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A New MAC Protocol for Network Load Sudden Change

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Abstract: Wireless sensor network generally runs in the dynamic physical environment which outside environment is constantly changing, once some sudden incident happens, sensor network task load will be caused changeable greatly which will affect the network system performance seriously. Therefore, it is very necessary to design a new MAC protocol for network load sudden change. In this study, based on analyzing the advantages and disadvantages of S-MAC protocol and existing methods, we put forward a new improved S-MAC protocol for network load changeable sharply which chooses different methods for different nodes to realize the equity of energy and time delay.

Key words: Wireless sensor network, network load sudden change, MAC

INTRODUCTION

On the basis of IEEE802.11 MAC protocols, Wei Ye, a American scholar put forward S-MAC protocol which has two design goals, saving network energy and meeting the extendibility of large wireless distributed network (Akyildiz *et al*., 2002; Chong and Kumar, 2003; Culler *et al*., 2004). S-MAC protocol design mainly adopts the four mechanisms as the followings (Cramer *et al*., 1999; Pottie and Kaiser, 2000; Zhang *et al*., 2006):

- Using cyclical sniffer and dormancy strategy
- Avoiding the message conflict and crosstalk problems
- Traffic-adaptive sniffer strategies
- Longer message transmission:

It is invariant for cycle time, sniffer time and dormancy time of S-MAC protocol not to meet the network load change. For that, Dam put forward T-MAC protocol which is at the condition of that the total time of sniffer and dormant is fixed, shorten the length of free sniffer time to reduce energy consumption. And D-MAC protocol is proposed for solving node high communication delay of S-MAC protocol (Zhang *et al*., 2011). A transmission cycle of a node is formed by sending phase, receiving phase and dormancy phase. The scheduling time of each node has some different migration which makes sending time of nodes same to receiving time and reduces the node communication delay.

In this study, based on analyzing the advantages and disadvantages of S-MAC protocol and existing methods, we put forward a new improved S-MAC protocol for network load changeable sharply which chooses different methods for different nodes to realize the equity of energy and time delay.

ADVANTAGES AND DISADVANTAGES OF S-MAC PROTOCOL

Compared with IEEE802.11 MAC protocol, S-MAC protocol has the following advantages: through the cycle sniffer and dormancy strategy, it can extend the node sleep time to reduce the node energy and it has better expansibility to meet the network topological structure changes. However, S-MAC protocols exist some shortages (Zhang, 2012):

- Nodes have no classification. S-MAC protocol adopts the same work mechanism to the network nodes. In the practical application, some nodes of the network perhaps perceive some unreliable message, even these data are too similarity although the node receive reliable data, so while meeting the specific network conditions, we can choose corresponding node for transmission. Nodes of S-MAC protocol participate in the competition of wireless channel which wastes the energy.
- Nodes can't meet the dynamic change of network flow. Through the cycle sniffer and dormancy strategy, S-MAC extends the node dormancy time. The length of node cycle time, sniffer time and dormancy time remain unchanged. So, with the network flow dynamic change, the sniffer time and dormancy time of nodes cannot be adjusted, in the big network flow situation, data perhaps cannot

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finish transmission and in the network small traffic situation, node is in the sniffer state which wastes a lot of energy

- High Node data transmission delay. For cycle sniffer and dormancy strategy of S-MAC protocol, if the network conducts multi-hop data communication, with the increase of the number of transmission jump, the transmission delay will be very high for node will send one message in one scheduling cycle

DESIGN OF NODES CLASSIFICATION

Wireless sensor network transfers by data way, Observer only want to know the index value measured in some area, but not is interested in the perceptual data of some node. Node density of wireless sensor network is very high, generally can reach 20 nodes per cubic meter. In the same or similar monitoring region, the data collected by nodes are very similar. In the limited scope meeting the application, if a certain number of nodes are chosen for data transmission, then network life will be prolonged.

Method of nodes classification: If a wireless sensor network with random distribution dense is chosen to observe the index value of a certain area. Data perceptions by Node have some similarity, the node data correlation is determined by computing message entropy and combination entropy of the two nodes message flow, respectively. Entropy function shows the correlation between space discrete distribution variables which can determine the node data correlation. To choose the node with the least correlation, the message flow relevant coefficient K is defined, the e relevant formulas are cited as the followed. The message entropy is:

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

That is, $p(x_i)$ is the probability of monitoring events acquired by node i, $p(y_j)$ is the probability of monitoring events acquired by the node j, n and is the sum of the possible acquisition event.

In the two-dimensional random variables composed by x_i, y_j, $p(x_i, y_j)$is their joint probability, the joint entropy is:

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

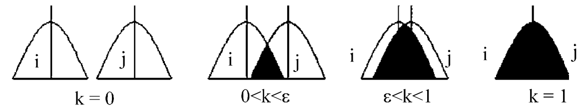

Fig. 1: Correlation of node perception information

Generally, $H(x, y) \le H(x)+H(y)$, if $H(x, y) = H(x)+H(y)$ then that can express the collection message of the two nodes is irrelevant, $H(x, y)/(H(x)+H(y))$ expresses the collection data relevant degree of node i and node j. The correlation coefficient is:

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

Obviously, the values field of K is [0, 1], K = 0 shows the node set of node i and node j is independent and K is bigger, the correlation of the two nodes is bigger. K = 1 shows the collection data of node i and node j are identical completely, the nodes are classified by the correlation coefficient of obtained nodes. According to the application requirements, if the threshold value of node correlation coefficient is $\varepsilon = 0.8$, the classification of node i is determined by the perception message flow of node i and perception message correlation coefficient K of the nodes in which existing related regional, if $\varepsilon < K \le 1$, the node is redundant node, if $0 \le K \le \varepsilon$, it is work node.

The correlation of the node perception message is shown in Fig. 1.

PROCESSING OF SYNCHRONIZING TIME AND NODE

Every sensor node has an independent dispatch table which saves all scheduling information of the nearby node. Node cycle radio clock is synchronous with messages group (SYNC), the neighbor node of the network know its information of dispatch table which can realize time synchronization. The virtual cluster is formed by the nodes with the same scheduling, in which, the nodes are divided into working nodes and redundant nodes according to the correlation coefficient. Work node goes into the sniffer situation, competing channel and transferring monitoring data state after synchronization time. Redundancy node goes into the dormancy state directly after synchronization time which can save network energy consumption further. Figure 2 shows the composition of different sensor node time frame.

NEW ENERGY SAVING DESIGN FOR MAC PROTOCOL

Define of relevant concepts

Energy consumption of sensor nodes: The consumption energy unit of sensor node includes wireless communication unit, sensor unit and processor unit, in which wireless communication unit consumes the most energy. Generally, consumed energy of 1 bit message communication 100 m distance equals to that of execution 3000 operation instruction approximately. When the network is running, wireless communication unit perhaps is in four different energy level state that are sending, receiving, free sniffer and dormancy, the energy of wireless communication unit in free sniffer is bigger than dormancy energy further.

Sensor node state: Sensor node will stay in cycle dormant state. When the timer overflows the node is awakened, then it goes in sniffer channel state. Through the mechanism of carrier sniffer, the node goes into competition channel and if the channel is in free, the node begins data transmission, otherwise, the node gives in for a period of time. When the node gets the return ACK data frames of receiving node, it will turn to the initial state of the node.

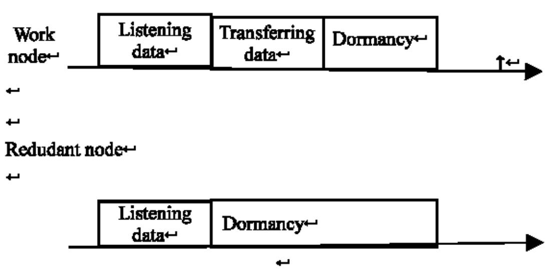

Fig. 2: Time frame constitute of different sensor nodes

Duty circle: The ratio of sniffer time length and the whole life cycle length and the whole cycle duration is the summation of sniffer and dormancy time. The Duty ratio is bigger, the energy consumption of node is more.

Throughput: In the conditions of no frame loss, node can receive and forward the maximum data rate.

Load rate: The ratio is current data transmission rate accounting for the biggest data transmission rate in bus which shows the important parameters of current network working state, is a percentage and the value is higher, the network load is larger.

DYNAMIC REGULATION FOR SNIFFER AND DORMANCY TIME

The single time frame of sensor node contains sniffer stage and dormancy stage. The cycle Sniffer /dormancy contrast figure of S-MAC protocol with the new protocol is shown in Fig. 3.

According to the analysis of S-MAC protocol, at the sniffer stage, nodes communicate with its nearby node, at the same time the cache message queue in dormancy transfer message. And the fixed time of sniffer and dormancy cannot meet the network load change. In practical applications, the network load is always dynamic changeable, when the load was small, the sniffer time is need short to save energy, but when the load is big, the dormancy time is needed short to reduce the delay.

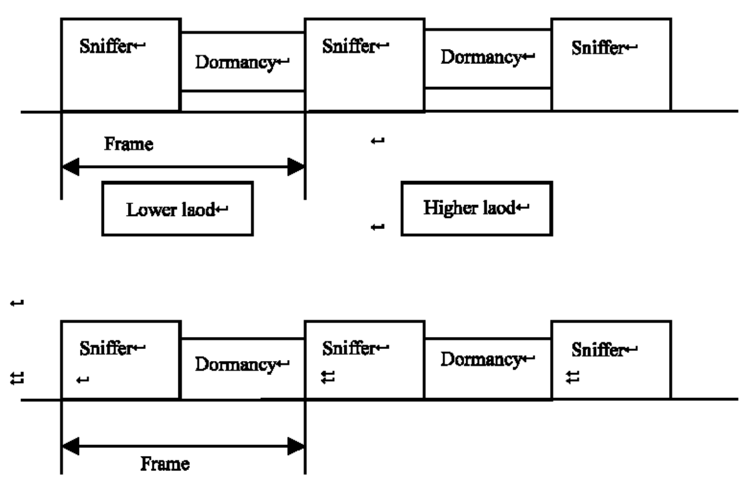

Fig. 3: comparisons of sniffer/dormancy stage between S-MAC and New-MAC

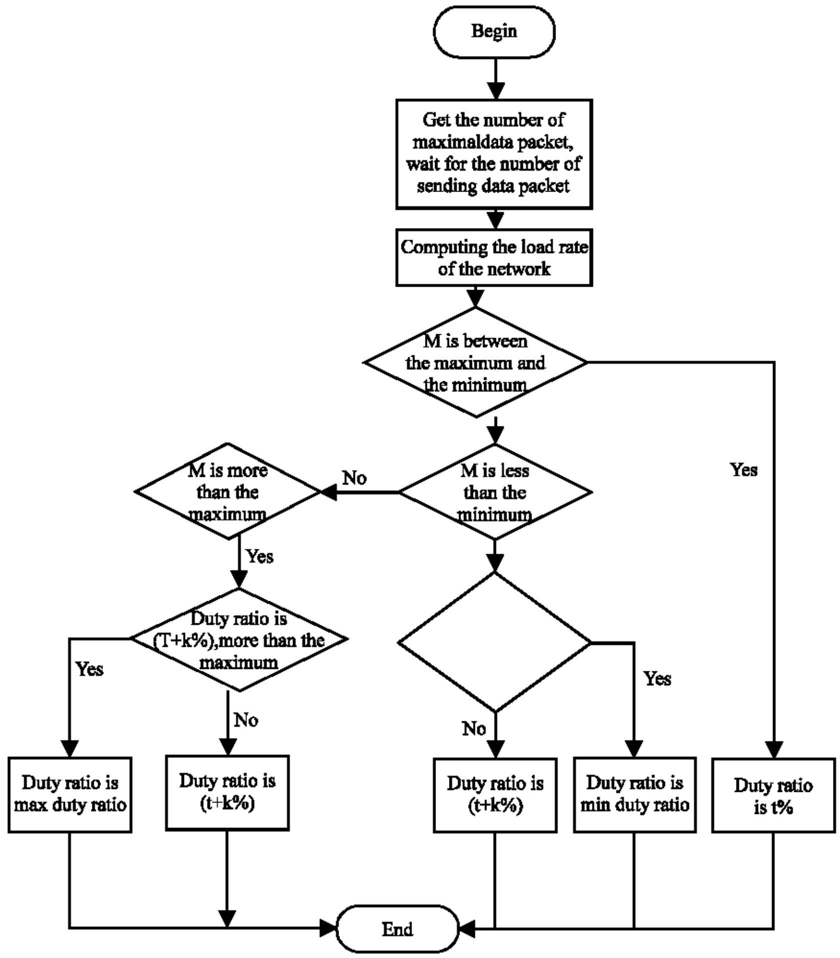

Fig. 4: Flow chart of the new protocol

Therefore, through the load changes of the node itself, the cycle length of node sniffer/dormancy cycle is adjusted appropriately to save energy and reduce the delay.

Improved protocol strategy: The specific algorithm is showed in Fig. 4.

The steps of the new protocol algorithm are as followed:

Step 1: Calculating the network load. The load is measured by the load rate, the node load rate m is defined by the number of packets in the sending message queue that is the ratio of the number of waiting packets and the largest number of the sending packet in the sending message queue

Step 2: If the load rate m is between the minimum and maximum result of network load, then it shows the network load is moderate and the new duty ratio of node is t % than the S-MAC fixed duty factor

Step 3: If the load rate m is less than minimum value of network load defined, then it shows that the network load is small. In order to reduce the network energy, the node idle sniffer of time is need to shorten, the new duty ratio is the fixed duty factor of S-MAC minus k% (k is defined by the node load rate), if the new duty ratio is less than the minimum duty ratio defined, then the new duty ratio equals to the minimum duty ratio defined, otherwise, the new duty ratio value remain unchanged

Step 4: If the load rate m is bigger than the maximum of the defined network load, then the network load is big. To reduce the message delay time, the node free sniffer time is need to increase, the new duty ratio is that the fixed duty ratio of

S-MAC plus k% (k is defined by m), if the new duty ratio is bigger than the maximum duty ratio defined, then the new duty ratio equals to the maximum duty ratio defined, otherwise, the new duty ratio value remain unchanged

Obviously, according to m, the network load can be concluded, through adjusting the sniffer cycle/dormancy cycle length of node appropriately, the new dispatch table message of the last node can be transferred to nearby nodes through radio.

If n is the duty ratio of the new protocol node, t is the duty ratio of S-MAC protocol, then in the whole cycle, the node has a least free sniffer time for forming a virtual cluster which is bigger than the time of sending SYNC message and RTS message. For saving energy, the node has a maximal free sniffer time, so the duty ratio has a scope $[n_{min}, n_{max}]$, node load rate m defines the value of k, node load is defined by the threshold of node load rate, when $m < m_{small}$, the network load is small and $m > m_{large}$, the network load is big.

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

```
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%;
}
The definitions of the parameters above are followed,
m: Network load rate,
Duty-circle£ºduty ratio of the work nodes
t%:duty ratio of load moderate(duty ratio of S-MAC)
nmin, nmax: The maximum and minimum values of duty ratio
```

According to the above analysis, the new protocol follows the design of the previous researchers which view is saving energy. In addition, the application environment of wireless sensor network is considered; the network running status is always changing. Combined with the main properties of sensor network (energy consumption, information delay) and the actual network dynamic environment, a new protocol algorithm is designed which superiority will be shown through the simulation experiments the next chapter.

EXPERIMENTS

In the experiment, simulation software NS2(n2-2.29) is adopted. In the simulation produce, the nodes of network are set unmovable. The new protocol for saving energy is improved based on S-MAC protocol. In the chapter, the new performance of MAC protocol is analyzed and some important parameters are compared with traditional S-MAC, IEEE802.11 protocol. For getting better comparison result, the simulation topology structure of the new protocol is same as S-MAC protocol.

Six nodes are deployed in the simulation scene, the nearby nodes distance of simulation topology is 150 m and the communication distance of the nodes is 250 m to ensure the signal jump data transmission of node. For every node of the sensor, the initial energy is set as 1000 J, in the sending situation, the energy consumption is 0.48J, in the receiving situation and the energy consumption is 0.44 J and in the dormant state, the energy consumption is 0.0001 J. The simulation time is 1000s, the simulation area is 500×500 m.

The fixed Duty-circle of S-MAC is 50% and for the new saving energy MAC, the minimum of the duty-circle is 25%, the maximum is 75%. The set node sends signal data package as 20s for the time cycle, for the network load is different, the time creases to 120s gradually. In the following, the comparison between the two protocols is at the energy consumption and time delay.

The energy consumption of the new saving energy MAC protocol is the least, showed as Fig. 5 When the network load is less, 33% is the lower than S-MAC protocol which is obviously very much. Then the new protocol adjusts Duty-circle dynamically to less the Duty-circle and extend the dormancy time of the node to reduce the energy. When the network load is more, the new protocol increase the Duty-circle, extend the listening time of node and increase the energy consumption. But the new and improved protocol chooses the nodes, such as the high redundancy node are in the dormancy state to reduce the energy consumption and the energy consumption of the new protocol is less than S-MAC protocol a little. Generally, comprised with IEEE802.11, S-MAC protocol, the new protocol can save more energy.

Showed in Fig 6, when the network load is more, the sensor node of IEEE802.11 protocol always sniffers the delay emerged by the no dormancy and the time delay is the minimum. The new protocol can raise the Duty-circle rate and the node dormancy time deduces to make its delay is less than that of S-MAC (about two times as the former). When the network load becomes small, the waiting delay of data pack in the waiting queue can be ignored and the three kinds delay is similar approximately.

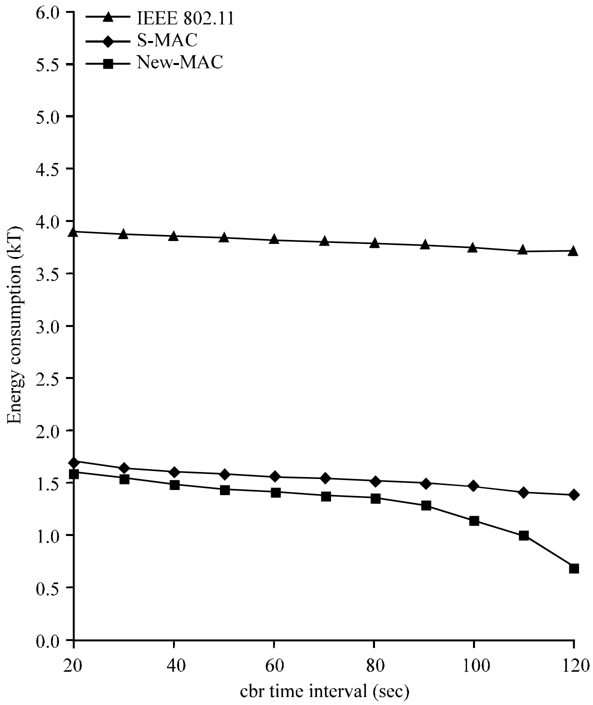

Fig. 5: Comparison of energy consumption

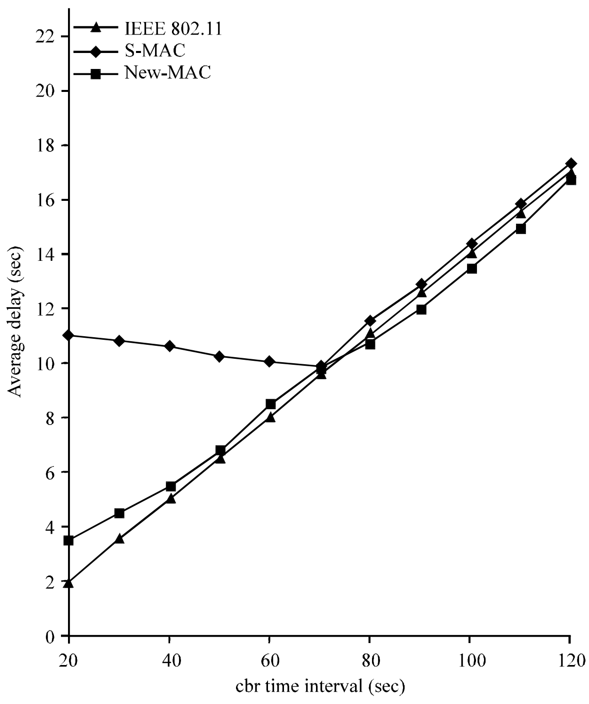

Fig. 6: Comparison of time delay

The performance of IEEE802.11delay and throughput is good, but vast network energy is consumed, so it is not suitable for wireless sensor network.

CONCLUSION

In this study, the concept and the main mechanism of S-MAC protocol is introduce, the advantages and disadvantages of S-MAC protocol are analyzed and the improved protocol based on S-MAC protocol is expound. For the great similarities of node perception data, the nodes are classified, different node chooses different treatment method. And for realizing the fairness of energy and time delay, a new no stationary of sniffer and dormancy method and a new MAC protocol are put forward which can save energy meeting network load mutation.

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