The Contentions Resolution Algorithms by Random Slot Multiple Access for DOCSIS Protocol

[#]Thanyawarat Pawasopon [1], Suvepon Sittichivapak [2]
[1] Department of Telecommunications Engineering,
King Mongkut's Institute of Technology Ladkrabang
Bangkok, Thailand, thanyawarat_p@hotmail.com
[2] Department of Telecommunications Engineering, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Bangkok, Thailand, kssuvepo@kmitl.ac.th

Abstract

Data–Over–Cable Service Interface Specifications (DOCSIS) permit the addition of high-speed data transfer to an existing Cable TV (CATV) system. In this paper, simple transmission protocol is considered. We propose random slot multiple access algorithm for contentions resolution. In this algorithm, *p*-persistence value for each user is prepared for mini-slot selection, and also, mini-slot in each slot and users are divided into groups. The user in each group will access to the allocated mini-slot with the designed persistence value. Then, the algorithm can reduce the collision problem when two or more users access to the same mini-slots. The system performances are analyzed and the result is shown in throughput and time delay of system.

Keywords : DOCSIS HFC network Cable modem Multiple access Groups division

1. Introduction

Data-Over-Cable Service Interface Specifications (DOCSIS) is *de facto* standard developed to define communication and operation support interface requirement a data-over-cable system.

Fig. 1 is shows DOCSIS architecture;

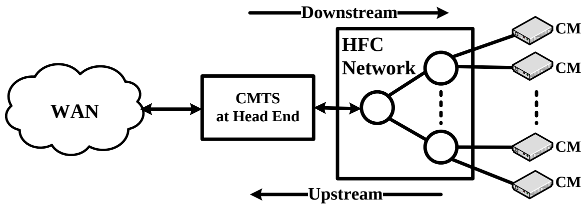

Figure 1: DOCSIS architecture.

In Hybrid Fiber-Coax (HFC) cable network, each branch is composed of downstream channel and an upstream channel. Cable Modem Terminal System (CMTS) at the Head End (HE) is the only transmitter on the downstream channel. The upstream channel is divided into fixed length time slot called mini-slots. Each frame of mini-slots consists of contention mini-slot (CS), are used for Cable Modem (CM) transmit a request, and data mini-slots (DS), are used to transmit data. The detailed mini-slot allocation of each frame is specified via a control message, called MAP, which is periodically transmitted by the CMTS on the downstream channel.

When any CM that wants to transmit data on the upstream channel, it first sends a request via the CS on upstream channel to the CMTS. After the CMTS has completely received CS, it uses the downstream channel to send feedback on CS to the station. The feedback indicates whether a CS was empty, successful, or contained a collision. If a request is successful, the CMTS will allocate an upstream bandwidth for the station in a future allocation MAP. If the request results in a collision, MAC will initiate a collision resolution process.

Random access schemes for packet networks require contention resolution algorithms and protocol for resolving packet collisions due to contention by the uncoordinated terminal. In this paper, we proposed simple contention resolution algorithm, called *random slot multiple access algorithm*, as explained in Section 2.

2. System Models

2.1 The Random Slot Multiple Access Algorithms

DOCSIS has a central control, called CMTS, and multiple users. Each user has a unique ID after registering into network. The CMTS schedules random access of all users to mini-slot. In order to reduce request packet collisions, access CS is designed. In the beginning of each frame, the CMTS broadcast a MAP massage to all users asking for access request. Every user then sends a request packet to CMTS during the CS

In this paper assume as all users have a ready data packet to send into CS, the CS slot is V slots, the number of user is n users and a user transmits only one request message in only one CS.

The random slot multiple access algorithm is algorithm that uses a p-persistence value resolves contention, when p is transmission require probability of each user which random in range [0,1]. Each user is sent a request packet in CS that designed for each p value. If there are two or more users selected same p value, the collision occurs.

Example, we assume that in one slot have 10 CSs. Then, we define user who selected p is 0.1 will be access in the 1st CS and other CS as same before .It illustrated in Fig. 2.

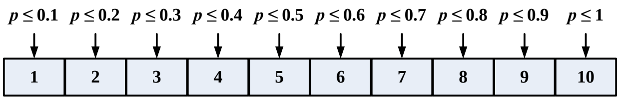

Figure 2: The random slot multiple access algorithms.

2.2 Groups Division

In this paper proposed groups division method two methods. The first method, number of CS and users are divided into two equivalent groups. The 1st group of users is accessed in the 1st group of CS as shown in Fig. 3.

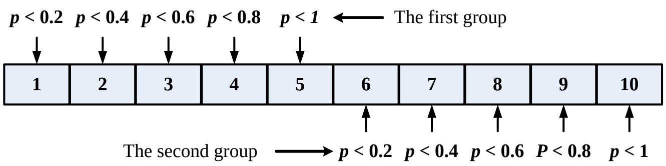

Figure 3: The division mini-slot two equivalent groups.

The other method liked above method but number of CS and users are divided into two unequal groups. It is shown in Fig. 4.

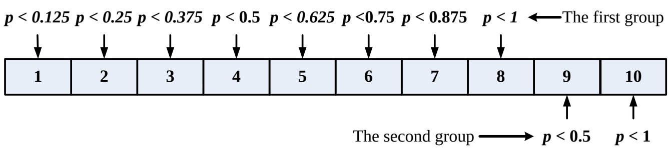

Figure 4: The division mini-slot two unequal groups.

3. Performance Analysis

3.1 Analysis of random slot multiple access

Let's consider that n users can get k CS for transmission can be expressed as below;

$$P_{in}(n) = \binom{n}{k} p^k (1-p)^{n-k} \qquad (1)$$

In this expression, each user persists to transmit with probability p. Let's S_k define the summation of all success probabilities in k given CS. It is

$$S_k = \frac{\binom{V}{k}\binom{n}{k} k!(V-k)^{n-k}}{V^n} \qquad (2)$$

On the condition that n users transmit packets in V slots, the probability $P_s(k \mid n,V)$ that k users get success is given by

$$P_s(k \mid n,V) = S_k \left[1 - S_1 + S_2 - S_3 + \cdots + (-1)^{\min(V-k,n-k)} S_{\min(V-k,n-k)}\right]$$
$$= \frac{(-1)^k V!n!}{V^n k!} \sum_{i=k}^{\min(n,V)} \frac{(-1)^i (V-i)^{n-i}}{(i-k)!(n-i)!(V-i)!} \quad ; \; 0 \le k \le \min(V,n) \qquad (3)$$

Therefore, equations (1) and (4), the result that the expected value of total CS accessed in one slot S is as follow:

$$S = J \cdot \sum_{n=1}^{\infty} \left[P_{in}(n) \cdot \sum_{k=1}^{\min(n,V)} k \cdot P_s(k \mid n,V) \right] \qquad (4)$$

When, J is message length that is generally distributed with mean data packets.

3.2 Analysis of groups division

Let's V_1 is number of CS of the 1st group and V_2 is number of CS of the 2nd group. Let's n_1 is number of users of the 1st group and n_2 is number of users of the 2nd group. Therefore the probability of k_1 users in 1st group and the probability of k_2 users in 1st group getting success may be directly obtained from equation (3).

$$P_1(k_1 \mid n_1,V_1) = \frac{(-1)^{k_1} V_1!n_1!}{V_1^{n_1} k_1!} \sum_{i=k_1}^{\min(n_1,V_1)} \frac{(-1)^i (V_1-i)^{n_1-i}}{(i-k_1)!(n_1-i)!(V_1-i)!} \qquad (6)$$

$$P_2(k_2 \mid n_2,V_2) = \frac{(-1)^{k_2} V_2!n_2!}{V_2^{n_2} k_2!} \sum_{i=k_2}^{\min(n_2,V_2)} \frac{(-1)^i (V_2-i)^{n_2-i}}{(i-k_2)!(n_2-i)!(V_2-i)!} \qquad (7)$$

Let's S_1 is the expected value of total CS accessed in one for group division. Then, S_1 is given by

$$S_1 = J \cdot \sum_{n=1}^{\infty} \left[P_{in}(n) \cdot \sum_{k=1}^{\min(n,V)} k \cdot \left[P_1(k_1 \mid n_1,V_1) + P_2(k_2 \mid n_2,V_2)\right] \right] \qquad (8)$$

3.3 Throughput and Delay

Normalize throughput is define as

$$T = \frac{S}{L} \quad ; \; L = \text{Size of CS} + \text{size of DS} \qquad (9)$$

And, normalized delay is given by

$$D = \frac{n}{T} + \frac{1}{\lambda} + 1 \quad ; \; \lambda \textit{ is arrival rate} \qquad (10)$$

3.4 The analysis result

In this paper, we define number of CS to 10 slots and 50 active users. In the unequal groups division, number of CS and active users are divided into 4/5 and 1/5.

From analysis of the success probability of random slot multiple access and groups division, the equivalent groups division has the most value as shown in Fig. 5.

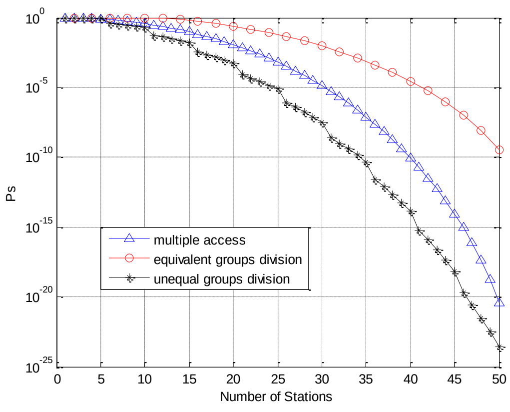

Figure 5: Ps VS number of stations

Because, it is the summation of success probabilities of each groups. In other hands, the unequal groups division has a great number of contentions in minority group. Then, the summation of success probability of each group has the least value. So the equivalent groups division has the best throughput and the best delay. And the unequal groups division has the least throughput and the least delay. They are shown in Fig. 6 (a) and (b).

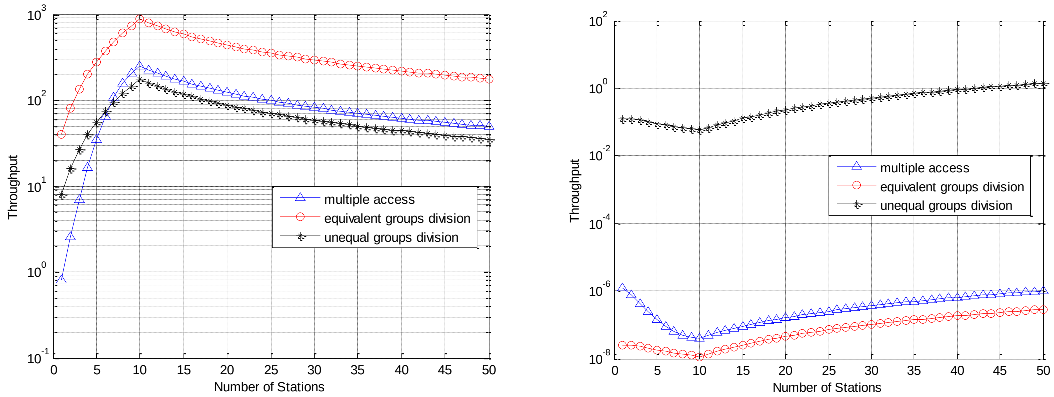

Figure 4: (a)Throughput VS number of stations (b)Delay VS number of stations

From Fig. 8 and Fig. 9, we can see that the efficiency of system is increased when number of active user have equal to number of the CS. Because one user can access in one CS then it hasn't the collision happen. When, numbers of user have more than number of the *CS*, the efficiency of system is reduced. Because it has the contention and the collision happened.

4. Conclusion

In this paper, the simple contention resolution algorithm is proposed by used *p*-persistence value resolves contention and randomly selected mini-slots processes are analyzed. From analysis of the probability $P_s(k\,|\,n,V)$ that k users get success in CS, we are learned that when the CS are divided into equivalent groups, it make for the system have increased efficiency. But, when the CS are divided into unequal groups, it make for the system have reduced efficiency.

References

[1] Data-Over-Cable Service Interface Specifications Radio Frequency Interface Specification CM-SP-RFIv1.1-C01-050907, Sep. 2005

[2] Tomoya Saito, Kyoko Kato and Hiroshi Inai , "A request cluster allocation method for DOCSIS CATV/HFC networks", *Proc. ICCS2002*, vol. 1, pp. 155-159.

[3] Wuyi Yue, Yutaka Matsumoto, "Performance analysis of multi-channel and multi-traffic on wireless communication networks", Springer, 2002The Contention Resolution Algorithms.

Acknowledgments

This work was supported by the Telecommunications Research and Industrial Development Institute, National Telecommunications Commission Fund (Grant No. PhD 011/2553) is gratefully acknowledged.