. Milenković, C. Sanders, E. Jovanov, "System architecture of wireless body area sensor network for ubiquitous health monitoring ," in *Journal of Mobile Multimedia*, Vol.1, No.4 ,2006, pp 307-326

[2] A. Milenkovic, C. Otto, E. Jovanov, "Wireless sensor networks for personal health monitoring: Issues and an implementation," *Computer Communications*, vol. 29, Issue 13-14, pp 2521-2533, Aug. 2006

[3] K.W.Goh, E. Kim, J. Lavanya, Y. Kim, "Issues in Implementing a Knowledge-based ECG Analyzer for Personal Mobile Health Monitoring," 28th *IEEE EMBS Annual International Conference* New York, Aug 30, 2006

[4] K. D. Nguyen, I. Cutcutache, S. Sinnadurai,, " Fast and Accurate Simulation of Biomonitoring Applications on a Wireless Body Area Network," *International Workshop on Wearable & Implantable Body Sensor Networks* Jun 2008

[5] I. G. Sene, A. F. Rocha, M. G. Barbosa, O. Nascimento, H. S. Carvalho, "Energy Efficient Simulator for Patient Monitoring in Body Sensor Networks," *International IEEE EMBS Conference* Vancouver, Canada, August 20-24, 2008

[6] X. Wu, B. Auriol, J. Cho, S. Lee, "Optimal Routing in Sensor Network for In home Health Monitoring with Multi-factor Considerations " *IEEE International conference on Pervasive Computing and Communications* in 2008

[7] Mark A. Hanson, Harry C. Powell Jr., Adam T. Barth, K. Ringgenberg, "Body Area Sensor Networks: Challenges and Opportunities*", IEEE Xplore* January 2009

[8] C Huasong, V. Leung, C. Chow, H. Chan," Enabling technologies for wireless body area networks: A survey and outlook," *IEEE Communication Magazine*, vol.47, Issue 12, pp 84-93, Dec. 2009

[9] H. Wang, D. Peng, W. Wang,, H. Sharif, H. Chen, "Resource-aware secure ECG healthcare Monitoring through body sensor networks," *IEEE Wireless Communication for E-Healthcare*, Feb.2010

[10] S. Ullah, B. Shen, S.M. Riazul Islam, P. Khan, S. Saleem, K. S. Kwak, "A study of MAC Protocols for WBANs," *Sensors* 2010, ISSN 1424-8220

[11] T. Yilamz, R. Foster, Y.Hao, "Detecting vital signs with wearable sensors," *Sensors* 2010, ISSN 1424-8220

[12] H. Wang, W. Wang, D. Peng, H. Hwa Chen, A Khoneyzhad, H. Sharif, "Resource- Aware Secure ECG Healthcare Monitoring Through Body Sensor Network", *IEEE, Wireless Communication* 2010.

[13] M.Chen, S. Gonzalez, A.Vasilakos, H. Cao, "Body Area Networks: A survey," *Springer Mobile Network Applications*, vol 16, pp 171-193, 2011

[14] B. Latre, B. Braem, I. Moerman, C. Blondia, P. Demeester, "A survey on Wireless Body Area Networks," *Wireless Network manuscript.*

[15] A.Hussain, N.Alam, K.S.Kwak, "Directional MAC approach for wireless body area networks," *Sensors* 201