

# Buffer Behavior under Dependent Packet Arrival Processes with Guaranteed Idle Epochs

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## Abstract

A discrete-time queueing system is considered in this paper. It consists of a buffer for the temporary storage of packets delivered by  $N$  fixed speed, slotted transmission lines, before they are forwarded to a fixed speed, slotted output line. The length of the output slot is assumed to be equal to one, which is the time required for the transmission of a single packet through the output line. The output slot boundaries define a discrete time axis,  $J$ , describing all potential arrival and departure instants. Let  $\tau_k \in \mathbb{Z}^+$  ( $\mathbb{Z}^+$  is the set of the positive integers),  $1 \leq k \leq N$ , be the length of the slot of the  $k^{\text{th}}$  input line. Arrivals through the  $k^{\text{th}}$  input line are declared at the boundaries of the corresponding slots, which are assumed to coincide with some instant in  $J$ . Let  $c_k \in \{0, 2, \dots, \tau_k - 1\}$  be the shifting of the first potential packet arrival instant with respect to instant  $j=0$ . Notice that for  $\tau_k > 1$ , the corresponding arrival process is guaranteed to deliver no packets at certain, well defined instants. These guaranteed idle time instants associated with the  $k^{\text{th}}$  input process with parameters  $(c_k, \tau_k)$  are given by the set  $I_k = \{j \geq 0 : (j - c_k)/\tau_k \text{ is not an integer}\}$ .

Let  $s_k$  denote the mechanism which generates the packets delivered through the  $k^{\text{th}}$  input line. When  $\tau_k > 1$ , the resulting packet traffic, described on axis  $J$ , presents memory, even if  $s_k$  is a memoryless mechanism. The resulting process delivers no packet with probability one over the time instants  $j \in I_k$  and delivers packets with some probability  $p_k$  over any other time instant. When  $s_k$  has memory (Markovian source) and  $\tau_k > 1$ , then the resulting packet process, as described on axis  $J$ , becomes more complicated. Arrivals over consecutive instants not contained in  $I_k$  maintain the memory as introduced by  $s_k$ ; no packets are delivered at time instants  $j \in I_k$ . When  $\tau_k$  is large, the amount of memory in  $s_k$  as seen from the buffer is small, in the sense that its effect on the intensity of the queueing problems in the buffer is small. When, in addition, a large number of independent input lines are multiplexed, then further reduction in the memory, as seen from the buffer, is expected. As a result, when  $\tau_k$ ,  $1 \leq k \leq N$ , and  $N$  have large values, an independent per output slot approximation on the cumulative packet arrival process is expected to perform satisfactorily. When  $\tau_k$ ,  $1 \leq k \leq N$ , and  $N$  have small values, such approximations are expected to fail to produce accurate results.

The behavior of a single buffer fed by arrival processes described as above has been analyzed. For a system with Markovian sources and small values of  $N$  and  $\tau_k$ ,  $1 \leq k \leq N$ , the results show that the induced packet delay differs significantly from that obtained under independent per input or output slot packet arrival processes. The results are also different from those obtained under arrival processes which maintain the full amount of memory, as introduced by the Markovian source; the latter is mostly due to the reduction of the intensity of the queueing problems caused by the guaranteed idle instants in the resulting packet process.