An Approximate Analysis of a Shared Buffer ATM Switch with a Single Hot-spot under Heterogeneous Bursty Input Traffic

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Abstract

Many ATM switch architectures have been proposed in the literature, and they vary significantly in terms of hardware complexity and performance potential. The buffering strategy is a crucial factor in this trade-off. In general, the complete sharing scheme provides a lower cell loss probability than the complete partitioning scheme by using the buffer space more efficiently. But, the major performance drawback of shared buffering arises in the area of fairness. The statistical sharing of the buffer space introduces the possibility of a small group of output ports hogging the buffer space to the detriment of ports supporting more well-behaved connections. Especially, these performance degradations are deepened when the unbalanced traffic patterns such as hot-spot traffic are considered.

This paper describes an approach to the analysis of an ATM switch with complete sharing scheme and a single hot-spot destination port. We first propose an efficient aggregation algorithm for superposing all the input processes to the switch. Then, an approximation method is provided for analyzing the switch performances such as cell loss probability. In this analysis, the buffer space of the switching system is decomposed into two parts, one for the address queue dedicated to the hot-spot and the other for remaining address queues loaded with balanced traffic. This approach is similar to that of [Hong, et al.;1993]. But, the authors of the previous study did not provide a systematic algorithm for superposing all the input processes to the switch. And, our approximation method seems to be more efficient than the maximum entropy method proposed in [Hong, et al.;1993], in a sense that our method does not require nonlinear equations to be solved or

any convergence criteria. Regarding the starvation effect of buffer hogging, some traffic control strategies including random access, priority access, and cell dropping are compared in terms of cell loss probability. Numerical examples of the proposed method are given, which are compared with simulation results.

We model the shared buffer non-blocking ATM switch with N input ports and d output ports by a discrete-time queueing system. The shared buffer size of the switch is M. Also, the possible number of cells in each virtual address queue dedicated to each output port is limited to M. The speed of each output port is deterministic, one cell per time slot, and equals to the speed of each input port. In a time slot, services for existing cells in each virtual address queue are processed at the beginning of the time slot, and then, the arriving cells at each input port are stored in the shared buffer. A cell will be lost if it arrives to find the shared buffer full.

Each independent cell arrival process at an input port is assumed to be bursty and modeled by an IBP (Interrupted Bernoulli Process). An input port in a time slot takes either ON state or OFF state. When the input port is in ON state at a time slot, one cell is generated with probability 1. When it is in OFF state, no cells are generated. Suppose that an input port i is in ON (or OFF) state at a time slot t. Then, at the next time slot t+1, it will move to OFF (or ON) state with probability α_i (or β_i), or it will remain in ON (or OFF) state with probability $1-\alpha_i$ (or $1-\beta_i$).

The probability that a cell arriving at an input port i is routed to the output port j is denoted by p_{ij}. We assume that every cell has the same branching probabilities regardless of the input port at which it arrived; i.e., $p_{ij}=p_j$ for i = 1,...,N such that $\sum_{j=1}^{d} p_j=1$, and that there exists a single hot-spot in a switch network. Let h be a ratio of hot-spot traffic to an input load. The rest of traffic will be routed to d output ports uniformly. Without loss of generality, we assume that the output port 1 is the hot-spot. The branching probabilities can be set as follows; p_1 = h + (1-h)/d and p_j = (1-h)/d for j = 2,...,d.

A Marcov chain with N dimensions and 2^N states is required to model the joint arrival process to the switch. To reduce the size of state space, we propose an input process aggregation algorithm. This algorithm consists of iterative procedures dealing with one individual arrival process in each iteration step. We first construct a 2-dimensional Marcov chain by considering the partially aggregated arrival process and one additive individual arrival process, and then, it is transformed to a 1-dimensional Marcov chain. Repeating these procedures until all N individual arrival processes are aggregated, we can obtain a single aggregated arrival process. The complexity of this algorithm is $O(N^3)$, and the reduced numbers of dimensions and states of a Marcov chain representing the aggregated arrival process to the switch are 1 and N+1, respectively. In the research performed on an ATM multiplexer level, it was observed that the approximate results using the previous concepts had a good accuracy. Specifically, the accuracy seems to be affected by the variability in the squared coefficient of variation of the cell interarrival time at each input port.

We analyze the queueing system by decomposing the buffer space into two parts, one for the address queue dedicated to the hot-spot; i.e., the 1-st address queue, and the other for remaining address queues loaded with balanced traffic, which is denoted by the symbol RAQ. For calculating the steady-state probability distribution of the queueing system under consideration, we must know the number of cells that depart from RAQ at a time slot. It depends on the number of non-empty queues in RAQ at the beginning of that time slot. Because each address queue in RAQ is loaded with balanced traffic, the probability that an arbitrary existing cell in RAQ belongs to the j-th address queue is expected to be 1/(d-1) for j = 2,...,d. By using this notion, we can develop a recursive algorithm for estimating Pr{D(n)=k} where D(n) is defined as the number of non-empty queues in RAQ at the beginning of the next time slot, given that there are n cells in RAQ at the end of an arbitrary time slot.

To eliminate the starvation effect of buffer hogging, we propose two traffic control strategies. One is the priority access strategy, the other is the cell dropping strategy. Under the priority access strategy, we assume that the priority of the traffic destined to RAQ is higher than that of hot-spot traffic to access the finite capacity buffer. And, under the cell dropping strategy, if a number of arriving cells to a full shared buffer are destined to the hot-spot, those cells are dropped. However, if they are to be placed in a number of address queues in RAQ, some cells at the end of the address queue dedicated to the hot-spot are dropped to make rooms for the new arrivals. Both the two policies behave identically with the random access strategy when the shared buffer is not full.

From the obtained steady-state probabilities, some performance measures such as cell loss probability can be derived. Comparisons with simulation data show that the approximate results have a good accuracy. We also observed that the performance of the switching system deteriorates as the degree of traffic unbalance gets higher, and that these performance degradations can be reduced by employing some traffic control policies such as priority access strategy or cell dropping strategy.