MAP/SM/1/b Model of Packet Buffer

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***Abstract*—In some implementations, packet buffers are limited to a fixed number of packets regardless their lengths. Service times in a queuing model of such implementation are proportional to the packet lengths. Since packet lengths are not independent, the traditional queuing models assuming independence of service times are not suitable for such implementations.**

The new queuing model for such types of packet buffers is proposed. The buffer is described as a finite FIFO queuing system with a Markovian Arrival Process (MAP) and semi-Markov (SM) service times. The new analytical results for the loss ratio, the local loss intensity or the total number of losses are developed. All results are suitable either for a transient or a stationary analysis.

I. INTRODUCTION

In the commonly used models the router interface is just a piece of memory drained at constant rate C bytes per second. This simple model is correct for some types of interfaces but not for all. In some types of devices (e.g Cisco ISR routers) the buffer can hold not more than a fixed number of packets regardless their lengths [1]. In [1] this type of a buffer was proposed to be called *packet oriented* and a standard buffer *byte oriented*.

For a packet oriented buffer, packet service is completed when an entire packet is removed from the queue. While for the byte oriented buffer only some part of a packet is removed upon service completion. This is the main problem with the real devices. Namely they have packet oriented buffers which are drained at the constant rate in bytes per second not packet per second. Since the packet is removed from the buffer(in store and forward packet oriented buffers) after it has been sent to the destination, the time required to complete this operation depends on the actual packet length. Thus the service process model has to reflect all the statistical properties of packet lengths, including their correlation.

IP network traffic has a rich correlation structure. Packet interarrival times are highly autocorrelated [2]. Similar behavior was observed for the packet lengths [3]. Finally, the packet lengths can be correlated with the interarrival times [4]. All these correlations will considerably affect the accuracy of any switching device model.

Among many attempts to model the correlation structure of IP traffic in respect to its queuing, the Markovian models have been proved to be a powerful tool. Despite the fact they can not accurately model selfsimilar and long range dependent behavior over all time scales, they can approximate them up to an arbitrary time scale, which often is enough. However, what is more important, in most cases Markovian traffic models lead to analytically solvable queuing models.

The most flexible traffic model from the Markov family is the Batch Markovian Arrival Process (BMAP). It can handle packet lengths and all the correlations observed in real traffic. It is also possible to construct an analytically solvable queue model with BMAP at the input [5], [6]. However, all of the models implicitly assume that buffers are byte oriented. According to the best authors' knowledge a model of a finite packet oriented buffer fed by the BMAP does not exist. This is not surprising because this model would be really complicated. However, if we assume packet lengths being independent of interarrival times the model gets simplified because the autocorrelation of packet lengths can be represented by the service time autocorrelation in the semi-Markov (SM) service process and the arrival process is reduced to the MAP process while retaining the interarrival times autocorrelation. Under this assumption the existing results for a general system $MAP/G/1/b$ can be generalized for much more complicated system $MAP/SM/1/b$ which happens to be a good model of a packet oriented router interface [7]. This generalization leads to the new analytical results for the loss ratio, the local loss intensity and the total number of losses in given time [7].

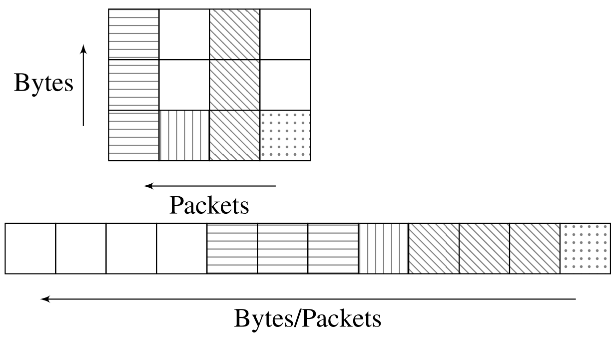

Fig. 1: Difference between packet (top) and byte (bottom) oriented buffers. Service times are represented by the columns so packet oriented buffer requires variable and correlated service times.

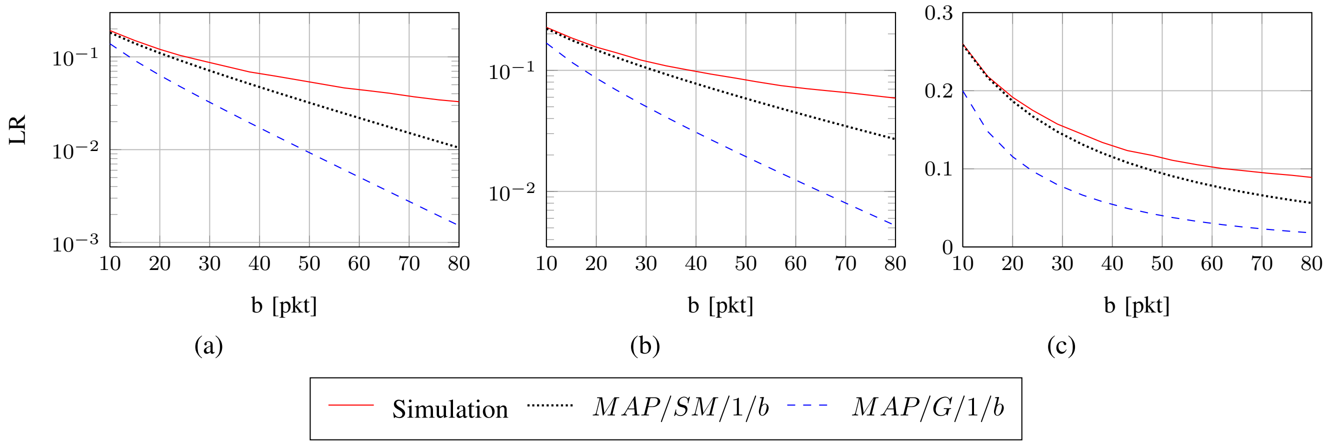

Fig. 2: Stationary packet loss ratio versus the buffer size for $\rho = 0.7$ (a), $\rho = 0.8$ (b) and $\rho = 0.9$ (c).

II. Approach

The model of a byte oriented queue fed by the BMAP is pretty simple. Since a memory block (e.g 1 B) is a job, and the link drains the buffer with constant number of bytes per unit time, the service time (time to send a single byte or other memory unit) is constant. In this model the interface is similar to the bucket leaking a fluid. The model can be written as $BMAP/G/1/b$ in Kendall's notation, where b is the total amount of memory.

The model gets complicated when the buffer is packet oriented. The queue is still drained with a constat number of bytes per unit time, however a single byte can no longer be identified as a job. Now the entire packet is a job and there is no need for a batch arrival (see Fig. 1), therefore BMAP is reduced to MAP i.e. the information about packet sizes is removed from the input process. However, this information can be transferred to the service process in a system $MAP/SM/1/b$. This can be visualized in Fig. 1 as a *transformation of batch byte arrival to batch byte removals*.

The semi-Markov process was used for model of service times because of two properties. First it has memory (autocorrelion) and the memory cames from Markov chain. Thus it can be easily combined with Markovian input. Second, generally distributed sojourn times of SM can represent service time of general distribution.

III. Evaluation

The proposed model was evaluated by comparing stationary packet loss ratio predicted by the model and observed in real trace drive simulations. The results for different utilizations are presented in Fig. 2 where the prediction of the model with independent service times is also presented. Poor accuracy of models with independent service times for large buffers indicate the need for models with correlated service times, especially for some modern devices since they have buffers larger than 128 packets [1]. The accuracy of the new model also decreases with growing buffer size, but this is due to inaccurate MAP estimator for large time scales. Better estimation procedure would increase accuracy.

The model presented in [7] is not limited to stationary analysis. All results are suitable either for a transient or a stationary analysis and it is possible to extend them beyond the loss process.

IV. Conclusion

Correct modeling of some implementations of packet buffers require autocorrelated service times in queuing models. For this purpose the existing analytical results for loos process in queues with independent service times were generalized to the case of correlated service times. The future work is to use the same approach for other queuing characteristics such as time to buffer overflow.

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