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RESEARCH ARTICLE

RESEARCH ON THE DISCRETE TIME THREE-DIMENSIONAL PROBABILITY CSMA PROTOCOL IN AD-HOC NETWORK

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ABSTRACT

A higher quality of controllability is provided for ad hoc networks through a slotted random CSMA protocol with three-dimensional probability. For this protocol, the system time is slotted into a time slot with high channel utilization realized by the choice of three parameters P1, P2 and P3. The protocol analyzes the throughput of the three-dimensional probability CSMA protocol with using the average cycle analysis methods. The correctness of the theory is verified through the simulation.

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INTRODUCTION

Ad hoc network: self-organizing networks, a specific network, peer to peer network, belonging to the network and exchange. It refers to a specific network temporary strain. By a plurality of mobile terminals, it's constituted by a radio communication network temporary strain. This network is temporary, no center, no need to rely on any non-standard network infrastructure. It can be called "self-organizing networks." Also it has called it a "specific network" because it is a very short distance of a particular connection, and only for short distance users, and because it is easy to join and leave, both the master, but also accused the network; it has been called "peer to peer network." [1].

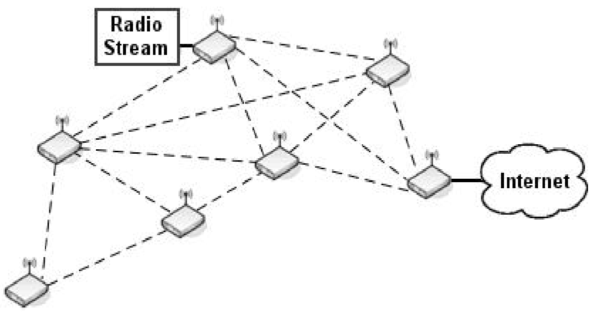

Fig 1 The Ad-hoc network typical structure

In Ad-hoc network, a plurality of network nodes share the same radio channel, since each node sends a packet random, in order to reduce collisions, the MAC layer protocol necessary to establish a shared channel access mechanism. Efficient MAC layer protocol is a hot topic for the Ad-hoc networks; the most common MAC layer protocol is carrier sense multiple access (CSMA) and a variety of other mechanisms [2].

In ad hoc networks, the traditional random multi-access protocols such as non-persistent CSMA or the one-persistent CSMA protocol without controllability of the system [3]. Even the p-persisten CSMA, the p-dectction CSMA which is proposed by Dongfeng Zhao professor or the two-dimensional CSMA protocol has some controllability to some process during the system but has no controllability to the total process of the system [4].

To improve the controllability of the system, this paper presents the discrete time three-dimensional probability CSMA protocol which can control the total process of the system through the three-dimensional probability: P1, P2 and P3. They control the three process of the system separately. With the three parameters, we can decrease the collision and improve the probability of packets sent successfully, improving the throughput of the system.

This paper uses the average cycle method to get the precise mathematical expressions of system throughput by rigorous mathematical derivation. At last the correctness of the theory is verified through the simulation.

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With the proposed protocol, when analyzing a network or debugging a device, we can change the information packets arrival rate during the different transmission processes to get the system throughput needed.

The three-dimensional probability CSMA protocol

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) [6].

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 [7].

A cycle period is T_n. The three events above continuously staggering circulate on the time axis and the cycle is variable T_n [8]. TP is the transmission period. Use three-dimensional probability: $P1$, $P2$, $P3$ to control the period of I events, CU events and CUI events separately.

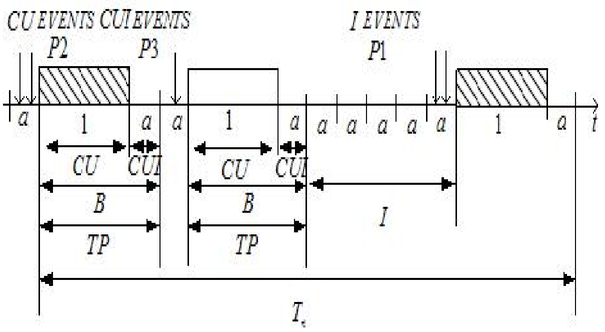

Fig 2 The model of the three-dimensional probability CSMA protocol

According to the new protocol, if the channel is idle, then the user decides to send an information packet probability $P1$; if the channel is busy, the user listens to the channel at probability $P2$ in the CU events; in the transportation period, if the channel is the first idle following the CU events, then 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.

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 [9];
- 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 [10].
- The arrival process of channel satisfies the Poisson process :

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

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

$$q_1^0 = e^{-ap_1G}, \tag{2}$$

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

$$q_1^1 = ap_1G_ie^{-ap_1G}, \tag{3}$$

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

$$q_2^0 = e^{-(ap_3+p_2)G}, \tag{4}$$

In the transmission period $(1+a)$, if there is only one information packet to be sent, its possibility is:

$$q_2^1 = (ap_3+p_2)Ge^{-(ap_3+p_2)G}, \tag{5}$$

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

$$P(N_I = i) = (e^{-ap_1G})^{i-1}e^{-(ap_3+p_2)G}, \tag{6}$$

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

$$P(N_B = j) = (1-e^{-ap_1G})(1-e^{-(ap_3+p_2)G})^{j-1}, \tag{7}$$

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

$$P(N_I = i, N_B = j) = (e^{-ap_1G})^{i-1}(1-e^{-ap_1G})$$

$$(1-e^{-(ap_3+p_2)G})^{j-1}e^{-(ap_3+p_2)G}, \quad (8)$$

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

$$E(N_I)=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} iP(N_I=i,N_B=j)$$

$$=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} i(e^{-ap_1G})^{i-1}(1-e^{-ap_1G})$$

$$(1-e^{-(ap_3+p_2)G})^{j-1}e^{-(ap_3+p_2)G}$$

$$=\sum_{i=1}^{\infty} ie^{-(ap_3+p_2)G}(e^{-ap_1G})^{i-1}\sum_{j=1}^{\infty}(1-e^{-ap_1G})(1-e^{-(ap_3+p_2)G})^{j-1}$$

$$=(1-e^{-ap_1G})\frac{1}{e^{-(ap_3+p_2)G}}e^{-(ap_3+p_2)G}\sum_{i=1}^{\infty}[(e^{-ap_1G})^{i}]'$$

$$=\frac{1}{1-e^{-ap_1G}}, \quad (9)$$

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

$$E(N_B)=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} jP(N_I=i,N_B=j)$$

$$=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty} j(e^{-ap_1G})^{i-1}(1-e^{-ap_1G_i})$$

$$(1-e^{-(ap_3+p_2)G})^{j-1}e^{-(ap_3+p_2)G}$$

$$=\sum_{i=1}^{\infty} e^{-(ap_3+p_2)G}(e^{-ap_1G})^{i-1}$$

$$\sum_{j=1}^{\infty} j(1-e^{-ap_1G_i})$$

$$=(1-e^{-ap_1G})\frac{1}{1-e^{-ap_1G}}e^{-(ap_3+p_2)G}$$

$$\sum_{j=1}^{\infty}[(1-e^{-(ap_3+p_2)G})^{j}]'$$

$$=\frac{1}{1-e^{-(ap_3+p_2)G}}, \quad (10)$$

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:

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

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

$$E(U_1)=E(N_{U_1})\times 1=\frac{ap_1Ge^{-ap_1G}}{1-e^{-ap_1G}}, \quad (12)$$

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

$$E(U_2)=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty}\sum_{K=0}^{i-1} KP(N_I=i,N_B=j)$$

$$=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty}\sum_{K=0}^{i-1} K(e^{-ap_1G})^{i-1}(1-e^{-ap_1G})$$

$$(1-e^{-(ap_3+p_2)G})^{j-1}e^{-(ap_3+p_2)G}$$

$$=(ap_3+p_2)G, \quad (13)$$

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

$$E(U)=E(U_1)+E(U_2)$$

$$=\frac{ap_1Ge^{-ap_1G}}{1-e^{-ap_1G}}+(ap_3+p_2)G, \quad (14)$$

The average length of B event is:

$$E(B)=E(N_B)\times(1+a)=\frac{1+a}{1-e^{-(ap_3+p_2)G}}, \quad (15)$$

Where $(1+a)$ represents the length of information packet whether it transmitted successfully or not in the TP cycle [11].

The average length of I event is:

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

The throughput of the new protocol in channel i is:

$$S=\frac{E(U)}{E(B)+E(I)}$$

$$=\frac{\frac{ap_1Ge^{-ap_1G}}{1-e^{-ap_1G}}+(ap_3+p_2)G}{\frac{1+a}{1-e^{-(ap_3+p_2)G}}+\frac{a}{1-e^{-ap_1G}}}, \quad (17)$$

Simulation

From the above analysis, the expression of the system throughput under the discrete time three-dimensional probability CSMA protocol with function of monitoring got. With the simulation tool-MATLAB R2010a, the simulation results are shown in Figure 2 to Figure 7. If not specified $a=0.01$.

Before the simulation, assume that:

- 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;
- The arrival process of the channel satisfy the Poisson process whose independent parameter is G, each arrival process on the channel is independent of each other ;
- The P is the probability of the discrete timeslot P-detection CSMA protocol which is proposed by Dongfeng Zhao professor;
- The packet length is 1.
  $a = 0.01$.

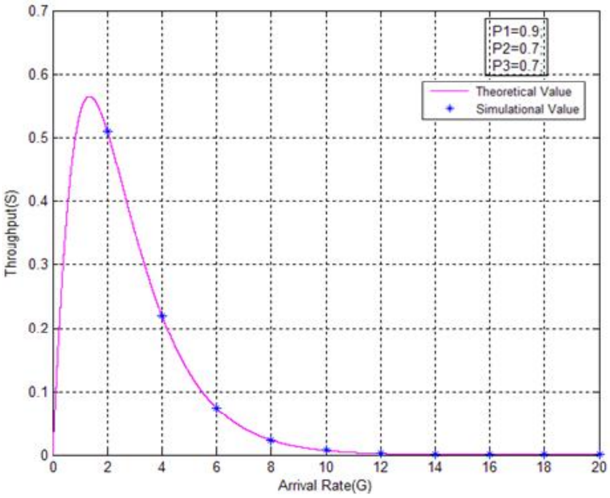

Fig. 3 The throughput of the new protocol

In Fig. 3, the simulation values of system throughput under the new protocol are consistent with the theoretical ones, verified the correctness of mathematical derivation done before.

When G becomes bigger, the system throughput is increase; especially when G is near 1.5, the system throughput is very high; next when G is bigger, the system throughput decreases.

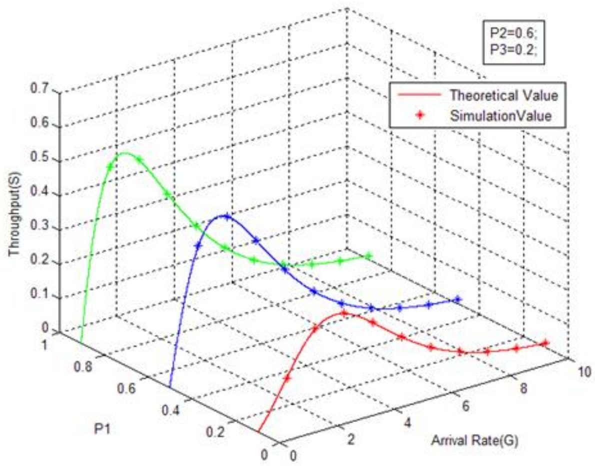

Fig. 4 The throughput of new protocol with variable P1

In the Fig. 4, the simulation values of system throughput under the new protocol are consistent with the theoretical ones, verified the correctness of mathematical derivation done before.

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; the utilization of channel resources is improved.

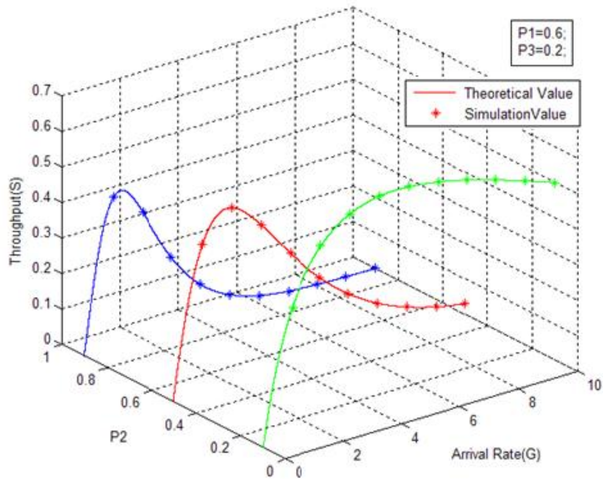

Fig. 5 The throughput of new protocol with variable P2

In the Fig. 5, the simulation values of system throughput under the new protocol are consistent with the theoretical ones, verified the correctness of mathematical derivation done before.

When $P2$ becoming bigger, the throughput will decrease; because when the channel is busy sending the packet, if the more new arrival information packets the more collisions will be; the utilization of channel resources decreases.

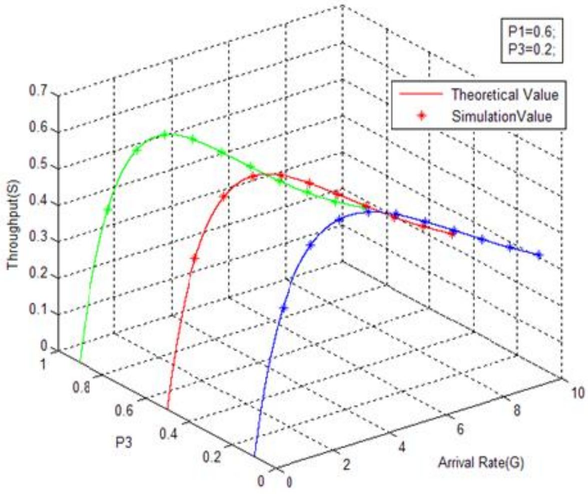

Fig. 6 The throughput of new protocol with variable P3

In the Fig. 6, the simulation values of system throughput under the new protocol are consistent with the theoretical ones, verified the correctness of mathematical derivation done before. When $P3$ becoming bigger, the throughput will decrease; because when the channel is busy sending the packet, if the more new arrival information packets the more collisions will be; the utilization of channel resources decreases.

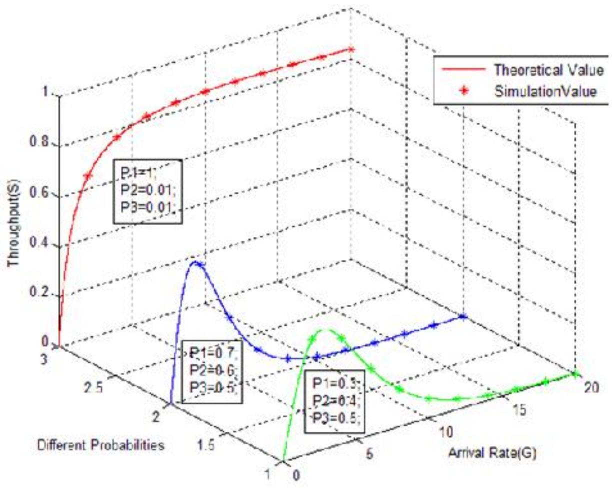

Fig. 7 The comparison of system throughput under the new protocol with different probabilities

In the Fig. 7, the simulation values of system throughput under the new protocol are consistent with the theoretical ones, verified the correctness of mathematical derivation done before.

From the figure, we can find that changing the variable $P1$, $P2$ and $P3$ at the same time to get value of the system throughput needed.

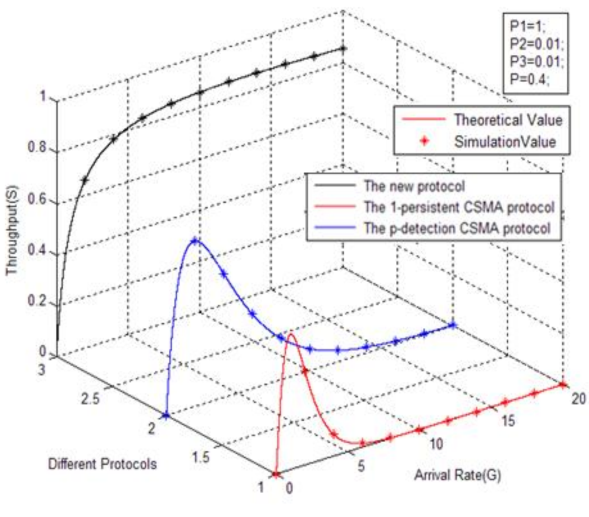

Fig. 8 The comparison of system throughput under the different protocols

In the Fig. 8, the simulation values of system throughput under the new protocol are consistent with the theoretical ones. When $a = 0.01$ $P = 0.4$ $P1 = 1$ $P2 = P3 = 0.01$, the throughput of the system under new protocol is bigger than the ones using the non-persistent CSMA protocol or the P-detection CSMA protocol, showing the priority than other protocols. On the whole, throughput of system using three-dimensional probability CSMA protocol can increases to a certain extent.

Through the above figures, we can find that when $a = 0.01$ $P1 = 1$ $P2 = P3 = 0.01$, the throughput of the system under new protocol is approaching 1. If we need the system throughput to get the value, we can set the parameters just as above.

CONCLUSIONS

The discrete time three-dimensional probability CSMA protocol, 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, improves the system controllability, gets the throughput needed, makes the circumstance we want when testing the network. Improving the utilization of channel resources, control the total process of the information transmission.

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