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Packet Scheduling by Buffer Management in MAC Protocol of Medical WBAN Monitoring Environment

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Abstract

Lately, the range of WBSN (Wireless Body Snesor Networks) applicability has expanded due to the support of the advanced wireless technology in the ubiquitous environment. WBSN is a network where various kinds of bio signals of the body are measured and then are processed and transmitted to neighboring monitoring and personal portable devices near human body. Current IEEE 802.15.4 MAC Protocol based on the FIFO (First Input First Output) principle allocates the time slot according to the order of requesting time for each node. However, this process may result in the increase the packet delay and a rate of packet loss when more packets than the available time slot attempt to transmit at the same time. Hence, in order to mitigate this performance degradation, we analyzed four types of the different scheduling scheme for effective controlling between the packet delay and packet loss in the system. The proposed buffer control applies the maximum delay restriction to new and previous data packets simultaneously in order to reduce the rate of the packet loss very effectively. Simulation results show that the proposes scheme attains the much smaller packet delay for the audio transmission and also reduces the packet loss for the audio and video packet transmission compared with the other schemes in view of availability of delayed packets as a effective data.

***Keywords**: WBSN, WBAN, CSMA/CA, TDMA, Time-Slot, Buffer, Packet*

1. Introduction

Wireless Body Area Network (WBAN) has great potential to revolutionize the future of healthcare technology. It has attracted a number of researchers both from the academia and industry in the past few years. WBAN supports a wide range of medical and Consumer Electronics (CE) applications [1]. A wireless body sensor network (WBSN) environment is an applied network that was advanced from a WBAN environment [2], that allows communication within a body based on wireless sensor networks (WSNs) [3]. It is an environment where the condition of a patient is monitored in real time by collecting various data from the tools or node transplanted inside or outside the body. In near future, the WBSN is expected to replace the conventional wired environments of medical surveillance or general monitoring system [4]. HMS (Healthcare Monitoring System) should implement Quality of Service (QoS) tools to ensure a certain quality level especially in terms of delay and packet loss as related applications require a very low or no data loss or waiting time for transmissions [5]. Carrier sensed multiple access/collision avoidance CSMA/CA [6] is a widely known MAC protocol, and is used when a numbers of nodes are transmitted in such a

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sensor network environment, and triggers extremely high consumption of energy of application systems through high frequency of idle listening and packet collision. So, there had already been many researches that studied the advantages of the time division multiple access TDMA scheme considering power consumption and reduction in delayed transmission of nodes or devices [7-8]. The IEEE 802.15.4 MAC protocol is a hybrid scheme that applies both the competition-oriented method, which is universally applied for data processing in the WBAN and WBSN environments, and schedule-oriented method [9]. But, the GTS allocation method of the IEEE 802.15.4 MAC protocol applies the FIFS (First In First Service) queuing method where the channels are allocated in the order the packets arrive, that causes inevitable delay in transmission, making it inadequate for transmission of the data [10]. Generally, if the packets of nodes failed to be scheduled in their time slots, they move to the buffer memory to get a next available time slot for packet transmission. Meanwhile, if they finally fail to transmit the data within his delay requirement, they are treated as the packet loss or failure since it is not effective as an available data packets. We analyzed four schemes included the proposed scheme in the initial data transmission and buffer data processing together with same delay restriction. The structure of this paper is as the following. In section 2, the conventional system model will be explained. In section 3, the four schemes included proposed MAC protocol will be discussed in detail. In section 4, the performance of every scheme will be examined, and these features will be analyzed. Finally, in section 5, the conclusion and future research topics will be presented. The figure 1 shows the concept of WBSN environment.

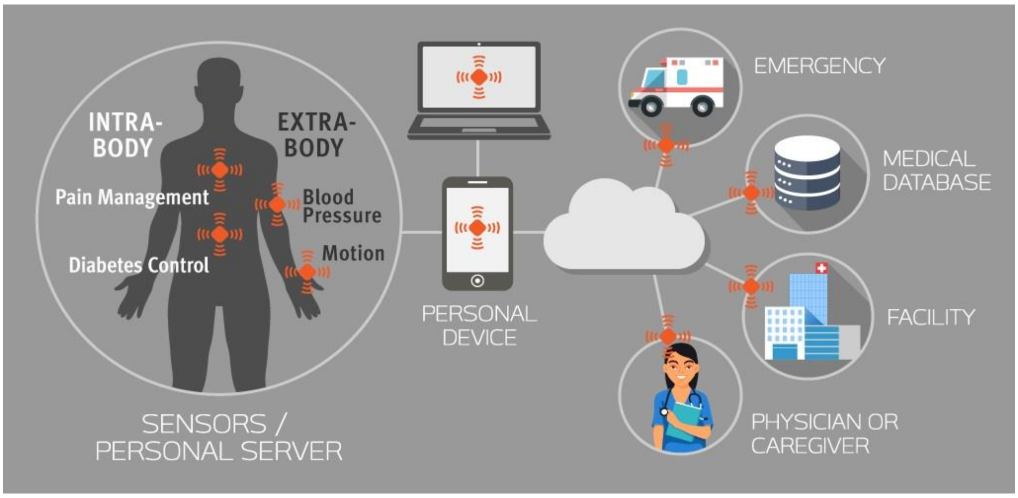

Figure 1. WBSN Concept

2. System Model

IEEE 802.15.4 MAC Protocol is the original scheme of WPAN (Wireless Personal Area Network) and WBAN system. It forms a Super-Frame structure where synchronization is executed through Beacon Frame. It is consisted of the active period where communication of data is carried out between the nodes and the coordinators and the inactive period where there is no communication of data. The active period is composed of 16 even slots and is formed based on sections of CAP (Contention Access Period), a competition-oriented method, and GTS (Guaranteed Time Slot) of CFP (Contention Free Period), a non-competition-oriented method that IEEE802.15.4 MAC Protocol may be referred as hybrid MAC Protocol. The device may be allocated with 1 coordinator or more than 1 GTS. Moreover, since there are 16 even slots in active period, as then more devices are allocated with

GTS, the length of CAP section is relatively reduced as well. IEEE 802.15.4 MAC Protocol may allocate GTS to the maximum 7 devices within the active period, and when all 7 are allocated, the rest of devices requesting GTS may not receive the GTS. The length of inactive period is also changeable by connection status of the between coordinator and nodes. However, IEEE 802.15.4 MAC protocol does not consider the transmission scheme of between initial packet and delayed buffer packet. WBSN environment is the assembly composed of each different node with limited numbers. In addition, since the main data is bio-signals, there are restrictions regarding energy. With different bio-signals of each patient, the data should guarantee reliability and fairness while being made easy for observation of bio-signals of patients at real time through display tools. The figure 2 shows the super-frame structure of IEEE 802.15.4 MAC protocol.

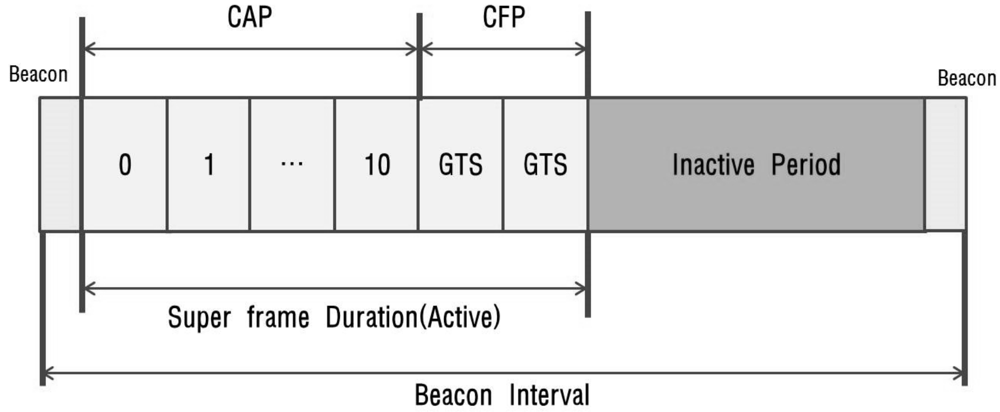

Figure 2. The Super-frame Structure of IEEE 802.15.4 MAC Protocol

Table 1 shows the WBAN requirements, which is based on the IEEE 802.15.6 Standard Documents [11]. We assume that the delay requirements in this paper are fully comply with the values of delay requirement in Table 1 throughout all the sections of this paper.

Table 1. WBAN Requirements

Application	Bit Rate	Delay	BER
Deep Brain Stimulation	< 320 Kbps	< 250 ms	10^{-10}
Drug Delivery	< 16 Kbps	< 250 ms	10^{-10}
Capsule Endoscope	1 Mbps	< 250 ms	10^{-10}
ECG	192 Kbps	< 250 ms	10^{-10}
EEG	86.4 Kbps	< 250 ms	10^{-10}
EMG	1.536 Mbps	< 250 ms	10^{-10}
Glucose Level Monitor	< 1 Kbps	< 250 ms	10^{-10}
Audio Streaming	1 Mbps	< 20 ms	10^{-5}
Video Streaming	< 10 Mbps	< 100 ms	10^{-3}

3. The Proposed Schemes

We analyzed that the situation that the simultaneous transmission of three different type of WBAN packets, which are EMG, Audio Streaming and Video Streaming. They have different maximum delay requirements, which are 20 ms, 100 ms and 250 ms, respectively. This kind of heterogeneous network can be occurred if both wearable CE and medical device transmit the packet at the same time. Figure 3 shows the super frame of the proposed MAC protocol. The proposed scheme assigns only the GTS for CAP and CFP as shown in in Fig. 3.

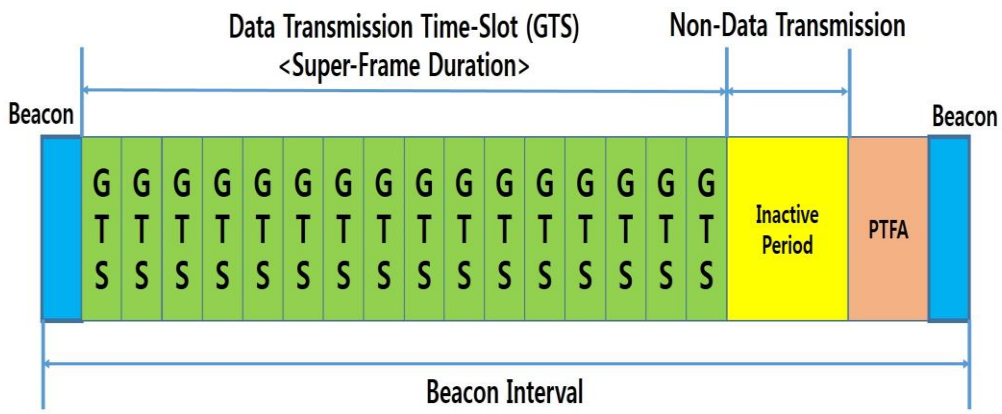

Figure 3. Super-frame Structure of the Proposed Schemes

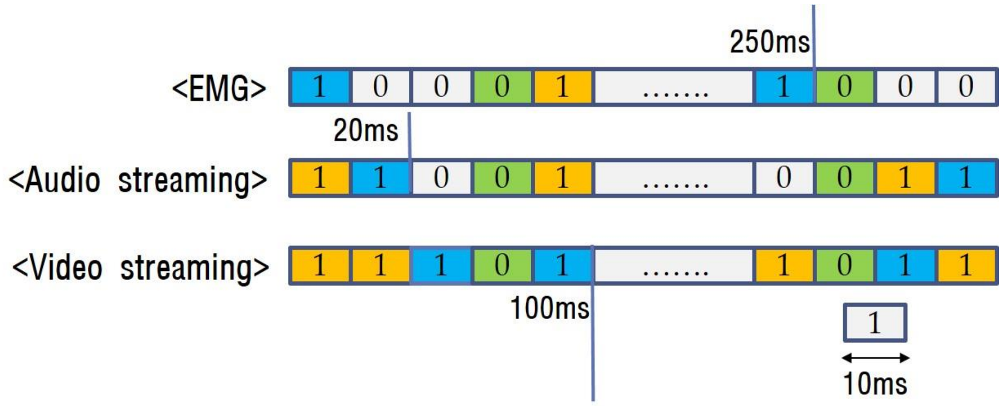

Figure 4. Time-slot scheduling of the Proposed Scheme

The figure 4 shows the time-slot scheduling of the proposed scheme. It also minimizes the Inactive Period to deal with the more packet transmission in current super frame. PTFA (Period of Time Slot Fore Allocation) frame decides the time slot allocation for the next super frame based on the information on the desired packet transmission in the next super frame, which gathered from all the nodes in the network. If two or more data packets attempt to transmit from coordinator for channel allocation at the same time the delay requirement is considered as the first priority and if one of them has the last opportunity to satisfy his maximum delay requirement, it can be transmitted with the first priority. Otherwise, if all of the collided packets are not close to the maximum delay requirement, the random selection is carried out for the next transmission data packet. The packets of nodes that failed to be scheduled in his time slots are moved to the buffer memory to get a next available time slot for packet transmission. So, the delayed packets try to catch the next time slot in the buffer, however, if they finally fail to transmit the data within each delay requirement, they are treated as the packet loss or failure since it is not effective as an available data packet. “0” means no packet transmission and “1” means the existence of packet transmission. Blue means the scheduled transmission in the corresponding time slot and yellow means the failure of transmission and they can be moved to buffer memory to wait for the next available time slot. Finally, green means the occurrence of no packet transmission in this time slot, hence, the scheduling for the delayed packets in the buffer is carried out according to the criterion of maximum delay requirements. Consequently, the proposed scheme applies the IEEE 802.15.6 based WBAN Requirement and also guarantee the data transmission of nodes with high packet data rate or short packet delay requirement in order to increase the effective network data rate and provide the QoS for the real time based data transmission.

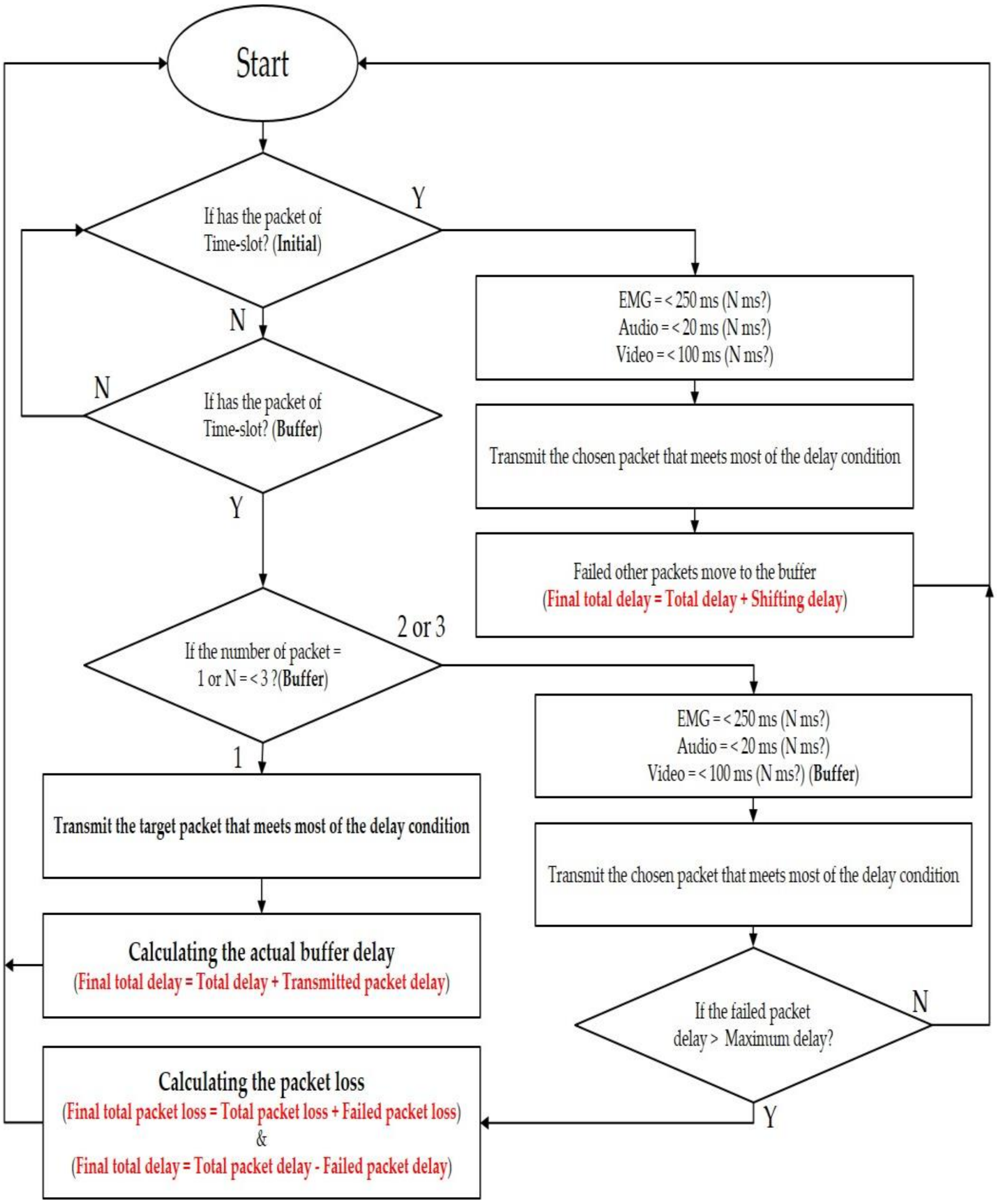

Figure 5. The Packet Transmission Process in the System

In this paper, the occurrence rate of each node data is assumed as same rate. The delay requirements from WBAN standard are applied in the initial data transmission environment and buffer packet transmission environment, the total transmission delay consider the delay of the packet that has been transmitted in the buffer. Also, the packets that failed to send within the maximum delay requirement of WBAN are treated as the packet loss. The proposed scheme is referred to as the DPL (Decreasing of the Packet-Loss) - MAC protocol [12]. Figure 5 shows the flow chart of the packet transmission processing of the buffer and also shows the principle of calculating the sum of total delay and the sum of total packet loss as the final performance measure.

3.1. All Random Scheme

All random schemes transmit the packet by random based scheduling for both the initial and the buffer stage in the decision of the next packet transmission. In other words, this scheme does not apply the delay requirements for each data packets for both initial packet transmission and other packet transmission from buffer with delayed packets

3.2. Packet Random Scheme (Non buffer Random Scheme)

Packet random scheme transmits the packet by considering WBAN delay requirement only in the packet transmission in the buffer. Hence, in the initial packet transmission, this scheme performs random scheduling for next packet transmission

3.3. Buffer Random Scheme (Non Packet Random Scheme)

Buffer random scheme transmits the packet by considering WBAN delay requirement only in the initial packet transmission. Then, this scheme does not consider any delay requirement in the buffer packet retransmission.

3.4. The Proposed DPL-MAC based Scheme

This scheme transmits the packet by considering WBAN delay requirement in both initial and buffer packet transmission.

In other words, it applies the maximum delay restriction to new and previous data packets simultaneously in order to reduce the rate of the packet loss very effectively.

4. Simulation Results

In this paper, our WBSN network environment was configured in a Star-Topology and the length of 1 Time-Slot was defined as 10 ms. Each cycle was made up of 100 Time-Slots, and the average collected from 100 cycles was calculated. In this paper, we assumed the same full amount of data in the same period. Additionally, the simulation environment is composed of both medical data and non-medical data. We only considered data transmission delay of the WBAN requirement except for the priority of each node. The occurrence rate of each data was defined as same rate (Audio 33%, Video 33%, EMG 33%). The functional assessment was executed under assumption that the total data will occupy 100% of the whole Time-Slot randomly. We examined the comparative analysis of each packet delay and packet loss of four schemes in the data traffic of 50%, 100% and 200%. The figure 6 describes the average packet delay performance for four schemes when the offered sum traffic is 50 % compared with available time slots as expected, the proposed scheme attains the smaller packet delay for the audio transmission which has smallest delay requirements in WBAN for real time transmission while EMG and video packets achieves the larger packet delay compared with the others. Figure 7 describes the rate of packet-loss performance for four schemes when the offered sum traffic is 50 % compared with available time-slots, respectively. The proposed DPL-MAC protocol indicates the smaller packet loss rate for the audio transmission which has smallest packet loss rate while EMG and video packets achieves the almost similar packet loss compared with the others.

Table 2. The Packet Delay under the Data Traffic 50%

	EMG	Audio	Video
All Random Scheme	6.4 ms	3.7 ms	6.9 ms
Packet, Buffer Non Random (DPL-MAC)	13.7 ms	0.5 ms	8.5 ms
Only Packet Random	7.3 ms	3.7 ms	6.7 ms
Only Buffer Random	11.9 ms	0.6 ms	9.3 ms

Table 3. The Packet-loss rate under the Data Traffic 50%

	EMG	Audio	Video
All Random Scheme	0 %	8.74 %	0 %
Packet, Buffer Non Random (DPL-MAC)	0 %	1.4 %	0.06 %
Only Packet Random	0 %	8.41 %	0.06 %
Only Buffer Random	0 %	1.6 %	0.06 %

The figure 8 indicates the average packet delay performance for four schemes when the offered sum traffic is 100 % compared with available time slots as expected, the proposed MAC protocol attains the smaller packet delay for between the audio data and the video data transmission while EMG packet achieves the larger packet delay compared with the others even if they still also satisfy the WBAN delay requirements. Figure 9 describes the rate of packet-loss performance for four schemes when the offered sum traffic is 100 % compared with available time-slots, respectively. The proposed DPL-MAC protocol indicates the smaller packet loss rate for between the audio data and the video data transmission than random scheme while EMG achieves the largest packet loss compared with the others.

Table 4. The Packet Delay under the Data Traffic 100%

	EMG	Audio	Video
All Random Scheme	51.8 ms	21.2 ms	78.5 ms
Packet, Buffer Non Random (DPL-MAC)	120.5 ms	10.8 ms	60.0 ms
Only Packet Random	63.6 ms	20.6 ms	71.2 ms
Only Buffer Random	108.2 ms	4.3 ms	100.3 ms

Table 5. The Packet-loss Rate under the Data Traffic 100%

	EMG	Audio	Video
All Random Scheme	1.35 %	24.07 %	7.86 %
Packet, Buffer Non Random (DPL-MAC)	5.6 %	10.04 %	3.8 %
Only Packet Random	3.56 %	21.75 %	5.03 %
Only Buffer Random	4.57 %	6.26 %	11.38 %

The figure 10 indicates the average packet delay performance for four schemes when the offered sum traffic is 200 % compared with available time slots as expected, the proposed MAC protocol attains the smaller packet delay for the audio data transmission while EMG packet and video packet failed to satisfy the WBAN delay requirement. Also, every scheme failed to satisfy the WBAN requirement for the EMG packet and video packet transmission. Figure 11 describes the rate of packet-loss performance for four schemes when the offered sum traffic is 200 % compared with available time-slots, respectively. The proposed DPL-MAC protocol indicates the smaller packet loss rate for the audio data transmission than the others while EMG achieves the largest packet loss compared with the others. Hence, In the high data traffic environment, when EMG packet and video packet processing, packet loss rate of the proposed MAC protocol increases rapidly. However, it can be confirmed that the proposed MAC protocol guarantee both the reduced packet delay and the reduced packet loss rate in comparison with other methods under the low data traffic environment.

Table 6. The Packet Delay under the Data Traffic 200%

	EMG	Audio	Video
All Random Scheme	266.6 ms	22.2 ms	101.9 ms
Packet, Buffer Non Random (DPL-MAC)	1113.2 ms	1.8 ms	175.2 ms
Only Packet Random	266.9 ms	21.9 ms	101.2 ms
Only Buffer Random	1008.5 ms	1.9 ms	176.6 ms

Table 7. The Packet-loss Rate under the Data Traffic 200%

	EMG	Audio	Video
All Random Scheme	49.05 %	52.33 %	48.76 %
Packet, Buffer Non Random (DPL-MAC)	81.03 %	8.13 %	61.18 %
Only Packet Random	50.84 %	51.4 %	48.05 %
Only Buffer Random	78.8 %	8.7 %	62.24 %

5. Conclusion

In this paper, we examined the performances of MAC protocol in WBAN based sensor networks. We proposed the buffer control with delay restriction in order to minimize the packet delay and packet loss rate for supporting the QoS and real time service transmission in the variable data traffic. We considered the actual delay of the buffer packet, hence, the proposed MAC protocol calculated the actual packet delay of the system by referencing whether the packet in the buffer is successfully transmitted or not. Simulation results was made to packet delay and packet loss rate for pure random scheme, packet random scheme, buffer random scheme and the proposed scheme with delay reduced buffer control. Through the simulation results, the proposed scheme improved the QoS of the overall system by minimizing the packet delay for audio packet transmission and also significantly reducing the the packet loss rate for EMG and video packet transmission in WBAN based healthcare monitoring network lower data traffic environment.

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References

[1] K. S. Kwak, S. Ullah and N. Ullah, "An Overview of IEEE 802.15.6 Standard", Applied Sciences in Biomedical and Communication Technologies (ISABEL), 3rd International Symposium, Rome, **(2013)**.
[2] J. S. Choi and J. G. Kim, "An Improved MAC Protocol for WBAN through modified frame structure", International Journal of Smart Home, vol. 8, no. 2, **(2014)**, pp. 65-76.
[3] J. S. Kim, J. H. Lee and K. W. Rim, "Energy Efficient Key Management Protocol in Wireless Sensor Networks", International Journal of Security and Its Applications, vol. 4, no. 2, **(2010)**.
[4] O. G. Morchon, H. Baldus and D. S. Sanchez, "Resource Efficient Security for Medical Body Sensor Networks", Wearable and Implantable Body Sensor Networks, International Workshop on, IEEE **(2006)**.
[5] A. Manirabona, S. Boudjit and L. C. Fourati, "A Priority-Weighted Round Robin scheduling strategy for a WBAN based Healthcare Monitoring System", Consumer Communications & Networking Conference (CCNC), 2016 13th IEEE Annual, Las Vegas, NV, USA, **(2016)**.
[6] LAN-MAN Standards Committee of the IEEE Computer Society, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification", IEEE, New York, USA, **(1997)**.
[7] S. A. Gopalan and J. T. Park, "Energy Efficient MAC Protocols for Wireless Body Area Network: Survey", Ultra-Modern-Telecommunications and Control Systems and Workshops(ICUMT), 2010 International Congress on, **(2010)**.
[8] H. T. Kwon and S. Y. Lee, "Energy-efficient multi-hop transmission in Body Area Networks", Personal, Indoor and Mobile Radio Communications, 2009 IEEE 20th International Symposium on, Tokyo, Japan, **(2009)**.
[9] IEEE 802.15.4 Standard-2003. Part 15.4, "Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Network (LR-WPANs)", IEEE Computer Society, **(2003)**.
[10] H. G. Lee, K. H. Lee and Y. T. Shin, "A Priority Based MAC Protocol for Emergency Data Transmission in Wireless Body Area Networks", Telecommunication Journal of the Institute of Electronics Engineers of Korea, vol. 49, no. 4, **(2012)**, pp. 26-33.
[11] R. Cavallari, F. Martelli, R. Rosini, C. Buratti and R. Verdone, "A Survey on Wireless Body Area Networks: Technologies and Design Challenges", IEEE Communications Surveys & Tutorials, vol. 16, no. 3, **(2014)**, pp. 1635-1657.
[12] R. H. Kim. R.H and J. G. Kim, "Buffer Control by Delay Limitation for WBAN based Healthcare Monitoring Network Environment", Asia-pacific Proceedings of Applied Science and Engineering for Better Human Life vol. 4, **(2016)**, pp. 97-101.

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