An Experimental Study of the distributed hybrid MAC protocol for wireless body area network

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Abstract: Wireless Body Area Networks (WBANs) is a collection of vital and electrical signals measured from various parts of the body to help analyze therapeutic approaches to patients using wireless data transmission. The significant data has to communicate with collision avoidance to obtain a high throughput. In this paper, a hybrid MAC layer communication is implemented between CSMA/CA and TDMA. CSMA/CA communication has been introduced to manage the TDMA sequence of transmissions without a central node. The experimental results in this system is using the real wireless devices, TelosB with the IEEE 802.15.4 standard. We studied the convergence speed of transmission sequence allocation which has been measured in the CSMA/CA period. This parameter has been evaluated for the network and energy efficiency in WBANs.

Keywords: WBANs, MAC protocol, CSMA/CA, TDMA

1. Introduction

Wireless communication technology helps to collect information from the patient's vital signs to see how it has changed in order to take timely assistance to the patient. The example of the signals in human body is heart rate, temperature, blood pressure, Electroencephalography (EEG), Electrocardiogram (ECG), Electromyography (EMG). They all are different data types and sizes. WBANs was developed to respond to medical technology applications. Currently, there is a communication design in the MAC layer that uses the advantages of each protocol to obtain a high data throughput, such as slotted ALOHA with time-division multiple access (TDMA) [1], or carrier sense multiple access with collision avoidance (CSMA/CA) with TDMA [2-4].

This research aims to develop a form of communication for distributed Wireless Body Area Networks (WBANs) with IEEE 802.15.6 standard that defines the needs of Wireless Body Area Networks. Nevertheless, in the real experiments were performed with the IEEE 802.15.4 standard to study the effects of attaching a communication node on the body and improving communication in the MAC Layer. In this paper, the efficiency of the transmission sequences without requiring a central node to manage all devices was measured. It provides the greater flexibility with respect to the different types and volumes of data for each sensor node.

2. MAC Protocol

The system in this paper studies a protocol for data communication in the MAC layer. It is designed to combine between CSMA/CA and TDMA to make the high network performance and energy efficient. In the first phase, it will be the use of CSMA/CA to compete for the order in which the data is transmitted. When the sequencing is complete, it enters the TDMA phase. We use CSMA/CA communication method to allocate the time interval for sending packets of each node in the system as well as utilize TDMA protocol to transmit packets for efficient communication and energy efficiency. When the node is not at the time of data transmission, it enters into sleep mode, making it more energy saving.

First, we have designed a CSMA/CA communication mechanism to compete for beacon transmissions to allocate a time interval within one T_{frame} to each node in the system so that they do not collide. Each node transmits and listens to the beacon from the previous and next node and adjusts its transmission interval according to equation 1 [5].

$$t_{curr}^{(k+1)} = (1-\alpha)t_{curr}^{(k)} + \alpha\frac{t_{prev}^{(k)}+t_{next}^{(k)}}{2} \quad (1)$$

Where $t_{curr}^{(k+1)}$ is the time interval for the node to send beacon packets in the next T_{frame}. α is called alpha which is a parameter that determines how much we are based on the time interval of your own or neighbor node. $t_{curr}^{(k)}$ is the time interval for the node to send beacon packets. $t_{prev}^{(k)}$ is the timing to receive beacon packets from the previous node. $t_{next}^{(k)}$ is the time interval to receive beacon packets from the next node.

3. Implementation

3.1 Experimental Setup

In the experiment, beacons are sent from the sensor node to another sensor node in the system to manage the data transmission without any collision. It applies with TelosB sensor nodes based on RF Chip Texas Instruments® CC2420 frequency band 2.4GHz ~ 2.485GHz and processed MCU TI MSP430F1611 RAM 10Kb with IEEE802.15.4 standard.

While the nodes send beacons, the base station receives the beacons from the nodes to store the results and collect them in the computer using TelosB as a base station connected to the computer via serial port with the baud rate of 115200 bps. As seen in Figure 1, the experiment has been set up.

3.2 Test Scenario

Test case I sends beacons between nodes in the network to

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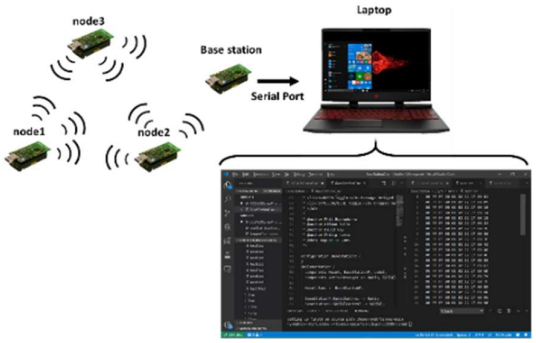

Figure 1. Architecture of the network system

prioritize transmission. We have selected the three alpha values between [0,1] and increased the number of nodes entering the network from 3 to 12 nodes. This can discover the effect on the number of cycles that go into convergence, as illustrated the parameters used for the experiment in the Table 1. While test case II sends beacons between nodes in the network with the fixed alpha at 0.85 and then scaled the T_{frame} for 1, 2 seconds and the ddynamic T_{frame} calculated from the second equation, where the number of nodes in the network affects the T_{frame} size, as demonstrated in Table 1.

$$T_{frame} = N_{nodes} \times T_{send} \quad (2)$$

From the equation, N_{nodes} is the number of nodes in the network and T_{send} is the time for sending data.

Table 1. Parameters used for the experiments

Parameters	Value (Test case I)	Value (Test case II)
Number of nodes	3, 6, 9, 12	3, 6, 9, 12
alpha	0.25, 0.55, 0.85	0.85
T_{frame} (seconds)	1	1, 2 and Dynamic

4. Results and Discussion

According to the test case I, the experiment adjusts alpha at 0.25, 0.55 and 0.85 respectively, it can be seen that the alpha value is 0.25 and 0.55 for the different number of nodes, they obtain the same number of cycles for convergence time to going to steady state. Whereas the alpha value is 0.85, the number of rounds entering the steady state is more than twice for three nodes in the system when comparing to other number of nodes as seen in Figure 2.

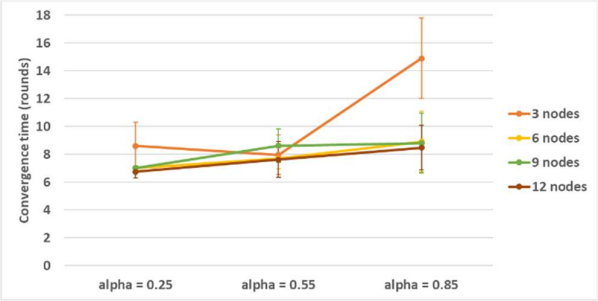

Figure 2. The number of rounds to entering the transmission period in test case I

From the experiments of the T_{frame} scaling according to the test case II, it can be considered that at one second and two seconds of the T_{frame} setting for three nodes take quite a long time for the number of cycles for convergence time when comparing to the other parameter settings as demonstrated in Figure 3.

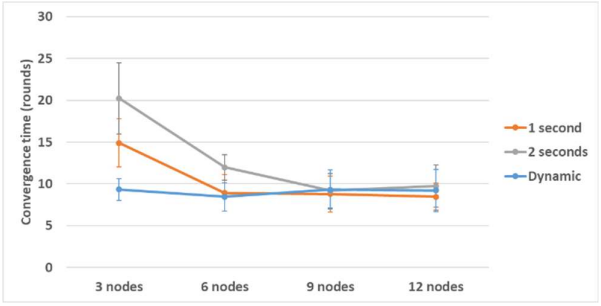

Figure 3. The number of cycles until steady state in test case II

From the experimental results, when the value of alpha increases, the intervals of neighboring nodes are used to affect the next beacons sending with regards to increase the number of cycles to enter the convergence. Moreover, when the size of the T_{frame} is resized to match the number of nodes in the network with dynamic T_{frame} case, it remains the number of cycles to reach until steady state constantly for the different number of nodes.

In future work, after we selected the suitable parameters from these experiments, we then study the prioritized network communication and sleep mode strategy for measuring the throughput and energy efficiency to present our distributed hybrid MAC protocol for WBAN application.

5. Conclusion

The MAC protocol both CSMA/CA and TDMA has been studied in real implementation for distributed wireless network. The experimental results show that the alpha parameter and the number of nodes in the system has not affected much in the number of cycles to go to steady state for entering to data transmission period.

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