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SUITABLE FOR NETWORK LOAD MUTATION OF THE MAC PROTOCOL

[1]XINGWEI ZHAI, [2]DEGAN ZHANG, [3]XUECHAO MING, [4]KE ZHENG, [5]YUXIA HU

[1] Instructor, Tianjin Key Lab of Intelligent Computing & Novel software Technology, Tianjin University of Technology.
[2] Asstt. Prof.,Key Laboratory of Computer Vision and System (Tianjin University of Technology), Ministry of Education,
[3.] Asstt. Prof., Tianjin University,
[4.]Asstt. Prof.,Nankai University,
[5.] Assoc. Prof.,Tianjin University of Technology,
E-mail: [1]zxw9908@126.com, [2]gandegande@126.com

ABSTRACT

With the development of IOT (things of internet), people propose more and more requirement about the wireless sensor networks performance for its key technology. It not only needs to meet the reliability of the networks, but also put forward higher requirement of the network life. A key factor influencing the network life is the network energy-limited. Therefore, energy-saving has become a key problem for the wireless sensor networks communication protocol design. an energy-saving MAC protocol based on network load mutations is designed. The protocol considers the redundancy problem between the sensor nodes data, takes different scheduling methods for different levels of nodes. A cording to the network load mutation, dynamically adjust to the detective and dormancy time. This method solves the unfairness of the network energy and delay, and can better satisfy changes in the complex network environment .

Keywords: *Network Load Mutation, MAC, Protocol, Energy-Saving, Wireless Sensor Network (WSN),*

1. INTRODUCTION

S-MAC Protocol is proposed by American scholar Wei Ye based on IEEE802.11 MAC Protocol. The design of this protocol has two objectives: to save network energy and to meet the extendibility of large wireless distributed networks [1]. It mainly adopts the following four mechanisms:

(1) Usage of the periodic listening and sleep strategy: Every node in the network sleeps periodically for some time and closes its radio-frequency circuit to reduce power consumption. After a certain duration, wake up this node based on the set timer. During wakeup, observe the node whether to communicate with other nodes or not. Combine the listening time and the sleep time and call it as the time frame. In order to satisfy different applications, set the listening time and the sleep time of the node. A virtual cluster is formed among the nodes of the sensor via negotiation in order to achieve the consistent sleep period in the nodes within the certain range and consequently shorten the idle listening time [3] [4]. The timetable of listening or sleep can be set for every node in the network. Nevertheless, to reduce the overhead on control messages, S-MAC Protocol uses periodic synchronous messages (SYNC) from the transmit clock, enabling the nodes in the network to understand the information about the schedule mutually and consequently achieving time synchronization in the nodes.

The stationary period listening and sleep strategy of S-MAC Protocol is shown in Figure 1.

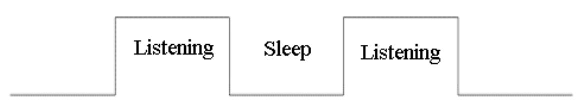

Figure 1. The Listening And Sleep Strategy Of S-MAC Protocol

(2) Avoidance of information conflict and crosstalk: By using physical carrier listening method, virtual carrier listening method and internal RTS/CTS (Request to Send/Clear to Send) signaling, S-MAC Protocol avoids information conflict and crosstalk.

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(3) Traffic adaptive listening strategy: If a node in the network is in a message communication, the nodes nearby can not enter the sleep state immediately after the transmission but maintain listening for some time. Supposing that the node receives RTS packet within this duration, it will receive messages immediately with unnecessary to wait for the next period, thus reducing delays in the transmission of information. Supposing that the node does not obtain RTS packet, it will enter the sleep state [6].

(4) Transmission of longer messages: S-MAC Protocol uses improved RTS/CTS signaling. In the channel reservation, what is required is the transmission time of entire longer messages, and meanwhile, longer messages to be transmitted are divided into several data packages consisting of short messages, improving the transmission efficiency of longer messages [9].

In consideration that the cycle time, listening time and sleep time in S-MAC Protocol are constant, it is difficult to satisfy the change in the network load. Dam etc. bring out T-MAC Protocol which shortens the idle listening duration and reduces the energy consumption in conditions that the total time set for listening and sleep is constant. D-MAC Protocol is proposed to settle the problem of high communication delay of the nodes in S-MAC Protocol. A transmission cycle of the node is composed of sending, receiving and sleep stages. The scheduling time of every node has a certain different offset, enabling the sending time of the node to be identical to the receiving time of the node and consequently reducing communication delay in the node.

2. ADVANTAGES AND DISADVANTAGES OF S-MAC PROTOCOL

Compared to IEEE802.11 MAC Protocol, S-MAC Protocol has the following advantages: through the periodic listening and sleep strategy, it extends the sleep time of the node, making the energy of the node reduced; and its extensibility is relatively good, satisfying the change in the network topology. However, S-MAC Protocol has some disadvantages:

(1) The nodes are not classified. S-MAC Protocol works by adopting the same mechanism in the nodes of the network. In the practical applications, what may be sensed by some nodes in the network is some unreliable information. What's more, even if some nodes in the network collect reliable data, they have too large similarity. In the conditions that certain network characteristics are satisfied, the corresponding nodes can be actually selected for transmission. All the nodes in S-MAC Protocol participate in the competition of wireless channels, resulting in energy consumption.

(2) The nodes can not satisfy the dynamic change in the network traffic. By Virtue of the periodic listening and sleep strategy, S-MAC extends the sleep time of the node. The cycle time, the listening time and the sleep time of the node remain unchanged. As you can see, with the dynamic change in the network traffic, the listening time and the sleep time of the node can not be regulated properly. In case of too high network traffic, the data may not be transmitted entirely. In case of too low network traffic, the node is in the listening state. Thus, much energy is consumed.

(3) High data transmission delay in the node. For the periodic listening and sleep strategy of S-MAC Protocol, in the event of multi-hop communication, the transmission delay may be very high with the increase of transmission hops for the node only sends one message in a scheduling period.

3. DESIGN OF NODE CLASSIFICATION

The wireless sensor network achieves transmission in the data-centric approach. The observer concerns only the index values to be measured in some a monitoring area but is not interested in sensory data of some a node. The density of nodes in the wireless sensor network is very high, generally reaching 20 nodes per cubic meter. In the same or similar monitoring area, the data collected by these nodes have very large similarity. Within the defined range to satisfy the applications, if all a certain number of nodes selected participate in the data transmission, it can extend the lifetime of the network.

3.1. Method To Classify The Nodes

Supposing that a wireless sensor network with intensive random distribution is selected to observe the index values in some an area, the data sensed by the node have certain similarity. Hereby, the similarity of the data from the node is determined by calculating the information entropy and combination entropy respectively of two node information flows . The entropy function represents the similarity between space discrete distribution variables. In order to select the nodes with small similarity, the definition represents the

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correlation coefficient of the information flow K. Several correlation formulas are cited below. The information entropy is:

$$\mathrm{H}(x) = -\sum_{i=1}^{n} p(x_i)\log_2 p(x_i) \qquad (1)$$

Where $p(x_i)$ is the probability of Node i to collect the monitoring event, $p(y_j)$ is the probability of Node j to collect the monitoring event and n is the sum of the events that may be collected.

In the bivariate random variable composed of x_i, y_j, $p(x_i, y_j)$ is their combined probability. Its combination entropy is:

$$\mathrm{H}(x,y) = -\sum_{i=1}^{n}\sum_{j=1}^{m} p(x_i, y_j)\log_2 p(x_i, y_j) \qquad (2)$$

Generally speaking, $\mathrm{H}(x,y) \le \mathrm{H}(x) + \mathrm{H}(y)$. $\mathrm{H}(x,y) = \mathrm{H}(x) + \mathrm{H}(y)$ means that information collected by two nodes is uncorrelated. $\mathrm{H}(x,y)/(\mathrm{H}(x)+\mathrm{H}(y))$ represents the degree of correlation of data collected in Nodes i and j. The correlation coefficient is:

$$K = 1 - \frac{\mathrm{H}(x,y)}{\mathrm{H}(x)+\mathrm{H}(y)} \qquad (3)$$

Obviously, the value range of K is [0,1]. $K = 0$ means data collected in Nodes i and j are mutually independent. Larger is K, larger is the correlation of two nodes. $K = 1$ means data collected in Nodes i and j are entirely identical. The nodes are classified based on the correlation coefficient K obtained from data sensed by the nodes. According to the practical application requirement, supposing Parameter ε =0.8 is the threshold value of the correlation coefficient of the nodes, the type of Node i is determined based on the correlation coefficient K of the information flow sensed by the node with the information mean sensed by the nodes in the related area it is in: if $\varepsilon \prec K \le 1$, it is a redundant node (high correlation status); and if $0 \le K \le \varepsilon$, it is a work node.

Figure 2 shows correlation of the information sensed in the node.

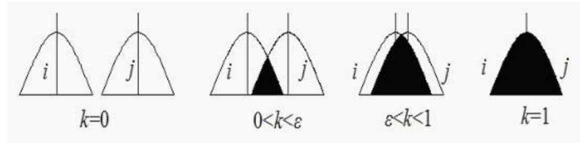

Figure 2. Correlation Of The Information Sensed In The Node

3.2. Synchronization Time And Node Processing

All the sensor nodes have an independent schedule which saves scheduling information of all neighbor nodes. Through the periodic radio clock synchronous messages (SYNC) packet of the node, neighbor nodes in the network understand its scheduling information, consequently achieving time synchronization. The nodes with the same scheduling form a virtual cluster. In the cluster, the nodes can be classified into work and redundant ones. After the synchronization time, the work nodes enter the states for example, listening, competitive channel and data monitoring and transmission, and the redundant nodes directly switch to the sleep state, further saving the network energy consumption. Figure 3 shows time frame constitutions of different nodes in the sensor.

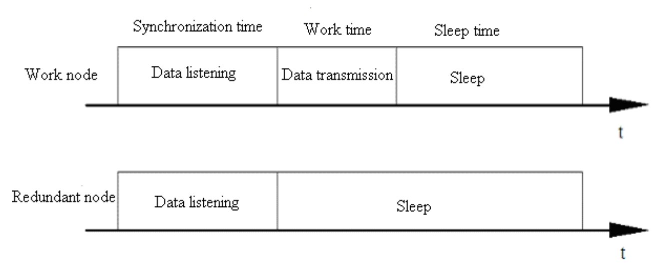

Figure 3. Time Frame Constitutions Of Different Nodes In The Sensor

4. DESIGN OF NEW ENERGY-SAVING MAC PROTOCOL

4.1. Definitions Of Related Concepts

(1). Energy consumption of sensor nodes: Energy units consumed by the sensor nodes are wireless communication unit, sensor unit and processor unit, of which the wireless communication unit consumes most energy. Generally, energy consumed in the information communication of 1 bit in a distance of 100 meters is roughly equivalent to that required to execute 3000 operation instructions. During the operation of the network, the wireless communication unit may be in four different energy levels including

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sending, receiving, idle listening and sleep. The

required by the wireless communication unit in idle listening is far more than that in sleep.

(2). States of sensor nodes: The nodes of the sensor enter the sleep state periodically. When the timer flows over and wakes up it, the node enters the listening channel state after wakeup. Through the carrier listening mechanism, the node enters the competitive channel. In case that the channel is idle, the node enters data transmission. Otherwise, the node yields for a while first. If the node obtains ACK data frames returned by the receiving note, it switches to the initial state of the node.

(3). Duty Circle: Ratio of the listening duration of the node to the duration of its whole period. The duration of the whole period is the sum time of listening and sleep. Larger is the duty circle, more energy is consumed by the node.

(4). Throughput: Data rate that the node can receive and forward in case of no frame loss.

(5). Load ratio: Ratio of the rate of current data transmission in the bus occupying the maximum rate of data transmission. It is an important parameter showing the work state of the current

energy

network. It is a percentage. Larger is the value, larger is the network load.

4.2. Dynamically-Regulated Listening And Sleep Times

A single time frame of the sensor nodes is composed of listening and sleeps stages. Figure 4 shows the periodic listening/sleep comparison chart between S-MAC Protocol and the new protocol.

Based on the analysis on S-MAC, in the listening stage, the node communicates with its neighbor nodes and transmits message queues cached in the sleep stage. The listening duration and the sleep duration are constant, so it can not satisfy the change in the network load. In the practical applications, the network load is always changed dynamically. If the load is low, short listening time is expected so as to save energy. If the load is high, short sleep time is expected so as to reduce the delay. Therefore, the duration of the listening period/the sleep period of the node can be properly regulated through the change in the load of the node, saving energy and reducing the delay

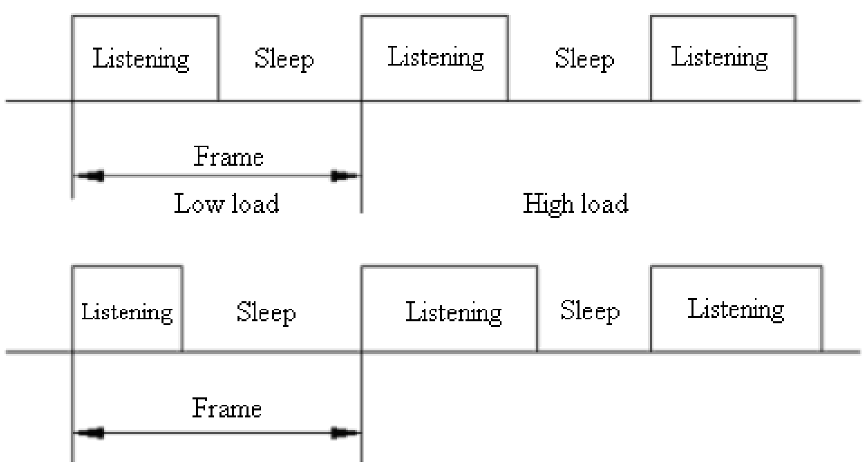

Figure 4. Listening And Sleep Comparison Chart Between S-MAC And New-MAC

4.3. Analysis On Improved Strategies Of The New Protocol

Figure 5 shows the detailed algorithm flow chart.

Algorithm steps of the new protocol:

Step One: First, calculate the network load. The load is determined based on the load ratio where the load ratio m of the node is defined by the number of data packages in the sent message queue, that is, the ratio of the number of data packages waiting to be sent to the maximum

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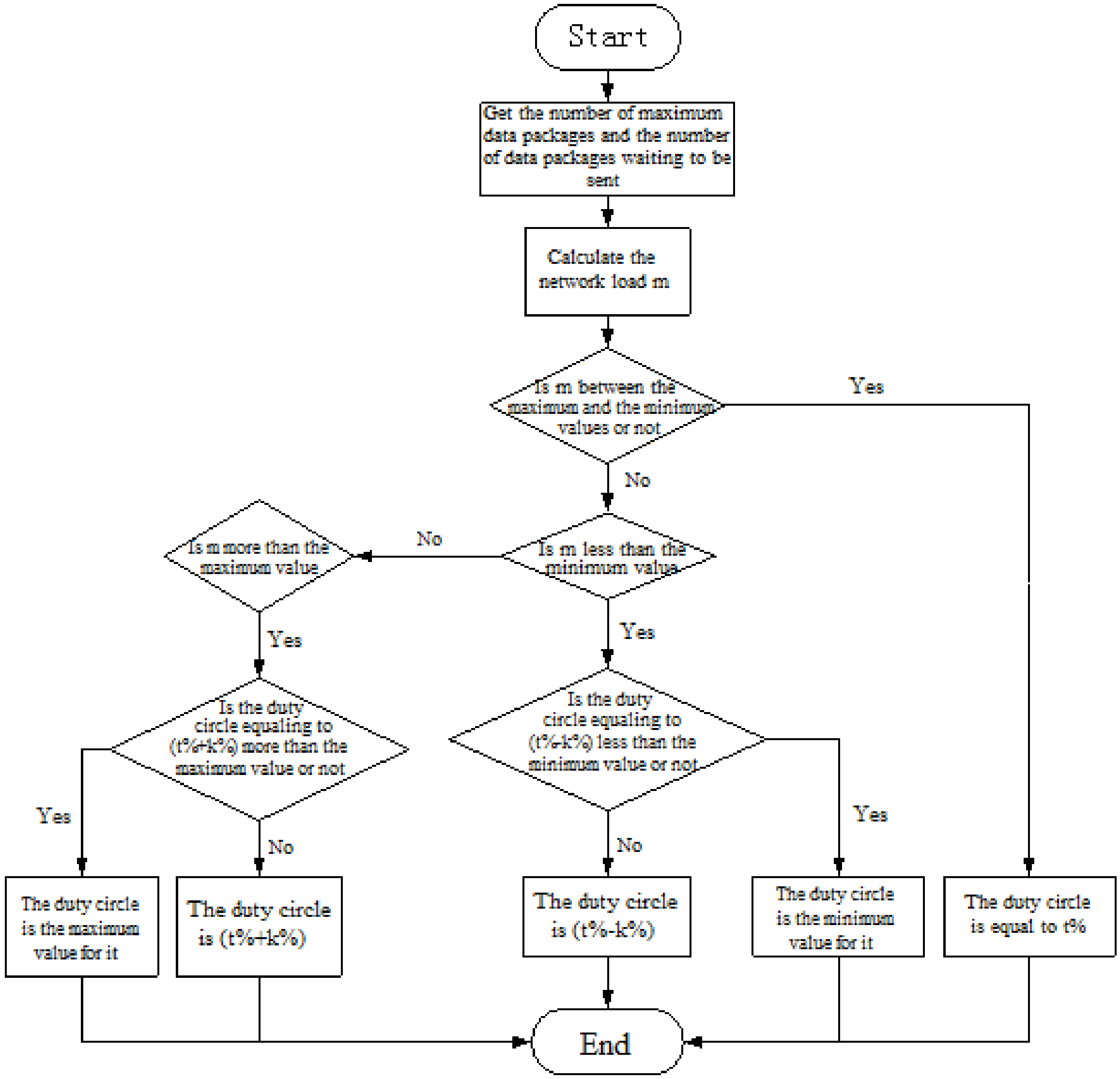

Figure 5. Algorithm Flow Chart Of The New Protocol

number of data packages that can be sent in the sent message queue. Step Two: If the load ratio m is between the minimum and the maximum values set for the network load, it means that the network load is moderate and the new duty circle of the node is t%, the stationary duty circle of S-MAC.

Step Three: If the load ratio m is less than the minimum value set for the network load, it means that the network load is relatively low. In order to reduce the network energy, it is necessary to shorten the idle listening time of the node and the new duty circle is the stationary duty circle of S-MAC minus k% (k is determined based on the load ratio m of the node). If the new duty circle is less than the set minimum one, it is equal to that set minimally. Otherwise, the value of the new duty circle remains unchanged.

Step Four: If the load ratio m is more than the maximum value set for the network load, it means that the network load is relatively high. In order to reduce the time of message delay, it is necessary to increase the idle listening time of the node and the new duty circle is the stationary duty circle of S-MAC plus k% (k is determined based on the load ratio m of the node). If the new duty circle is more than the set maximum one, it is equal to that set maximally. Otherwise, the value of the new duty circle remains unchanged.

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Obviously, obtain the network load based on m, properly regulate the durations of the listening period/the sleep period of the node, and finally, transmit new scheduling information of the node to its neighbor nodes via radio. The duty circle of the node in the new protocol is expressed as n. The unchanged duty circle of S-MAC Protocol is t. In the entire period, in order to form the virtual cluster, the node has one minimum idle listening time which is more than the time of the node to send SYNC and RTS messages. In order to save energy, the node also has one maximum idle listening time. So you can see, the duty circle has a certain range $[n_{min}, n_{max}]$. k is set based on the load ratio m of the node and the load of the node is defined based on the threshold value of the load ratio of the node. If $m \prec m_{small}$, the network load is low. If $m \succ m_{large}$, the network load is high.

Through the above analysis, the specific algorithm of the new improved protocol is:

```
If(msmall<m<mlarge){
   Duty-circle=t%
  };
If(m<msmall)
{
  float k,n;
float k=f(m);   Duty-circle=t%-k%;
  if(Duty-circle<nmin)
    Duty-circle=nmin;
    else Duty-circle=t%-k%;
}
If(m>mlarge)
{
  float k=f(m); Duty-circle=t%+k%;
  if(Duty-circle>nmax)
   Duty-circle=nmax
   else Duty-circle=t%+k%;
}
```

Definitions of parameters:

m: network load ratio;

Duty-circle: duty circle of the work node;

t%: duty circle when the load is moderate (duty circle of S-MAC);

nmin, nmax: maximum and minimum values of the duty circle.

Based on the above analysis, the new protocol still follows the design of MAC Protocol of previous researchers from aspects of saving energy. Additionally, taking into consideration the particular application environment of the wireless sensor network and that the operation state of the network is always continuously changed and combining main performance (energy consumption, information delay) of the sensor network with the practical dynamic environment of the network, the author designs a new protocol algorithm

5. CONCLUSION

The author introduces the concept and main mechanisms of S-MAC Protocol, analyzes its advantages and disadvantages and proposes the existing improved protocol based on S-MAC Protocol. In this paper, the author considers large similarity in sensory data of the nodes, classifies the nodes and selects different processing methods for different nodes. In the particular environment, the network load may be changed dramatically sometimes. In order to achieve the fairness between energy and delay, a new energy-saving MAC Protocol applicable to dramatic change in the network load is proposed in the new non-stationary listening and sleep method.

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