A Improved Channel Access Algorithm for IEEE 802.15.4 WPAN

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Abstract

The IEEE 802.15.4 standard is able to achieve low power transmissions in low-rate and short-distance wireless personal area network (WPAN). The CSMA/CA algorithm is used for contention mechanism that collision and retransmission occur. If a collision occurs, CSMA/CA algorithm executes retransmission operation. So it's very important to decrease retransmission count. In this paper, we propose a channel access algorithm for IEEE 802.15.4 LR-WPAN. To performance analysis, we use OPNET network simulator. The proposed algorithm decreases the transmission delay, energy consumption, dropped packet and throughput is more increase, so the proposal algorithm is more efficient than the IEEE 802.15.4 standard .

Keywords: *IEEE 802.15.4 LR-WPAN, CSMA/CA Algorithm, Channel Access Algorithm*

1. Introduction

The IEEE 802.15.4 standard [1] is uniquely designed to meet the requirements of the low rate wireless personal area network to enable wireless sensor network applications. The IEEE 802.15.4 standard specifies the physical layer and the MAC sublayer for Low-Rate Wireless Personal Area Networks. In LR-WPAN, a single central controller, termed the PAN coordinator, exists. The LR-WPAN can operate either in a beacon-enabled mode or in a non beacon-enabled mode. The operation mode is determined by the PAN coordinator.

To access the channel, the IEEE 802.15.4 MAC protocol employs CSMA/CA algorithm and there is a high probability that collision and retransmission occur. The 802.15.4 beacon-enabled mode makes many collisions. If a collision occurs, CSMA/CA algorithm executes retransmission operation. However, in WSNs, transmit operations consume high energy. So it's very important to decrease retransmission count.

In this paper, we design a channel access algorithm for IEEE 802.15.4 LR-WPAN. The proposed algorithm divides 4 Group of network topology. To access the channel, nodes of each group set defaults value of *BE*(*Backoff Exponent*) and *CW*(*Contention Window*) by my group. And same group nodes set different staring time delay that apply RSSI. So the probability of collision and retransmission in total networks are more decrease.

The structure of the paper is organized as follows: Section 2 describes IEEE 802.15.4. MAC; Section 3 describes the proposal channel access algorithm; Section 4 presents the transmission delay, energy consumption, dropped packet and throughput, and Section 5 concludes this paper.

2. IEEE 802.15.4 MAC

The features of the IEEE 802.15.4 MAC are beacon management, channel access, GTS management, frame validation, acknowledged frame delivery, association, and disassociation.

In addition, the IEEE 802.15.4 MAC provides hooks for implementing application-appropriate security mechanisms.

2.1. Superframe

The IEEE 802.15.4 [2, 3] standard allows the optional use of a superframe structure. The format of the superframe is defined by the coordinator. The superframe is bounded by network beacons sent by the coordinator and is divided into 16 equally sized slots. Optionally, the superframe can have an active and an inactive portion. During the inactive portion, the coordinator may enter a low-power mode. The beacon frame is transmitted in the first slot of each superframe. If a coordinator does not wish to use a superframe structure, it will turn off the beacon transmissions. The beacons are used to synchronize the attached devices. Figure 1 show that the superframe structure.

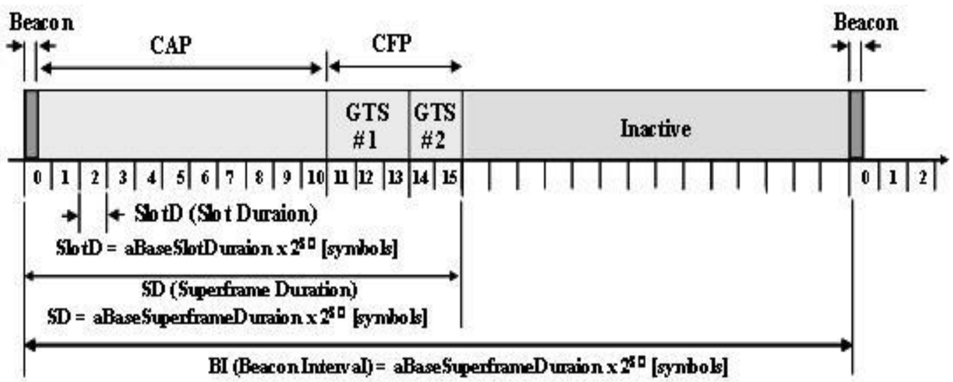

Figure 1. The Superframe Structure

The superframe can have an active and an inactive portion. The active portion consists of CAP (Contention Access Period) and CFP (Contention Free Period). Any device wishing to communicate during the CAP shall compete with other devices using a slotted CSMA/CA mechanism. On the other hand, the CFP contains GTS (guaranteed time slots).

2.2. Slotted CSMA/CA Algorithm

The slotted CSMA/CA [4] maintaining three counters in each device for channel access control. Notably, NB is the number of backoff trials for packet transmission. BE is the backoff exponent for generating a random backoff duration for which a device has to wait before attempting carrier sensing, and CW is the value of the contention window slots for clear channel assessment (CCA) after the random backoff duration. Table 1 shows that range and default value of *BE*.

Table 1. Range and Default Value of *BE*

Attribute	Default Value	Range
macMinBE	3	0-*macMaxBE*
macMaxBE	5	3-8
macMaxCSMABackoff	4	0-5

Based on the counters, the medium-access process of slotted CSMA/CA for a device is as follows [5]:

(1) The slotted CSMA/CA shall first initialize the *NB*, the *CW*, and the *BE* and then locate the boundary of the next backoff period. The BLE subfield in the superframe sets to 0, the *BE* shall be initialized to the value of macMinBE. If the BLE subfield in the superframe sets to 1, this value shall be initialized to the lesser of 2 and the value of macMinBE.

(2) The slotted CSMA/CA shall delay for a random number of complete backoff periods in the range 0 to $2^{BE}-1$.

(3) The slotted CSMA/CA request that the PHY perform a CCA then the CCA shall start on a backoff period boundary.

(4) If the channel is assessed to be busy, the MAC sublayer shall increment both the *NB* and the *BE* by 1, ensuring that *BE* shall be no more than *macMaxBE*. And it shall also reset *CW* to 2. If the value of the *NB* is less than or equal to the *macMaxCSMABackoffs*, the slotted CSMA/CA algorithm shall return to step (2). If the value of *NB* is greater than *macMaxCSMABackoffs*, the slotted CSMA/CA algorithm shall terminate with a channel access failure status.

(5) If the channel is assessed to be idle, the MAC sublayer in a slotted CSMA/CA system shall ensure that the contention window has expired before commencing transmission. To do this, the MAC sublayer shall first decrement the *CW* by one and then determine whether it is equal to 0. If it is not equal to 0, the slotted CSMA/CA algorithm shall return to step (3). If it is equal to 0, the MAC sublayer shall begin transmission of the frame on the boundary of the next backoff period.

3. Proposal Channel Access Algorithm

To access the channel, the IEEE 802.15.4 MAC protocol employs CSMA/CA algorithm. The proposal algorithm divides 4 group, sets a *BE* and *CW* of CSMA/CA algorithm by group. Figure 2 shows that network model for proposal Algorithm

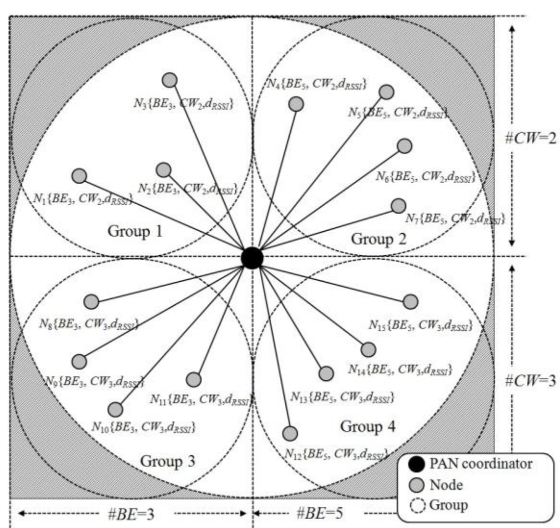

Figure 2. Network Model

The defaults value of *BE* of group1, group 3 set *BE* is 3 and group2, group 4 set *BE* is 5. Additional the defaults value of *CW* of group1, group 2 set CW=2 and group 3, group 4 set

CW=3. Additionally, to reduce probability of collision for access the channel in my group, we set N_{st}^{i}(starting time of nodes) using routing distance(from node to PAN coordinator) by RSSI(Received Signal Strength Indicator).

we assume that P_t is transmit power, G *is RF benefit and* λ is propagation of the wave. The P_r (received power) is follows:

$$P_r = P_t \frac{G_t G_r \lambda^2}{(4\pi d)^2} \tag{1}$$

The PL_F (free space path loss not consider RF benefit)s is follows:

$$PL_F[dB] = 10\log\frac{P_t}{P_r} = -10\log(\frac{\lambda}{4\pi d})^2 \tag{2}$$

The log path loss is follows:

$$PL(d) = PL(d_0) + 10n\log(\frac{d}{d_0}) \tag{3}$$

If $d_0 = 1$, N_{st} is follows:

$$N_{st} = -(A + 10n\log_{10} d) \tag{4}$$

The N_1, N_2 and N_3 in group 1 value of *BE* and *CW* are equal. However, N_1, N_2 and N_3 different starting time. So the probability of collision and retransmission in total networks are more decrease

4. Performance Analysis

In this section, we prove that the proposal algorithm more effective than the current standard through the transmission delay, energy consumption, dropped packet and throughput. We define that the standard is the *Std*. and the proposal algorithm is the *PA*. Then we compare with the *Std*. and the *PA*.

For performance analysis of the *PA*, we use OPNET network simulator. We consider a typical wireless sensor network in a surface of (100 m x 100 m) with one PAN coordinator and 16 identical nodes (randomly spread) generating the poisson distributed arrivals, with the same mean arrival rate. we set packet size(*MHR*+*MSDU*) is 404(104+300)*bits*, Ack Frame is 11 bytes, *SO* and *BO* are 3 and duration time of the simulation is 5 *sec*, Figure 3 shows that comparison of performance analysis for *Std*. and *PA*.

In the 0 second to 1 second period, the Transmission delay, Energy consumption, Dropped packet and throughput rapidly increase because of the many nodes send the packet to the PAN coordinator. And then after about 1.3-1.5 second, each performance factor are slowly decreases. The transmission delay of *PS*. reduces the about 1.65% than the *Std.*, energy consumption of *PS*. reduces the about 2.08% than the *Std.*, dropped packet of *PS*. reduces the about 2.63% than the *Std*. and throughput of *PS*. reduces the about 7.98% than the *Std.* Therefore, proposal algorithm is more effective than the IEEE 802.15.4 standard.

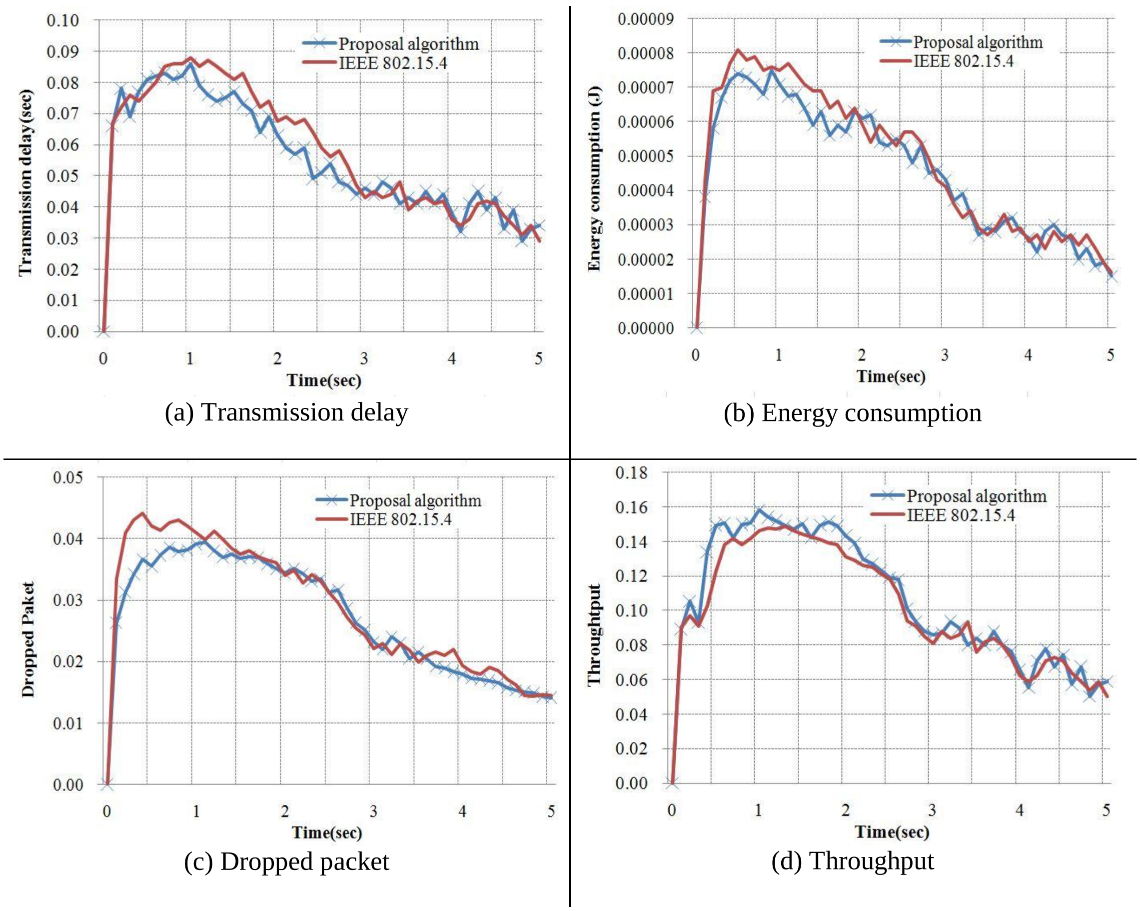

Figure 3. Comparison of Performance Analysis for *Std*. and *PA*.

5. Conclusions

The IEEE 802.15.4 standard, widely used in wireless sensor network, specifies the CAP and the CFP. To access the channel, the IEEE 802.15.4 MAC protocol employs CSMA/CA algorithm and there is a high probability that collision and retransmission occur. The 802.15.4 beacon-enabled mode makes many collisions. If a collision occurs, CSMA/CA algorithm executes retransmission operation. However, in WSNs, transmit operations consume high energy. So it's very important to decrease retransmission count.

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In order to evaluating the performance of proposed algorithm, the proposed algorithm is more effective than the IEEE 802.15.4 standard on the transmission delay energy consumption, dropped packet and throughput.

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