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Discrete Random Contention System with Variable Packet Length

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Abstract

The paper researches the random contention system in-depth using the average cycle method, then gets the formulas of the systemic throughput, free rate and collision rate with variable packet length. The simulation results verify the correctness of the theory, meanwhile, gets some conclusions that the different arrival rate G is how to affect the main source of the throughput with variable packet length. It has some researching significance.

Keywords: *the average cycle method, S-ALOHA, throughput, arrival rate*

1. Introduction

The communication network in Twenty-first Century has become an important element of the rapid development of human society. Fiber-based wireline broadband networks, has achieved human dream of "unlimited bandwidth". While, Wireless mobile communication network, makes the human realize that the information is transmitted, exchanged, transfered, and received in the moving. At present, humans are trying to achieve “unlimited bandwidth” in the wireless communication network, only to invent advanced wireless communications technology, human society will be enter into a more wonderful realm of freedom.

In the modern wireless communication networks [1-2], random multi-access technology has been one of the key technologies of wireless communication network, therefore, the research in random multiple access technology is of great significant to the wireless communication network, which is the only reason why numerous scholars put their continuous efforts on it over the years. However, with the development of scientific and tchnologyical progress, random multi-access technology also needs to keep up with the pace of the development.

Random multiple accesses [3-4], also known as random access, the features are that all data terminals can send information packets randomly on their own terms, and expect that there will not collide with other information packets when sending information. However, there will be an inevitable collision that cause the information packets transmission failure when a plurality of terminals sending information packets on the channel simultaneously. Then, In the random contention system, throughput is an important performance indicator.

In order to improve the systemic throughput, this paper proposed a new random access protocol, the discrete random contention system with variable packet length after study some random contrntion systems [5-14]. In the system, the successful packet length is variable, the conflict packet stop sending information at the end of the time slot, that is the length of time slot is per unit length equals to the length of conflict packet. This system is proposed to improve the throughput but increase the complexity of the system.

2. The Description of Analytical Methods

Assume that the Slotted ALOHA systemic timeline is divided into equal length, and the length of each time slot is L on the channel. With no limit on the number of system terminals, the packet signal arriving at any time will be transmitted in the beginning of next slot. Therefore, there will be three interleaved random kinds of events which occurred in the Slotted

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ALOHA system, (1) the packet is sent successfully (U); (2) the packet conflict (B); (3) idle timeslot (I).

As shown in the Figure 1, the collision event and idle event composite to be seen as a kind of event, then events occurring on the time axis are reduced into two events, that is the event that the packet was sent successfully (U) and the composite event (BI), and these events on the timeline is the endless cycle occurs, the cyclical time variable is said Tu.

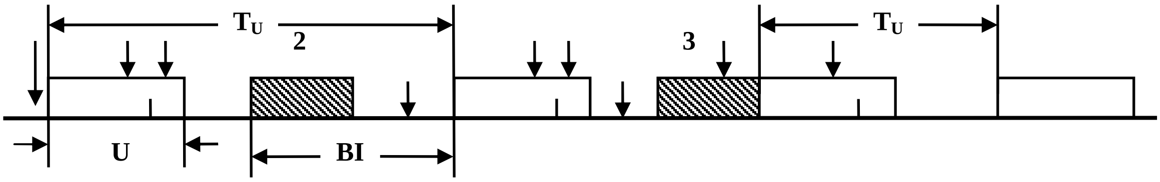

Figure 1. The Random Event Graph of Random Contention System

Before analyze the system performance, the assumption is shown as following:

1. Assume that the information packet arrival on the channel is subject to the Poisson distribution with an independent parameter G, where G is the arrival rate.
2. The channel is ideal; the packet on the channel is not affected by any noise and interference.
3. Assume that the channel on the time axis is divided into slot of equal length, and each slot length is L.
4. It is assumed that if the arriving packet conflict in the collision or idle period, which will be stopped sending at the end of the time slot.
5. It is assume that there are information packets arrived on the channel when the channel is busy transmitting the information packet, then the packets arrived within this range postponed to send the information packet in the beginning of the next slot after the packet is successfully transmitted.

The probability of the packet is transmitted successfully within a time slot is:

$$P_U = P(1) = \frac{(Gt)^k e^{-Gt}}{k} = GLe^{-GL}$$

The probability of no packet on the channel is:

$$P_I = P(0) = \frac{(Gt)^k e^{-Gt}}{k} = e^{-GL}$$

The probability of the packets conflict on the channel is:

$$P_B = 1 - P(0) - P(1) = 1 - GLe^{-GL} - e^{-GL}$$

The joint probability that appears i successful events and j composite events continuously in a cycle period is:

$$P(i, j) = (GLe^{-GL})^i \left(1 - GLe^{-GL}\right)^j$$

The average number of the successful event is:

$$E(i) = \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} iP(i, j) = \sum_{i=1}^{\infty}\sum_{j=1}^{\infty} i(GLe^{-GL})^i \left(1 - GLe^{-GL}\right)^j = \frac{1}{1 - GLe^{-GL}}$$

The average number of the composite event is:

$$E(j)=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty}jP(i,j)=\sum_{i=1}^{\infty}\sum_{j=1}^{\infty}j(GLe^{-GL})^{i}\left(1-GLe^{-GL}\right)^{j}=\frac{1}{GLe^{-GL}}$$

The mean length of the successful event is:

$$E(U)=E(i)L_U=\frac{L_U}{1-GLe^{-GL}}$$

The probability that appear k composite events is:

$$P(BI=k)=(1-GLe^{-GL})^{k}=\sum_{l=0}^{k}C_k^l(e^{-GL})^{l}(1-e^{-GL}-GLe^{-GL})^{k-l}$$

Then the average number of idle event is:

$$E(N_I)=\sum_{i=1}^{\infty}(GLe^{-GL})^{i}\sum_{k=1}^{\infty}\sum_{l=0}^{k}lC_k^l(e^{-GL})^{l}(1-e^{-GL}-GLe^{-GL})^{k-l}=\frac{1}{GL(1-GLe^{-GL})}$$

The average number of collision event is:

$$E(N_B)=\sum_{i=1}^{\infty}(GLe^{-GL})^{i}\sum_{k=1}^{\infty}\sum_{l=0}^{k}(k-l)C_k^l(e^{-GL})^{l}(1-e^{-GL}-GLe^{-GL})^{k-l}=\frac{1-e^{-GL}-GLe^{-GL}}{GLe^{-GL}(1-GLe^{-GL})}$$

The mean length of the composite event BI in a cycle period is:

$$E(BI)=E(N_B)L_B+E(N_I)L_I=\frac{L_B(1-e^{-GL}-GLe^{-GL})+L_Ie^{-GL}}{GLe^{-GL}(1-GLe^{-GL})}$$

The average of Tu is:

$$E(T_U)=E(U)+E(BI)=\frac{L_UGLe^{-GL}+L_B(1-e^{-GL}-GLe^{-GL})+L_Ie^{-GL}}{GLe^{-GL}(1-GLe^{-GL})}$$

The systemic throughput is:

$$S_U=\frac{E(U)}{E(T_U)}=\frac{L_UGLe^{-GL}}{L_UGLe^{-GL}+L_B(1-e^{-GL}-GLe^{-GL})+L_Ie^{-GL}}$$

The free rate of the system is:

$$S_I=\frac{E(I)}{E(T_U)}=\frac{L_Ie^{-GL}}{L_UGLe^{-GL}+L_B(1-e^{-GL}-GLe^{-GL})+L_Ie^{-GL}}$$

The collision rate of system is:

$$S_B=\frac{E(B)}{E(T_U)}=1-S_U-S_I=\frac{L_B(1-e^{-GL}-GLe^{-GL})}{L_UGLe^{-GL}+L_B(1-e^{-GL}-GLe^{-GL})+L_Ie^{-GL}}$$

3. Theoretical Calculation and Simulation Experiment

On the basis of the above analysis, we conducted computer simulations on the Slotted ALOHA system, the experimental parameters are the same with the theoretical parameters, the length of the slot and packet are both unit length. The results are shown in the Table 1.

Table 1. The Comparison of Experiment Value and Theoretical Value

G	Su		Eu		E(Tu)	
	experiment value	theoretical value	experiment value	theoretical value	experiment value	theoretical value
0.1	0.090495	0.090484	1.0994	1.0995	8.229800	8.229600
0.3	0.222260	0.222250	1.2859	1.2858	1.920700	1.920600
0.5	0.303270	0.303270	1.4351	1.4353	0.845180	0.845180
0.7	0.347570	0.347610	1.5328	1.5328	0.462760	0.462810
0.9	0.365880	0.365910	1.5769	1.5771	0.286420	0.286450
1.1	0.366120	0.366160	1.5775	1.5777	0.191790	0.191810
1.3	0.354260	0.354290	1.5485	1.5487	0.135350	0.135370
1.5	0.334690	0.334700	1.5029	1.5031	0.098956	0.098966
1.7	0.310530	0.310560	1.4506	1.4505	0.074088	0.074088
1.9	0.284150	0.284180	1.3969	1.3970	0.056354	0.056350

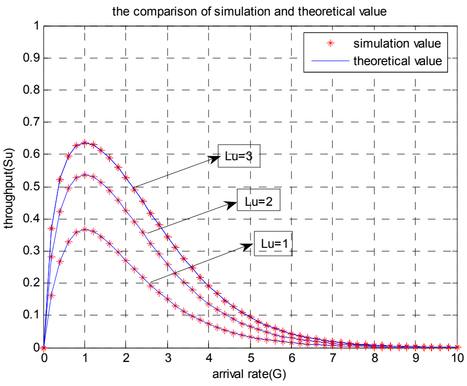

Figure 2. The Changing Curve of the Systemic Throughput with Different Lu

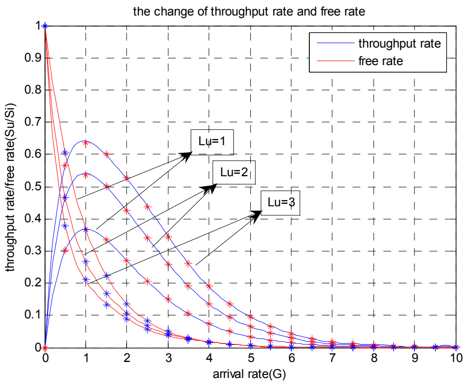

Figure 3. The Changing Curve of the Systemic Throughput and Free Rate with Different Lu

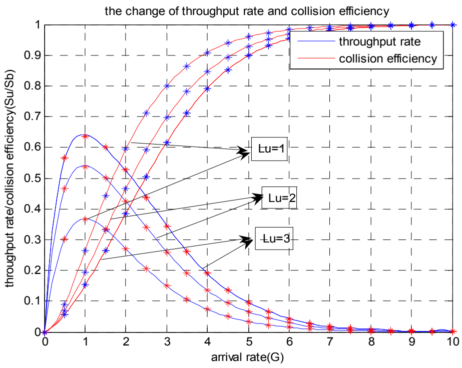

Figure 4. The Changing Curve of the Throughput and Collision Rate with Different Lu

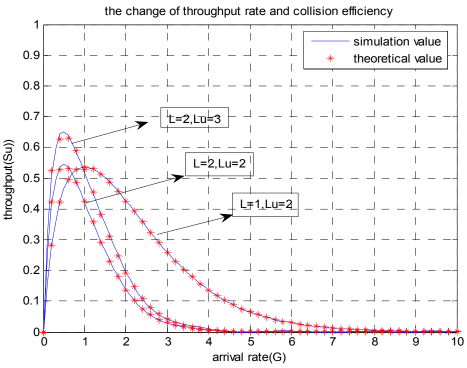

Figure 5. The Changing Curve of the Systemic Throughput with Different L

From above tables and graphs, we can receive:

(1) With the increases of the successful packet length Lu, the maximum throughput of the system also increases, and reached the maximum in the arrival rate G=1. For example, when Lu=1, the maximum throughput S is 0.368, and when Lu=2, Smax=0.537, and when Lu=3, Smax=0.626, the system throughput is obvious has been improved.

(2) As the increase of the successful packet length Lu, the increased value of the systemic throughput is approximately equal to the reduction of the free rate with smaller arrival rate G. That is the increase of the systemic throughput is mainly derived from the reduction of the free rate as the increase the Lu with smaller G.

Table 2. The Change of Lu and Si

G	Su		Si		Lu=1 →	Lu=2
	Lu =1	Lu =2	Lu =1	Lu =2	△Su	△Si
0.2	0.16375	0.28141	0.81873	0.70353	0.11766	0.1152
0.8	0.35946	0.52883	0.44933	0.33052	0.16937	0.11881
1	0.36788	0.53788	0.36788	0.26894	0.17	0.09894
3	0.14936	0.25990	0.04978	0.04331	0.11054	0.00647

As shown in Table 2, when the arrival rate G=0.2, the successful packet length change from 1 to 2, the increased value of throughput △Su = 0.11766, the reduction of the free rate △Si=0.1152, the two is approximately equal in value. The increased value of throughput is bigger and bigger than the reduction of the free rate as the increase of the arrival rate G. In other words, the reduction of the free rate has not provided the increase of the throughput.

(3) As the increase of the successful packet length Lu, the increased value of the systemic throughput is approximately equal to the reduction of the collision rate with bigger arrival rate G. That is the increase of the systemic throughput is mainly derived from the reduction of the collision rate as the increase the Lu with bigger G.

Table 3. The Change of Su and Sb

G	Su		Sb		Lu=1 →	Lu=2
	Lu =1	Lu =2	Lu =1	Lu =2	△Su	△Sb
2	0.27067	0.42603	0.59399	0.46747	0.15536	0.12652
3	0.14936	0.25990	0.80085	0.69678	0.11054	0.10407
5	0.03369	0.13652	0.95957	0.84641	0.10283	0.11316
8	0.002683	0.005353	0.99698	0.99431	0.00267	0.00267

As shown in Table 3, when the arrival rate G=2, the successful packet length change from 1 to 2, the increased value of throughput △Su = 0.15536, the reduction of the collision rate △Sb=0.12652, the two is approximately equal in value. And with the increasing G, the reduction in value of the collision rate even more than the increase of the throughput.

(4) The slot length L does not affect the value of the maximum throughput, it just change the value of G reaches the maximum throughput. When the L is increased, the system will be achieving maximum throughput in smaller G.

4. Conclusion

The S-ALOHA system we researched before both with slot length and packet length are unit length, but in this paper, we further research slotted ALOHA communication system, develop the analysis method of literature [2] and get the expression of the throughput, free rate and collision rate when the packet length changes. Simulation results verify the correctness of the theory, at the same time get the main source of the throughput while the packet length increase and the influence of the throughput affected by time slot, has a certain significance. So we know the inadequacies of the system increase the cost and complexity of control system.

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