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An Improved MAC Protocol with Delay Limitation for Medical Wireless Body Sensor Networks

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Abstract

With advanced wireless communication technology and the ubiquitous environment, the scope of WBSN applicability has expanded. 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. The MAC Protocol proposed in this paper is the TDMA based MAC (Medium Access Control) Protocol, based on CSMA/CA environment. The proposed MAC protocol refers to priorities of different bio signals with different characteristics and sets up minimum transmission delay time and reduces the mean packet loss of the system. It also guarantees the transmission of bio signal nodes with relatively low priorities to improve the QoS of the whole transmission.

Keywords: WBSN, CSMA/CA, TDMA, GTS, DTD-MAC, Channel Allocation

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1 Introduction

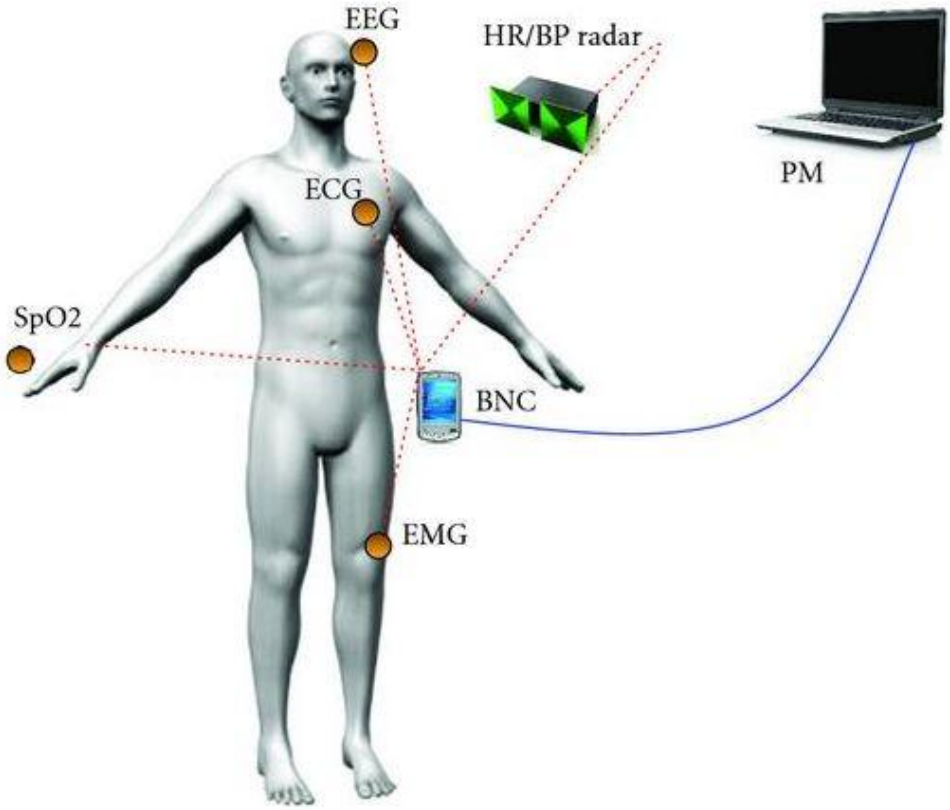

Fig 1. WBSN Environment

WBSN (Wireless Body Sensor Network) shown in Fig. 1, as an application network advanced from WBAN [1], is a part of WSN (Wireless Sensor Network) [2]. In the environment, bio signal data are collected from devices or nodes on the body or implanted in the body. The patient's health conditions are monitored in real time. WBSN indicates that it will be necessary to study the wire-based medical environment and monitoring environment in the near future [3]. CSMA/CA(Carrier Sensed Multiple Access/Collision Avoidance) [4] causes a great deal of energy consumption of application systems because of frequent Idle Listening and Packet Collision. Accordingly, it is found that TDMA (Time Division Multiple Access)

technique is better in terms of power consumption and transmission delay reduction of Nodes or Devices [5] [6].

2 The Bio-MAC Protocol

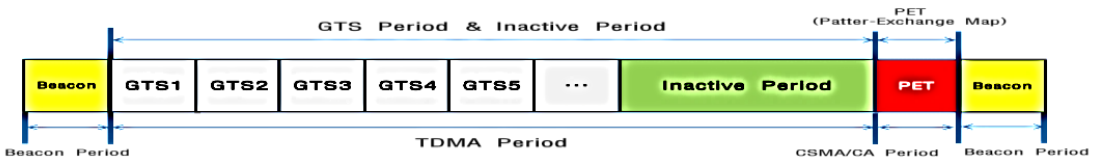

Fig 2. Structure of Bio-MAC Protocol Super Frame [7]

Fig. 2 illustrates the structure of Bio-MAC Protocol Super Frame. The CDMA/CA based MAC Super Frame structure with the TDMA type, optimized in WBSN environment, was made in the process of changing IEEE 802.15.4 MAC Protocol [8] in the conventional Zigbee environment. Beacon Time-Slot is the period of synchronizing Super Frame every cycle. TDMA based scheduling process allocates a channel to each GTS(Guaranteed Time-Slot) Time-Slot, the period during which nodes with different bio signals guarantee data transmission as much as the Time-Slot. PET (Pattern Exchange Map) Time-slot is the period during which scheduling information on GTS Time-Slots to be allocated in the next cycle is transmitted to Coordinator in the current cycle in advance. Inactive Period is the sleeping period of Time-Slots which doesn't execute channel allocation, and goes into low-power Mode.

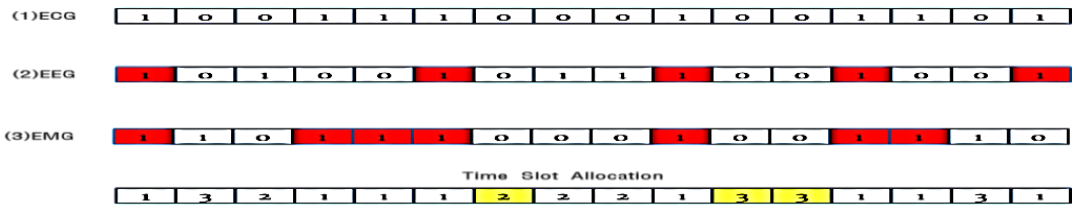

Fig 3. Example of Bio-MAC Pattern Scheduling

As shown in Fig. 3, in PET period, Coordinator distinguishes the priority of each bio signal node. Compared to nodes with relatively low priorities, nodes with high priorities execute GTS allocation by priority. Nodes with low priorities put data in their buffer and transmit the it in the channel period during which there is no data transmission. Therefore, compared to nodes with high priorities, nodes with low priorities have continuous transmission delay.

3 The Proposed MAC Protocol

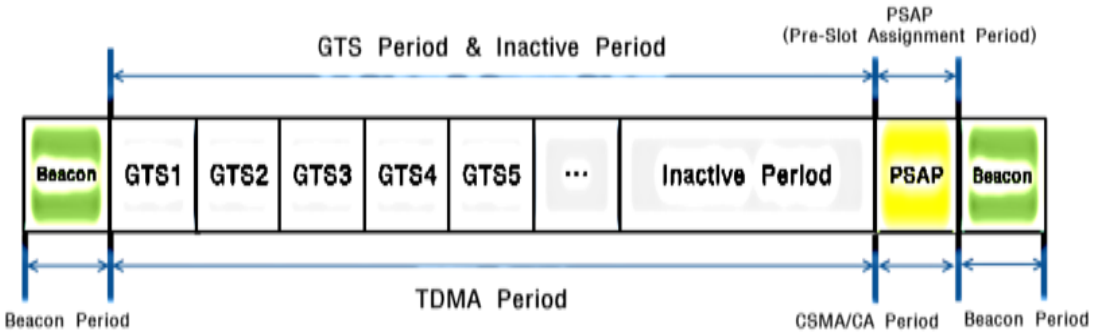

Fig 4. Super Frame of DTD-MAC Protocol

The proposed MAC Protocol is shown in Fig. 4. Its Super Frame has the same type and structure as the Bio-MAC Protocol Super Frame, and the operation in each Frame period is nearly similar. However, in the proposed protocol, PBM(Pattern-Bit Map) in PSAP(Pre-Slot Assignment Period), which is equivalent to PET period of Bio-MAC Protocol Super Frame is quite different from in the existing Bio-MAC Protocol. The proposed MAC Protocol applies the delay requirements of IEEE 802.15.6 WBAN(Wireless Body Area Network) shown in Table 1. If the requirements of BAN environment are not met [9], the data of each application are not effective.

Table 1. Requirements of WBAN Application

Application	Bit Rate	Delay	BER
Deep Brain Stimulation	< 320Kbps	< 250ms	10^{-10}
Drug Delivery	< 16Kbps	< 250ms	10^{-10}
Capsule Endoscope	1Mbps	< 250ms	10^{-10}
ECG	192Kbps	< 250ms	10^{-10}
EEG	86.4Kbps	< 250ms	10^{-10}
EMG	1.536Mbps	< 250ms	10^{-10}
Glucose Level Monitor	< 1Kbps	< 250ms	10^{-10}
Audio Streaming	1Mbps	< 20ms	10^{-5}
Video Streaming	< 10Mbps	< 100ms	10^{-3}
Voice	50~100Kbps	< 100ms	10^{-3}

To prevent excessive delay of data which nodes with low priorities have, the proposed method transmits relevant data by priority if it reaches the maximum delay tolerance time which is used to keep data effectiveness [10]. The proposed method is aimed at decreasing delay, and thus is named DTD-MAC (Decrease of Transmission Delay). In the proposed protocol, each node attempts data transmission for channel

allocation, and when it reaches the maximum delay of 250ms, it receives an allocated channel first regardless of its existing priority. In general, In the period during which all nodes do not transmit data for channel allocation, the data in each node's buffer is transmitted based on the existing priority for nodes. But, in the proposed scheme, if it exists that the buffer data from previous nodes reaches the maximum delay of 250ms from the first delay point, the relevant node's data transmission is transmitted with first priority. The packets of the node which failed to transmit data after the maximum delay are regarded as packet loss. In the Bio-MAC, in case that, each node transmits data in the current cycle and the next available cycle, the priority of each node is applied in same manner. However, DTD-MAC protocol takes into account data transmission within the maximum delay by priority on the basis of the point where transmission delay occurs. Also, by excluding ineffective data which cause excessive transmission delay, the proposed protocol is expected to decrease the mean transmission delay. It also prevents particular bio information from being transmitted exclusively, and thereby fairly guarantee transmission QoS in the real-time data processing environment.

4 Performance Comparison

In this paper, the WBSN environment is established as Star Topology. One Time-Slot was set to 50ms, and one cycle consists of 100 time slots. In one cycle, data was transmitted five times, and the mean value was calculated. Data occurrence probability of each ECG, EEG, and EMG Node was based on Table 1. As a result, on the basis of EEG, ECG data was set to 2-fold, and EMG data was set to 18-fold. Additionally, every 250ms, when each node failed to transmit data, it was tallied up to Packet Loss Data (DTD-MAC) and Invalid Data (Bio-MAC). Fig. 4 illustrates the mean transmission delay per packet of each MAC Protocol. As shown in Fig. 4 and Fig. 5, DTD-MAC Protocol decreased mean transmission delay and mean packet loss far more than Bio-MAC.

Bio-MAC Protocol takes into account a priority of each node at the time of executing channel allocation, which cause some nodes with low priority continuously fail to receive an allocated channel. Hence, it means the long transmission delay in their buffer and then it results in have a higher probability of Invalid Data in the final stage. As a result, the protocol increases the overall transmission delay of the system. However, DTD-MAC Protocol applies not only each node's priority, but also to the maximum delay tolerance with serving a role of guaranteed transmission after the transmission point. Therefore, the protocol guarantees the valid transmission of bio information which has low priority. We also deals with as a packet loss for the ineffective data that exceeds the maximum delay tolerance in the previous cycle for the real-time processing. Hence, this delay restriction prevents any additional unnecessary transmission, and also decrease the overall mean transmission delay per packet in the system compared with the conventional Bio-MAC protocol.

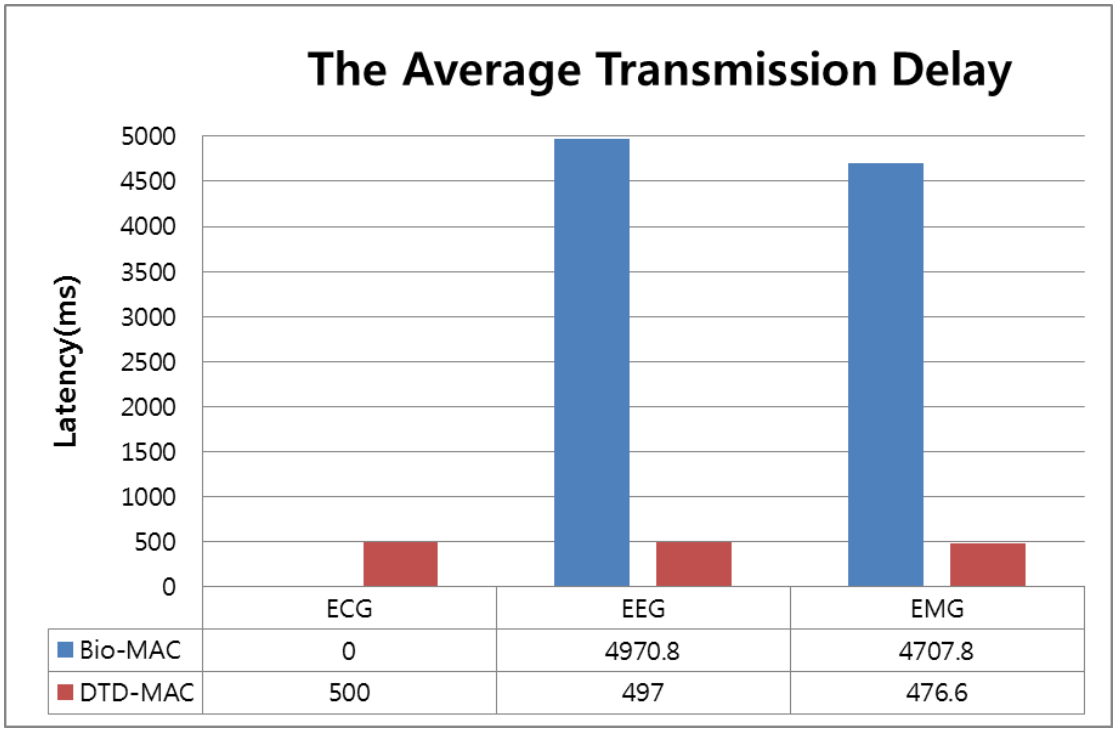

Fig 5. Comparison of the average transmission delay on the transmission of various Bio signal

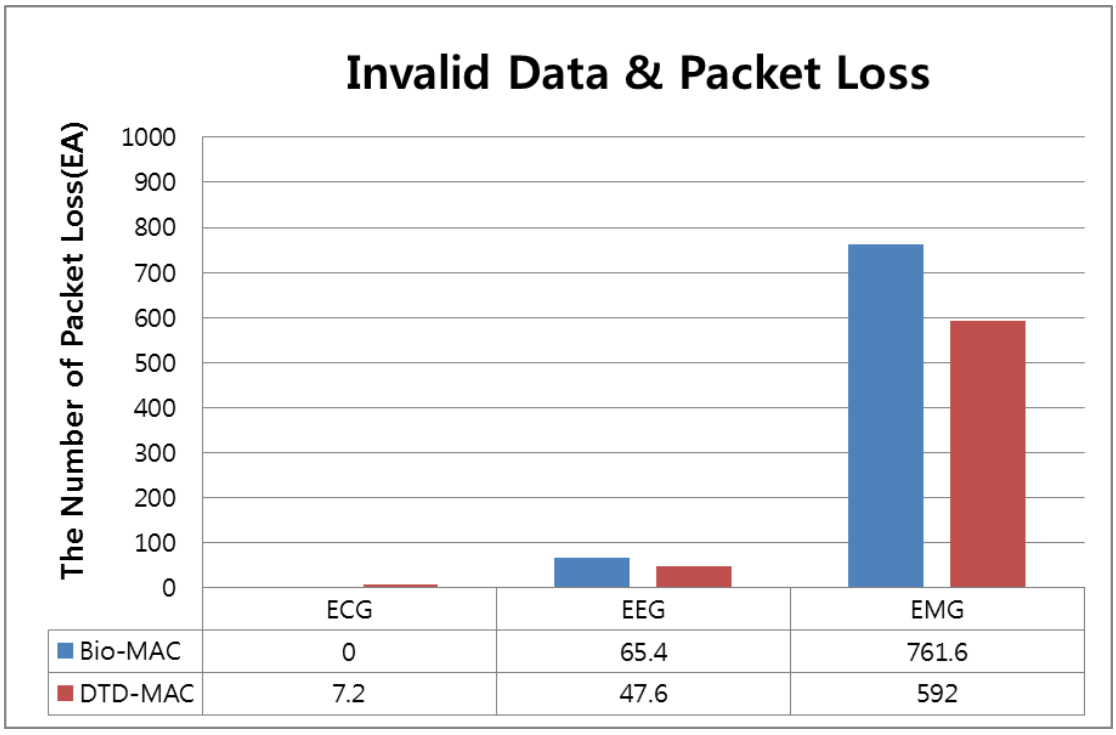

Fig 5. Comparison of the Invalid data (Bio-MAC) & The average Packet Loss

5 Conclusion

The existing Bio-MAC Protocol takes into consideration the current cycle and each node's priority at the time of executing channel allocation. As a result, it is possible for the nodes with low priorities to continue to have long transmission delay. But in the environment requiring real time based application, it also may cause the inefficient data of the previous cycle with higher priority is likely to be transmitted regardless that it is not needed in the current cycle. For this reason, the protocol has the risk of operational error. However, the proposed DTD-MAC Protocol executes channel allocation process by limiting as 250 ms for target application according to the delay requirement of the WBAN environment. Therefore, it gives transmission priority to them in order to guarantee the channel allocation for each node in a systematic manner. Also, the nodes which failed to be transmitted in the maximum cycle are added into packet loss. Hence, the proposed scheme can prevent unnecessary transmission delay results from the conventional priority based channel scheduling. In future studies, it is necessary to derive the enhanced approach to guarantee the stable QoS in a dynamic environment where bio sensor nodes are added and excluded in a way of more complex mutual distribution and more tight performance requirement.

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