A Tutorial on Multi-Channel CSMA

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The discussion is a simplified form of [1].

A multichannel network consists of a set of parallel sub-channels. Let W bandwidth of the total system is allocated to M sub-channels.

$$W = \sum_{i=1}^{M} W_i \tag{1}$$

Suppose, packet is generated in Poisson distribution process with the rate of λ packets/sec .

In equilibrium condition, total system throughput, normalizing time to T_0 units, is defined as $S = \lambda T_0$.

Let λ_i is the number of packets/sec transmitted in steady-state on ith channel.

The throughput of the channel i is $S_i = \lambda_i T_i$ (normalized to T_i time units).

Now

$$\lambda = \sum_{i=1}^{M} \lambda_i \tag{2}$$

Hence

$$S = T_0 \sum_{i=1}^{M} \frac{S_i}{T_i} \tag{3}$$

Let the total traffic offered including the new and rescheduled packets γ packets/sec (Poisson distribution process)

Measuring time in T_0 units, the offered traffic is

$$G = \gamma T_0 \tag{4}$$

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If the sub-channels are randomly chosen, traffic offered to ith channel is Poisson with rate γP_i where P_i is the probability of choosing the channel i.

Now, for a single sub-channel i, the offered traffic measured in T_i time-units is

$$G_i = \gamma P_i T_i = \frac{G}{T_0} P_i T_i = G P_i \frac{W}{W_i} \tag{5}$$

And corresponding propagation delay normalized to T_i is

$$a_i = \frac{a_0 T_0}{T_i} \tag{6}$$

For a single sub-channel, the CSMA throughput from Tobagi's work [2] is

$$S_i = \frac{G_i e^{-a_i G_i}}{G_i(1+2a_i) + e^{-a_i G_i}} \tag{7}$$

In case of M equal channels

$$W_i = \frac{W}{M}; T_i = M T_0; a_i = \frac{a_0}{M}; P_i = \frac{1}{M} \tag{8}$$

From equation 3

$$\begin{aligned}
S &= T_0 \sum_{i=1}^{M} \frac{S_i}{T_i} \\
&= T_0 \sum_{i=1}^{M} \frac{1}{T_i} \frac{G P_i \frac{T_i}{T_0} e^{-\frac{a_0}{M}\frac{GWP_i}{W_i}}}{\frac{GWP_i}{W_i}(1+\frac{2a_0}{M}) + e^{-\frac{a_0}{M}\frac{GP_iW}{W_i}}} \\
&= G \sum_{i=1}^{M} \frac{P_i e^{-\frac{a_0}{M} G \frac{1}{M} M}}{G \frac{1}{M} M (1+\frac{2a_0}{M}) + e^{-\frac{a_0}{M} G}} \\
&= G \frac{M \frac{1}{M} e^{-\frac{a_0}{M} G}}{G(1+\frac{2a_0}{M}) + e^{-\frac{a_0 G}{M}}} \\
&= \frac{G e^{-\frac{a_0 G}{M}}}{G(1+\frac{2a_0}{M}) + e^{-\frac{a_0 G}{M}}}
\end{aligned}$$

References

[1] M. A. Marsan and D. Foffinella, "Multichannel local area network protocols", *IEEE Journal on selected areas in communications*, vol. 1, no. 5, pp. 885–897, Nov. 1983.

[2] L. Kleinrock F.A. Tobagi, “Packet switching in radio channels: Part i”, *IEEE Trans on Comm*, vol. 23, 1975.