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DISCRETE-TIME PRIORITY QUEUES WITH PARTIAL INTERFERENCE[1]

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ABSTRACT

A class of discrete time priority queueing systems with partial interference is considered. Packet-radio communication networks that use a certain mode of operation fall into this class. In these systems N nodes share a common channel to transmit their packets. One node uses a random access scheme while other nodes access the channel according to their preassigned priorities. Packet arrivals are modeled as discrete-time batch processes, and packets are forwarded through the network according to fixed prescribed probabilities.

Steady-state analysis of the class of systems under consideration is provided. In particular, we present a recursive method for the derivation of the joint generating function of the queue lengths distribution at the nodes in steady-state. The condition for steady-state is also derived. A simple example demonstrates the general analysis and provides some insights into the behavior of systems with partial interference.

1. INTRODUCTION

The survey paper by Kobayashi and Konheim [1] discusses many models of discrete-time queueing systems. Such systems have been receiving increased attention in recent years [2-4] due to their usefulness in modeling and analyzing various types of communication systems. Packet-switched communication networks with point-to-point links between the nodes, where data packets are of a fixed length, motivated most of these models. The models in [2-4] are of tandem nature since in point-to-point networks the transport of a packet from its source to its destination involves the transmission of the packet over a succession of links. The fixed packet length assumption induces the discrete-time nature of the models.

In this paper we consider a class of discrete-time priority queueing systems with partial interference. Consideration of these systems have been primarily motivated by the class of packet-switched communication networks called the multi-access/broadcast networks, or packet-radio networks. In these communication networks all nodes share a common channel through which they transmit their packets and from which they extract packets destined to them, hence the multi-access nature of these networks. In addition, when a node transmits a packet through the shared channel, all nodes that are within its transmission range hear this transmission, thus inducing the broadcast nature of the system.

We assume that the channel time axis is slotted into intervals of size equal to the transmission time of a packet. All packets are assumed to be of fixed and equal size. The nodes are synchronized so that they may start transmission of a packet only at the beginning of a slot, hence the discrete-time nature of the system. All nodes are assumed to have *infinite* buffers.

One of the most crucial issues in multi-access networks is the protocol required to transmit packets on a shared channel in a distributed environment. For a survey of multi-access protocols the reader is referred to [5]. The design and analysis of multi-access protocols is not trivial. This is due to the following two facts that hold for packet-radio networks: (i) If two or more nodes transmit packets during the same slot to the same node, then the overlap in transmission destroys all packets involved in the transmission; (ii) A transmitting node is unable to receive packets transmitted by other nodes of the system. These two facts together with the broadcast nature of the network give rise to statistical dependence between the queues at the nodes of the network. In most cases this dependence is rather complicated and therefore, there is little hope to obtain analytical results for general multi-access protocols and for general network configurations. The purpose of this paper is to analyze a rather general network configuration with a specific mode of operation.

One mode of operation that can be accomplished in multi-access networks is a conflict-free mode. This can be achieved if every node knows perfectly which are the nodes that have packets ready for transmission at the beginning of each slot. This is possible in systems that have a central scheduler that schedules the transmissions according to information it receives from the nodes, or in systems where the nodes exchange this information between themselves [6]. Generally, any order of transmission can be used, in particular, priority can be easily implemented. Yet, if there are some nodes that cannot exchange information with the scheduler or with other nodes, on which nodes have packets ready for transmission, then their transmissions cannot be accommodated in a conflict-free mode of operation and they should use some random access scheme [5].

The class of discrete-time queueing systems that we consider in this paper consists of systems having $N-1$ nodes that access the channel in a conflict-free mode according to fixed priorities that are preassigned to them. No two nodes have the same priority and a given node is allowed to use the channel in a given slot only if it has a packet ready for transmission and all nodes with higher priority have empty queues. In addition, there is an extra node in the system that cannot be accommodated in the conflict-free mode of operation and therefore is allowed to use the channel in any slot on a random basis. If the node uses the channel along with any other node then their packets are destroyed and must be retransmitted, hence the interfering feature of the systems under consideration.

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