IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 2, February 2016

Survey on Wireless Body Area Network

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Abstract: Recent advancement of wearable computing and wearable sensor devices has empowered the development of Wireless Body Area Networks (WBANs). Wireless body area network is made up of remotely connected miniaturized sensors placed in, on or around the Human Body, which provides continuous monitoring of physiological signs to support medical, lifestyle and entertainment applications. First, we focus on some applications with special interest in patient monitoring. Then the open research issues and challenges are pointed out. Finally, an overview of MAC and network layer is given.

Keywords: WBAN, healthcare, routing, MAC, WSN.

I. INTRODUCTION

In the last few years the consideration of specialists toward Wireless Body Area Networks (WBANs) has greatly increased. In WBAN, miniaturized sensors and actuators are placed in or on the body, which enhance and support new medical and healthcare services. These embedded sensors are responsible for sampling, processing and transmitting physiological signals of patient. The assembled information can be sent continuously to a hospital or clinic giving remote access to physicians and nurses, or can be processed locally to trigger a treatment procedure when needed [1].

Protocols that are proposed for wireless sensor networks aren't appropriate for WBAN, because of the unique features and application prerequisites of BAN [2]. To illustrate this point, the differences between BAN and WSNs are listed as follows:

1) Deployment and Density: The number of sensor/ actuator nodes embedded by the user relies on various factors. In BAN, sensor nodes are placed on or in the human body or can be attached with clothes. Moreover, BANs don't utilize relay nodes to adapt to different types of failure—an otherwise common design provision in conventional WSNs. Consequently, BANs aren't node-dense. While WSNs are typically installed in places that may not be effortlessly available by administrators, which requires that additional nodes put to make up for hub disappointments.

2) Data Rate: Most WSNs are utilized for event based observing, where event can happen at sporadic interims. Whereas, BANs are utilized for enrolling human's physiological activities which might happen in a more intermittent way, and might bring about the application's information streams showing moderately stable rates.

3) Path Loss: In BAN, the propagation of the waves happens in or on a (extremely) lossy medium, the human body. Therefore, the waves are weakened significantly before they reach to the receiver.

4) Mobility: The devices are situated on the human body that can be in movement. WBANs should therefore be robust against continuous changes in the system topology. Whereas, WSN nodes that are normally viewed as stationary.

II. APPLICATIONS OF WBAN

The foremost purpose of standardizing WBAN by IEEE is to improve the standard of quality of life of human beings. Thus, WBAN is not only limited to medical applications but also applicable to non medical field [3]. One of the significant medical applications is remote health checking. In the past, health observing is done through number of electrical equipment however now, because of Body Area Sensor Network this electronic health monitoring has gotten to be portable in nature since patient can be in movement while light weighted sensor nodes gathers the health related information. That is the reason eHealth has now been advanced to mHealth [4].

A. Medical Applications

Wearable Health Monitoring Systems (WHMS) are live illustration of applications of BAN in the medical field [2].In this system, No of sensor nodes are placed in or on the Patient's body. These sensors are having information like blood pressure, heartbeat rate, blood pressure etc. Sensor nodes send this information to the gateway node. The gateway then delivers its data via a cellular network or the Internet to a remote location such as an emergency centre or a doctor's room based on which an action can be taken.

- **Sleep Staging**

Sleep is an important behaviour and regular physiological function which consumes one-third of our everyday life. Today there are thousands of people who suffering from sleep disorders. The results of such issue can be entirely serious and lead to cardiovascular illnesses. WBANs are capable of delocalization of the intelligence and instruments in their sensor nodes and removal of all cables.

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- **Asthma**

A WBAN is provide real-time log of the allergic agents in the air and providing real time feedback to a physician, which can save millions of patients suffering from asthma.

- **Cardiovascular Diseases**

Cardiovascular diseases are known as the main reason of death for 17 million individuals annually, which can be significantly diminished or prevented with appropriate health care strategies. Myocardial Infarction (MI) can be enormously decreased by monitoring episodic events and other unusual conditions through WBAN technology [14].

- **Cancer Detection**

Cancer death rates are estimated to increase by 50%, reaching up to 15 million by 20209. Events which require pre-diagnosis like tumours and cancer causing cells can be detected using BAN sensors enabled with diffusion based molecular-communication.

B. Non-Medical Applications

Some of the non-medical applications of WBAN are as follows:

- Emotion detection
- Entertainment Applications
- Emergency alarms
- Body gesture recognition
- Armature Sports training
- Secure Authentication:
- wars to sense soldiers (whether alive or not)

III. CHALLENGING OPEN ISSUES

Designing a body area network is a difficult task as there are a broad range of options. There are some issues which have to be dealt while using this new emerging technology [5]. Some of the important issues are covered in this section.

A. Interoperability

In WBAN, data must have to exchange across different technology like Zigbee (IEEE 802.15.4), Bluetooth (IEEE 802.15.1), and Wi-Fi ((IEEE 802.11 But all these technologies differ from each other, all have different requirements related to frequency bandwidth, data rate etc. The system would have to migrate from one network to another network and during this transfer the connectivity should not be interrupted.

B. Energy Consumption

Energy in WBANs is considered as one of the significant problems and challenges and deeply needs investigations and solutions. In BAN, Frequent replacement of nodes must be avoided especially when nodes are implanted within the human body because they are not easily accessible. Because of this, one has to consider the trade off between the energy capacity and energy consumed by the processing and communication operations in order to use energy efficiently.

C. Reliability

The low transmission power and tiny sized antenna of wireless sensor devices will affect signal to noise ratio that cause a higher bit error rate and decrease the reliable coverage area. However, reliable data transfer of data in WBANs and medical monitoring systems is crucial. Reliability in the data delivery in a network can be measured by Packet Delivery Ratio (PDR) and Bit Error Rate (BER). PDR represents the ratio of the number of packets received by the receiver to the number of packets generated by the sender, while BER represents the ratio of the number of error bits to the number of bits generated by the sender. The reliable data transmission should be investigated for low power body sensor networks which still a challenge for BASNs.

D. Node Heterogeneity

In WBSNs, sensor nodes are most likely heterogeneous. Specific applications of WBANs may require heterogeneous data collection from different sensors with different sampling rates. Therefore, QoS support in WBANs may be quite challenging.

E. Interference

There are chances of collision and packet loss due to Body Area Networks sensors come in each other's range. There must be a way so that nodes will recognize that they belong to which network so, that minimum interference will occur.

F. Data Aggregation

To save energy in BAN, data aggregation is the best choice. Data received from different sensors is gathered before being transmitted to the next hop node. When data aggregation is not used, this means that the packet size sent to the next hop node will be larger.

IV. MAC LAYER

The number of MAC-protocols specifically developed for WBANs is limited. Two major categories of MAC protocols are contention- based and schedule-based [6]. For the former, CSMA/CA is a typical example, while TDMA is a typical scheme for the latter. Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) protocols are example of contention-based MAC protocols. In these type of protocols, nodes contend for the communication channel to send data. If channel is idle data can be sent otherwise node defers its transmission. These protocols are scalable with no strict time synchronization constraint. In schedule-based protocols such as Time Division Multiple Access (TDMA) protocols, the channel is divided into fixed or variable time slot. These slots are assigned to nodes and each node transmits during its slot period.

When a node communicates with other nodes, it drains most of its energy. Reasons of this drainage are idle listening, over transmitting, overhead of control packet, collision and fluctuations in traffic. WBAN has three major MAC approaches to minimize energy utilization.

A. Low Power Listening

In the Low power listening (LPL) method, Node usually stays in sleep mode and keeps track of the channel activity after short intervals. If the channel is idle the nodes go into

sleep mode, otherwise they stay on the channel to receive the data. This is also called channel polling. Due to the varying traffic in LPL, performance is degraded. However, periodic traffic rates method can be applied to improve the performance of LPL. Wise MAC [7] protocol is based on the LPL. It uses non-persistent CSMA technique and sampling preamble to minimize the idle listening.

B. Scheduled Contention

Scheduled-contention mechanism is a sum of scheduled and contention based schemes, which acquires scalability and collision avoidance. The contending nodes in contention based protocols give rise to packet collision because all the contending node wants to transmit data through channel. Sensor MAC(S-MAC) [8] is a good example of a schedule contention based MAC protocol in which the default mode of sensor nodes set as low duty mode. This protocol introduces the concept of coordinated sleeping among neighbouring nodes. The node remains in sleeping mode and become active.

C. TDMA Mechanism

TDMA technique uses a super frame structure which composed of fixed time slots allocated by a base-station or a coordinator. The time slots are allocated based on the traffic requirements [6]. In TDMA, node gets a time slot whenever it has data to send or receive. Otherwise, it goes into sleep mode. TDMA performs well in terms of energy consumption and enhance the network Lifetime. However, It consumes extra energy due to frequent synchronization. TDMA based protocol are Preamble based TDMA (PB-TDMA), Body-MAC (BMAC) and Med MAC

V. NETWORK LAYER

Designing efficient routing protocols in WBANs is a significant task because of the specific requirements of the wireless environment [9]. WBANs have severe energy constraints in terms of transmit power compared to traditional sensor and Ad Hoc networks as node replacements or charging is not an easy task for implanted sensor nodes. Therefore, it is critical for WBANs to have a longer network lifetime to avoid constant recharging and replacement of nodes attached to a person. Additionally, a WBAN has more frequent topology changes and a higher moving speed, whilst a WSN has static or low mobility scenarios.

In this section, we present a general overview of the existing routing algorithms, which may be classified as temperature-aware routing protocols, cluster-based routing protocols, probabilistic routing protocol, cross-layered routing protocols and QoS-aware routing protocols,.

1. Thermal Aware Routing

Thermal aware or temperature aware routing protocols take node temperature as a metric to select the path to reach the destination. The goal of the protocols is to maintain the node temperature underneath the temperature safety level and to slow down the temperature rise rate, so that it does not damage the human body. The amount of radiation energy absorbed by the body tissue is defined as the Specific Absorption Rate (SAR) [10] shown below,

$$\mathrm{SAR} = \frac{\sigma|\mathrm{E}|^2}{\rho}\,(\mathrm{W/Kg})$$

Where ‘σ’ is electrical conductivity of tissue, ‘E’ is induced electric field by radiation and ‘ρ’ is density of tissue.

2. Cluster-based Algorithms

Next class of routing protocols in WBANs are Cluster-based routing algorithms that divide nodes in WBANs into different clusters and assign a cluster-head for each cluster. Data is routed through the cluster-heads from the sensors to the sink. The goal of this class of routing protocols is to diminish the number of direct transmissions from the sensors to the base station. However, the enormous overhead and delay relative to cluster selection are the main drawbacks of these protocols.

3. Probabilistic Algorithms

Probabilistic routing protocols regularly update their cost function based on the link state information, and select their path along with minimum cost routes [3]. However, these protocols involve a large number of transmissions for updating link-state information.

4. Cross-Layer Algorithms

Cross-layer design is a way to enhance the efficiency and interface between the protocols in a wireless network by linking two or more layers from the protocol stack [11, 12]. However these protocols have low energy consumption, high throughput and fixed end-to-end delay, they cannot provide high performance in scenarios with high path loss and body movements.

5. QoS-based Routing Algorithms

The QoS-aware routing protocols are modular-based protocols and use different modules for different types of QoS metrics that operate in coordination with each other [13].The modules used in this method are the power efficiency module, the reliability-sensitive module, the delay-sensitive module and the neighbour manager.

Hence, these approaches supply higher reliability, lower end-to-end delay and higher packet delivery ratio. However, these protocols mainly suffer from high complexity due to the design of several modules based on different QoS metrics.

VI. CONCLUSION

In this survey, a review of the on-going research in WBANs in terms of applications, routing, MAC layer is given. Additionally a comparison of WBANs with respect to WSNs is presented. A WBAN is expected to be a very constructive technology with potential to offer a wide range of benefits to patients, medical personnel and society through constant monitoring and early detection of possible problems. Engineers, researchers and practitioners from multiple disciplines must mutually try hard to conquer technical roadblocks in order to bring the vision of ubiquitous healthcare network to reality.

DOI 10.17148/IJARCCE.2016.5223

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DOI 10.17148/IJARCCE.2016.5223