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A Traffic-Adaptive Duty-Cycle MAC Protocol for Multi-hop Wireless Sensor Networks

Seong Cheol Kim[1], Jun Heon Jeon[1], Joong Jae Kim[1]

[1] Sangmyung University, Seoul, South Korea
sckim@smu.ac.kr, cloud0305@naver.com, Joongjae.kim@gmail.com

Abstract. In this paper, we propose a traffic-adaptive duty-cycle MAC protocol which reduces data transmission delay from source node to destination node and node energy consumption in multi-hop Wireless Sensor Networks. An operation cycle of the proposed MAC protocol is consists of four periods as in LO-MAC. But in the proposed MAC protocol all the nodes in the data path repeat the Sleep periods only when an event occurs. And during Data period nodes immediately go into sleep mode with overhearing the PION packet. Performance evaluation shows that the proposed MAC protocol improves the transmission delay and the throughput compared to the RMAC.

Keywords: Delay, Energy-efficient, Multi-hop, MAC, WSNs

1 Introduction

In wireless sensor networks (WSNs), large amounts of small sensor nodes are interconnected in an ad-hoc manner to transmit data from many sensor nodes to the destination node. But these small sensor nodes use batteries and replacing the batteries may be difficult. So it is very important for MAC protocol to save energy consumption of each sensor node to prolong the network lifetime [1][2]. Many MAC protocols are suggested for this purpose. MAC protocol of WSNs may be divided into three categories; synchronous MAC protocol, asynchronous MAC protocol, and hybrid MAC protocol. The proposed MAC protocol belongs to a synchronous MAC protocols. The related synchronous MAC protocols are DW-MAC [3], RMAC [4], and LO-MAC [5]. Demand Wakeup MAC(DW-MAC) uses a synchronous MAC protocol in a multi-hop WSNs. The legacy synchronous MAC protocols such as S-MAC [1] and T-MAC [2] do not support multi-hop data transmission. DW-MAC protocol has fixed Sync, Data, and Sleep periods and uses scheduling frame (SCH) to support efficient multi-hop data transmission. A Routing-enhanced duty cycle MAC (RMAC) also has Sync, Data, and Sleep periods and uses Pioneer Control Frame (PION) to determine multi-hop path. Low overhead MAC (LO-MAC) protocol works same as the RMAC protocol. Carrier sensing (CS) period is added to Sync, Data, and Sleep periods. During CS period a node with pending data uses busy tone and only busy tone received nodes wakeup to take part in the data transmission. Data transmission can be done during Sleep period like in RMAC.

Some protocols use duty-cycling (wakeup and sleep period) to save energy. The main problem in these protocols is packet transmission delay [1][2]. Since nodes in a

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sleep state do not act in data transmission, delay from source node to destination increases. So in real-time applications like surveillance or monitoring, the duty cycling mechanism is not adequate. In this paper we suggest an MAC protocol which may provide end-to-end data transmission and reduce node energy consumption for multi-hop wireless sensor networks. In the proposed MAC protocol, nodes in a path from source node to destination follow different entire time periods depend on the data traffics.

2 A Traffic-Adaptive MAC Protocol

The proposed MAC is designed for applications like object tracking and wild animal monitoring. In these applications an event occurring is not common. So a low data transmission is usually carried out. When an event occur, continuous object tracking observation is required. This generates lots of data transmission from the sensor nodes to sink node. So DW-MAC, RMAC, and LO-MAC are not adequate for this environment. A frame of proposed MAC protocol is composed of six periods; Sync, CS 1, DATA, SLEEP, and CS 2.

2.1 Multi-hop transmission

When a source node has data packets to send, it will send a busy tone in CS period. And the nod sends a PION packet to its neighbor node during Data period. The PION packet will be delivered to its final destination node. The PION packet contains the following information: Current node's address, next node's address, NAV (as in IEEE 802.11[6]), the number of hops and the destination of the current flow [4]. Data packet transmission is done during Sleep period through the route, which was determined with PION packet. If the source node gets more data to send, then sends a busy tone to its child node during CS2 period. This busy tone will be transmitted to the final sink node and all the nodes along the path know another data transmission. So an additional data transmission can be done without repeating Sync, CS1, and Data periods. So total data transmission delay can be reduced.

2.2 Energy-efficient mechanism

The main purpose of the proposed MAC protocol is to enhance the RMAC and LO-MAC protocol. So the proposed MAC protocol adapts some characteristics of RMAC and LO-MAC. In other words, the proposed MAC protocol uses the PION packet, and the divided periods Sync, Data, and Sleep periods concept from RMAC. It also uses CS period and overhearing for acknowledgement from LO-MAC protocol. However, the proposed MAC protocol works differently when an event occurs and burst data should be transmitted. In this case only Sleep periods are repeated. The proposed MAC protocol can save more energy by using early sleep mode. This early sleep mode can be done during Data period. In RMAC and LO-MAC protocol, a PION packet is delivered to its final destination node during Data period. After sending a

PION packet to its child node, a source node stays in wakeup mode until Sleep period starts without doing anything. And the intermediate nodes also stay in wakeup mode. In the proposed MAC protocol a sender node goes to sleep mode after sending PION packet and overhearing the transmission between intermediate nodes. All other intermediate nodes also go into sleep mode early, so energy consumption can be reduced. The operation of the proposed MAC protocol is shown in the figure 1. As shown in the figure, sleep mode insertion of the source and intermediate nodes in the Data period and the repeated Sleep period is the key idea of the proposed MAC protocol.

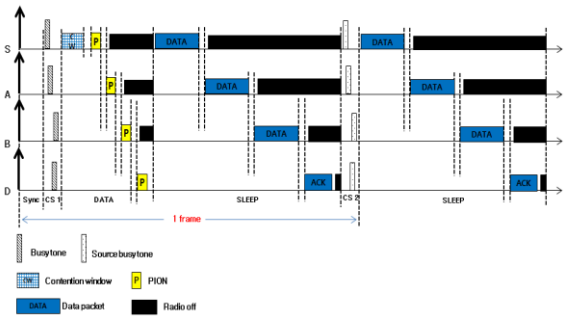

Fig. 1. Mechanism

3 Performance Evaluation

Table 1. Network parameters.

Parameters	Value
Bandwidth	20kbps
Rx power	0.5W
Tx range	250m
Tx power	0.5 W
Idle power	0.45 W
Sleep power	0.05 W
Carrier sensing range	550m
Contention window	64ms
DIFS	10ms

In this section performance evaluation of the proposed MAC protocol is compared to related works based on analytical computation. We used the same parameters used in [4]. Table 1 shows the used simulation parameters. We use typical high traffic load for Wireless Sensor Networks. In this evaluation we assume that source node is generated random number of data packet from 1 to 7. Comparison of the average energy consumption of each sensor node is show in the Fig. 3. As shown in the figure we find that our mechanism shows better energy saving than others. Also comparison of the average delay of data packet transmission is show in the Fig. 3. As shown in the

figure we find that our transmission method shows better low latency than other method.

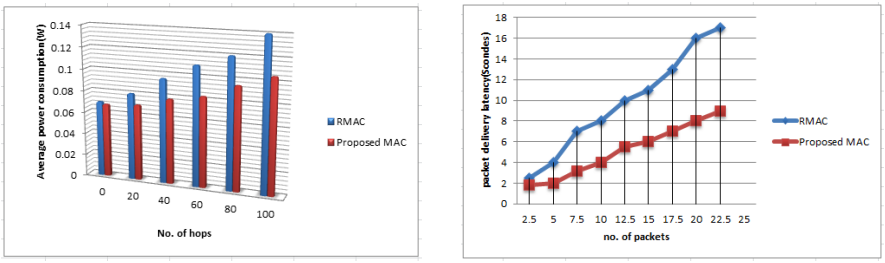

Fig. 3. Average power consumption of sensor in no. of hops & Packet delivery latency of sensor in no. of packets

4 Conclusion

In this paper, we have presented an energy efficient low latency MAC protocol for multi-hop Wireless Sensor Networks. The proposed MAC protocol was designed for the applications such as object tracking and wild animal monitoring. In these applications, low data rate transmission is usually required. But when an object appears, large amounts of data traffics are generated and source nodes have to send these data as soon as possible to the destination node. The proposed MAC protocol is a duty cycling contention-based. When an event occurs only data transmission periods may be extended to send more data quickly, so transmission delay can be reduced and energy consumption may be reduced.

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