A Dynamic Threshold Selection Policy for Retransmission in MAC Layer Multicast *

Prasanna Chaporkar
ESE, University of Pennsylvania
Philadelphia, PA 19104
prasanna@seas.upenn.edu

Saswati Sarkar
ESE, University of Pennsylvania
Philadelphia, PA 19104
swati@ee.upenn.edu

1 Dynamic Threshold Transmission Policy

At the MAC layer, a transmission can be intercepted by all the nodes in the transmission range of the sender. Though this broadcast nature of wireless transmissions can potentially improve the efficiency of multicast, it also introduces critical challenges. The multicast specific challenge is that *some* but *not all* the receivers may be ready to receive, due to the interference caused by transmissions in their neighborhood. The readiness state of a receiver depends on the network load. If the sender transmits only when all the receivers are ready, then the system may become unstable. If the sender, however, transmits when only a few receivers are ready, then the packet will be lost at the receivers that were not ready; this leads to high loss. We have shown that the multicast nature of transmissions change the fundamental relations between QoS parameters like throughput, stability and loss, e.g., a strategy that maximizes the throughput does not necessarily maximize the stability region or minimize the packet loss [2]. We have provided transmission strategies that maximize throughput subject to stability and loss constraints [2]. In [2], we have assumed that the packet can be transmitted only once at the MAC layer. A sender may, however, achieve a higher throughput by transmitting a packet several times till most of the receivers receive the packet. But additional transmissions increase the power consumption and the network load; this imposes a limit on the number of such transmissions.

We consider a multicast session with a single source and G receivers. *We address the problem of minimizing the expected time for delivering a packet to at least Z receivers, while transmitting the packet at most K times.* Note that the parameters K and Z are determined by the power and loss constraints respectively. We assume that a receiver is ready with probability p in each slot.

The following example demonstrates that multiple transmissions may increase the throughput. Assume that the sender always has a packet to transmit. Also, every packet must be delivered to all the receivers. Let $G = 2$ and $p = 0.5$. The maximum throughput without retransmissions ($K = 1$) is $\frac{1}{2}$, and with retransmission ($K = 2$) is $\frac{2}{3}$. We propose in Figure 1 a strategy, denoted as the *Dynamic Threshold Policy (DTP)*, to achieve the above mentioned optimization objective.

*This research was supported in part by NSF grants ANI01-06984 and NCR02-38340.

Procedure Dynamic_Threshold_Policy(K, Z)
begin

Initialize the system state $(k, z) = (0, 0)$.
while $(z < Z)$ **do**
Select a threshold $T(k, z)$ in state (k, z) as per the dynamic program in Figure 2.
Transmit when the number of ready receivers (say r) that have not received the packet before is at least $T(k, z)$.
Update the system state after transmission as follows.
$k = k + 1$ and $z = z + r$.

end

Figure 1: Pseudo code for the *DTP*.

Procedure DP_for_Retransmission_Thresholds(K, Z)
begin

$\mathcal{S}(k, z) \equiv$ the minimum expected time to deliver a packet to at least Z receivers from state (k, z).
$T(k, z) \equiv$ the threshold selected in state (k, z).
$P_{t,u}(k, z) \equiv$ the probability of delivering the packet to u receivers that have not already received the packet, when threshold is t and the system state is (k, z).
$s_t(k, z) \equiv$ the expected time to transmit when threshold is t and the system state is (k, z).

For every $z \in \{1, 2, \ldots, G\}$
$\mathcal{S}(K-1, z) = s_{Z-z}(K-1, z)$ if $z < Z$ and 0 o.w.
$T(K-1, z) = Z - z$ if $z < Z$;
for $(k = K - 2$ to $1)$ **do**
for $(z = 1$ to $Z)$ **do**
$\mathcal{S}(k, z) = \min_{0 \leq t \leq Z-z} \left\{ s_t(k, z) + \sum_{u=t}^{G-z} P_{t,u}(k, z)\mathcal{S}(k+1, z+u) \right\}$,
$T(k, z) = \arg\min_{0 \leq t \leq Z-z} \left\{ s_t(k, z) + \sum_{u=t}^{G-z} P_{t,u}(k, z)\mathcal{S}(k+1, z+u) \right\}$
$\mathcal{S}(0, 0) = \min_{0 \leq t \leq Z} \left\{ s_t(0, 0) + \sum_{u=t}^{G} P_{t,u}(0, 0)\mathcal{S}(1, u) \right\}$;
$T(0, 0) = \arg\min_{0 \leq t \leq Z} \left\{ s_t(0, 0) + \sum_{u=t}^{G} P_{t,u}(0, 0)\mathcal{S}(1, u) \right\}$;

end

Figure 2: Pseudo code for the dynamic program that computes the thresholds used in the DTP.

System state is a tuple (k, z), where k is the number of times the packet has been transmitted and z is the number of receivers that have received the packet.

Theorem 1 *The dynamic threshold policy minimizes the expected time for delivering a packet to Z or more receivers while transmitting the packet at most K times. The quantity $\mathcal{S}(0, 0)$ is the minimum expected time.*

Refer to [1] for the proof of Theorem 1. The computational complexity of the dynamic program to compute the thresholds used in DTP is $O(KZ^2)$. Once the threshold values are computed, every step of DTP has $O(1)$ complexity.

References

[1] P. Chaporkar and S. Sarkar. DTP: A transmission policy for efficient MAC layer multicast. Tech report, Univ. of Pennsylvania, http://www.seas.upenn.edu/~swati, 2003.

[2] P. Chaporkar and S. Sarkar. Stochastic control techniques for throughput optimal wireless multicast. *Proceedings of CDC'03*, Maui, Hawaii, USA, 2003.