# A CSMA/CA based TDMA Protocol for MAC Layer in Wireless Sensor Networks

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## Abstract

*This paper is presented as hybrid protocol for MAC layer in Wireless Sensor Networks (WSNs). It combines contention and schedule-based methods. Time slots are assigned at deployment and reassigned when significant changes in topology. Time slot assignment is designed by semi-distributed manner. A base station is considered as a master only for its one-hop children because nodes are also memory (buffer)-constrained ones in real world. When a base station sends token to its neighboring nodes all the way through the largest-hop nodes and token is sent back to the base station causing the overflow of buffer or the time slot assignment table may be damaged during token is passing through all the nodes. To avoid this problem, time slot assignment is only considered as the two-hop neighbors from each parent.*

## 1. Introduction

The wireless sensor networks (WSNs) are used in a wide range of applications to capture, gather and analyze live environmental data [1]. The wireless sensor network architecture typically consists of a large number of sensor nodes scattered among an area of interest and are networked together collaboratively gather data from the environment and send back to the base station. The sensor nodes [2] communicate one another through the wireless channel to self-organize into multi-hop network and forward the collected data towards the base station. In a wireless sensor network, sensors nodes are low cost, resource-constrained devices and are often deployed randomly [3]. Unlike other wireless networks, it is generally impractical to charge or replace the exhausted battery, which gives way to the primary objective of maximizing node/network lifetime. As a result, energy efficiency is a crucial necessity in a medium access control protocol for wireless sensor networks. The major sources of energy waste in MAC protocol are collision, control packet overhead, idle listening, and overhearing [4].

To reduce this energy waste, energy–efficient MAC protocol is presented in this paper. This protocol is based on contention as well as schedule-based method which are necessary to be assigned time slot. Unlike other wireless or wired networks, it is unattainable which node is responsible for assigning time slot and therefore centralized approach is unsuitable for WSNs. On the other hand, it is also impractical to adopt decentralized (distributed) method causing complexity which is one of the major power-consumers. Therefore, semi-distributed time slot assignment is presented in this paper.

The remainder of this paper is organized as follows. In Section 2, the former MAC protocols for WSNs are briefly discussed and some problems adapting the MAC protocol is mentioned. Section 3 describes the proposed energy-efficient MAC protocol which reduces not only collision but also overhearing and idle listening. Finally, conclusion and further work are described.

## 2. Related Work

Locally managed synchronizations and periodic sleep-listen schedules based on these synchronizations form the basic idea behind the Sensor-MAC (S-MAC) protocol [5]. One of the disadvantages of S-MAC is the broadcast data packets do not use RTS/CTS which increases collision probability. In the proposed system, CSMA/CA protocol is applied during the initialization phase. Therefore, collision is able to be avoided. Moreover, S-MAC is based on contention protocol. The nature of contention-based protocol can be the result of increment in not only collision but also idle listening and overhearing.

Z-MAC [6] is a hybrid MAC protocol that starts off as CSMA and switches to TDMA if network load increases. Nodes execute a distributed schedule algorithm known as DRAND to get a TDMA slot. In the proposed system, two-hop nodes run semi-distributed algorithm and parent of nodes only help child nodes to get TDMA slot. Therefore early death problem of parent nodes can also be eliminated.

FlexiTP [7] is TDMA-based protocol for WSNs. A token is generated from the base station through the farthest nodes to get TDMA slot. When the token is sent back to the base station, TDMA assignment is successful and data transmission starts. If the token is damaged, the base station retransmits a new token, causing both energy and time waste. In the proposed system, instead of using token, the message that I (parent or base station) have got the nth time, you (the child node) will get the next one is generated only among two-hop neighbors to get TDMA slot. Therefore, topology changes can be guaranteed and mobility also may be guaranteed.

## 3. The Proposed System

The proposed MAC protocol for WSNs consists of two main parts: initialization phase and TDMA assignment phase. Initialization phase includes collecting nodes with the help of base station by means of CSMA/CA which is one of the contention-based protocols. In TDMA assignment phase, time slots are assigned in the way of simple semi-distributed manner.

### 3.1 Initialization Phase

In this phase, base station initially broadcasts message to collect the neighboring child nodes and then child nodes attempt to collect their own child nodes and sends back information to base station.

#### 3.1.1 Base Station Broadcast Phase

Base station broadcasts synchronization frame to all neighbor nodes. BS knows that it has children by overhearing the broadcast message of his potential children. Base station waits the ACK and information from his neighbors until all neighboring nodes collect their children. In figure 1, a scenario for broadcasting message from a base station to nodes is illustrated.

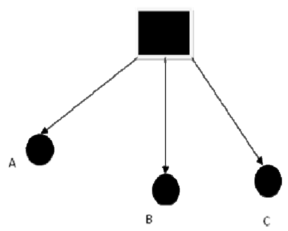


Fig. 1. Broadcast message from BS to nodes

#### 3.1.2 The Function of Child Nodes

As soon as the neighbors of BS have known that they are the children of BS, they prepare for broadcast message to search their children according to random backoff time to avoid collision. When the neighboring nodes receive the broadcast message, they accept the parent of them which has the smallest hop count. The neighboring nodes also save other parents broadcast messages which have larger hop counts than the parent node for the backup purpose. After that, they try to send ACK message to their parents using CSMA/CA as depicted in Figure 2.

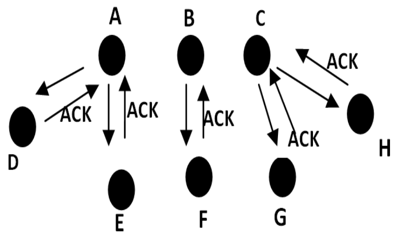


Fig. 2. The parent nodes (A, B, C) send parents request broadcast message and the child nodes send Ack message to their parents using CSMA/CA.

After collecting all neighboring child nodes' information, each parent node try to send (confirmation message) ACK message to Base Station using CSMA/CA as shown in Figure 3.

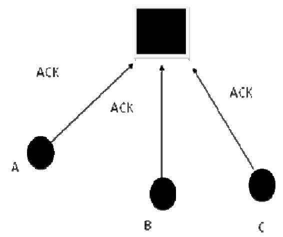


Fig. 3. ACK message from nodes to BS

After that, BS sends each child node to get TDMA assignment in accordance with the priority (The node that has the largest number of child nodes wins the first priority). As soon as the node has received the TDMA assignment from BS, it sends "Do-Priority-Assignment" to their children by means of random calculation that sorts each node to avoid collision.

### 3.2 TDMA Assignment Phase

It is critical to assign TDMA slot for each node because all nodes are not only homogenous devices but also resource-constrained ones. Therefore, it is appropriate to assign TDMA slot as not only distributed manner but also simple way. The proposed system puts forward simple semi-distributed TDMA algorithm as the following example as shown in Figure 4 and Table 1.

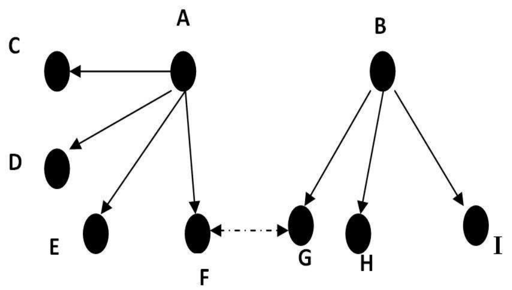


Fig. 4. Example of TDMA Slot Assignment

Suppose that random calculation of node A sorts as C, D, F, and E and those of node B H, G, and I respectively. C first catches the TDMA time slot 0 and sends it get slot 0. After that, A catches slot 1 and send it to D. Node D obtains time 2 and A gets time 3 again and F holds time slot 4 and Node A and E get time slot 5 and 6 respectively. After that, A sends back BS the information that it has won time 1, 3 and 5. And then, BS gets time slot 6 and sends to its child node B.

As far as node B is concerned, node B first wins time 0 and and 2 respectively. When node G attempts to get time slot, it gets the next time of Node F because it overheard node F's time slot. So, it gets time slot 5. Node B again gets time 0 and node I wins time 1.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| C | A | D | A | F | A | E | reserved |
| B | H | B | | | G | BS | reserved |
| B | I | | | | | | reserved |

Table.1. An example of semi-distributed TDMA Assignment Table

To become a trade-off, slot 7 is not assigned and other time slots may be empty. Within each time slot, each node communicates one another using CSMA/CA like S-MAC. The owner of time slot is the most priority and other nodes that want to communicate wait the Carrier Sense that it is indicated that the medium is free or not.

## 5. Conclusion

The proposed system is expected to be the collision free as well as reduction in idle listening and overhearing. As a consequence of this, it is expected to be more energy-efficient than any other protocol. After the TDMA assignment has been completed, all nodes wait the only listen state of each time slot and can sleep if the medium is free.

As further work, this system will be implemented and tested the results compared with existing protocols using NS-2[8] which is the most popular simulator developed for wired and wireless networks simulation.

## 6. References

[1] A. Datta, "*Application-specific Reliable Datatransfer in Wireless Sensor Networks*", PhD Thesis, Faculty of the Louisiana State University and Agricultural and Mechanical College, The Department of Computer Science , August 2007.

[2] I. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "*Wireless sensor networks: A survey*" , Computer Networks 38 (4), 2002.

[3] L. Chaari and L.Kamoun, "*Wireless sensors networks MAC protocols analysis*", Journal of Telecommunications, Volume 2, Issue 1, April 2010.

[4] K. Sohraby, D. Minoli, T. Znati, " *Wireless Sensor Networks: Technology, Protocols, and Applications*", Wiley-Interscience, A John Wiley & Sons, Inc., Publication, 2007.

[5] W. Ye, J. Heidemann, and D. Estrin, "*Medium Access Control with coordinated adaptive sleeping for wireless sensor networks*" , IEEE/ACM transactions on networking, vol. 12, no. 3, June 2004.

[6] I. Rhee, A. Warrier, M. Aia and J. Min, "*Z-MAC: A hybrid MAC for wirelsee sensor networks*", ACM international conference on embeded networked sensor systems; November 2005.

[7] W. L. Lee, M. Datta and R. Cardell-Oliver, "*FlexiTP: A flexible-schedule-based TDMA protocol for fault-tolerant and energy-efficient wireless sensor networks*", IEEE transactions on parallel and distributed systems, vol. 19, no. 6; June 2008.

[8] The network simulator ns-2, http://www.isi.edu/nsnam/ns/