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Control-Minislot First-Come First-Serve Protocol

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Abstract — **A new protocol for a random access channel is proposed and evaluated. The channel is divided into a control subchannel, which is used to resolve conflicts between users, and a data subchannel, which is used to transmit the data. The protocol used to resolve conflicts is the best performance splitting protocol designed so far: Gallager's First-Come First-Serve Algorithm. The proposed protocol achieves an optimum performance in throughput and a very good performance in delay.**

I. Introduction

In this paper we are concerned with the design of a random access protocol that allows an infinite number of bursty users (Poisson traffic) to share a single error-free synchronous channel. This problem has received considerable attention since the introduction of Aloha in 1970 by Abramson. Capetanakis proposed in 1977 the first Collision Resolution Algorithm (CRA), that provides a maximum throughput of 0.43. Gallager's First-Come First-Serve algorithm [1], which achieves a maximum throughput of 0.4877, is the best algorithm designed so far for conflict resolution.

Control Minislots increase the maximum throughput by dividing the channel into fixed length frames, and each frame into k control minislots (CMS's) of length δ -the control subchannel- and one data slot (DS) of length 1 -the data subchannel-, with $\delta \ll 1$. MFA, AARA and DQRAP are protocols that use CMS's. Of those, DQRAP [2] is the one that provides the best performance.

The protocol we propose, Control-Minislots First-Come first-Serve (CMS-FCFS), uses the best conflict-resolution algorithm designed so far, Gallager's FCFS, to resolve collisions in the CMS's. All the collision resolution process is done in the CMS's, and data slots are only used for successful transmissions.

II. Description of CMS-FCFS Protocol

CMS-FCFS executes a collision resolution algorithm for packet requests in the control minislots. Successful requests are stored in a reservation queue, and then, the packets corresponding to these requests are transmitted in the data slots with success guaranteed, in the order determined by the reservation queue.

As all the resolution process for collided requests is done in the minislots, a data slot will never be wasted in a collision. Of course, control minislots will be wasted, but this is not harmful for the throughput, since the minislot length is much smaller than the data slot's ($\delta \ll 1$). This is the key point in CMS-FCFS's good performance.

The CRA used in CMS-FCFS is Gallager's FCFS. Each frame is divided in k intervals of length $\delta + 1/k$, called windows, and each window corresponds to a control minislot in the next frame. CMS-FCFS then works exactly as FCFS, with windows in CMS-FCFS as the slots in FCFS. The information that in FCFS was placed in slots, in CMS-FCFS will be placed in the control minislots corresponding to each window.

In the case that the reservation queue contains no entries, users transmitting a request during a frame are required to also transmit the corresponding packet during the same frame. This provides the immediate access feature. Note that even though this rule permits collisions to occur in data slots, these data slots would otherwise be empty.

III. CMS-FCFS Performance

Eqs. (1) and (2) are the results of approximate analyses for the throughput (S) and the delay (D). In Eq. (2) a negligible value of δ has been assumed. Both results are supported by simulations.

$$S_{\text{CMS-FCFS}} = \min\left(k\, S_{\text{FCFS}}\left(\lambda\left(\frac{1}{k}+\delta\right)\right), \frac{1}{1+k\delta}\right) \quad (1)$$

$$D_{\text{CMS-FCFS}} \approx \frac{1}{k}\left(D_{\text{FCFS}}\left(\frac{1}{k}\right)-\frac{1}{2}\right)+\frac{1}{2(1-\lambda)}+ + (1-\text{ErC}(\lambda,1))\left(1-e^{-\lambda}\right)+1 \quad (2)$$

IV. Conclusion

CMS-FCFS is the only medium access control protocol designed so far that using only two control minislots achieves a throughput almost equal to one (0.97 when $\delta = 0$). When more than two minislots are used, DQRAP achieves a similar performance to CMS-FCFS. Considering this, CMS-FCFS could find its application in channels where, because of a high value of δ, a minimum number of control minislots is desired. This statement is supported by the results shown in the following table (for each value of δ, the value of k has been chosen such that the system throughput is maximized; this value of k is found in parenthesis).

δ	CMS-FCFS	DQRAP	AARA	MFA
0.01	0.971 (3)	0.971 (3)	0.863 (7)	0.654 (14)
0.02	0.943 (3)	0.943 (3)	0.849 (5)	0.597 (8)
0.05	0.885 (2)	0.869 (3)	0.742 (3)	0.514 (4)
0.1	0.812 (2)	0.769 (3)	0.674 (2)	0.445 (3)
0.2	0.695 (2)	0.625 (3)	0.603 (1)	0.359 (2)

References

[1] R.G. Gallager, "Conflict resolution in random access broadcast networks," *in Proc, AFOSR Workshop Communication Theory and Applications*, Provincetown, MA, Sept. 17-20, 1978, pp. 74-76.

[2] W. Xu and G. Campbell, "A distributed queueing random access protocol for a broadcast channel," *Computer Communications Review*, vol. 23, no. 4, pp. 270-278, Oct. 1993.

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