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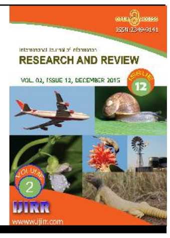

Review Article

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

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ABSTRACT

Wireless Ad-hoc networks, is mainly applied to build a small home local area wireless network. The main features are as follows: network autonomy, dynamic topology, changes in bandwidth limitations and link capacity, multi-hop communication, distributed control, limited security. Typically, the mobile wireless network thanks to a radio channel, limited power, distributed control and other reasons, will be more vulnerable to security threats than wired networks. The paper proposed a multi-channel three-demission probability CSMA protocol based on three-way handshake mechanism for wireless Ad-hoc networks. By introduction of the inquire response $RTS-CTS$ mechanism increases the reliability and stability of the system, reducing the collision possibility of the information packets to a certain extent, improves the channel utilization; by the use of the multi-channel mechanism, not only enables the channel load balancing, but also solves the problem of the hidden terminal and exposed terminal. Therefore, such system ensures the safety and reliability of the communication system to reduce the collision probability and increase the throughput. The computer simulations show that choices of three-demission probability have a great influence on the system throughput, make the system meet the different priorities with different QoS both efficiently fairly.

INTRODUCTION

The concept of Ad-hoc mode is the same as the direct connection of twisted pair on and before, is P2P connections, so it can not communicate with the other networks. General wireless terminal device such as PMP, PSP, DMA and other use is ad-hoc mode. Family wireless LAN set up, I think we all know the easiest way to have a wireless network card installed two computer-implemented wireless Internet, one of the computers connected to the Internet can share bandwidth. As shown below in Fig.1, the formation of LAN configuration will be completed based on the wireless Ad-Hoc. Ad-Hoc is a structure eliminates the wireless AP and starting to build a peer network architecture, so long as each other wireless network card installed on your computer you can achieve wireless connectivity; its principle is a computer network hosts to establish a point to point connection equivalent virtual AP, and other computers can be connected directly to the network interconnection and shared through this point.

By eliminating the wireless AP, it is very simple for network to set up Ad-Hoc wireless LAN process, but most of the wireless LAN transmission distance in the indoor environment is usually about 40m, when it exceeds this effective transmission distance, you can not communicate between each other ; therefore this mode is very suitable for some simple and even temporary wireless Internet needs. This technology quickly penetrates into all areas of civilian communications from the military communications, and has a great development (Jing Qu *et al*., 2006; Xuming, 2003). But in the wireless Ad Hoc network, the large number and the mobility of terminal nodes leading to abnormal precious of the wireless channel resources, the hidden and exposed terminal problems exist in the Ad Hoc network are the major factors always limiting the development and using of mobile Ad Hoc network (Conti and Giordano, 2014; Gandhi and Arya, 2014). Therefore, the study of how to use the channel resources of wireless Ad Hoc network efficiently, increase the system capacity, improve security and stability of the computer network communication, resolve the hidden and exposed terminal problems, and so on, is urgent and significant (Xiaoping Wu, 2006 ; Jayasuriya *et al*., 2004; Wang *et al*., 2013). This paper proposes a new wireless Ad Hoc network protocol, the multi-channel three-dimensional probability CSMA Ad Hoc network protocol based on three-way handshake mechanism, on the basis of a lot of domestic and foreign excellent papers and references.

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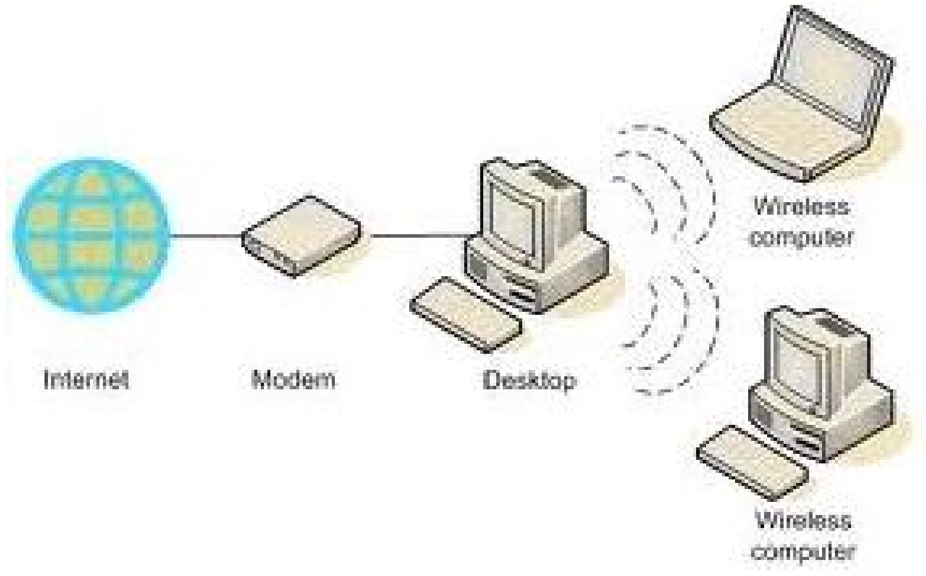

Fig.1. The network structure of Ad Hoc network

The paper obtains the analytic expressions of system throughput, each priority throughput, the average system delay and energy consumption of the new protocol by using the average cycle analysis method and building mathematical model, then conduct a computer simulation (Dongfeng Zhao, 1999; Dongfeng Zhao *et al*., 1997). Simulation results show that, the protocol this paper proposed not only increase the reliability and stability of the system, resolve the "hidden terminal" and "exposed terminal" problem exist in the Ad Hoc network, ease the channel congestion to a certain extent, reduce the collision probability of information packets, and improve the utilization of the channel by adding the inquire response mechanism, but also realize the channel load balancing, meet the different priorities business with different QoS requirements by taking advantage of the priority control of multi-channel multi-service (Cheng *et al*., 2014).

The analysis of the proposed protocol

The analysis of the protocol model

In the network, assuming that nodes have different service requirement have different priorities, setting N traffic channels in the system, the node occupies the channel according to their business priorities. Assume that each priority unlimited the number of users, the priority from low to high in order is priority 1, priority 2… priority N (Jia, 2008). 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, as shown in Fig.2. The arrival information packets on the channel i subject to the $Poisson$ distributionwith arriving rate G_i , the arrival packets of priority r on the channel i subject 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 rate is $G_i = G(i = 1, 2, ..., N)$ (Min and Kwon, 2013). The multichannel mechanism owning N channels is showed in Fig.2.

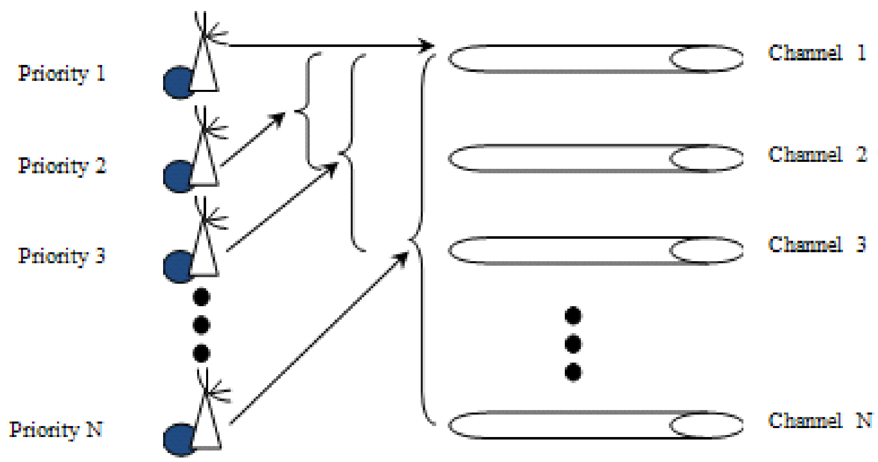

Fig.2. The multichannel mechanism owning N channels

According to the new protocol, if the channel is idle, then the user decides to send an information packet probability P_1; if the channel is in transmission time, the user listens to the channel with probability P_2 and P_3 repectively in time 1 and a. This control strategy, P_1, P_2 and P_3 by three-dimensional selection enables the system utilization and throughput is guaranteed under different load. The channel model of three-dimensional CSMA protocol based on three-way handshake mechanism is shown in Fig.3.

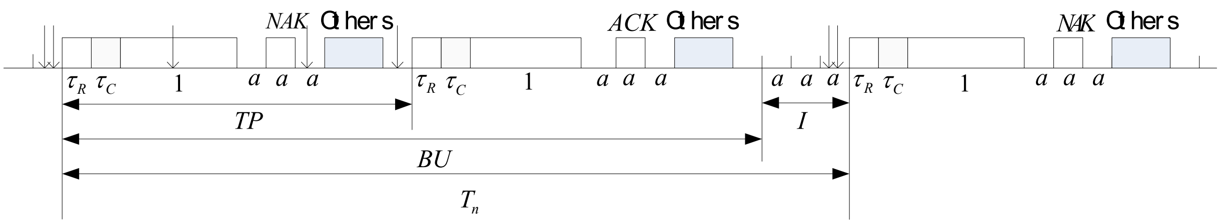

Fig. 3. The channel model of three-dimensional CSMA protocol based on three-way handshake mechanism

In this model, 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.

In the model of three-dimensional probability CSMA wireless Ad Hoc network protocol based on three-way handshake mechanism, and the total length of a transmission period is: $\frac{32}{23}(1+3a+\tau_R+\tau_C)$, where the total length of the data field is: $(1+3a+\tau_R+\tau_C)$, the total length of other field is: $\frac{9}{23}(1+3a+\tau_R+\tau_C)$ (Zhenjia Lei, 2006).

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 analysis of the protocol throughput

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 arrival process of channel satisfies the Poisson process whose independent parameter is G, each arrival process on the channel is independent of each other;

When there are n information packets arriving, the process of channel satisfying the Poisson process, the probability is：

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

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

$$q_1^0=e^{-ap_1G_r} \quad (2)$$

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

$$q_1^1=ap_1G_re^{-ap_1G_r} \quad (3)$$

At the transmission period: $\frac{32}{23}(1+3a+\tau_R+\tau_C)$, if there is no information packets to be sent in channel r, its possibility is:

$$q_2^0 = e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r} \tag{4}$$

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

$$q_2^1 = \{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r} \tag{5}$$

In a cycle T_n, the possibility of continuous i idle events in channel r is:

$$P(N_{I_r}=i) = (e^{-ap_1G_r})^{i-1} e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r} \tag{6}$$

In a cycle T_n, the possibility of continuous j B events in channel r is:

$$P(N_{B_r}=j) = (1-e^{-ap_1G_r})(1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r})^{j-1} \tag{7}$$

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

$$\begin{aligned} P(N_{I_r}=i, N_{B_r}=j) &= (e^{-ap_1G_r})^{i-1}(1-e^{-ap_1G_r}) \\ &\quad (1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r})^{j-1} e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r} \end{aligned} \tag{8}$$

The average number of i continuous I events in a cycle T_n in channel r is:

$$\begin{aligned} E(N_{I_r}) &= \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} iP(N_I=i, N_B=j) \\ &= \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} i(e^{-ap_1G_r})^{i-1}(1-e^{-ap_1G_r}) \\ &\quad (1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r})^{j-1} e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r} \\ &= \frac{1}{1-e^{-ap_1G_r}} \end{aligned} \tag{9}$$

The average number of j continuous B events in a cycle T_n in channel r is:

$$\begin{aligned} E(N_{B_r}) &= \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} jP(N_I=i, N_B=j) \\ &= \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} j(e^{-ap_1G_r})^{i-1}(1-e^{-ap_1G_r}) \\ &\quad (1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r})^{j-1} e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r} \\ &= \frac{1}{1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r}} \end{aligned} \tag{10}$$

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

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

$$E(N_{U_{r1}})=\frac{q_1^1}{1-q_1^0}=\frac{ap_1G_re^{-ap_1G_r}}{1-e^{-ap_1G_r}} \tag{11}$$

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

$$E(U_{r1})=E(N_{U_{r1}})\times 1=\frac{ap_1G_re^{-ap_1G_r}}{1-e^{-ap_1G_r}} \tag{12}$$

Secondly the average length of continuous K U events in the TP time in a cycle in channel r is:

$$\begin{aligned}E(U_{r2})&=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty}\sum_{K=0}^{i-1}KP(N_I=i,N_B=j)\times 1\\&=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty}\sum_{K=0}^{i-1}K(e^{-ap_1G_r})^{i-1}(1-e^{-ap_1G_r})\\&\quad(1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r})^{j-1}e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r}\\&=\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r\end{aligned} \tag{13}$$

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

$$\begin{aligned}E(U_r)&=E(U_{r1})+E(U_{r2})\\&=\frac{ap_1G_re^{-ap_1G_r}}{1-e^{-ap_1G_r}}+\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r\end{aligned} \tag{14}$$

The average length of B event in channel r is:

$$E(B_r)=E(N_{B_r})\times\frac{32}{23}(1+3a+\tau_R+\tau_C)=\frac{\frac{32}{23}(1+3a+\tau_R+\tau_C)}{1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r}} \tag{15}$$

The average length of I event in channel r is:

$$E(I_r)=E(N_{I_r})\times a=\frac{a}{1-e^{-ap_1G_r}} \tag{16}$$

The throughput of the three-dimensional probability CSMA protocol in channel r is:

$$\begin{aligned}S_r&=\frac{E(U_r)}{E(B_r)+E(I_r)}\\&=\frac{\frac{ap_1G_re^{-ap_1G_r}}{1-e^{-ap_1G_r}}+\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r}{\frac{\frac{32}{23}(1+3a+\tau_R+\tau_C)}{1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r}}+\frac{a}{1-e^{-ap_1G_r}}}\end{aligned} \tag{17}$$

In the N channels of wireless communication system, because this channel model is a load equilibrium model, so the arrival probabilities of each channel are the same, that is to say:

$$G_1 = G_2 = G_3 = \cdots = G_i = \cdots = G_N = G \tag{18}$$

Basing on the above analysis and computational formula of the systemic throughput, the system total throughput is:

$$S' = NS_j = N\frac{\frac{ap_1G_re^{-ap_1G_r}}{1-e^{-ap_1G_r}} + \{p_2 + [\frac{32}{23}(3a+\tau_R+\tau_C) + \frac{9}{23}]p_3\}G_r}{\frac{\frac{32}{23}(1+3a+\tau_R+\tau_C)}{1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r}} + \frac{a}{1-e^{-ap_1G_r}}} \tag{19}$$

Assuming that the length of information packet sent by the business with priority l successfully in average cycle period of channel j is: $E(U_j^{(pl)})(j \le l)$.

Then according to the above analysis, we can get the throughput with the priority l:

$$\begin{aligned} S_{pl} &= (\sum_{i=1}^{l}\frac{1}{N-i+1})S_j \\ &= (\sum_{i=1}^{l}\frac{1}{N-i+1})\frac{\frac{ap_1G_re^{-ap_1G_r}}{1-e^{-ap_1G_r}} + \{p_2 + [\frac{32}{23}(3a+\tau_R+\tau_C) + \frac{9}{23}]p_3\}G_r}{\frac{\frac{32}{23}(1+3a+\tau_R+\tau_C)}{1-e^{-\{p_2+[\frac{32}{23}(3a+\tau_R+\tau_C)+\frac{9}{23}]p_3\}G_r}} + \frac{a}{1-e^{-ap_1G_r}}} \end{aligned} \tag{20}$$

Experimental Classification Results and Analysis

The paper simulate the multi-channel three-dimensional CSMA wireless Ad Hoc network protocol based on three-way handshake mechanism using MATLAB 7.0 based on the above theoretical analysis. Computer results are shown in Fig.4 to Fig.10.

Based on the above analysis, with the use of simulation tool: MATLAB R2010a, the simulation results are shown as following. During the simulation, transmission delay time: $a = 0.01$, packet length is: $\frac{32}{23}(1+3a+\tau_R+\tau_C)$.

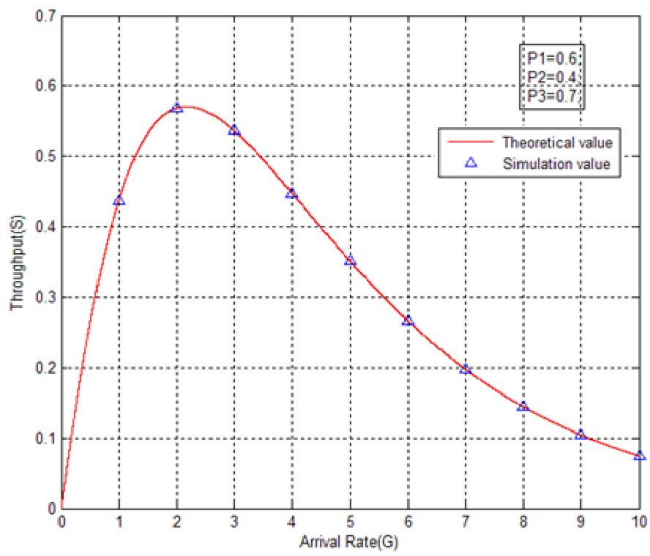

Fig. 4. The throughput of the protocol for channel r

In the Fig. 4, at the beginning, when the arrival rate increases, the system throughput also increased; then throughput reaches its maximum under the condition. Finally, with the increasing amount of the arrival rate, the system throughput decreases. The simulation values of system throughput under the protocol are consistent with the theoretical ones.

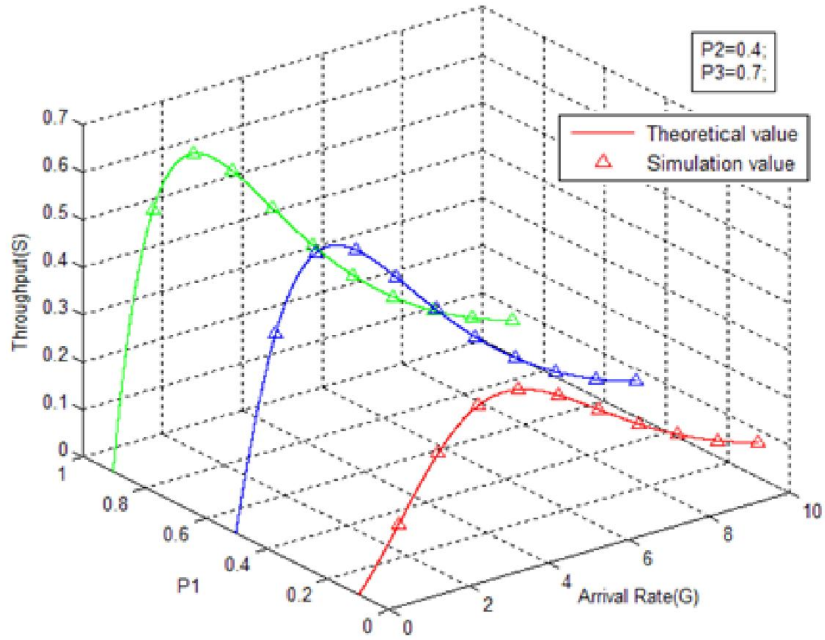

Fig. 5. The throughput of the protocol with variable parameter P1

From the Fig. 5, the theoretical value and simulations are highly unified of the multi-channel three-dimensional CSMA wireless Ad Hoc network protocol based on three-way handshake mechanism, and also show that the correctness of above analysis. With the $P1$ increases, the system throughput is increases too. This is laying that when the arrival rate is small, if the probability of arrival information sent is too small at the I events, the channel resource is not fully utilized. Thus, if we increase the probability of the arrival information transmitted, we can improve the efficiency of channel resources and increase the value of the system throughput.

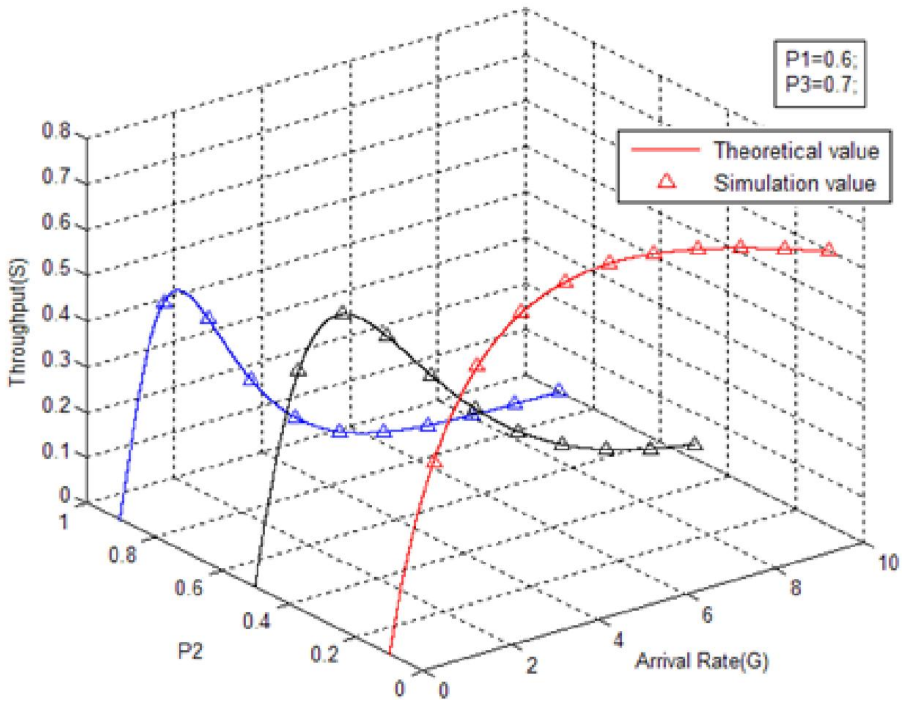

Fig. 6. The throughput of the protocol with variable parameter P2

In the Fig. 6, when $P2$ becoming bigger, the throughput will decrease; because when the channel is busy sending the packet, the more new arrival information packets to send at the CU events the more collisions will be.

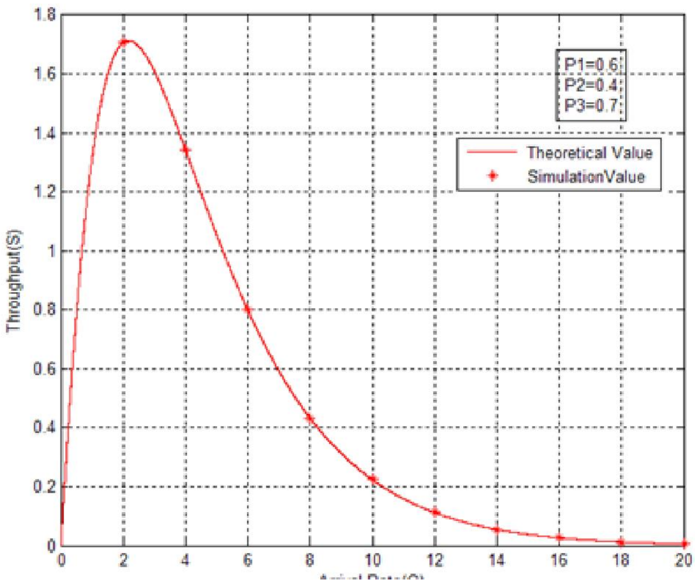

Fig. 7. The throughput of the new protocol with 3 channels

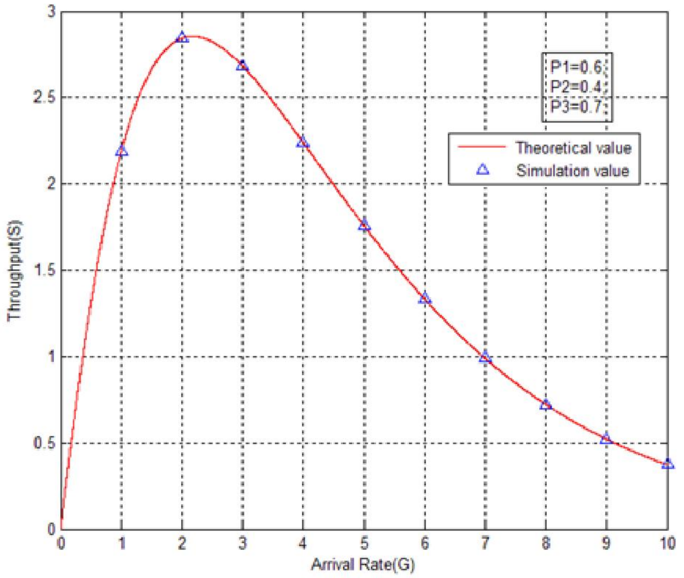

Fig. 8. The throughput of the protocol with 5 channels

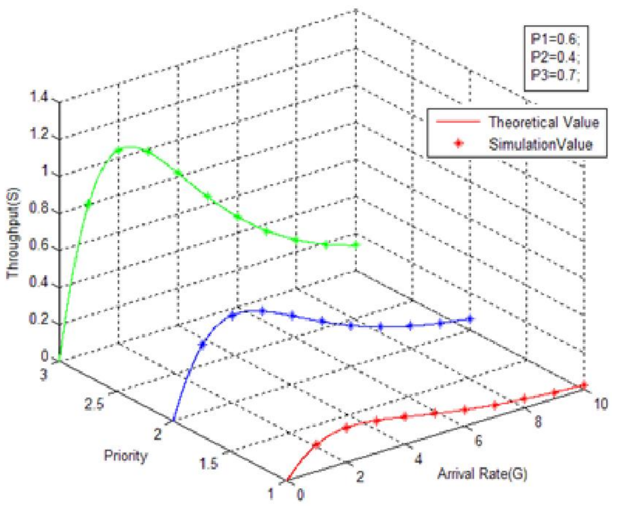

Fig. 9. The comparison of 3 channels with different priorities

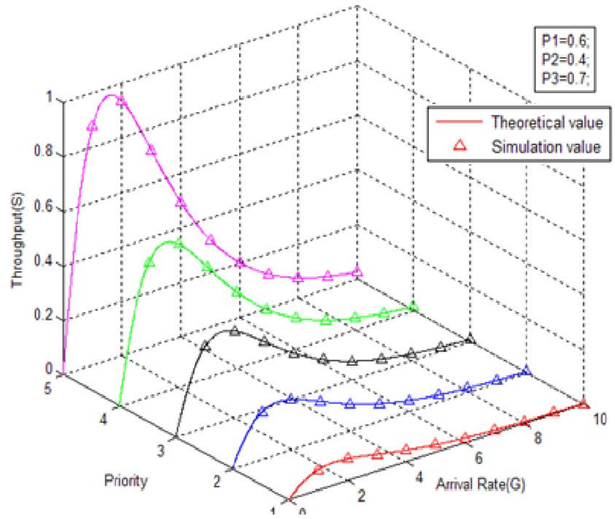

Fig. 10. The comparison of 5 channels with different priorities

From Fig.7 to Fig. 10, the simulation values of system throughput under the protocol are consistent with the theoretical ones. Regardless of the grade level, no matter what the load, each priority services in the system can always get enough channel resources and throughput to meet their business needs. Only high-priority businesses get richer resources, while lower priority traffic gets less, but it does not fail. The applications of multi-channel mechanism both meet the requirements of high-priority multi-channel, and also allow the channel distribution have fairness. With the total number of channels increases, the value of the protocol's total system throughput will increases; the channel resources can distribute to every channel according to their priority according to their own priority separately; when the priority is higher, the corresponding single channel will get more network resources than the lower priorities; thus the value of throughput with higher priority channel is bigger than others with lower priorities. With the multi-channel mechanism, the network resources utilization has been improved significantly.

Conclusion

In this paper, introduce the basics of wireless Ad-hoc networks; it is mainly applied to build a small home local area wireless network. Wireless Ad-hoc network is an autonomous system constituted by a mobile host; the main features are as follows: network autonomy, dynamic topology, changes in bandwidth limitations and link capacity, multi-hop communication, distributed control, limited security. Typically, the mobile wireless network thanks to a radio channel, limited power, distributed control and other reasons, will be more vulnerable to security threats than wired networks.

The paper proposed multi-channel three-demission probability wireless Ad Hoc network CSMA protocol based on three-way handshake mechanism. The introduction of the inquire response $RTS-CTS$ mechanism increases the reliability and stability of the system, reducing the collision possibility of the information packets to a certain extent, improves the channel utilization; by the use of the multi-channel mechanism, not only enables the channel load balancing, but also solves the problem of the hidden terminal and exposed terminal. Therefore, such system ensures the safety and reliability of the communication system to reduce the collision probability and increase the throughput, especially when the system is in light load, so the system has an excellent throughput performance.The computer simulations show that choices of three-demission probability have a great influence on the system throughput.

Acknowledgements

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