The Application of Binary Exponential Backoff Algorithm for WIA Wireless Network

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Abstract. The WIA industrial wireless network which based on IEEE802.15.4 standard. The network will produce some network conflicts and data loss phenomenon with the expansion of network scope and the increasing of amount of data in the network. In view of this kind of phenomenon. This paper introduces a binary exponential backoff algorithm. We establish experimental model to simulation analysis. We obtained simulation model under the condition of stable network. It can reduce the probability of collision between nodes when the node sends data packets to the other node.

Introduction

With the development of technology of Internet of things. The wireless networks have penetrated into all aspects of life. The technology of wireless communication are widely used in the field of industrial especially. The wireless network appears which provides a better solution for many industrial applications which is not suitable for wiring. Because the wireless network has the advantages of flexible layout and low power and establish the network quickly. It obtained the rapid development and application in industry field[1]. The phenomenon of wireless network conflict is easy to appear when the nodes send data. It will get more serious along with the application of increased and the expansion of network scale and a large of data appeared between communication nodes at the same time. This paper presents a solution which introduces the binary exponential backoff algorithm. It can reduce the probability of collision between communication nodes in WIA wireless network.

WIA Industrial wireless network

WIA industrial wireless network is the network communication protocol which is developed based on IEEE802.15.4 standard. It can be widely used in the wireless network system. For example, industrial process measurement and the equipment monitoring of industrial field [2]. It has independent intellectual property rights in China. The protocol includes spread spectrum communication and multi hop communication and Mesh network technology and so on. It has strong anti-interference ability and low power consumption and real-time data transmission and so on. It is very suitable for the bad work environment and the personnel are not easily arrived place. The WIA industrial wireless network can meet the need of users who need low cost requirements. It makes the user achieve the whole ubiquitous sense of industry’s process. We get real-time monitoring parameters and to make optimization control. The energy is saved and quality of products is better at last. The message between nodes becomes more and more with the increasing applications and the number of node. The data conflict between nodes always occurs. The phenomenon of data packet lose are also occasionally. We make use of ACK started confirming and retransmission mechanism to deal with the problem. If the sending node is not received ACK from the receiving node. The data is retransmitted until it receives an ACK. But this ways does not
reduce the probability of data collision when the network scale is large and communication information is more. It is directed against this phenomenon. The abinary exponential backoff algorithm is introduced to deal with the problem which data collision and packet lose between communication nodes.

The abinary exponential backoff algorithm

The binary exponential backoff algorithm is also called two yuan exponential back off method. The node will send out data repeatedly when the communication meets conflict. It will double the average of delay after each data communication conflict. BEB provides a method which treat repeat communication data. The data attempt to repeatedly transmit data. If it transmits failure will lead to a longer backoff time[3]. It can help node have a smooth waveform. If the WIA wireless network does not use the backoff algorithm. It will lead to two or more nodes attempt to transmit data simultaneously which will lead to more serious conflict occurs.

The Simulation of Binary Exponential Backoff Method

There is a contention window parameter W in the binary exponential backoff method. The time which is called contention window is divided into W+ 1 slots. The slot is numbered into zero and one and two until w. The number is called backoff value. The contention window contains the number of slots which is known the contention window length [4]. The range of parameter W is from CWmin to CWmax. The contention window parameter W of node is CWmin at the beginning of. The initial contention window length is L0. The value of L0 is CWmin+1. The operation process of BEB algorithm is to random choose parameter. The name of parameter is K. It is called backoff value. We can choose the value from zero to W for K. And then set K backoff slots for it. The node immediately sends the data when k is zero. The slot is divided to monitor channel if it is empty. The backoff value reduces one when the monitor channel is empty. The node will send out the data when the backoff value reached to 0. The node will set a timer after sent all the data. The node does not receive ACK frame from receiving node if the timer has consumed time. The sending node wills double the length of current contention window and restarts the BEB algorithm. Then select a new backoff value. It will send this frames which was not confirmation when the new backoff value reach to zero. The current competitive window reaches to CWmax+1 which is maximum value. The length of contention window is not doubled after the node transmits frame failure. But it still needs to enable the BEB algorithm to select a backoff value. No matter under what circumstances, once the node sends a frame successfully. The length of contention window will reset the initial value to L0. The value of W is CWmin.

We will assume that the conflict of nodes is the same in each backoff stage in the previous research process. And then accord it to analyze the models. The probability of conflict is defined as multiple nodes simultaneously detect the channels that are occupied. It will choose probability of backoff or give up transmission. We can get the average data rate of conflict through the experiment as shown in table one. Different backoff stage conflict rate. We set CWmin is 32 and CWmax is 1024 in the simulation experiment. The maximum backoff factor is 7. The conflict rate is similar in each backoff stage when the numbers of nodes are unchanged. We can get this conclusion from analysis of the experimental data in the network. The conflict rate will increases with the number of nodes increases. So we assume the consistency of has certain rationality. We set each node conflict rate is p0 in each backoff stage in the new model.

Table 1 Different backoff stage conflict rate

<table>
<thead>
<tr>
<th>Number of Nodes</th>
<th>Average Collision Rate</th>
<th>Backoff 0</th>
<th>Backoff 1</th>
<th>Backoff 2</th>
<th>Backoff 3</th>
<th>Backoff 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.2907</td>
<td>0.2589</td>
<td>0.2720</td>
<td>0.2982</td>
<td>0.2785</td>
<td>0.3411</td>
</tr>
<tr>
<td>20</td>
<td>0.4066</td>
<td>0.3856</td>
<td>0.3943</td>
<td>0.4122</td>
<td>0.3899</td>
<td>0.4211</td>
</tr>
<tr>
<td>30</td>
<td>0.4591</td>
<td>0.4489</td>
<td>0.4356</td>
<td>0.4601</td>
<td>0.4599</td>
<td>0.4912</td>
</tr>
<tr>
<td>40</td>
<td>0.4975</td>
<td>0.4901</td>
<td>0.5012</td>
<td>0.5034</td>
<td>0.5098</td>
<td>0.4831</td>
</tr>
</tbody>
</table>
The node is transferred in the limited backoff stage. It will be transferred to the initial backoff state after each transmission is finished. Otherwise, the node will move to the next backoff state. The backoff state transmit diagram as shown in Fig. 1. The parameter $B_k$ expresses the $K$ backoff stage. The value range of parameter $k$ is from zero to $L$. We set the maximum backoff order is $m$ and the maximum backoff coefficient is $L$. The parameter $m$ Less than $L$. The node will give up the chance of transmitting data if it does not get the transmission opportunity when it attempts $L$ times backoff. It will return to the initial backoff state.

![Fig.1 The backoff state transition diagram](image)

Every node has the same backoff state transition diagram in the whole network. So we can make each backoff stage as an independent service line. All network nodes are distributed in different backoff queue. The node will be transferred in different queues. The whole network will be a closed network system.

In the process of data transmission of WIA wireless network. There is a time delay phenomenon between nodes when node sends data each other if the number of nodes increased or the node sends more data. These can lead to data conflicts rate becomes larger. We set all nodes are distributed by 2000 meters long and 2000 metres wide. The nodes are distributed randomly. Each node selects target node to communication randomly. The channel without be interfaced. If the signal is detected busy when the node in the backoff process. The backoff counter is frozen. Waiting for a time slot and continue backoff. The probability of nodes being monitored busy will be more serious with the number of load or nodes increase obviously. The frozen counter will be more. The time of backoff process will be extended. The simulation parameters table 2 as follows:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slot</td>
<td>5us</td>
</tr>
<tr>
<td>Channel Rate</td>
<td>128kbps</td>
</tr>
<tr>
<td>Packet Length</td>
<td>2048bit</td>
</tr>
<tr>
<td>Number of Retransmission</td>
<td>10</td>
</tr>
</tbody>
</table>

The experimental conditions. A number of nodes are fixed. Changing the size of sending packets. Another group, the send packet size is fixed. Changing the number of nodes in the experiment. The average delay from one node to the other node as shown in Fig.2 and Fig.3. Fig.2 The number of node fixed. Fig.3 sending packet fixed.

![Fig.2 The number of node fixed](image)  ![Fig.3 Sending packet fixed](image)

We can conclude from the experimental analysis. The average delay between the nodes will increase with the number of nodes addition and the send packet more. The conflict probability will become larger between nodes with the delay increasing. We use BEB algorithm. In order to ensure node to the other node timeliness. We use retransmission mechanism data communication between nodes.

We select backoff slots from the initial backoff window with uniform probability after the node receives the data of upper node. The backoff counter is closed if the channel is detected busy in backoff process. It will continue backoff after a slot. It will join another channel when the counter decrements to zero. It comes back to the initial stage If the packet is sent successfully. The send time will be timeout If the packet collision occurs. It is removed from the transmit buffer until
the packets are transmitted successful or the backoff value reach to timeout threshold. The conflict probability is showed in parameter $p$ when the packets access channel. It is the probability when the node detects channel is busy. We set the backoff counter value of $t$ is $b(t)$. $s(t)$ is backoff stage. The two-dimensional stochastic process $(s(t), b(t))$ constitute a discrete Markov chain. We introduce state $(-1,0)$ is empty for the transmit buffer. The packet is removed from buffer when data is sent successfully or timeout. The node becomes $(-1,0)$ state. It is show in Fig.4 The Markov Chain Mode of BEB Backoff Algorithm.

Fig.4 Markov Chain Mode of BEB Backoff Algorithm

$$i \in [0, \infty), \phi_i$$ is probability that the node sends data collision and does not timeout. The state value from $(m+i, 0)$ to $(m+i+1, 0) \sim (m+i+1, W_m-1)$. The parameter $W_i$ is the size of retransmission backoff window. $b_{ij} = \lim_{t \to \infty} p(s(t) = i, b(t) = j)$. The parameter $b_{ij}$ represents the steady-state distribution of Markov chains. Equation 1.

$$\begin{align*}
b_{0j} \cdot (1 - p) &= b_{1,0} \cdot \frac{W_{i-1}}{W_0}, \quad j \in [1, W_0 - 1] \\
b_{ij} \cdot (1 - p) &= b_{i-1,0} \cdot \frac{W_{i-1}}{W_i}, \quad j \in [1, m - 1] \\
b_{ij} \cdot (1 - p) &= b_{i,m} \cdot \frac{W_{m-1}}{W_m}, \quad i \in [1, m - 1] \\
b_{i,0} \cdot q &= \sum_{k=0}^{m-i} (b_{i+k} \cdot (1 - p)) + \sum_{k=m-i}^{m} (b_{i+k} \cdot (1 - \phi_{k-i})) + b_{20,0}, \quad i \in [1, m - 1] \\
b_{0,0} \cdot \phi_m &= \sum_{k=1}^{m-i} (b_{i+k} \cdot (1 - p)) + \sum_{k=m-i}^{m} (b_{i+k} \cdot (1 - \phi_{k-m+i})) + b_{20,0}, \quad i \in [m, 19]
\end{align*}$$

(1)

The node starts transmitting the data packet when $j \in [0,20]$ and $b(t) = 0$. The parameter $\tau$ is the probability that the node transmits packet within a time slot. Equation 2.

$$\tau = \sum_{i=0}^{20} b_{i,0} = f_2(p, \phi, m, n)$$

(2)

Because the probability of node conflict is parameter $p$ which equal one node transmit data probability in other ($n-1$) nodes at least. Equation 3.

$$p = 1 - (1 - \tau)^{n-1}$$

(3)

It shows that the probability of node conflict has a relationship with the node sends a packet slot. So that verify the validity of model analysis. We use NS2 simulation platform. The test parameters of physical layer and MAC layer refer literature 5 [5]. The experimental results is shown in Figure 5. Relationship of Backoff Window and Collision Rate. We can see from Fig. 5 that the data transfer conflict rate becomes larger with the increasing of nodes in the network. The parameter $W_0$ of minimum backoff window become large and the data transmission collision probability may be decreased from the figure shows. The analyzing of the model has consistency with the result of simulation. It indicates the validity of model analysis.

**Conclusion**

The BEB algorithm is introduced into WIA wireless network to solve the problems of network conflicts in the case of large-scale networks and large amount of data. There is a certain relationship between the number of nodes and the collisions rate of data through modeling and simulation analysis. We introduce backoff mechanism to analyze the impact that competition affect transmission rate. We verify the validity of model from the experimental simulation results.
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Jianlong-Huang, Male, Born 1981, Master, Assistant researcher, Research for wireless sensor networks Smart grid and so on.

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