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International Journal of Current Advanced Research
Vol 4, Issue 11, pp 495-498, November 2015

ISSN: 2319-6505

International Journal of Current Advanced Research

ISSN: 2319 - 6475

RESEARCH ARTICLE

THE DISCRETE TIME THREE-DIMENSIONAL PROBABILITY CSMA PROTOCOL WITH THREE-WAY HANDSHAKE MECHANISM IN WSN

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A R T I C L E I N F O

Article History:

Received 15th August, 2015
Received in revised form 21st September, 2015
Accepted 06th October, 2015
Published online 28st November, 2015

Key words:

WSN, three-dimensional probability, CSMA, RTS / CTS, throughput.

A B S T R A C T

WSN which is a very important emerging technology in the information age, has caused great concerning all over the world, compared with current Wireless LAN, Mobile Communications Networks, Cellular Communications, Wireless Sensor Network has much more development potential. IEEE802.11 provides the following solutions. The use of RTS / CTS protocol, and set the upper limit of the number of bytes transferred, ensuring the plurality of mutually invisible transmitting station at the same time send a signal to the same receiving site. This paper presents the discrete time three-dimensional probability CSMA protocol with three-way handshake mechanism, and uses the average cycle analysis methods system throughput. The correctness of the theory is verified through the simulation.

INTRODUCTION

Wireless Sensor Network (Wireless Sensor Network, WSN) which is a very important emerging technology in the information age, has caused great concerning all over the world, compared with current Wireless LAN, Mobile Communications Networks, Cellular Communications, Wireless Sensor Network has much more development potential. Wireless Sensor Network is composed of a large number of distributed sensor nodes for task-based self-organizing network for data collection and transmission, to provide users with useful information [1]. It is widely applied in lots of fields, such as military defense, industry control, agricultural control, health care, rushing to deal with an emergency rescue, counter-terrorism and anti-terrorism, environmental monitoring, a remote control to hazardous area and so on However, due to its inherent networking site communications ability, computing speed, storage capacity and energy and other constraints, therefore, Wireless Sensor Network has great challenge and vast space in-depth studying. Wireless Sensor Network will become one of the most potential technologies in the twenty-first century.

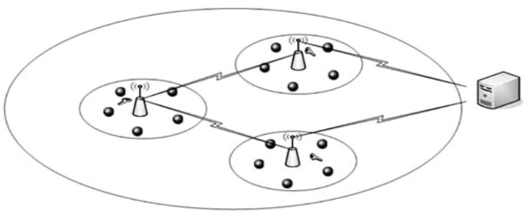

Fig 1 The network structure of WSN

The role of the MAC layer is to provide fair, reliable, efficient scheduling mechanism to allocate radio channel resources, MAC protocol performance is directly related to the performance of the wireless channel utilization and the entire network [2]. It has always been important and difficult research among scholars. RTS / CTS protocol: request to send allowed to send protocol, it is equivalent to a handshake protocol, mainly used to solve the "hidden terminal" problem. "Hidden terminal" (Hidden Stations) refers to the base station A send information to the base station B, station C is not detected A also sends to B, A and C at the same time it sends a signal to B, causing signal conflict, eventually leading to send to B signals are lost. "Hidden terminal" occurred in large units (usually in an outdoor environment), which will bring efficiency losses, and the need for error recovery mechanisms. When you need to transfer large files, it especially needs to eliminate "hidden terminal" phenomenon [3].

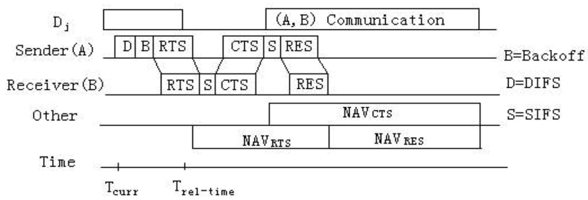

Fig 2 The RTS/CTS protocol.

IEEE802.11 provides the following solutions. In the parameter configuration, the use of RTS / CTS protocol, and set the upper limit of the number of bytes transferred. Once the data to be transferred is greater than this upper limit, that startup RTS / CTS handshaking protocol: First, A sends RTS to B signal that A would like to send a number of data B, after B receives RTS, CTS signal to send out to all the base stations, show ready, A can be sent, and the rest wish to B base station for transmitting data sent is suspended; the two sides in the successful exchange RTS / CTS signals (i.e. complete the handshake) before starting the actual data transfer, ensuring the plurality of mutually invisible transmitting station at the same time send a signal to the same receiving site, the actual site can only be received by the receiver can respond to that site CTS transmission, to avoid the conflict [4]. Even if there is a conflict, it is only when sending RTS, in this case, since the receiving site cannot receive CTS message, we go back to the competition with DCF protocol provides a mechanism to assign a random timing value retreated, and waiting for the next medium is idle DIFS (Distributed Inter-Frame Space) competition after sending RTS, until it succeeds. This paper presents the discrete time three-dimensional probability CSMA protocol with three-way handshake mechanism, and uses the average cycle analysis methods system throughput, combine the three-dimension probability CSMA with the RTS / CTS handshaking protocol.

THE MODEL

In the proposed protocol, there will be three random events: Event that information packets are sent successfully(U events). Event that information packets collide with each other (the collision appears, C events). Event that there are no information packets in the channel arrive, the channel is idle (I events).These three events are forced into: the channel is idle (I events) event, the channel is busy (CU events) and the channel is idle following the CU events (CUI events); the packet is sent successfully or unsuccessfully (combined C events with U event, denoted by CU event); force the CU events and the CUI events into B events.A cycle period is T_n. TP is the transmission period. Use three-dimensional probability: $P1$, $P2$, $P3$ to control the period of I events, CUI events and CU events separately.

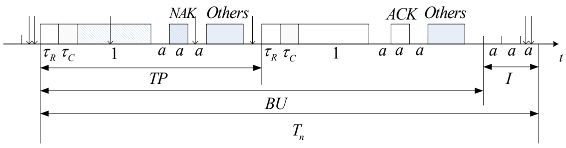

Fig 3 The model of three-dimensional probability CSMA protocol with three-way handshake mechanism.

According to the new protocol, if the channel is idle, then the user decides to send an information packet probability $P1$; in the transportation period, if the channel is the first idle following the CU events, then the user listens to the channel at probability $P2$; if the channel is busy, the user listens to the channel at probability $P3$ [5]. This control strategy, $P1$, $P2$ and $P3$ by three-dimensional selection enables the system under different load utilization and throughput is guaranteed. According to the three-way handshake mechanism, RTS signal is produced and its length of time slot is: τ_R; CTS signal is produced and its length of time slot is: τ_C; monitoring signal is produced and its length of time slot is: a ,then the length of the Transmission cycle is changed to: $\frac{32}{23}(1+3a+\tau_R+\tau_C)$

Analysis of the model

Before analyze the system performance, first do the following assumptions:

- The channel is ideal with no noise and interference;
- The basic unit of the system control clock is a, the information packets arrived at time a will transmit at the starting time of the next slot;
- The channel propagation delay is a ,the packet length is unit length and is an integral multiple of a [6];
- The arrival process of channel satisfies the Poisson process whose independent parameter is G, each arrival process on the channel is independent of each other ;
- The channel using three-dimensional probability CSMA protocol with multichannel mechanism, the information packets need to be sent at the first slot in the transmission period can always detecting the state of the channel at last moment;
- During the transmission of information packets, the phenomenon of packet collisions occur inevitably, and continues to be sent after a random time delay, it sends will not produce any adverse effects on the arrival process channel.

The two nodes conducted a short frame data exchange according to the new protocol, notifying the other nodes that they will occupy the channel for data transmission. Length of

The transmission period is: $\frac{32}{23}(1+3a+\tau_R+\tau_C)$

The arrival process of channel satisfies the Poisson process:

$$P(n)=\frac{(aG)^n e^{-aG}}{n!} \qquad (1)$$

In I events, at idle time slot a, if there is no information packets to be sent, its possibility is:

$$q_1^0=e^{-ap_1G} \qquad (2)$$

In I events, at idle time slot a, if there is only one information packet to be sent, its possibility is:

$$q_1^1=ap_1G_ie^{-ap_1G} \qquad (3)$$

At the transmission period, if there is no information packets to be sent, its possibility is:

$$q_2^0=e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]} \qquad (4)$$

In the transmission period: $\frac{32}{23}(1+3a+\tau_R+\tau_C)$, if there is only one information packet to be sent, its possibility is:

$$q_2^1=\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]\,e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]} \qquad (5)$$

In a cycle, the possibility of continuous i idle events is:

$$P(N_I=i)=(e^{-ap_1G})^{i-1}e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]} \qquad (6)$$

In a cycle, the possibility of continuous j B events is:

$$P(N_B=j)=(1-e^{-ap_1G})(1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]})^{j-1} \qquad (7)$$

In a cycle, the possibility of continuous i I events and j B events is:

$$P(N_I=i,N_B=j)=(e^{-ap_1G})^{i-1}(1-e^{-ap_1G})(1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]})^{j-1}e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]} \qquad (8)$$

The possibility of $E(N_I)$, the average number of i continuous I events in a cycle is:

$$E(N_I)=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} iP(N_I=i,N_B=j)$$
$$=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} i(e^{-ap_1G})^{i-1}(1-e^{-ap_1G})$$
$$(1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]})^{j-1}e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}$$
$$=\sum_{i=1}^{\infty} ie^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}(e^{-ap_1G})^{i-1}$$
$$\sum_{j=1}^{\infty}(1-e^{-ap_1G})(1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]})^{j-1}$$
$$=(1-e^{-ap_1G})\frac{1}{e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}}e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}$$
$$\sum_{i=1}^{\infty}[(e^{-ap_1G})^i]'$$
$$=\frac{1}{1-e^{-ap_1G}} \tag{9}$$

The possibility of $E(N_B)$, the average number of j continuous B events in a cycle is:

$$E(N_B)=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} jP(N_I=i,N_B=j)$$
$$=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} j(e^{-ap_1G})^{i-1}(1-e^{-ap_1G_i})$$
$$(1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]})^{j-1}e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}$$
$$=\sum_{i=1}^{\infty} e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}(e^{-ap_1G})^{i-1}$$
$$\sum_{j=1}^{\infty} j(1-e^{-ap_1G_i})$$
$$=(1-e^{-ap_1G})\frac{1}{1-e^{-ap_1G}}e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}$$
$$\sum_{j=1}^{\infty}[(1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]})^j]'$$
$$=\frac{1}{1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}} \tag{10}$$

To the discrete time three-dimensional probability CSMA protocol with function of monitoring, the information packets are sent successfully in two cases.

Firstly the number of information packet transmitted successfully in I events are:

$$E(N_{U_1})=\frac{q_1^1}{1-q_1^0}=\frac{ap_1Ge^{-ap_1G}}{1-e^{-ap_1G}} \tag{11}$$

The average length of information packet transmitted successfully in I events is:

In a cycle, the average length of time slot that information packet has been successfully sent in a cycle is:

$$E(U)=E(U_1)+E(U_2)$$
$$=\frac{ap_1Ge^{-ap_1G}}{1-e^{-ap_1G}}+\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3] \tag{14}$$

The average length of B event is:

$$E(B)=E(N_B)\times\frac{32}{23}G[1+(3a+\tau_R+\tau_C)]$$
$$=\frac{\frac{32}{23}G[1+(3a+\tau_R+\tau_C)]}{1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}} \tag{15}$$

Where $\frac{32}{23}G[1+(3a+\tau_R+\tau_C)]$ represents the length of information packet whether it transmitted successfully or not in the TP cycle.

The average length of I event is:

$$E(I)=E(N_I)\times a=\frac{a}{1-e^{-ap_1G}} \tag{16}$$

The throughput of the new protocol in channel i is:

$$S=\frac{E(U)}{E(B)+E(I)}$$
$$=\frac{\frac{ap_1Ge^{-ap_1G}}{1-e^{-ap_1G}}+\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}{\frac{\frac{32}{23}G[1+(3a+\tau_R+\tau_C)]}{1-e^{-\frac{32}{23}G[p_2+(3a+\tau_R+\tau_C)p_3]}}+\frac{a}{1-e^{-ap_1G}}} \tag{17}$$

Simulation

From the above analysis, the expression of the system throughput under the discrete time three-dimensional probability CSMA protocol with three-way handshake mechanism got. With the simulation tool-MATLAB R2010a, the simulation results are shown in Figure 4 to Figure 7. If not specified $a=0.01$.

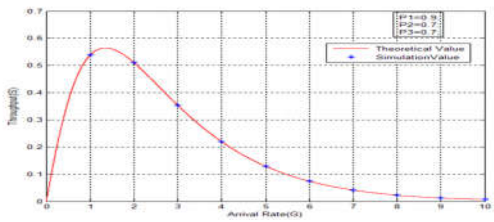

Fig 4 The throughput of the new protocol

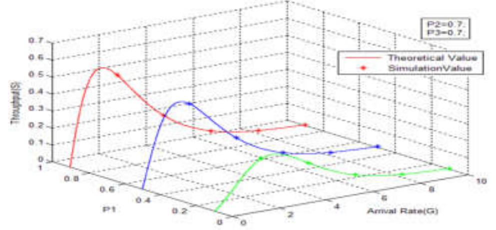

Fig 5 The throughput of new protocol with variable P1

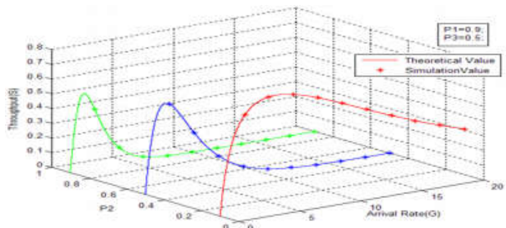

Fig 6 The throughput of new protocol with variable P2

From Fig. 4 to Fig. 6, the simulation values of system throughput under the new protocol are consistent with the theoretical ones. First, when $P1$ becoming bigger, the throughput will increase, especially with small value of G; because when the channel is idle, the probability of an information packet sent successfully will increases. But by contrast, when $P2$ becoming bigger, the throughput will decrease; because when the channel is busy sending the packet, the more new arrival information packets the more collisions will be.

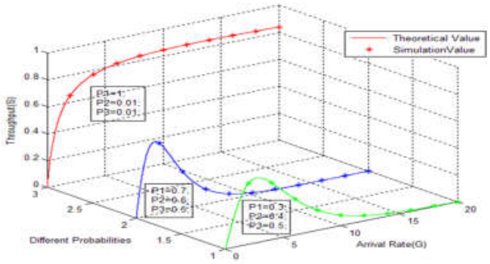

Fig 7 The comparison of system throughput under the new protocol with different probabilities

In the Fig. 7,when $a = 0.01$ $P1 = 1$ $P2 = P3 = 0.01$, the throughput of the system under new protocol is approaching 1, much bigger than the other probabilities. Thus we can change the probabilities to obtain different system throughput.

CONCLUSIONS

The discrete time three-dimensional probability CSMA protocol with three-way handshake mechanism, using the average cycle method, gets the precise mathematical expressions of system throughput by rigorous mathematical derivation. The correctness of the theory is verified through the simulation. By three-dimensional probability and the monitoring mechanism, improves the system controllability, gets the throughput needed, makes the circumstance we want when testing the network. With three-way handshake mechanism, ensuring the plurality of mutually invisible transmitting station at the same time send a signal to the same receiving site, the actual site can only be received by the receiver can respond to that site CTS transmission, to avoid the conflict.Even if there is a conflict, it is only when sending RTS, in this case, since the receiving site cannot receive CTS message, we go back to the competition with DCF protocol provides a mechanism to assign a random timing value retreated, waiting for the next medium is idle DIFS (Distributed Inter-Frame Space) competition after sending RTS, until it succeeds, improve the utilization of channel resources, simple and convenient to improve the safety and reliability of packet transmission.

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