Fragmentation in MAC IEEE 802.15.4 to Improve Delay Performance in Wireless Body Area Network (WBAN)

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Abstract. A Medium Access Control (MAC) protocol plays a significant role in enhancing the performances of Wireless Body Area Network (WBAN). This technology is commonly implemented IEEE 802.15.4 standard that works under CSMA/CA protocol. In addition, WBAN deals with probability of high traffic occurrence due to collection bulk of medical data that are generated from several bio-sensors through a continuous monitoring of patient’s health. This phenomenon could result to congestion in the network which may lead to increment in delay and packet loss that could collapse the network. The increment in these two performances could lead to wrongly diagnosed of the diseases as well as late in medical help. Hence, the proposed mechanism aimed to reduce the delay through fragmenting the packets by decrementing the slot time in MAC 802.15.4 protocol under different number of number nodes with constant packet size and bit rate. The performances of the proposed mechanism are measured in terms of delay and packet loss by using OMNeT++ simulator tool. Based on the collected results, the proposed mechanism has shown a promising result in reducing the delay which means that it has improved the network performance of WBAN.

1. Introduction

A Wireless Body Area Network (WBAN) is one of the advanced technologies derived from Wireless Sensor Networks (WSN). It specifically focuses on the remote health monitoring applications by offering a continuous health monitoring over a longer period of time and real-time feedback to the user and medical staffs [1]. It is made up of several tiny of intelligent health sensors that can be wearable or implanted in the body. These sensors will be integrated and communicated through existing wireless technologies such as IEEE 802.15.4 and Internet. This has enable medical personnel to remotely monitor the condition of health of users without constraining the movement and daily activities of the user [2]. Additionally, this technology provides an earlier detection of any abnormalities in the vital signals of the body such as heart rate and blood pressure. Due to possibility of dealing with heavy traffic of data transmission, this technology is really stringent to delay and packet losses especially when there is a presence of network congestion as increment in these performances could degraded the overall performances of the system. In short, it is in need of a prompt and timely delivered of medical assistance which could save the user’s life and reduce the risk of mortality. Thus, a proper choice of MAC protocol is strictly needed to gain optimum performances in terms of delay, Packet Delivery Ratio (PDR) and throughput of the system.
There are two types of Multiple Access Control (MAC) protocols that are commonly adapted in WBAN such as Carrier Sense Multiple Access (CSMA) and Time Division Multiple Access (TDMA) according to [3][4]. However, the sensors in WBAN commonly use IEEE 802.15.4 technology that implements CSMA mechanism to communicate in the system. This technology offers low-data rate of 250Kbps which is suitable to be adopted in medical application [5]. CSMA is known as a contention-based protocol where it listens first before transmitting any data to the destination node of the shared medium. It has been further developed into Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) and Carrier Sense Multiple Access/Collision Detection (CSMA/CD). But, CSMA faces a strict restriction in utilizing maximum bandwidth and throughput during increment number of nodes and rate of transmission. This is due to the risk of collision occurrence between packets and acknowledgement (ACK) frame in a certain time duration. Moreover, the performances of WBAN could severely impacted if there is a transmission of longer packet size which will be more elaborated in the next section. Hence, suitable selection of slot time and fragmentation of packets are highly recommended to improve the network performances in the WBAN and to guarantee its reliability as well.

To solve the above-mentioned problem, fragmentation of packet is done by exploiting a random values of slot time of MAC IEEE 802.15.4 protocol in order to measure the delay performances of WBAN under constant packet size with different number of nodes. To the best of our knowledge, this is the first attempt of this method to enhance the WBAN performances. The rest of the paper is organized as follows. Section 2 discussed on the previous and related works on IEEE 802.15.4 and its fragmentation in WBAN. Section 3 elaborates the mechanism of the proposed method and used value of parameters for the WBAN simulation purpose. Section 4 presents the detailed analysis on the output of delay performances in the WBAN. Finally, Section 5 concludes and presents some future works on the WBAN.

2. Related Works

2.1. Mechanism of IEEE 802.15.4

As aforementioned in earlier section, IEEE 802.15.4 works on CSMA protocol which is particularly implemented CSMA/CA. This mechanism operates as if the medium is found busy, the node needs to wait for a certain duration before transmitting the data and re-listening to the shared medium whether it is free or not. The difference between CSMA/CA and CSMA/CD is the transmission is deferred for a random exponential back-off when it detects of busy medium [6]. To be exact, the deferred transmission of packet in the CSMA/CA mechanism at the end of the superframe can lead to high delay due to insufficient time to complete the transmission process since it increases the probability of the collisions. The collision of these data could be more severed if there is existence of network congestion. Also, this could be worst when it involves with the transmission of longer packet size.

This CSMA/CA can be divided into two categories such as beaconless of Unslotted CSMA/CA and beacon-enabled of Slotted CSMA/CA in the IEEE 802.15.4 [7] [8]. For the delay stringent application as medical application, a proper tuning of slot time is really important to lessen the delay which can ensure the information and medical help can be timely arrived. Hence, this paper is focused to study the mechanism of Slotted CSMA/CA in MAC IEEE 802.15.4 protocol.

The CSMA/CA initiates the number of Back-Off (NB), Back-Off Exponent (BE) and Contention Window (CW) which have default value of 0, 2 and 2 respectively. The value of BE can be varied between [2, macMinBE] which macMinBE has default value of 3. Later, node delay for a random number of uniformly generated Back-Off period (BP) that lies between [0, 2BE -1] is started to count down. The operation must begin at the boundary of BP. Once the Back-Off time expires to 0, the algorithm performs 1st Clear Channel Assessment (CCA1) to assess the channel condition. The CW is
The 2nd CCA which is termed as CCA2 is carried out if CW is not equal to 0. These CCAs are done to avoid any potential collisions between acknowledgement (ACK) packet. Then, the node starts to transmit data and waits for acknowledgement (ACK) packet from Coordinator.

It is worth to state that, if the channel is sensed as idle again after the successful transmission of packet, the remaining BP should be sufficient for the next transmission of packet and ACK. In contrast, if CCA1 or CCA2 spots the channel is busy, the value of BE and NB is incremented by 1 and CW is re-initialized to 2. Meanwhile, increment in BE means there is a high probability for longer delay of Back-Off. In this case, BE and NB can reach to their maximum value of 5 which is known as aMaxBE and macMaxCSMABackoff correspondingly [9]. If the maximum value of macMaxCSMABackoff is reached, a failure report will be sent to the higher layer and the packet is discarded. Else, the algorithm goes back to previous step and the Back-Off operation is re-initiated. To simplify, the MAC algorithm for Slotted CSMA/CA in IEEE 802.15.4 is depicted in the flowchart as shown in Figure 1.

![Slotted CSMA/CA algorithm](image)

**Figure 1.** Slotted CSMA/CA algorithm [10]

### 2.2. Data Fragmentation Scheme

The fragmentation of data is also done in the MAC protocol as well. Fragmentation is defined as a chunking a large packet into smaller one. Sending a smaller packet will shorten the time taken for the packet to arrive at the destination. In other words, there will be a reduction in delay which directly improve the performance of the system. Nevertheless, MAC and PHY overhead are added to the frame of fragmented data.

In [11], data fragmentation is done in WSN for IEEE 802.15.4 which deal with small beacon interval application. In this work, a smaller data is sent in a small Back-Off period that are not being used in IEEE 802.15.4. This means the fragmentation of data payload is depending on the remaining number of Back-Off periods. For instance, the current remaining Back-Off period are 8, then the node can only transmit its data for only 5 Back-Off period. The data is fragmented according to the value of 5 Back-Off period. This work has achieved reduction in collision and high aggregation of throughput. However, this work does not consider about delay performance which is one of the crucial measurements in the WBAN. In other work[12], the ACK frame is used when the fragmentation is not employ. On the other hand, if the fragmentation is done, the ACK frame is not used to achieve short transmission time and this mechanism followed Markov chain under a non-saturation traffic by means
there is no incoming of new packet until the packet is fully served. This mechanism managed to achieve high utilization of bandwidth as well as improve the throughput and decrease the delay.

3. Proposed Method

A suitable packet size of WBAN is ranging from 30 to 60 bytes [13]. In this study, the packet size of 30 bytes is chosen as smaller packet size reduces the transmission delay and contains less bit error in packet. Theoretically, it requires 1 millisecond in order to have a successful packet transmission of 30 bytes under IEEE 802.15.4 which has bit rate of 250 Kbps. This can be calculated using (1).

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\text{Slot time, } T (s) = \frac{\text{Length of Packet (bits)}}{\text{Bit rate (bits per second)}}
\]  

However, setting up this slot time value could result in high delay which could cause negative impact to the overall performances of WBAN. This phenomenon could lead to late in medical assistance and might increase the risk of death to the patient. This is especially true during dealing and transmitting larger packet size that can cause inevitable collision and waste the channel utilization in IEEE 802.15.4 Hence, the packets of 30 bytes should be fragmented into a smaller size under certain slot time. In short, the relationship between length of packet size is directly proportional to the slot time in the MAC protocol of the system under a constant bit rate.

The proposed method aims to reduce the transmission delay in the WBAN which could lessen the impact of network congestion by fragmenting the data through decreasing the value of slot time which ranging from 0.2 to 1.0 milliseconds. This experiment is carried out under different number of nodes from 20 to 60 and constant bit rate of 250Kbps and Contention Window (CW) of 31.

The simulation of WBAN network to test the proposed method is carried out in OMNeT++ simulator [14] using MAC protocol of IEEE 802.15.4 slotted under CSMA/CA. The details of other parameter setting is tabulated in Table 1 as follows.

| Parameters          | Value       |
|---------------------|-------------|
| Packet Size         | 30 bytes    |
| Data Rate           | 250 Kbps    |
| Coverage Area       | 50m x 50m   |
| Routing Protocol    | AODV        |
| Simulation Time     | 200 seconds |

4. Results and Discussions

This section highlights on output analysis from the performance of proposed method in terms of delay, percentage packet loss, throughput and Packet Delivery Ratio (PDR) in the WBAN.

4.1. Average Delay

Average delay reflects the time taken for all packets to be transmitted from source to destination. This delay is measured between slot time of 0.2 to 1.0 millisecond for fix packet size of 30 bytes. The obtained results are conveyed in Figure 2.
In general, it can be clearly seen that there is an increment pattern of delay performances under different number of nodes through varying slot time. As slot time increases, the delay increases as well. Theoretically, more packets are generated when the number of nodes are increased. Thus, it would take longer time to transfer the packets to the destination. The packets have to wait for a longer time in order to accessing the medium during detecting the condition of the channel. This condition could prevent timely medical help and misdiagnose of the disease. From the graph, as short slot time is used, it brings to the decrement in delay and thus promise an efficient transmission of data across the network. This would increase the reliability of WBAN as well. From the plotted results, the proposed mechanism has shown a promising effects in the delay performances of the WBAN.

4.2. Percentage Packet Loss

Percentage packet loss indicates number of loss packets during transmitting and receiving data from the source to the destination.

From Figure 3, the maximum rate of packet loss is noted during number of nodes are 60 compares to 20 and 40 nodes. With this major difference in loss of packets, the tendency of congestion to occur is high. Specifically, under slot time of 0.2 milliseconds, there is less number of packets loss in the WBAN compares to slot time of 1.0 milliseconds. This result has verified that implementing short slot time lead to less packet loss as more packets have been successfully accessed the medium.
4.3. Throughput

Throughput refers to the total number of successful bit transmission in a specific period of time.

Figure 4: Throughput performance for proposed fragmentation

From Figure 4, low throughput is detected as the number of nodes are increased. However, in slot time of 0.2 milliseconds, the value of throughput is higher compared to 1.0 milliseconds for 20, 40 and 60 nodes. As slot time increases, throughput is slowly decreased which means many packets fail to access the channel due to longer waiting time to be served. The packets might be dropped and needed for retransmission. This has reduced the reliability of the WBAN. Hence, deploying short slot time conveys best performance in terms of throughput.

4.4. Packet Delivery ratio (PDR)

It reveals the ratio of number of received packets at destination to the number of transmitted packets by the source.

Figure 5: Packet Delivery Ratio (PDR) performance for proposed fragmentation

As reflects in Figure 5, the PDR is high for 20 nodes compared to 60 nodes for different slot times. This shows that a high number of packets have successfully received at the destination. Precisely, in slot time of 0.2 milliseconds, the probability of congestion phenomenon is less to present for number of nodes from 20 to 60. Thus, more packets are able to be served in the network. In short, the proposed mechanism shows better performance in PDR for high number of nodes.
5. Conclusion

A high delay would worsen the network performance of WBAN which could lead to packet loss especially critical packets. Based on this experiment, a fragmentation scheme to the packets through decrementing the slot time has contributed to the significant reduction in delay of WBAN. This study will be furthered boosted by modifying this scheme to be suitably adopted according to the level of importance of the packets such as normal, abnormal and critical packets in the WBAN.

6. References

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