Enhanced MAC Protocol to reduce latency in Wireless Sensor Network

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Abstract. The proposed MAC protocol is similar to conventional CSMA/CA protocols, except that it does not use a time-varying contention window from which a node randomly selects a transmission slot. To reduce the latency for the delivery of event data from sensor nodes, a fixed-size contention window with a non-uniform probability distribution of transmitting in each slot is selected.

Keywords: Sensor Network, Contention Window, CSMA/CA, DCF, MAC.

1 Introduction

This paper thoroughly analyzes the operating mechanism and characteristics of ubiquitous sensor networks from the viewpoint of developing a more suitable MAC protocol. One of the most important issues in sensor networks is improving the battery life; in fact, several researches have focused on this issue over the last few years [1-4]. This paper focuses on designing a method that can effectively decrease the data transmission delay in a sensor network to the greatest extent possible.

The MAC protocol proposed in this research differs from conventional ones in the following respects. The contention window size is regularly optimized so as to minimize the latency. In addition, the geometric probability distribution is specifically designed to replace the uniform probability distribution that is conventionally used in order to differentiate the selection probability during the process of selecting the transmission slot[5-7].

2 Proposed MAC Protocol

The probability distribution function of such a property can be derived by multiplying the probability with which preceding slots cannot be selected by that with which succeeding slots can be selected based on an arbitrary slot for all slots, as shown in Fig. 1.

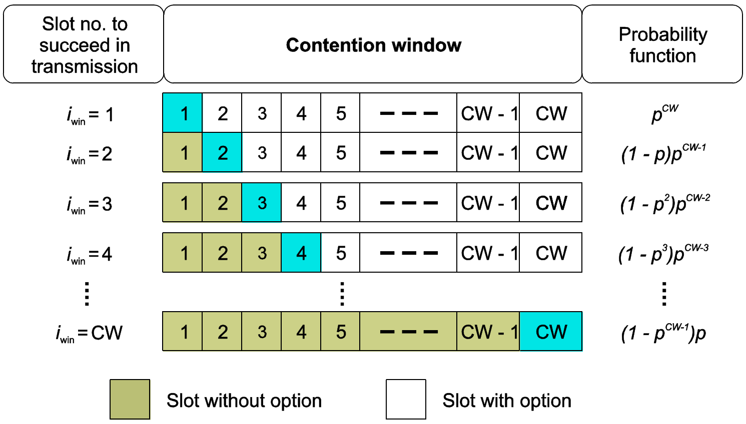

Fig. 1. Probability of selecting a slot to minimize contention between nodes.

In order to maintain such an optimum selection method, if the probability distribution function is derived using the probability with which preceding slots are not selected and that with which succeeding slots are selected based on an arbitrary slot, it could be said that the probability *f(i)* with which each sensor node selects the *i_th* slot within the range of the contention window follows a geometric distribution with a parameter *p*, and therefore, the probability mass function can be given by the following equation.

$$f(i) = \begin{cases} (1-p^{i-1})p^{CW-i+1}, & i = 1, \cdots, CW \\ 0, & otherwise \end{cases} \quad (1)$$

The selection probability at the *i_th* slot is the highest when $N_i = N_1$, and N_i has the property that it is constantly reduced from N_1 to 1 as the stages proceed. Therefore, when N_i is relatively large and S_i is small, the probability with which a sensor only selects the *i_th* slot in the condition in which all the slots prior to this slot are not empty can be given as follows.

$$N_i S_i (1 - S_i)^{N_i - 1} \cong N_i S_i e^{-N_i S_i} \quad (2)$$

If $N_i S_i$ is assumed to be constant in the above equation, the probability with which the *i_th* slot is selected gradually decreases as we proceed toward the last slot. In other words, in order to efficiently deal with several nodes (*N*) that are competing to access the medium using a small contention window that has a fixed size, it is necessary to select a scheme in which the number of nodes accessing the medium reduces at a constant rate (Δ).

$$\frac{N_{i+1}}{N_i} = \Delta \ (0 < \Delta < 1) \quad (3)$$

The following condition is satisfied if $p = \Delta$ in equations (1) and (3).

$$N_i S_i \cong N_{i+1} S_{i+1} \quad (4)$$

The probability of selecting a slot for each sensor can be derived from equation (1) as follows.

$$\frac{S_i}{S_{i+1}} = \frac{(1-p^{i-1})p^{CW-i}}{(1-p^i)p^{CW-i}} \cdot p \approx p \quad (5)$$

This could be developed for the slots before *CW_th* by the following equation.

$$\frac{S_1}{S_2} \cdot \frac{S_2}{S_3} \cdot \cdots \cdot \frac{S_{CW-1}}{S_{CW}} = p^{CW-1} \tag{6}$$

The result given below can finally be obtained by applying this equation to equation (4) and perform the following procedure.

$$\frac{N_1}{N_2} \cdot \frac{N_2}{N_3} \cdot \cdots \cdot \frac{N_{CW}}{N_{CW-1}} = p^{CW-1} \qquad \therefore \frac{N_{CW}}{N_1} = p^{CW-1} \tag{7}$$

As mentioned above, if it is established that $N_{cw-1} = 1$ for the *CW_th* slot to be selected by only an active sensor, then $1/ N_1 = p^{cw-1}$. This is finally given by the equation below.

$$\therefore \ p = N_1^{\frac{-1}{CW-1}} \qquad (0 < p < 1) \tag{8}$$

Then, if it is assumed that $N = N_1$ using equation (8), the optimum probability of selecting a slot, *p*, can be calculated. In other words, if a medium is accessed by using a contention window having 32 slots in a network consisting of 256 sensor nodes, the value of *p* is determined to be approximately 0.8 .

3 Conclusion

The proposed MAC protocol is highly adaptable in that it can constantly maintain the transmission rate to the greatest extent possible even if the environment changes frequently and unexpectedly.

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