MAC Protocols for Wireless Body Sensor Network

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doi: https://doi.org/10.21467/proceedings.114.33

Abstract

Wireless Body Area Networks, also known as the Wireless Body Sensor Networks, provides the monitoring of the health parameters in remote areas and where the medical facility is not available. Wireless Body Sensor Networks contains the body or placement of the sensors on body for measuring the medical and non-medical parameters. These networks share the wireless medium for the transmission of the data from one place to another. So the design of Medium Access Control is a challenging task for the WBSNs due to wireless media for less energy consumption and mobility. Various MAC protocols are designed to provide less energy consumption and improve the network lifetime. This paper presents the study of these existing MAC layer protocols based on different QoS parameters that define the network quality.

Keywords: Wireless Body Area Networks, Quality of Service (QoS), Physiological Parameters, Healthcare Monitoring, IEEE 802.15.4, MAC, T-MAC, Biosensors

1 Introduction

An aging population indicates the quality of health services in both the developed and under-developing countries. According to WHO, between 2015 and 2050, the number of aged people will increase from 900 million to 2 billion which can be 12% to 22% of the global population [1]. It took more than 100 years for France's population aged 65 or above from the total population to double from 7% to 14%, and on the other side, countries like Brazil, China, and India will take lesser than 25 years for the same growth [2]. So, aging gives numerous challenges for the whole world population because senior people lose their ability to take care of themselves due to chronic diseases, physical or mental disabilities [3]. Due to disability of taking care elder people needs to be 24 hours surveillance of their family members and doctor. But it is complicated for people to provide help to the patient by staying 24 hours in their homes. To solve this problem, smart health monitor applications are designed, which improve home care for the elderly and disable people [4] within the homes. By developing these health applications, one can quickly know the health status of elder and disabled people. To design the healthcare application Wireless Sensor Network plays a vital role in developing healthcare applications. In particular, Body Area Networks (BANs) offers possible health care solutions for the elder and disabled people for short-range WSNs to improve the patient care and cost of the healthcare systems. Body Area Networks deals with the implantation of the medical sensors invasively and non-invasively on the body that monitor vital life signs of patients. These medical sensors collect the patient information and report the central unit or gateway, known as a BAN coordinator, for processing the data or further transmission on outside networks [5] as shown in the Fig.1. In Wireless body area networks, the patient's medical information has been sent to the doctor wirelessly, so this can create traffic and different security issues. The different MAC layer standard protocols are used to avoid the data traffic during the information exchange to overcome the said issues. In recent years, researchers and industry have focused on developing the MAC protocol standards specification for medical and non-medical areas [6]. Out of those standards, IEEE 802.15.6 is a new standard (developed by IEEE 802.15 group 6) designed for the Body

Proceedings DOI: 10.21467/proceedings.114; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-8-8

Area networks [7] with low power consumption, short-range communication, low cost, and less complexion. Medium Access Protocols are derived from the IEEE standard 802.15.4.This paper presents the different MAC layer protocols for the wireless body area networks regarding medical data security.

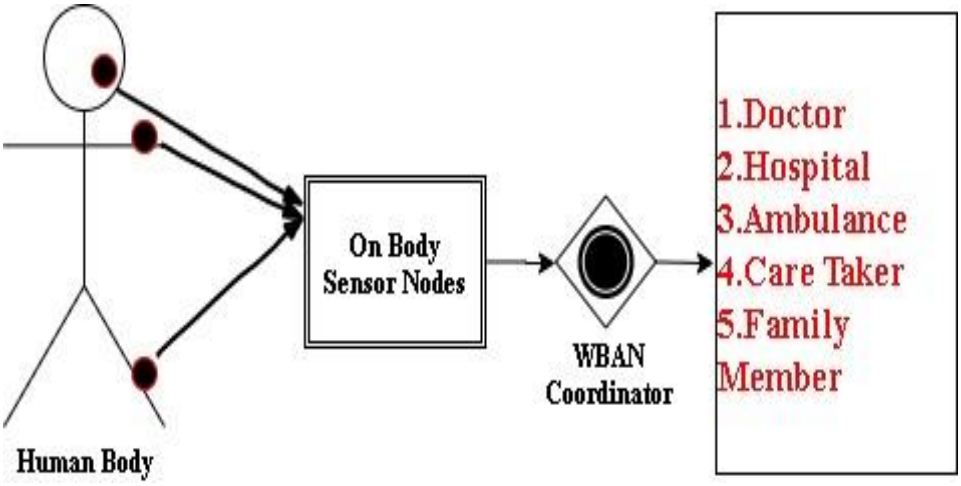

Fig.1- Architecture of Wireless Body Area Network [5]

2 Data Security and Privacy Issues in Wireless Body Sensor Network

The sensor network provides healthcare applications to monitor the medical and non-medical parameters like temperature, heart rate, respiration rate, pulse rate, location, etc. at home and office along with the areas where the medical facility is not available. Data security and privacy are the main concerns in wireless body sensor networks because they are transferred wirelessly. During the data transmission, the unauthorized person can access the transmitted data and misuse it. Other security attacks are malicious nodes, Intrusion attacks, Interception, Blackhole attack, Sinkhole attack, and layered attack, which occur during the transmission of the data [8]. Malicious node is the unknown node in the network which becomes the part of the network for generating the error message and delivers the message to destination node. Intrusion attack refers to the unauthorized activity in the network and steals the valuable information from the message packet. On the other side sinkhole attack affects the routing of the data in the network. It will attract the network traffic by giving the fake routing update. The author in [9] classified the security attacks into two categories, i.e., passive and active attacks. Passive attacks occur during the routing of the data. The attacker may change the source and destination address of the packet and can steal the information. Active attacks are more harmful than passive attacks. The criminally-minded hacker can use the information for criminal purposes, and it can be dangerous for the human being. So to overcome the security and privacy issues, different approaches are taken in the past years. The researchers and industries have focused on designing the various essential management techniques and MAC layer protocols for security purposes.

3 MAC Layer Protocols for Wireless Body Sensor Network

In the Wireless Body Sensor Network, the sensor nodes are responsible for collecting the medical and non-medical data of the patient. So the nodes consume more energy in this process. In Wireless Sensor Network, energy consumption is one of the major concerns for reliable transmission. The nodes should consume less power or strength. By keeping this in mind, various researchers have been focused on designing the protocols for less energy consumption. The MAC protocols can be divided into two categories, i.e., Contention Based MAC Protocol and Contention Free Mac Protocol [10]. The contention-based MAC protocols are based on the CSMA, i.e., Carrier Sense Multiple Access, in which the sensor node competes for the channel to transmit the data. If the channel is busy, the node will not transmit its information until

the channel becomes redundant for carrying the data. On the other side, contention-free MAC protocols use the TDMA technique, i.e., Time Division Multiple Access, in which time slots are given to every sensor node to transmit the data in its allotted time slots. On the basis of this author in [11] designed the IEEE 802.15.4 MAC protocol with the GTS management scheme which is the most popular TDMA based technique for less energy consumption during communication. In [12], the authors explain the IEEE 802.15.6 standard, which defines the MAC layer with the different physical layers specifications along with the allocated frequency band.

Body Sensor Networks defines the measurement of the patient's physiological and non-physiological parameters non-invasively and transmit data collected related to these parameters to the authorized person. Based on this, authors in [13] define the H-MAC protocol to improve the energy efficiency of the BSNs. The protocol exploits the heartbeat rhythm for better energy efficiency. The biosensors are used to extract the human heartbeat rhythm, and the waveform peaks of the rhythm signal are detected by the biosensor's collected information. Following the rhythm, biosensors can achieve time management without having to turn on their radio to receive constant timing information from a central controller. This process of time management can be reducing the energy cost of the network and the lifetime of the network can be extended. In Body Sensor Network, enormous data has to be sent through the channel. In which the traffic increases throughout the track, and this causes overlapping of the data. IEEE 802.15.4 standard Medium Access Protocols do not provide the required Quality of Service (QoS) because they do not control the data traffic in Wireless Body Area Networks. To overcome the above-said problem, authors in [14] introduced a traffic-aware MAC, i.e., TA-MAC protocol, in which time slots are given dynamically to the sensor nodes on the bases of traffic priority. The proposed protocol's performance compared with the existing IEEE 802.15.4 MAC protocol in the term of QoS (Quality of Service) parameters, i.e., transmission time, throughput, energy efficiency, and collision ratio.

The Wireless Body Sensor Networks are delightfully increasing interest because of their suitability for many applications. Network lifetime is another big issue for deploying the Wireless Body Sensor Networks for healthcare applications. To avoid this problem, a modified super frame structure of the IEEE 802.15.4 based MAC protocol has been proposed by [15], which addresses the above-said issue and improves the nodes' energy consumption. The CSMA/CA mechanism has been used to implement this protocol, which is a contention-based mechanism. The priorities to the sensor nodes are assigned according to data type and size. The nodes in the network used the wake-up radio mechanism for active and sleep mode of body sensors which leads to save the energy of the nodes and network lifetime time will increase. The discrete-time finite-state Markov model has been used to know the status of the biosensors nodes. The performance of the network has been evaluated based on energy consumption and delay. If the energy consumption is less in the network, it will increase the network lifetime during emergency data transmission.

Furthermore, to improve network performance in energy consumption, an approach has been taken by [16]. The authors focused on the access methods and access mechanism used in the IEEE 802.15.6 standard in the MAC layer. The performance of the network has been evaluated based on energy consumption for short range communication.

Medium access methods play a significant role in determining the quality of service provided by medical devices. IEEE 802.15.6 is a standard that includes the different types of medium access methods, i.e., CSMA/CA, polling access schemes, and a combination of these techniques. Based on these polling access schemes, authors in [17] proposed a medium access method to extend the network's lifetime, which is based on the sleeping scheduled for contention and polling access. The authors have introduced another approach for increasing the network lifetime in [18]. The authors used the medium access and polling access methods

of the MAC layer. The performance of the network is determined by QoS parameters like received packets, successfully transmitted packets, and low latency.

Wireless Body Sensor Network is a network of wearable computing devices and provides real-time monitoring in remote areas to diagnose various life threatening diseases. For proper measurement of the physiological data, the system should provide reliable communication, data security and data privacy. This is an enormous challenge in designing the WBSNs. Another challenge in the WBSNs is the design of the Medium Access Control due to the wireless transmission characteristics of the data. And there is a need to fulfill both the requirements, i.e., mobility and energy efficiency. The authors in [19] present the comparative study of the existing MAC protocols, i.e., IEEE 802.15.6, IEEE 804.15.4, and TMAC based on delay and throughput and energy consumption.

Another MAC protocol has been introduced by [20] named S-MAC, which is designed for the wireless sensor network. Wireless Sensor Networks are battery-operated computing devices that contain typical applications such as environmental monitoring, health monitoring, etc. The nodes in the wireless sensor networks remain active when there is no task to do, which can affect the network lifetime. So, there is a need to deploy such type of networks in which nodes remains inactive when there is no task to do but becomes active when something detected in the network; such type of network is called Adhoc fusion network. Based on these applications, the S-MAC protocol uses the 3 novel techniques to reduce energy and support self-configuration. S-MAC and T-MAC protocols are also known as the duty cycle protocols having low power consumption. The duty cycle has been fixed in S-MAC protocol, which means useless wake-ups can be consumed through energy. The T-MAC protocol was introduced to change the duty cycle, depending on the data traffic to avoid this problem. This can result in less power consumption and avoid useless wake-ups.

Another MAC protocol has been proposed by [21], known as Hybrid Unified-slot Access (HUA) protocol. This protocol was designed for the Wireless Body Sensor Network to improve power efficiency and reliability. This protocol supports multiple physical layer technologies, including the Ultra-Wide Band (UWB). The slotted ALOHA is used in the contention access period (CAP) to request the slot allocation i.e. particular time slots are allotted to the sensor nodes to send their information. The Mini-slot method is designed to improve the efficiency of the contention. Moreover, sufficient slot allotment in the contention-free period (CFP) makes HUA adaptive to the different traffic, medical and non-medical applications. The Urgency-based MAC (U-MAC) protocol has been proposed by [22]. The sensor nodes deliver urgent information based on the high priority signal by cutting off the number of packets retransmission, which is unuseful. The U-MAC protocol has been implemented mathematically by considering the star network with the IEEE 802.15.4a standard configuration at a 2.4 GHz frequency band.

As use of wireless and wireless sensor networks have been increased for medical applications, the researchers have been begun to focus more on designing WSN based applications. In these applications, service quality is needed to provide reliable data communication over the vast data stream. Based on this, authors in [23] proposed a system called BodyQoS, which demonstrates the body sensor network's quality of service. The architecture of the BodyQoS is asymmetric in which most processing is done on a resource-rich aggregator, which minimizes the load on the sensor nodes. A fundamental MAC is developed in BodyQoS to make it radio-agnostic, allowing BodyQoS to schedule wireless resources without knowing the accomplishment details of the primary MAC protocols. When the adequate bandwidth of the channel degrades due to RF interference or body fading effect, BodyQoS adaptively schedules the remaining bandwidth to meet QoS requirements.

Wireless Body Area Networks uses the wireless medium for interchange of the data which gives the great challenge for designing the MAC protocols for the network due to the inappropriate traffic, energy consumption, and network lifetime and data latency. Priority MAC protocol [24] is designed to solve the

above said problems. In PMAC protocol the priority is given to the coordinator which continuously transmits the beacons for the synchronization and data channels are separated from the control channels. For the less energy consumption a sleep mode is also used for the wearable sensors which also increase the network lifetime. Furthermore a MAC model is designed by [25] to reduce the energy consumption by the nodes in the network. For this purpose a fuzzy logic based system is integrated in each body sensor to deal with multiple cross-layer input variables of diverse nature in an independent manner. In this manner the collision free time slots are given to the body sensors which reduces the time and packet delay and energy efficiency increased. YNU MAC protocol is based on cluster topology for the gaining of the high throughput in the network by using the SIFS, DIFS and backoff in contention window which gives the appropriate channel utilization[26]. It is based on the CSMA/CD access mechanism technique. MEB MAC protocol i.e. Medical Emergency Body MAC protocol inserts listening window dynamically in the contention free periods which gives the minimum delay tolerance in emergency data traffic.

4 Conclusion

Wireless Body Sensor Networks provide measuring the healthcare parameters for medical applications and location service for non-medical applications. The need for a suitable MAC protocol has been increased due to the wireless medium. This paper presented the study of the available MAC protocols introduced by various authors in past years. The MAC layer protocols, i.e., IEEE 802.15.4, T-MAC, S-MAC, HUA, U-MAC, etc. provide less energy consumption and increases the network lifetime. Network QoS (Quality of Service) is the main requirement for the validation of the network performance. The network's performance has been evaluated based on delay, throughput, the number of packets received network load, and energy consumption.

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