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Design of MAC Protocol for Efficient Data Storage and Transmission Using Reinforce Learning

Hyun Joo Park[1], Seong Cheol Kim[2]*

[1] Department of Smart Information and Telecommunication Engineering, Sangmyung University, 31066, Cheonan, Korea; cathy2369@smu.ac.kr

[2] Department of Convergence Electronics, Sangmyung University, 20, Hongjimun 2-gil, Jongro-gu, Seoul, Korea; sckim@smu.ac.kr

Abstract: In this paper, we propose a data storage and transmission algorithm using Reinforce learning to store and transmit according to priorities to increase the efficiency of the wireless sensor network. The protocol not only stores data by applying the priority of data but also guarantees priority transmission with various probabilities during transmission. The transmission data is divided into Event Data and Normal Data according to the content and stored in the transmission queue by priority using RL-Classifier. Besides, to apply the priority of data when transmitting the data stored in the queue, the transmission probability is applied differently. It can be seen that performance is improved through comparison with QAML-MAC, which has been proposed to improve data storage and transmission efficiency.

Keywords: *MAC protocol, Priority aware, Reinforce-learning, Throughput, Quality of Service*

1. Introduction

The application range of wireless sensor networks is wide. In a hyper-connected society, the quality of human life is improved in various forms. In the environmental field, it is used in the field of noise and air pollution detection, water pollution level measurement, and natural disaster management. Also, in the medical field, it can be said that the role of wireless sensor networks in the field of hospital patient management and remote medical support using home networks. Also, it is used in a wide range of fields that are difficult to enumerate, such as inventory management in logistics and distribution, toll collection in transportation, and telematics [1]. The studies on the various applications listed above are conducted under the premise that the functions of connection and data collection, which are the basic properties of wireless sensor networks, basically operate according to human thinking [2]. This focuses only on normal operation functions for data collection and storage and is not suitable for the circumstance that requires customized data transmission based on collected data and discriminatory results on data properties in discussions on service quality. It also shows that the network quality of service cannot be improved because normal data and event-driven data are transmitted to the sink direction without distinction [4]. Many studies of the MAC protocol so far have focused on energy consumption in data transmission. However, QoS support according to application needs is also a very important problem to be solved. [6][7][8][10]. In this paper, to improve the quality of service by classifying data transmission emergency and characteristics, we propose an algorithm that helps efficient transmission for improving the quality of service by applying the reinforcement learning algorithm of artificial intelligence when storing data in the transmission queue. By applying artificial intelligence theory that reflects the emergency and characteristics of data transmission to the queue storage algorithm, it is expected that the efficient transmission of data, as well as energy saving at the node, is possible. And the life of the entire network may be prolonged. To improve the quality of network service, the data collected will have different transmission urgency according to their characteristics. Then they are divided into normal transmission data with low priority and emergency data requiring emergency transmission with high priority [4][6]. Normal data are data that are regularly collected in the environmental field or have a measured value within a certain range [4][5]. If the measured value is observed within the pre-defined threshold value, the priority is low. Since it has the property of regular transmission, it is stored in the normal transmission queue. In other cases, if the measured value is out of range or the degree of change is different from the generally observed change, then it is classified as Event Data and saved to the queue with high priority.

The rest of the paper is organized as follows. The related works are discussed in Section 2. In Section 3, the structure and operation method of the RL-Classifier will be explained. In Section 4, performance comparison id made, and in Section 5, the conclusion of this paper is made.

2. Related Works

2.1 EQ-MAC

EQ-MAC [5] was proposed for service differentiation among cluster-based protocols. Here QoS is supported through Classifier MAC and channel access MAC that classifies traffic according to priority. However, EQ-MAC is only applicable to a one-hop structure between sensor nodes and head nodes, so it is difficult to apply to WSNs with multi-hop. EQ-MAC operation is shown in Figure 1.

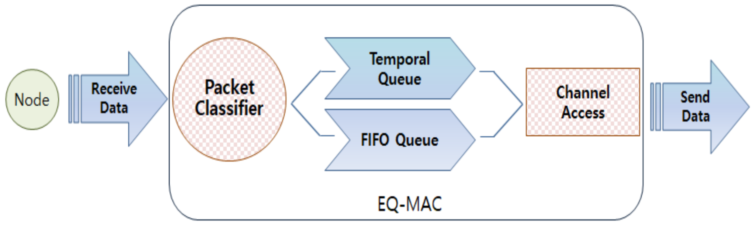

Figure 1. EQ-MAC Operation

2.2 Q-MAC

Next, in the Q-MAC structure, QoS is supported by differentiating services based on priority [6]. Priority is determined based on the content of the application point of view and the number of traversed hops provided at the MAC layer. It is an advantage to judge data transmission emergency from two points of view, but it did not take into account the surrounding environment of the packet and thus did not reflect various network changes. Figure 2 shows the operation of Q-MAC protocol.

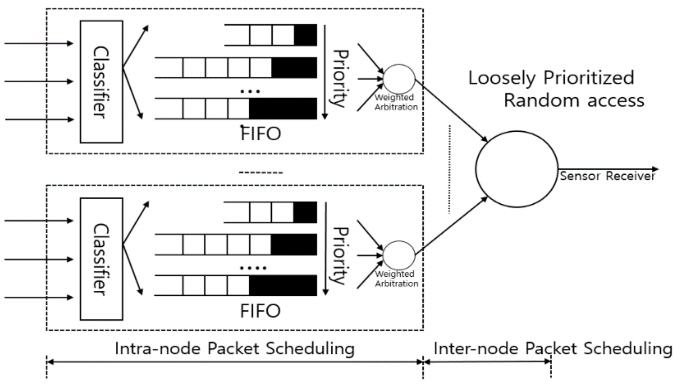

Figure 2. Q-MAC Operation

2.3 QAML-MAC

Also, QAML-MAC is the same as Q-MAC in that the transmission priority varies according to the urgency of the packet, but energy efficiency and delay are improved by changing the transmission order and different schedules of transmitted packets according to the destination of the transmitted packet. It can be reduced [6]. However, this algorithm has the disadvantage of not reflecting the characteristics of the various data generated in the actual network because it does not reflect the characteristics of the neighboring network or does not have flexibility in transmission when storing the queue.

3. Protocol Operation Method

3.1 Priority Application

Since the header of the network data packet stores generation information, data length, and destination information, you can know the nature of the data by understanding the contents of the header. To divide input data according to the transmission emergency, we propose a method of classifying input data into RL Classifier and storing it in a queue. RL Classifier uses the transmission success rate and transmission failure rate as arguments of the reward function for effective data classification through reinforcement learning. Priority is given differently according to the urgency of the node and the nature of the traffic.

3.1.1. Agent Reward Value Setting for Priority Classification

When data is collected from the node, the data is classified using the information in the header. The information included in the header is the location of the data generation and the destination address. The notation for the state probability is as follows. Since the agent operates differently according to the probability value, the input value in the following equation affects the result value of the state probability [11]. In the policy π, the current state S_k selects action α, the next state S_{k+1}, and the expected reward value is E_π. The equation (1) is a function that determines the reward value, and it can be seen that both the reward in the current state and the policy π are affected. Figure 3 shows the node's reward mark by destination.

$$V^{\pi}(S) = E_{\pi}\{\sum_{k=0}^{\infty} \gamma^{k} rk(s_k, \pi(s_k)) | s_0\} = s \tag{1}$$

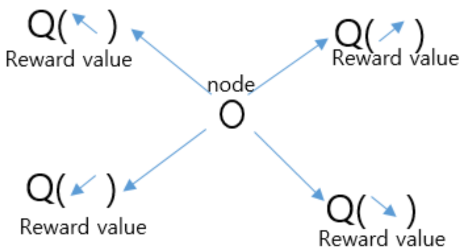

Figure 3. Node's Reward mark by destination

3.1.2. Set Reward Value for Transmission According to Priority

For normal data with low transmission urgency, Q has a low reward value. The reward value operates as a function that uses an input value as an argument and reducing the value involved in determining the duty cycle. To determine the transmission probability, using the state-action pair by Q-learning. Equation (2) shows the Q-value to determine the transmission probability P. R(s, a) means reward-value when action is taken in state S [11].

$$Q^{\pi}(s,a) = R(s,a) + \gamma\pi \sum_{s'=S}^{\infty} P_{ss'}(a) V^{\pi}(s') \tag{2}$$

It is necessary to reduce the duty cycle to reduce energy consumption. The Figure 4 shows the size of DIFS and CW according to the priority.

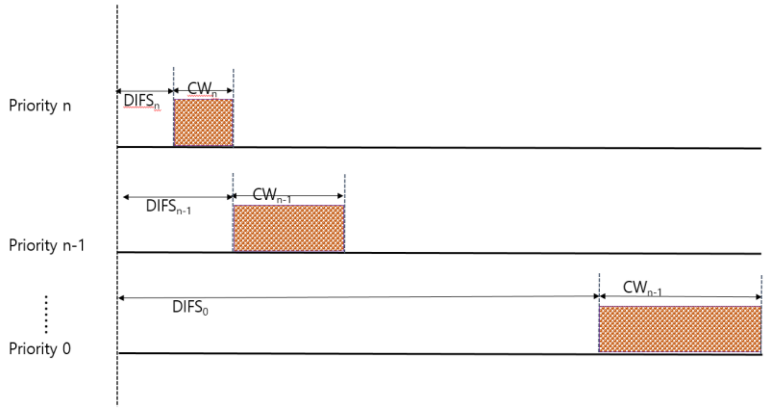

Figure 4. Example of CW control for transmission according to priority in the existing MAC

In the proposed MAC protocol, the Q-value is adjusted and applied to the duty cycle according to the priority. To reduce the reward value of the duty cycle transmission probability, the normal data or low priority data is replaced with a value obtained by adjusting the input value variable for Q-value adjustment to a small value. Since event-driven data has a high priority and must be transmitted first, the Q-value is needed to be increased. And the priority application is ensured by adjusting the storage probability of the Q-value. The Q-value with the high priority is executed with 1-e probability, and by randomly arranging the probability of e. This operation helps the transmission efficiency and guarantee priority transmission.

3.1.3. Packet Event Detection and Transmission Policy for Priority Classification

The normal data is transmitted according to the reward value in consideration of energy-saving and transmission efficiency. Event occurrence can be known as the following phenomenon.

A. Sudden Change in Queue Size

If the rate of change in the queue size increases rapidly, it is recognized as an event. When an event occurs in this way, the measured data needs urgent transmission. First, the queue in which transmission is recognized is given a large Q-value of the agent's reward value so that the event data is saved.

B. Sudden Change in Measured Data

If the value of the measured data changes rapidly, it is considered that an event has occurred. Then the measured data is given a high priority.

3.2. Protocol Operation Method

The operation of the proposed protocol is as follows. The collected data is classified using the reinforcement learning algorithm, then the classified packets are stored in the queue according to the priority. For this, the data input to the node divides the transmission emergency according to the state value of the storage queue and adjusts the action reward function. The variables that determine the action reward value and state value are decided by the content of the node itself and the traversal value of the MAC layer. Class determination is made by a special classification device called

RL-Classifier. RL-Classifier uses artificial intelligence's reinforcement learning algorithm to differentiate data and store it in each queue [9]. Figure 5 shows the data storage scheme of the proposed protocol.

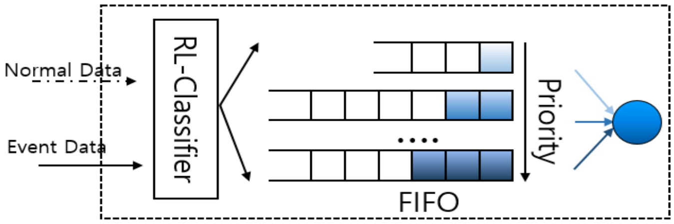

Figure 5. The proposed MAC operation

Priority is applied to data transfer after being stored in the queue. Contention Window size is used for priority packet transmission The contention window size control allows data transmission with different priorities for each class by adjusting the reward value when the window size control function is applied. Figure 6 shows the diversity of the number of transmission slots according to the priority when transmitting data. When transmitting the data remaining in Q, event data is first assigned to enable priority transmission.

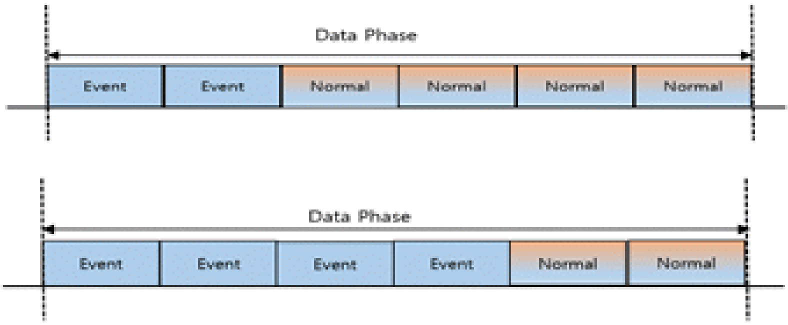

Figure 6. Various arrangement of slots for priority application

4. Performance Evaluation

A simulation was used to demonstrate the superiority of the proposed protocol. Table 1 shows the network and energy parameters of the sensor node used in the simulation. Figure 7 shows the comparison of the delay between the R-QAML MAC protocol and the existing MACs. It can be seen that the average delay is low for data with priority. Since the SMAC protocol does not support priority, the average delay of all transmitted data is displayed.

Table 1. Simulation Environment

Parameter	Description	Value
Duty Cycle		10
Data_CW	Maximum Window Size	63
Short_CW	Minimum Window Size	31
P_t	Transmit Power Consumption	0.2818
P_r	Receive Power Consumption	0.0.3682
P_{idle}	Idle Power Consumption	0.3442
P_{sleep}	Sleep Power Consumption	0.00005
P_{init}	Initial Energy	1000

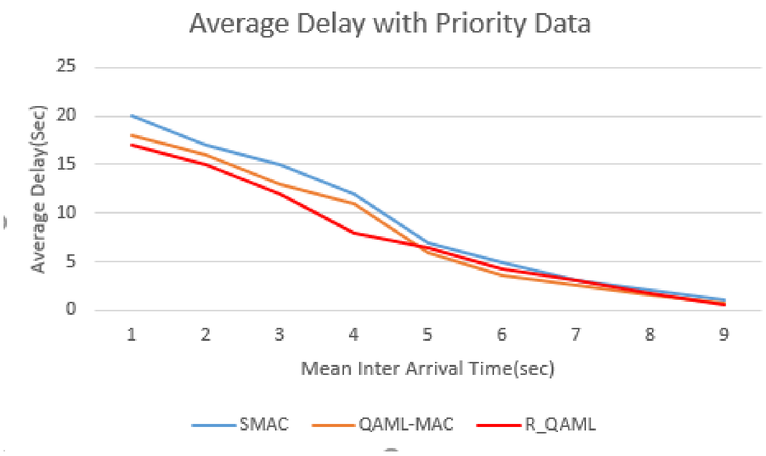

Figure 7. Comparison of Average Delay with Priority Data

5. Conclusion

In this paper, we propose a data storage and transmission algorithm using Reinforce learning to store and transmit according to priorities to increase the efficiency of the wireless sensor network. Also, it was found that the average packet transmission was smaller than that of the related researches protocols. The proposed algorithm increases storage and transmission efficiency by applying the most basic method of artificial intelligence. A study will be conducted on the effects of parameters used in the future on the performance.

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*Corresponding Author: Seong Cheol Kim.

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