Delay Optimal Design of Wireless Medium Access Protocol

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ABSTRACT

The delay optimal design of the wireless medium access protocol is one of important issues in wireless networks. To this end, we consider a simple Medium Access Control (MAC) protocol, called the renewal access protocol (RAP), that is recently proposed as a substitute of the IEEE 802.11 distributed coordination function (DCF) which is a dominant MAC protocol in today's Wireless Local Area Networks (WLANs). It is shown that the RAP provides optimal throughput and high short term fairness.

In this work, we focus on the delay optimal design of the RAP. Noting that the delay performance of the RAP strongly depends on the selection distribution, we formulate and analyze an optimization problem to obtain a delay optimal selection distribution. We also investigate the performance of the RAP with the delay optimal selection distribution.

RENEWAL ACCESS PROTOCOL

The renewal access protocol (RAP) is a simplified version of the IEEE 802.11 DCF in the sense that it has only one parameter, called the backoff counter [1]. In the RAP, each terminal transmits its packet whenever its backoff counter becomes zero as the same manner in the IEEE 802.11 DCF. After a packet transmission, the transmitting terminal selects a new backoff counter value from a *fixed* sized window according to *a priori* given selection distribution *regardless of the packet transmission result*. The backoff counter value in the RAP is decremented by one every time slot where there is no packet transmission in the network, but is frozen during a packet transmission time in the network, if any. We consider the RTS/CTS mode in this paper, but the analysis for the basic access mode is the same if some parameter values are suitably adjusted. The transmission of data packets, ACK packets, and RTS/CTS packets in the RAP is exactly the same as that in the IEEE 802.11 DCF. Note that the delay performance of the RAP strongly depends on the selection distribution.

DELAY OPTIMAL DESIGN

We assume that each terminal has a buffer to accommodate its packets at the MAC layer. Let $A(t)$ denote the number of packets newly generated at the tagged terminal during $[0, t]$. We assume that $A(0) = 0$ and that $A(t)$ has stationary increments.

Let $C(t)$ be the *cumulative* packet service process during the interval $[0, t)$ at the tagged terminal, and $Q(t)$ denote the number of packets in the queue of the tagged terminal at time t

with $Q(0) = 0$ and $Q(t) \geq 0$ for all $t \geq 0$. Then the queueing process $\{Q(t).t \geq 0\}$ satisfies

$$Q(t) = \sup_{0 \leq s \leq t} \{A(t) - A(s) - (C(t) - C(s))\}.$$

With the above queueing process we formulate the following optimization problem to obtain the delay optimal selection distribution. For each $\eta > 0$,

$$\begin{aligned} \text{minimize} \quad & \textstyle\sum_{k=1}^{M} e^{\eta k} p_k. \\ \text{subject to} \quad & \textstyle\sum_{k=1}^{M} k p_k = K + p, \\ & \textstyle\sum_{k=1}^{M} p_k = 1, \\ & -p_i \leq 0, \ 1 \leq i \leq M. \end{aligned}$$

where K and p are values related with the expectation of the selection distribution and $\{p_k, 1 \leq k \leq M\}$ are the probability mass function of the selection distribution of the RAP. By solving the optimization problem, we obtain the delay optimal selection distribution. With the delay optimal selection distribution we investigate its performance.

REFERENCES

1. Kim, Y., and Hwang, G., "Design and Analysis of Medium Access Protocol: Throughput and Short-term Fairness Perspective." accepted for publication in *IEEE/ACM Transactions on Networking*, March 2014, available at *http://queue.kaist.ac.kr/∼guhwang*.