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ANALYSIS OF MULTI-CHANNEL TWO-DIMENSIONAL PROBABILITY CSMA AD HOC NETWORK PROTOCOL BASED THREE-WAY HANDSHAKE MECHANISM

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Abstract- In wireless Ad Hoc networks, large number and flexible mobility of terminals lead to the rarity of wireless channel resources. Also the hidden and exposed terminal problem exists in the Ad Hoc network which is the major factors restricting its development and applying. Considering these factors, this paper proposes a new CSMA protocol: multi-channel two-dimensional probability CSMA for wireless Ad Hoc network protocol based on three-way handshake mechanism, and analyzes the system throughput, delay of information packet, energy consumption and other properties under the control of the proposed protocol. By using the cycle analysis method, computer simulation results not only verify the theoretical analysis, but also show that the protocol has the optimum performance. The proposed protocol can not only reduce the collision probability of information packets to some extent, improving the channel utilization, reducing the waste of channel resources, but also achieve the balancing of load in a variety of wireless Ad Hoc network services, meeting the needs by different priorities with different QoS, and ensuring the systematic efficiency and fairness.

Index terms*:* Two-dimensional CSMA, multi-channel, three-way handshake, throughput, QoS.

I. INTRODUCTION

Since the late 1990s, a new network technology emerged rapidly in the field of wireless communication and wireless self-organization mobile communication network: *Ad Hoc* network [1, 2]. This technology quickly penetrates into all areas of civilian communications and the military communications at the high speed of development.

In the wireless *Ad Hoc* network, the large number and the flexible mobility of terminal nodes lead to the precious of wireless channel resources [3, 4]. The hidden and exposed terminal problems exist in the *Ad Hoc* network, which are the major factors limiting the development and applying of mobile wireless *Ad Hoc* network [5, 6, 7]. Therefore, the study of how to make the best use of the channel resources efficiently, increase the system capacity, improve security and stability of the computer network communication as well as resolve the hidden and exposed terminal problems has been considered as the research topic and difficulty of wireless *Ad Hoc* network.

This paper proposes a practical wireless *Ad Hoc* network protocol on the basis of many research papers: multi-channel two-dimensional probability CSMA for wireless *Ad Hoc* network protocol based on three-way handshake mechanism (MCPDCSMA). These papers have reported the analytic expressions of system throughput, throughput of each priority, average system delay and energy consumption of MCPDCSMA by using the average cycle analysis method [8, 9]. Through the computer simulation, the results show that the proposed protocol not only increases the reliability and stability of the system, resolves the "hidden terminal" and "exposed terminal" problem existing in the *Ad Hoc* network, avoids the channel congestion to a certain extent, reduces the collision probability of information packets, improves the utilization of the channel by adding the inquire response mechanism, but also realizes the balancing of channel load, meets the different needs by varied priorities with different QoS by taking advantage of multi-channel mechanism [10].

The rest of this paper is organized as follows: Section 2 introduces the working conditions, model description as well as the derivation of expression for the proposed schemes, and simulation results along with discussions are presented in section 3, and the paper concludes with section 4.

II. MULTI-CHANNEL TWO-DIMENSIONAL PROBABILITY CSMA BASED THREE-WAY HANDSHAKE MECHANISM

a. Analysis of model

In the wireless *Ad Hoc* network, assuming that nodes have different service requirements by different priorities, setting N traffic channels in the system, the node occupies the channel according to their business priorities. Further assume that each priority has unlimited users, and the priority from low to high in order: priority 1, priority 2… priority N [11]. Priority 1 occupies the channel 1; priority 2 occupies channel 1 and channel 2…; priority i occupies channel 1 to channel i, and so on, which is shown in Figure 1. The arrival information packets on the channel i conform to the *Poisson Distribution* [12] with arriving rate G_i. The arrival packets of priority r on the channel i conform to the *Poisson Distribution* with arriving rate $\lambda_i = G_i / (N - i + 1)$. At this point, the system load balancing, the arrival rate of each channel is $G_i = G(i = 1, 2, ..., N)$.

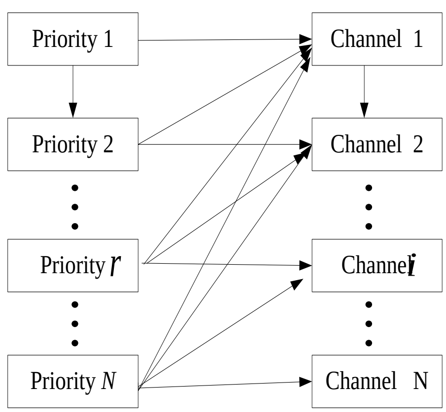

Figure 1. The system model of multi-channel CSMA

The receiver and sender both exchange a short data frame when terminal user sends information packets. The sender receives a reply from the receiver, then the user decides to send information packets with probability p_1 when the channel is idle, or gives up sending it with probability $(1 - p_1)$; when the channel is busy, the user continues probing the channel state with probability p_2, or gives up probing with probability $(1 - p_2)$. Once the channel is idle, the user will send information packets in the next slot with probability p_1. After the data has been received, the receiver then sends a confirmation to the sender.

The IEEE 802.3 MAC frame structure [13] is shown in Figure 2., the frame size is the minimum frame length: 64 bytes, including the destination address, source address, length types, data and checksum. In the model of two-dimensional probability CSMA for wireless *Ad Hoc* network protocol based on three-way handshake mechanism, the total length of a transmission period is $\frac{32}{23}(1+3a+\tau_R+\tau_C)$. The total length of the data field is $(1+3a+\tau_R+\tau_C)$, while the total length of other field is $\frac{9}{23}(1+3a+\tau_R+\tau_C)$.

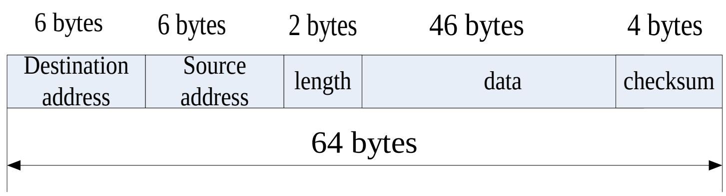

Figure 2. IEEE 802.3 MAC frame structure

The transmission period is divided into the following sections under the control of the protocol: an interrogation signal RTS, the response signal CTS, an information packet transmission time 1, ACK monitoring signal a, other information content $\frac{9}{23}(1+3a+\tau_R+\tau_C)$ and the delay time a.The channel model of two-dimensional CSMA protocol based on three-way handshake mechanism is shown in Figure 3.

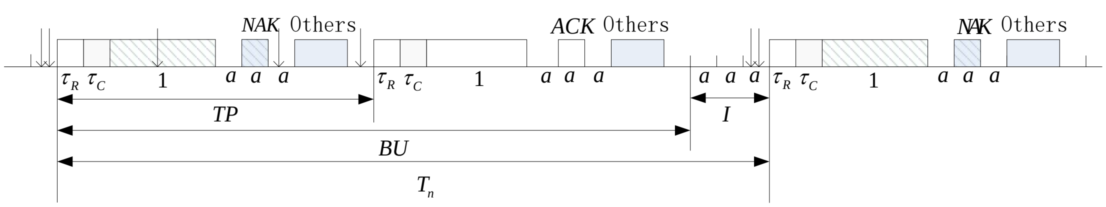

Figure 3. Model of two-dimensional CSMA protocol based on three-way handshake mechanism

b. Analysis of system throughput

In order to analyze the throughput and other important performance parameters of the system, we make the following assumptions:

① The channel is ideal without noise and interference.

② The maximum transmission delay of the channel is a; the slot length of the channel is a; the information packet length is unit length of 1, and it is integer multiples of a.

③ The timeline of the channel is divided by a; the information packets arrive within any a and is sent at the starting time of the next slot.

④ The access to the channel is two-dimensional CSMA protocol based on three-way handshake mechanism, and the arrival process of information packets in the channel is Poisson *Process* with independent parameter G.

⑤ The information packets needing to be sent in the first slot of transmission period TP can always detect the channel state at the last time.

⑥ The collided packets will be retransmitted in the following slots, and the retransmission process has no effect on the arrival process.

We set up mathematical model according to the above theoretical analysis and have the following expressions:

The probability that there are n information packets in the channel i within time t is

$$p(n) = \frac{(G_i t)^n}{n!} e^{-G_i t} \tag{1}$$

The probability that there is m information packets within n which decide to transmit with probability p_1 is

$$p(m) = \sum_{n=m}^{\infty} p(n) C_n^m p_1{}^m (1 - p_1)^{n-m} = \frac{(G_i p_1 t)^m}{m!} e^{-G_i p_1 t} \tag{2}$$

The probability that there are h information packets within n which continue to probe the channel state with probability p_2 is

$$p(h) = \sum_{n=m}^{\infty} p(n) C_h^h p_2^h (1 - p_2)^{n-h} = \frac{(G_i p_2 t)^h}{h!} e^{-G_i p_2 t} \tag{3}$$

The number of information packets which probes the channel state persistently with probability p_2 is h. Information packets decide to transmit with probability p_1 is k within time t on the channel i, and its probability is

$$p(k) = \sum_{h=k}^{\infty} p(h) C_h^k p_1^k (1 - p_1)^{h-k} = \frac{(G_i p_1 p_2 t)^k}{k!} e^{-G_i p_1 p_2 t} \tag{4}$$

The probability that there is no information packet to be transmitted within an idle slot a on the channel i is

$$q_a^0 = p(m = 0) = e^{-G_i p_1 a} \tag{5}$$

The probability that there is only one information packet to be transmitted within an idle slot a on the channel i is

$$q_a^1 = p(m=1) = G_i p_1 a e^{-G_i p_1 a} \tag{6}$$

The probability that there is no information packet to be transmitted within a transmission period $\frac{32}{23}(1+3a+\tau_R+\tau_C)$ on the channel i is

$$q^0_{\frac{32}{23}(1+3a+\tau_R+\tau_C)} = e^{-G_i p_1 p_2 \frac{32}{23}(1+3a+\tau_R+\tau_C)} \tag{7}$$

The probability that there is only one information packet to be transmitted within a transmission period $\frac{32}{23}(1+3a+\tau_R+\tau_C)$ on the channel i is

$$q^1_{\frac{32}{23}(1+3a+\tau_R+\tau_C)} = \frac{32}{23} G_i p_1 p_2 (1+3a+\tau_R+\tau_C) e^{-\frac{32}{23} G_i p_1 p_2 (1+3a+\tau_R+\tau_C)} \tag{8}$$

Then in a cycle period T_n, the probability that i idle events I and j busy events BU continuously appear on the channel i is

$$P(N_I = i, N_{BU} = j) = (e^{-G_i p_1 a})^{i-1}(1-e^{-G_i p_1 a}) e^{-\frac{32}{23} G_i p_1 p_2 (1+3a+\tau_R+\tau_C)} (1-e^{-\frac{32}{23} G_i p_1 p_2 (1+3a+\tau_R+\tau_C)})^{j-1} \tag{9}$$

The average number of idle state on the channel i in a cycle period T_n is

$$E(N_I) = \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} i p(N_I = i, N_{BU} = j) = \frac{1}{1-e^{-G_i pa}} \tag{10}$$

The average number of busy state on the channel i in a cycle period T_n is

$$E(N_{BU}) = \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} jP(N_I = i, N_{BU} = j) = \frac{1}{e^{-\frac{32}{23} G_i p_1 p_2 (1+3a+\tau_R+\tau_C)}} \tag{11}$$

Before calculating the average number of time slots occupied by successful information packets in the next cycle period, we give the following definition:

U_1: There is only one packet to be transmitted with probability p_1 at the last time slot in the idle period, and this packet will be sent successfully in the next slot.

U_2: The information packets arriving during busy period while probing the channel state continuously with probability p_2 in the transmission period and there is the only one packet to be transmitted with probability p_2 when the channel is idle. Finally the packet is transmitted successfully during the next transmission period.

According to the above definition, we make the following analysis:

① Within a cycle period T_i, the average number of time slot occupied by U_1 in the channel i is $E(N_{U1})$, because U_1 is the event that there is only one packet to be transmitted with probability p_1 at the last slot of idle period, then we get

$$E(N_{U1}) = \frac{q_a^1}{1-q_a^0} = \frac{Gp_1 a e^{-Gp_1 a}}{1-e^{-Gp_1 a}} \tag{12}$$

② Within a cycle period T_i, the average number of time slot occupied by U_2 in the channel i is $E(N_{U2})$, because U_2 is the only one information packet transmitted successfully in the next transmission period $(1+2a+\tau_A)$ with probability p_2 while the channel is idle, it is one of information packets probing the channel state continuously with probability p_2 in the transmission period TP, then we get

$$E(N_{U2}) = \frac{q^1_{\frac{32}{23}(1+3a+\tau_R+\tau_C)}}{q^0_{\frac{32}{23}(1+3a+\tau_R+\tau_C)}} = \frac{32}{23} G p_1 p_2 (1+3a+\tau_R+\tau_C) \tag{13}$$

Therefore, the average number of time slots occupied by successful packets in a cycle period T_n is

$$E(N_U) = E(N_{U1}) + E(N_{U2}) = \frac{aGp_1 e^{-Gp_1 a}}{1-e^{-Gp_1 a}} + \frac{32}{23} G p_1 p_2 (1+3a+\tau_R+\tau_C) \tag{14}$$

The average length of time slots occupied by successful packets in a cycle period T_n is

$$E(U) = E(N_U)\times 1 = \frac{aGp_1 e^{-Gp_1 a}}{1-e^{-Gp_1 a}} + \frac{32}{23} G p_1 p_2 (1+3a+\tau_R+\tau_C) \tag{15}$$

The average length of time slots occupied by busy state in a cycle period T_n is

$$E(BU) = E(N_{BU})\times \frac{32}{23}(1+3a+\tau_R+\tau_C) = \frac{\frac{32}{23}(1+3a+\tau_R+\tau_C)}{e^{-\frac{32}{23}Gp_1 p_2 (1+3a+\tau_R+\tau_C)}} \tag{16}$$

The average length of time slots occupied by idle state in a cycle period T_n is

$$E(I) = E(N_I)a = \frac{a}{1-e^{-Gp_1 a}} \tag{17}$$

Combined the definition of the channel throughput $S_i = \frac{E(U_i)}{E(BU_i)+E(I_i)}$ and the above analysis, we derive the throughput of channel i under two-dimensional probability CSMA protocol based on three-way handshake mechanism $RTS-CTS$ is

$$S_i = \frac{\dfrac{aG_i p_1 e^{-G_i p_1 a}}{1-e^{-G_i p_1 a}} + \dfrac{32}{23}G_i p_1 p_2(1+3a+\tau_R+\tau_C)}{\dfrac{\frac{32}{23}(1+3a+\tau_R+\tau_C)}{e^{-\frac{32}{23}G_i p_1 p_2(1+3a+\tau_R+\tau_C)}} + \dfrac{a}{1-e^{-G_i p_1 a}}}$$
$$= \frac{e^{-\frac{32}{23}G_i p_1 p_2(1+3a+\tau_R+\tau_C)}\left(aG_i p_1 e^{-G_i p_1 a} + \frac{32}{23}G_i p_1 p_2(1+3a+\tau_R+\tau_C)(1-e^{-G_i p_1 a})\right)}{\frac{32}{23}(1+3a+\tau_R+\tau_C)(1-e^{-G_i p_1 a}) + ae^{-\frac{32}{23}G_i p_1 p_2(1+3a+\tau_R+\tau_C)}} \tag{18}$$

In the N channels of wireless communication system, channel load balancing, $G_1 = G_2 = G_3 = \cdots = G_i = \cdots = G_N = G$, combining with computational formula of system throughput $S = \sum_{i=1}^{N} \frac{E(U_i)}{E(BU_i)+E(I_i)}$, we get the system throughput of two-dimensional probability CSMA protocol based on three-way handshake mechanism

$$S = NS_i = \frac{Ne^{-\frac{32}{23}Gp_1 p_2(1+3a+\tau_R+\tau_C)}\left(aGp_1 e^{-Gp_1 a} + \frac{32}{23}Gp_1 p_2(1+3a+\tau_R+\tau_C)(1-e^{-Gp_1 a})\right)}{\frac{32}{23}(1+3a+\tau_R+\tau_C)(1-e^{-Gp_1 a}) + ae^{-\frac{32}{23}Gp_1 p_2(1+3a+\tau_R+\tau_C)}} \tag{19}$$

According to the analysis, under the control of MCPDCSMA, the throughput for the priority l is

$$S_{pl} = \left(\sum_{i=1}^{l}\frac{1}{N-i+1}\right)\frac{e^{-\frac{32}{23}Gp_1 p_2(1+3a+\tau_R+\tau_C)}\left(aGp_1 e^{-Gp_1 a} + \frac{32}{23}Gp_1 p_2(1+3a+\tau_R+\tau_C)(1-e^{-Gp_1 a})\right)}{\frac{32}{23}(1+3a+\tau_R+\tau_C)(1-e^{-Gp_1 a}) + ae^{-\frac{32}{23}Gp_1 p_2(1+3a+\tau_R+\tau_C)}} \tag{20}$$

c. Analysis of average information packet delay

Before analyzing the system delay, we give the following assumptions: the inquired response signal can always be transferred correctly; ignoring the response time of the confirmed signal. Set the average retransmission delay to R ,and R is the average delay of a set of signals to be sent twice.

$$R = 1+\tau_R+\tau_C+a+\frac{9}{23}(1+\tau_R+\tau_C)+\frac{4a}{23}+4a+\delta = \frac{32}{23}(1+\tau_R+\tau_C+3a)+a+\delta \tag{21}$$

$(G/S-1)$ is the average number of retransmitted information packets. Then the average transmission delay of information packets can be expressed as

$$D = (G/S-1)R+1+\tau_R+\tau_C+a+\frac{9}{23}(1+\tau_R+\tau_C)+\frac{4}{23}a = (G/S-1)R+\frac{32}{23}(1+\tau_R+\tau_C)+\frac{27}{23}a \tag{22}$$

Combined with the above expression of throughput and the average transmission delay, the average information packets delay of channel i for two-dimensional probability CSMA based on three-way handshake mechanism can be derived as the following

$$D=\left(\frac{\frac{32}{23}G(1+3a+\tau_R+\tau_C)(1-e^{-Gp_1a})+Gae^{-\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)}}{e^{-\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)}(aGp_1e^{-Gp_1a}+\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)(1-e^{-Gp_1a}))}-1\right)R+\frac{32}{23}(1+\tau_R+\tau_C)+\frac{27}{23}a \quad (23)$$

d. Analysis of system energy consumption

The main energetic expense of the system in communication aspect is divided into three parts: the energy consumed while detecting channel SPD, energy consumed while sending packets SPS and energy consumed while receiving packets SPR [14, 15].

Assuming the transmitting power of sensor node is P_{tx}, receiving power is P_{rx}, detecting channel power is P_{dd}.

For the channel i, the number of TP when the channel is busy in a cycle period T_i is $23E(BU_i)/32(1+3a+\tau_R+\tau_C)$. The number that the information packets arrived within "τ_R", "τ_C", "1", "a", "$\frac{9}{23}(1+\tau_R+\tau_C)+\frac{4a}{23}$" in the busy period probing the channel state and determining to transmit a packet with probability p_2 is $(\frac{32}{23}(1+\tau_R+\tau_C)+\frac{27a}{23})G_i p_2$, and its average time is $\frac{32}{23}(1+\tau_R+\tau_C)+\frac{73}{23}a$. The number of terminal nodes adhering to detecting the channel state and determining to transmit a packet with probability p_2 within "$4a$" is $4ap_2G_i$. Its average time is a. Then in a cycle period T_i, the total energy consumption of all the terminal nodes on the channel i is

$$SPD_i=\frac{G_i p_2[(\frac{32}{23}(1+\tau_R+\tau_C)+\frac{27a}{23})(\frac{32}{23}(1+\tau_R+\tau_C)+\frac{73}{23}a)+4a^2]P_{dd}}{e^{-[\frac{32}{23}(1+3a+\tau_R+\tau_C)+a]G_i p_2}} \quad (24)$$

Meanwhile, the total energy consumption of information packets successfully retransmitted on the channel i is

$$SPR_i=\left(\frac{\frac{aGp_1e^{-Gp_1a}}{1-e^{-Gp_1a}}+\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)}{\frac{4}{23}a+\frac{32}{23}(1+\tau_R+\tau_C)}\right)P_{rx} \quad (25)$$

The average number of information packets transmitted with probability p_1 on the channel i at the first TP in the idle period is

$$ASF_i = ap_1G_i \tag{26}$$

The average number of information packets transmitted with probability p_1 on the channel i of each TP in the busy period is

$$ASL_i = G_i p_1(\frac{32}{23}(1+3a+\tau_R+\tau_C)+a) \tag{27}$$

Then in a cycle period T_i, the energy consumption of sending information packets by all the terminal nodes is

$$SPS_i = [ap_1G_i + G_i p_1(\frac{32}{23}(1+3a+\tau_R+\tau_C)+a)((\frac{\frac{aGp_1e^{-Gp_1a}}{1-e^{-Gp_1a}}+\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)}{\frac{4}{23}a+\frac{32}{23}(1+\tau_R+\tau_C)}-1)]P_{tx} \tag{28}$$

Since each channel load balancing, in a cycle period, the energy consumption of all nodes in the system is

$$\begin{aligned} ECA &= \sum_{i=1}^{N}\frac{SPD_i+SPR_i+SPS_i}{E(T_i)} \\ &= N\{\frac{G_ip_2[(\frac{32}{23}(1+\tau_R+\tau_C)+\frac{27a}{23})(\frac{32}{23}(1+\tau_R+\tau_C)+\frac{73}{23}a)+4a^2]P_{dd}}{e^{-[\frac{32}{23}(1+3a+\tau_R+\tau_C)+a]G_ip_2}}+(\frac{\frac{aGp_1e^{-Gp_1a}}{1-e^{-Gp_1a}}+\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)}{\frac{4}{23}a+\frac{32}{23}(1+\tau_R+\tau_C)})P_{rx} \\ &\quad [ap_1G_i+G_ip_1(\frac{32}{23}(1+3a+\tau_R+\tau_C)+a)((\frac{\frac{aGp_1e^{-Gp_1a}}{1-e^{-Gp_1a}}+\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)}{\frac{4}{23}a+\frac{32}{23}(1+\tau_R+\tau_C)}-1)]P_{tx}\}/E(T_i) \end{aligned} \tag{29}$$

where $E(T_i) = E(I_i) + E(BU_i) = \dfrac{\frac{32}{23}(1+3a+\tau_R+\tau_C)}{e^{-\frac{32}{23}Gp_1p_2(1+3a+\tau_R+\tau_C)}} + \dfrac{a}{1-e^{-G_ip_1a}}$

III. SIMULATION RESULTS AND ANALYSIS

Based on the above theoretical analysis, the paper simulates the multi-channel two-dimensional CSMA for wireless *Ad Hoc* network protocol based on three-way handshake mechanism using MATLAB 7.0. Computer simulation results are shown from Figure 4 to Figure 15.

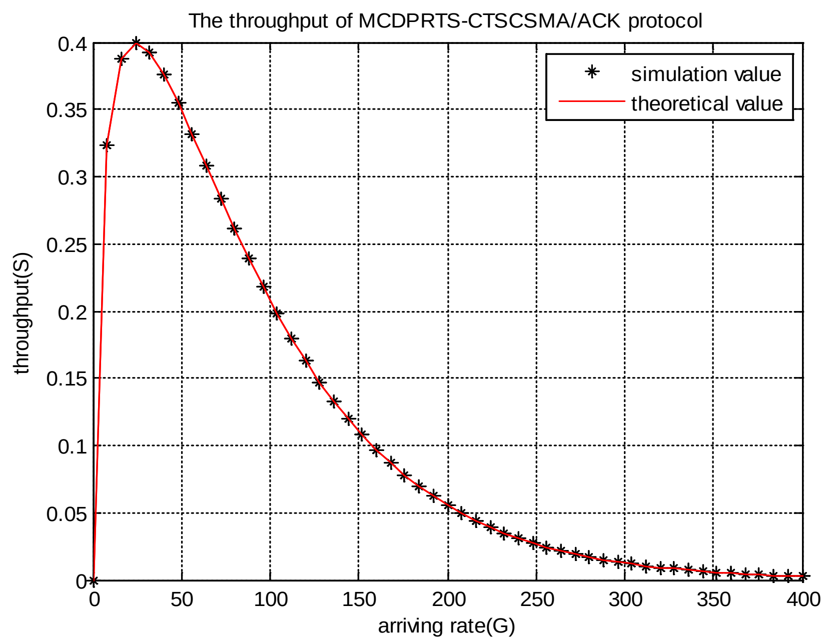

Figure 4. The throughput of MCPDCSMA $(a = 0.1, p_1 = p_2 = 0.1, \tau_R = 0.01, \tau_C = 0.007)$

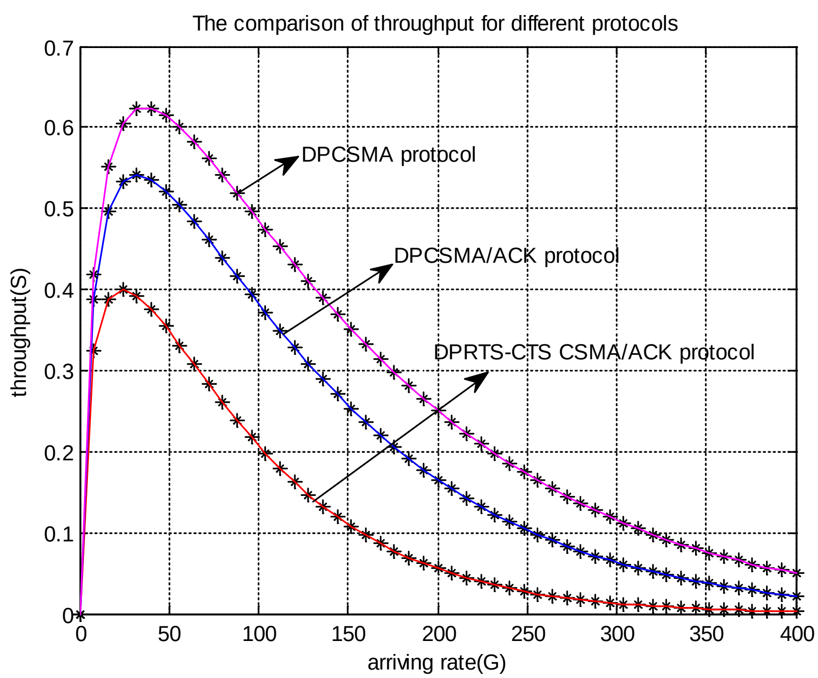

Figure 5. The comparison of system throughput under three different protocols $(a = 0.1, p_1 = p_2 = 0.1, \tau_R = 0.01, \tau_C = 0.007)$

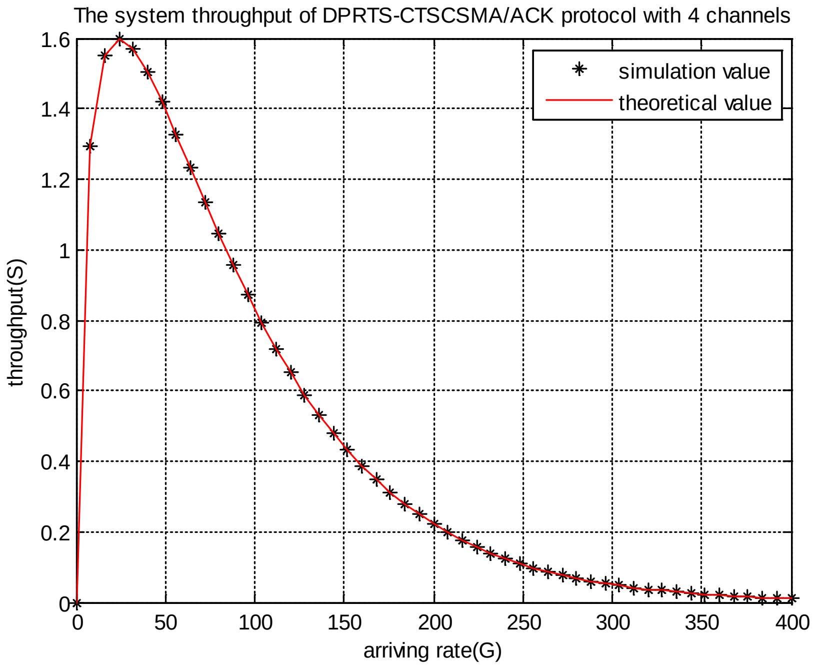

Figure 6. The system throughput with 4 channels

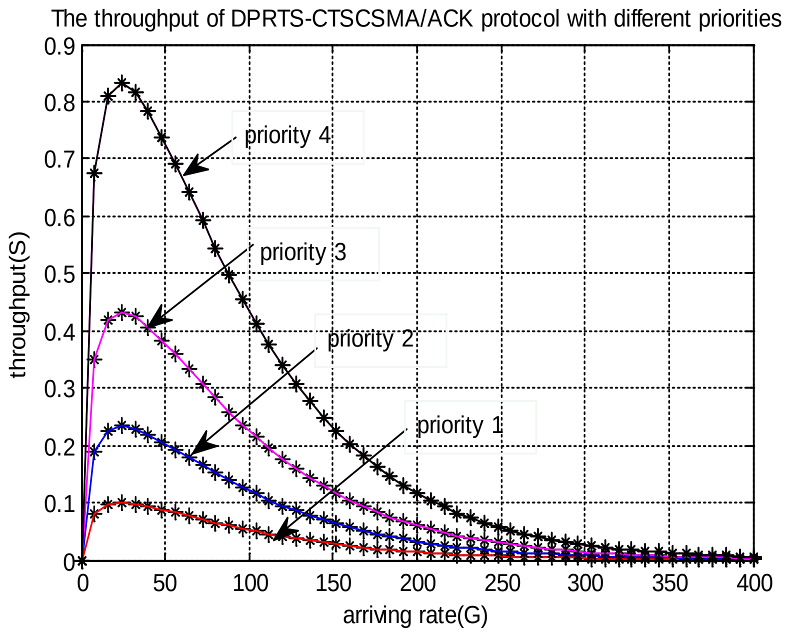

Figure 7. The throughput of different priorities with 4 channels

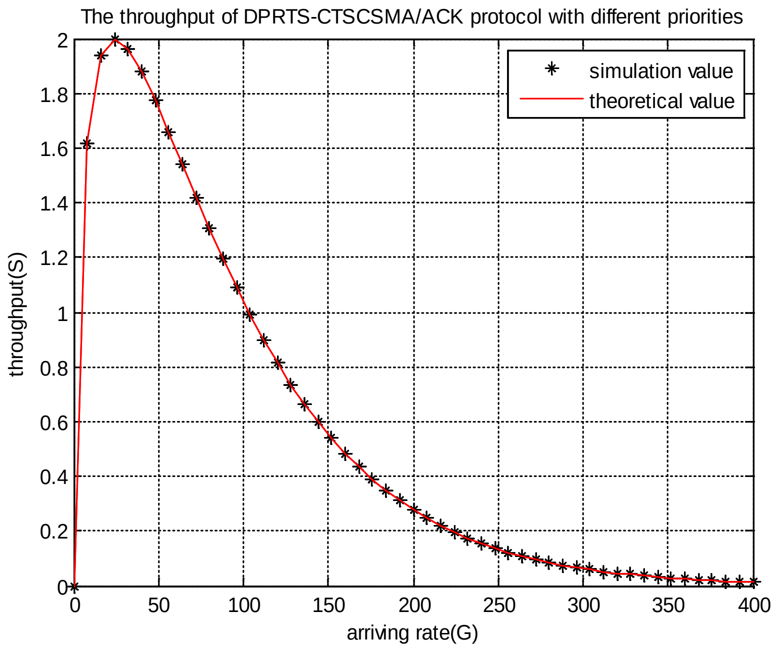

Figure 8. The system throughput with 5 channels

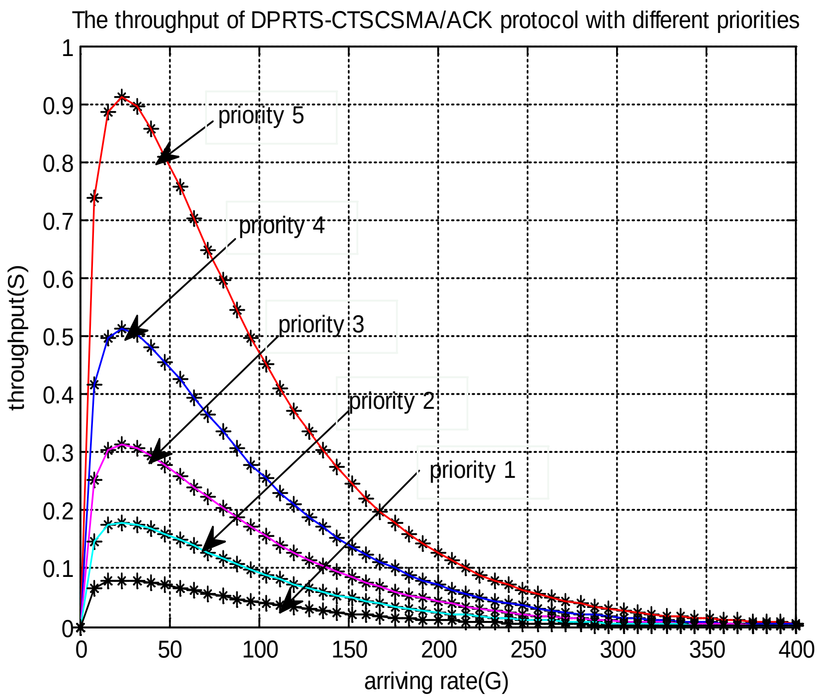

Figure 9. The throughput of different priorities with 5 channels

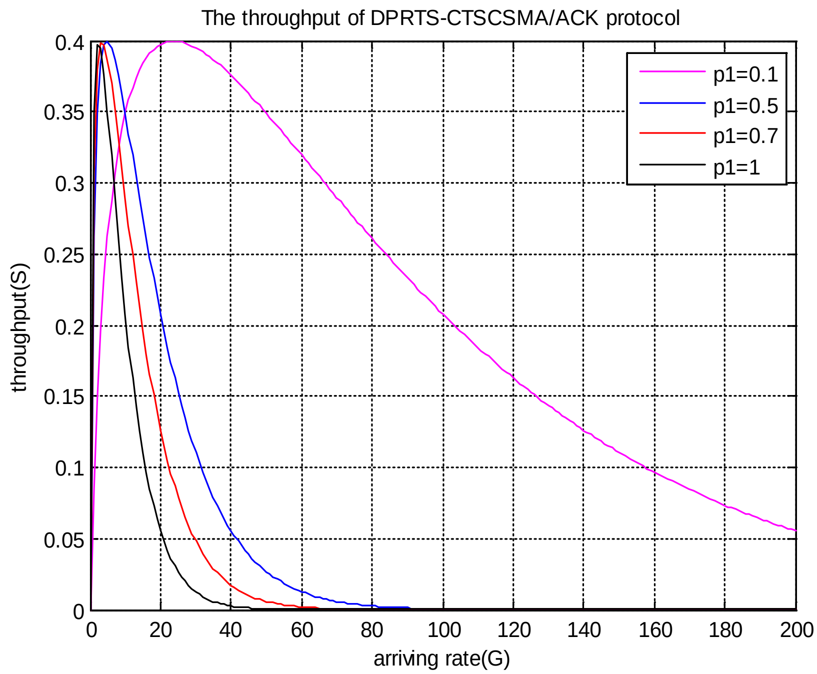

Figure 10. The comparison of system throughput with different p_1 and $a = 0.1, p_2 = 0.1$

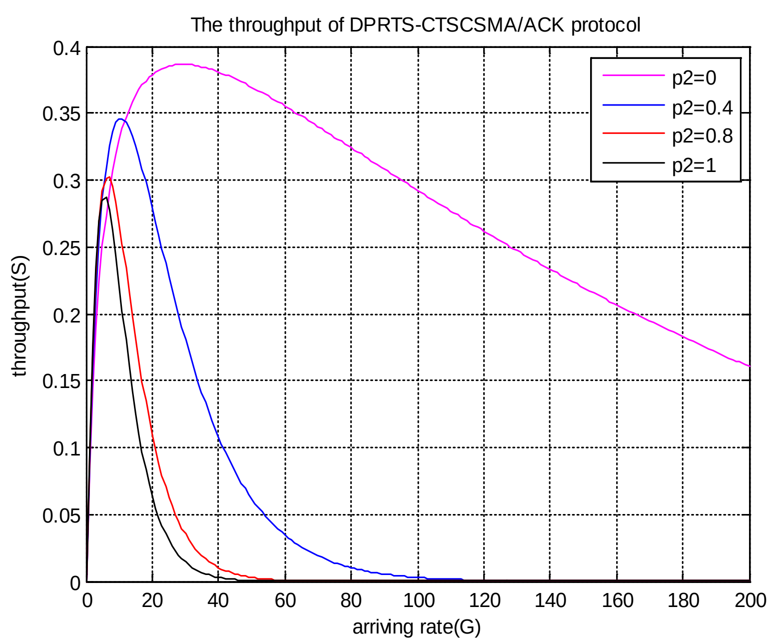

Figure 11. The comparison of system throughput with different p_2 and $a = 0.1, p_1 = 0.1$

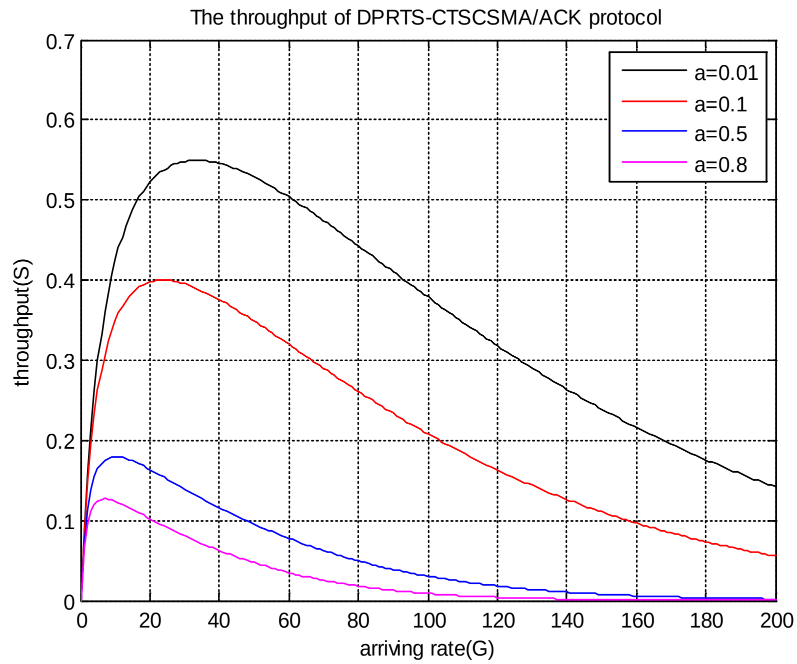

Figure 12. The comparison of system throughput with different a and $p_1 = 0.1, p_2 = 0.1$

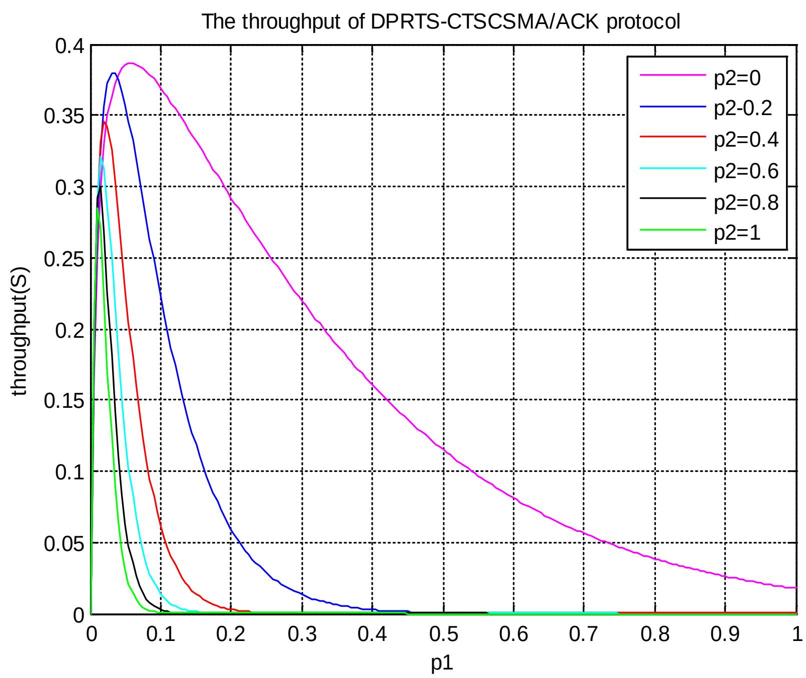

Figure 13. The comparison of system throughput with different p_1 , p_2 and $a = 0.1, G = 50$

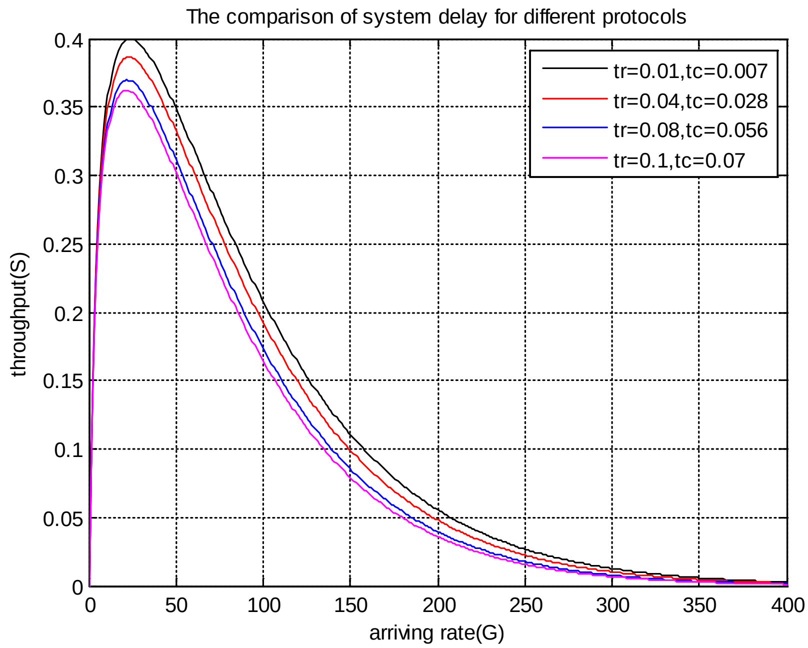

Figure 14. The comparison of system throughput with different τ_R, τ_C

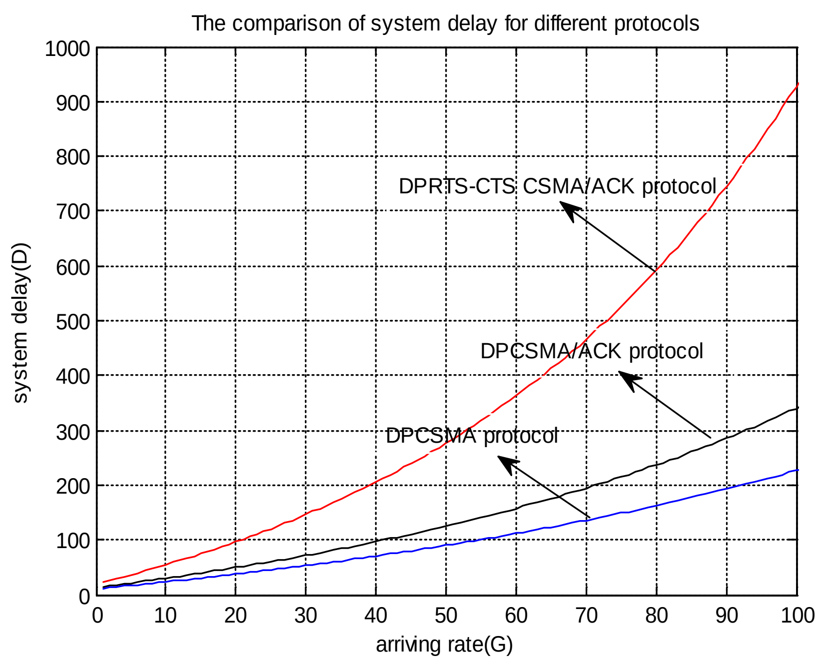

Figure 15. The comparison of system delay for different protocol

From the above simulation results, we can conclude that the multi-channel two-dimensional CSMA for wireless *Ad Hoc* network based on three-way handshake mechanism has the following characteristics:

(1) The theoretical values and simulations are highly unified under the multi-channel two-dimensional CSMA for wireless *Ad Hoc* network based on three-way handshake mechanism, it denotes the correctness of above analysis. Meanwhile, the throughput of two-dimensional CSMA for wireless *Ad Hoc* network based on three-way handshake mechanism has decreased due to the introduction of response mechanism. System delay has increased because the system functions become relatively complex; communication packets transmitted carry more other control information; the channel resources occupied by communication system become more and more; the energy consumption will increase inevitably, leading to the increase of system delay. However, such system ensures the safety and reliability of the communication system, reducing the probability of collision and increasing the throughput especially when the system is in light load. So the system has an excellent throughput performance.

(2) Regardless of the grade level, no matter how the load is heavy or light, each priority services in the system can always get enough channel resources and throughput to meet their business needs. Only high-priority businesses can get more resources, while lower priority gets less without fail. The applications of multi-channel mechanism both meet the requirements of high-priority as well as fairness.

(3) Whether the system delay a, or detecting probability p_1, or probing probability p_2, the impact on system throughput is particularly evident. The selection of p_1 and p_2 mainly depends on the system load. When the load is light, we can choose larger value of p_1 and p_2 to make the system throughput and utilization high. While the system is heavily loaded, we can select smaller value of p_1 and p_2 to reduce the probability of collision and improve the system throughput. From the view of system, the smaller the delay a is, the greater system throughput will be.

(4) The smaller the τ_R, τ_C parameter is, the greater the system throughput will be. This is due to the frame length of inquire-answering signal reduce, the effective data contained in a data frame will be more, the greater the throughput of the system will be.

(5) Compared with the other type protocols of two-dimensional probability, DPCSMA/ACK and DPCSMA protocol, the system delay using the DPRTS-CTS CSMA/ACK protocol has been increased. Therefore the protocol can ensure the reliability of information transmission by adding monitoring mechanism, which is bound to increase the system consumption.

IV. CONCLUSION

Due to the dynamic and flexible network topology, *Ad Hoc* network can realize wireless transmission services for data, voice, and video in harsh environmental condition. Therefore, *Ad Hoc* network has a great prospect in development no matter in the military or in civilian areas. The wireless channel access protocol of Ad-Hoc network have been regarded as the key research and difficult points, and the system throughput, channel utilization and system delay all depend on the practical protocol.

The paper proposed multi-channel two-dimensional probability CSMA protocol for wireless *Ad Hoc* network based on three-way handshake mechanism. The introduction of the response $RTS-CTS$ mechanism increases the reliability and stability of the system, avoiding the collision possibility of the information packets to a certain extent, improving the channel utilization; the use of the multi-service priority control enables the channel load balancing, but also solves the problem of the hidden and exposed terminal. The computer simulation experiments show that the choice of detecting probability, probing probability and system delay have a great influence on the system throughput.

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