A Control Protocol Based on Binary Tree Conflict Resolution Algorithm Combined with Probability Detection and 1-persistent CSMA

Cuixian Li, Hongwei Ding, Yingying Guo, Yifan Zhao, Jing Nan, Tong Zhang

Abstract. This paper puts forward a joint control protocol based on binary tree conflict-resolving algorithm combined probability detection and 1-persistent CSMA. Under the protocol, all terminals use the joint control protocol of p-detection and 1-persistent to access the channel before sending information packets, and transmit packets immediately when the channel is idle, but when there are any collisions on the channel, the system will use isolated binary tree conflict-resolving technology to decompose the impacted packets. Meanwhile, the paper analyzes the protocol and gets the computational formula of the throughput for the protocol by building a mathematical model and using the average cycle method and compared with the joint control protocol of p-detection and 1-persistent. And finally, the paper gives the MATLAB simulation results. The results not only show that the correctness of the theoretical analysis and illustrates the validity of the protocol, but also gives some meaningful conclusions. Therefore, it is very necessary and important to integrate the binary tree conflict-resolving technology into the joint control protocol of p-detection and 1-persistent under high load, which can the successful probability and channel utilization.

Keywords: Binary tree conflict-resolving algorithm, probability detection, 1-persistent CSMA, random multiple access technology, throughput, average cycle method.

1. Introduction

Wireless sensor network [1, 2] consists of a large number of randomly distributed sensor nodes through wireless communication technology, which is a network constituted by the self-organizing way. It combines sensor technology, information processing technology and network communication technology; it is also a new field of information technology. Wireless sensor network [9] has the function of data acquisition, processing and transmissions. Its low-power, low-cost, distributed and self-organizing features make it a wide range of applications. The development of wireless sensor networks was first

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Supported by the National Natural Science Foundation of China (61072079);
Natural Science Foundation of Yunnan Province (2010CD023);
Graduate Scientific Research Fund of Yunnan University (ynuy201047).

originated in military applications such as battlefield detection, now wireless sensor is used in civilian monitoring, such as environmental and ecological monitoring, health care, home automation, and traffic control and so on.

Random multiple access control protocol [3] is an important access control protocol. It is widely used in satellite communications systems, local area networks, and computer networks and other communication systems. With the development of information network technology, many terminals must share the same transmission channel, but because the terminals send information packets independently and randomly, it results in collisions easily, thereby resulting in loss of information packet and even transmission failure. In order to reduce the probability of occurrence of collision information packet, researchers putted forward CSMA mechanism, it will sense the channel status before sending information packets, and the packets are transmitted immediately if the channel is idle, otherwise, it will give up sending and go on sensing the channel. These mechanisms reduce the probability of collision to improve the performance of the system to some extent, so when collisions happens on the channel, it is very necessary to introduce a reasonable conflict-resolution mechanism to resolve the conflicts.

This paper puts forward a joint control protocol based on binary tree conflict-resolving algorithm combined probability detection and 1-persistent CSMA based on the combination of random multiple access technology and conflict-resolving technology. Under the protocol, all terminals use the joint control protocol of p-detection and 1-persistent to access the channel before sending information packets, and transmit packets immediately when the channel is in idle, but when there are any collisions on the channel, the system will use isolated binary tree conflict-resolving technology to decompose the impacted packets. Meanwhile, the paper gives the mathematical expression of the throughput by using the average cycle method. And finally analyze the performance of the protocol according to the simulation experiments, illustrates the validity of the protocol.

2. The description of the joint control protocol based on the binary tree conflict resolution technology combined p-detection and 1-persistent CSMA

2.1 Mathematical modeling method

The terminals listen to the channel status before sending information packets in p detection and 1-persistent CSMA control protocol [4-8], and the packets will be transmitted with probability 1 when the channel is sensed in idle state, but when listen to the channel is busy, the user site sense the channel with probability p, and send data immediately with probability 1, the mechanism reduce the probability of collision on the channel greatly. However, due to the presence of the transmission delay and the increasing of the arrival rate and other factors, p detection and 1-persistent CSMA control protocol can not to avoid collision completely, especially when the system has a larger load. Then, the introduction of a reasonable collision resolution mechanism can effectively increase the system performance. The binary tree conflict-resolving mechanism (algorithm) can decompose and retransmit the impacted information packets effectively and reasonably.

The paper builds and describes a control protocol model based on binary tree conflict-resolving algorithm [10, 11, 13] combined with probability detection and 1-persistent. Description of the process is shown in Fig.1.

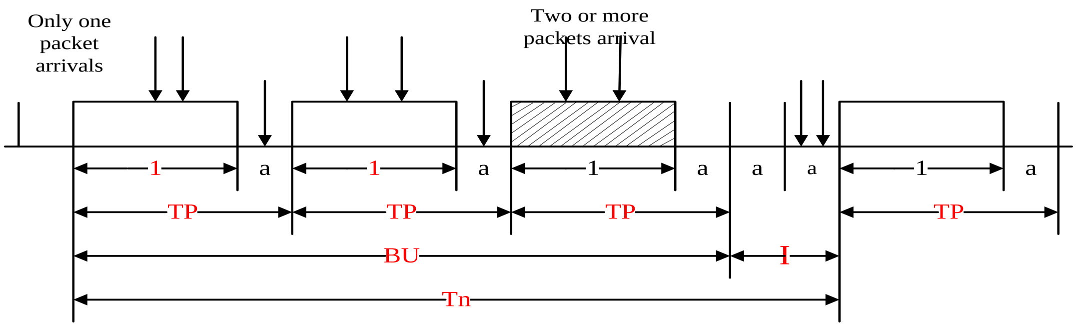

Fig.1 the control protocol model based on binary tree conflict-resolving algorithm combined with probability detection and 1-persistent

The control mechanism of the protocol is described as follows: if only one packet arrives at the last slot of the idle period, the information packet will been sent successfully in the next time slot. If there are two or more active terminals simultaneously listen to the channel is idle, then they send the information packet at the start of the next time slot simultaneously, these information packets collide in the channel, then the system decompose the impacted packets using the binary tree conflict-resolving algorithm.

During this time, the other terminal stops sending packets until all the impacted packets decomposed, then the system reuse p detection and 1-persistent CSMA protocol.

2.2 The joint probability distribution

Before analyze the system performance, the assumptions are shown in the following:

1. It is a discrete-time system and the length of the time slot is a, the length of information packet is 1 equals to an integral multiple of a.

2. The information packets arrival on the channel follows the Poisson distribution with an independent parameter G, and the impacted packets retransmitted in the following time in the random multiple access system also follows Poisson distribution ($P(n)=\dfrac{(tG)^n e^{-tG}}{n!}$).

3. Let U denotes an event that information packet transmission successfully, B denotes an event that information packet conflict, and I denotes another event that the channel is in the idle time, BU denotes channels that are in a busy period.

4. Let $P\{N_{BU}=i\}$ denote the probability of that appear i composite events BU continuously, and the number of U in the event BU is x.

5. Let $P\{N_I=j\}$ denote the probability of that appear j idle events I continuously.

6. Let $P\{N_I=j, N_{BU}=i\}$ denote the joint probability that appears i composite events BU and j idle events I continuously.

7. S denotes the systemic throughput.

The probability of no packets in a time slot on the channel is e^{-aG}, and then the probability of no packets in a transmission period on the channel is $e^{-p(1+a)G}$, so we have the following formulas:

The probability that appear i composite events BU continuously in a busy period is

$$P(N_{BU}=i)=(1-e^{-aG})(1-e^{-P(1+a)G})^{i-1}$$

The probability that appear j idle events continuously in a idle period is

$$P(N_I=j)=e^{-P(1+a)G}(e^{-aG})^{j-1}$$

The joint probability that appear i composite events BU and j idle events I continuously is

$$P(i,j)=(1-e^{-aG})(1-e^{-(P+a)G})^{i-1}e^{-(P+a)G}(e^{-aG})^{j-1}$$

2.3 The Calculation of the Throughput

Before calculate the throughput, the summation is set as follows:

1. The channel is ideal without noise and interference.
2. The conflicted information packets will be decomposed and retransmitted in the following idle slot, and the retransmitted packets make no difference to the arrival process of the channel [12].
3. The arrival packets are sent based on the p-detection and 1-persistent CSMA control protocol, and the conflicted information packets will be decomposed using the isolated binary tree conflict-resolving algorithm and then retransmit in the following idle slot, but during this time, the new arrival packets are sent based on non-persistent CSMA protocol until all the conflicted packets transmitted complete, then the channel recover using p-detection and 1-persistent protocol.

The average number of idle time slots in a cycle period is

$$E(N_I)=\frac{P_0}{P_0(1-P_0)}=\frac{1}{1-e^{-aG}}$$

$$P_0=e^{-aG}$$

P_0 is the probability of no packet arrival on the channel in a time slot.

The average number of time slots that the arrival packets be transmitted successfully is

$$E(N_U)=\frac{P_1}{P_0(1-P_0)}=\frac{(P+a)Ge^{-(P+a)G}}{e^{-aG}(1-e^{-aG})}$$

$$P_1=(P+a)Ge^{-P(1+a)G}$$

P_1 is the probability of that the packet sent successfully in a time slot.

The average number of time slots that has x packets conflict on the channel in a cycle period is:

$$E(N_{Bx})=\frac{P_x}{P_0(1-p_0)}=\frac{\left[(P+a)G\right]^x e^{-(P+a)G}}{e^{aG}(1-e^{-aG})x!}$$

$$P_x=\frac{\left[(P+a)G\right]^x e^{-(P+a)G}}{x!}$$

P_x is the probability of that has x packets conflict in a time slot.

The average length of the free timeslot in a cycle period on the channel is

$$E(I^*) = E(N_I)a = \frac{a}{1-e^{-aG}}$$

The average length of the successful packets in a cycle period on the channel is

$$E(U) = E(U) \times 1$$

$$E(U^*) = E(N_U) \times (1+a) = \frac{(1+a)(P+a)Ge^{-(P+a)G}}{e^{-aG}(1-e^{-aG})}$$

The average length of that has x packets conflict on the channel in a cycle period is

$$E(B_x) = E(N_{Bx})x = \frac{x\left[(P+a)G\right]^x e^{-(P+a)G}}{e^{aG}(1-e^{-aG})x!}$$

$$E(B_x{}^*) = E(N_{Bx})(1+a)(1+L_x) = \frac{\left[(P+a)G\right]^x e^{-(P+a)G}(1+a)(1+L_x)}{e^{aG}(1-e^{-aG})x!}$$

L_x is the average length of time slot that needed when using the isolated binary tree conflict-resolving algorithm to decompose the conflicted packets[4].

Therefore, the throughput is

$$S = \frac{E(U) + \sum_{x=2}^{\infty} E(B_x)}{E(I^*) + E(U^*) + \sum_{x=2}^{\infty} E(B_x)} = \frac{(P+a)Ge^{(P+a)G}}{ae^{pG} + (1+a)[e^{(p+a)G} - 1] + (1+a)\sum_{x=2}^{\infty} \frac{L_x\left[(P+a)G\right]^x}{x!}}$$

3. The numerical analysis of the joint control protocol based on the binary tree conflict-resolving technology combined p-detection and 1-persistent CSMA.

According to the theoretical analysis, we simulate the control protocol of P-Detection and 1-persistent CSMA, and the joint control protocol combined P-Detection and 1-persistent CSMA based on binary tree conflict-resolution algorithm. Before simulate the protocol, the simulation environment is assumed as following:

1. The channel is ideal without noise and interference.
2. The channel arriving rate is G.
3. The length of each packet equals to unit length.

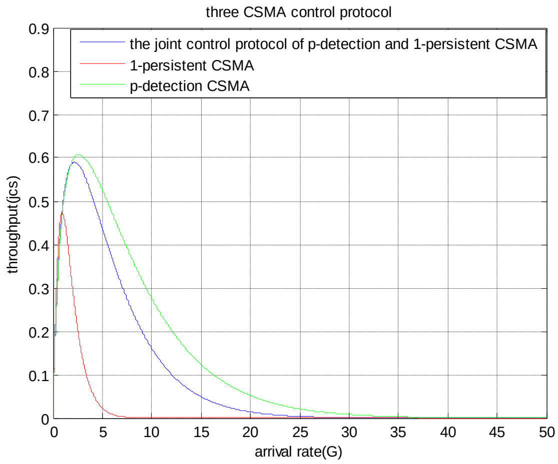

Fig.2 The throughput of three CSMA control protocol

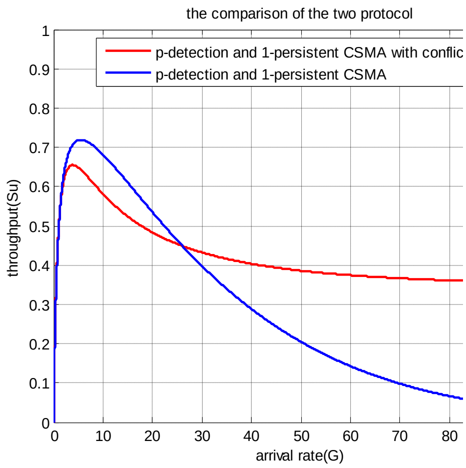

Fig.3 The throughput of the two protocol when a=0.05, p=0.001

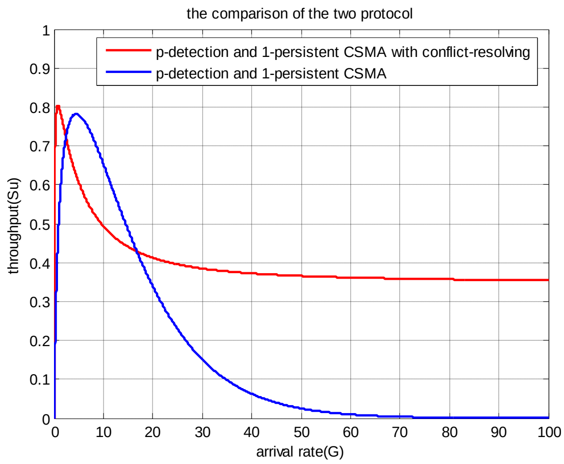

Fig.5 The throughput of the two protocol when a=0.01, p=0.1

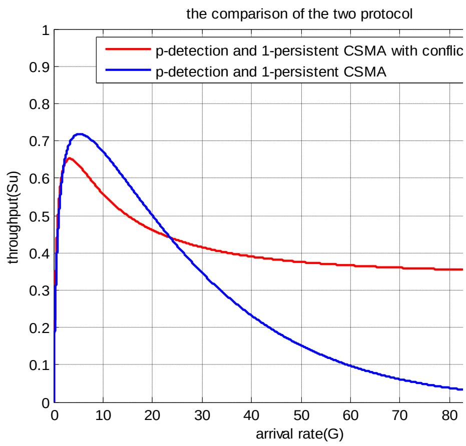

Fig.4 The throughput of the two protocol when a=0.05, p=0.01

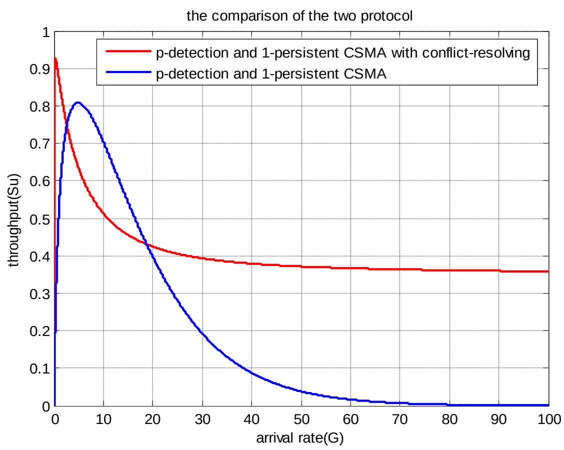

Fig.6 The throughput of the two protocol when a=0.001, p=0.1

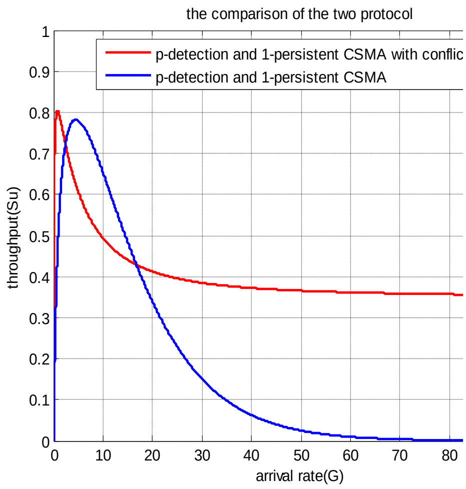

Fig.7 The throughput of the two protocol when a=0.01, p=0.1

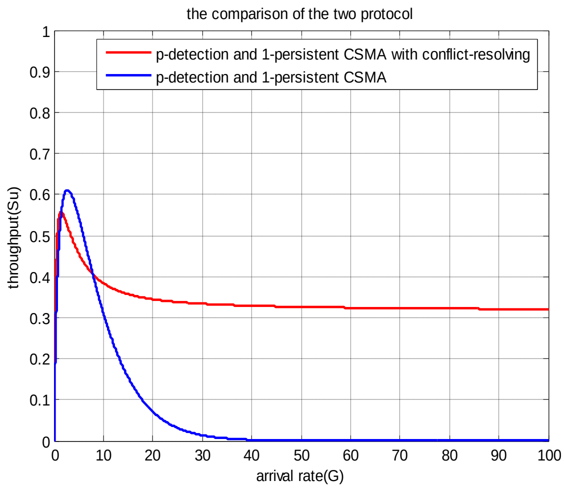

Fig.8 The throughput of the two protocol when a=0.1, p=0.1

From Figure 2 to Figure 8, we can obtain:

1. The joint control protocol of p-detection and 1-persistent has a maximum throughput 0.624, and is higher than 1-persistent protocol and p-detection protocol. Then in the light loading, the control protocol of p-detection and 1-persistent can improve channel utilization.

2. The joint control protocol of p-detection and 1-persistent has a higher throughput than that of the control protocol based on binary tree conflict-resolving algorithm combined probability detection and 1-persistent CSMA in a small arrival rate G. That is because when G is small, the impacted probability of the information packets is very small, and then the joint control protocol of p-detection and 1-persistent can send packets successfully.

3. For the overall system, the control protocol based on binary tree conflict-resolving algorithm combined probability detection and 1-persistent CSMA has a better performance than the joint control protocol of p-detection and 1-persistent, such as has a higher throughput, especially in a larger arrival rate G.

4. With the increase of the arrival rate G, the throughput of the joint control protocol of p-detection and 1-persistent decreases rapidly, but the throughput of the control protocol based on binary tree conflict-resolving algorithm combined probability detection and 1-persistent CSMA decreases gradually and finally maintained at about 0.5.

5. With the increase of the value of a and p, the throughput of the joint control protocol of p-detection and 1-persistent drop to 0 quickly. And the throughput of the control protocol based on binary tree conflict-resolving algorithm combined probability detection and 1-persistent CSMA also decrease quickly but remain in a stable value in the end. This fully shows the superiority of the protocol.

4. Conclusion

This paper mainly introduces the joint control protocol based on binary tree conflict-resolving algorithm combined probability detection and 1-persistent CSMA, then obtains computational formula of the throughput by building a mathematical model and using the average cycle method and compared with the joint control protocol of p-detection and 1-persistent. Therefore, it is very necessary to integrate the binary tree conflict-resolving technology into the joint control protocol of p-detection and 1-persistent under high load, which can the successful probability and channel utilization.

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ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China (61072079); Natural Science Foundation of Yunnan Province (2010CD023); Graduate Scientific Research Fund of Yunnan University (ynuy201047).Thanks for the seriously guidance of Professor Dongfeng Zhao.

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