Traffic Characterization for Class of Service Packets with Optical Based Packet Switches

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INTRODUCTION

Local area networks traffic and Internet traffic have been analyzed for the last 25 years to obtain accurate characteristics that will be used in traffic models. Traditionally, traffic sources were simulated using a Poisson process model, that had the advantage of being easily generated. But as real traffic has been studied, it has been shown that real traffic properties differ from Poisson traffic properties. When designing new communication systems, different alternatives have to be compared with respect to performance, as a first step. In particular when no implementations is available, modeling is often the only way to evaluate quantitatively the alternatives. Besides a model for the system operation, there is a need for traffic models describing the characteristics of the load of the system resource.

Current Internet backbones require high−capacity transport networks as well as high−capacity packet routers in order to properly handle large amounts of traffic fluxes and the optical technology is taking a significant role to achieve this objective. Fiber transport capacities have reached the terabit per second range thanks to wavelength multiplexing techniques. To avoid capacity gaps with the Wavelength Division Multiplexing (WDM) transport network, packet routers need throughput capacities of the same order of magnitude [1]. On one hand, the introduction of optical functions provides the possibility of reaching high throughputs avoiding bottlenecks coming from the high electronic router complexities. On the other hand, all optical routers match the packet routing and WDM network capabilities in a single layer. Optical buffers have special characteristics with respect to conventional electronic buffers, and thus need a special analysis [2], as they take profit of the advances in optical technology to implement all optical routing and buffering functions. The complexity of the optical buffer is independent of the total buffer capacity and its performance highly depends on the internal delay line configuration.

In this paper we address the problem of finding a delay line configuration that minimizes the buffer complexity while maintaining the overall router performance. An optical buffer has been simulated with three traffic sources types, and in three different delay lines configurations. The traffic generators are completely characterized in terms of their packet inter−arrivals probability and their packet size distribution. These sources fill the optical buffer queues and the output traffic is then analyzed.

OPTICAL PACKETS BUFFERING

All optical routers need optical buffers to solve packet contentions. An all optical router with N input/output fiber ports is considered and the set of D transmission delay lines inside the optical router is called the optical buffer. A possible buffer configuration directly connects each subset of D/N delay lines to one output. The resulting all−optical router configuration is output buffered.

Figure 1 shows an output optical buffer made up with 5 fiber delay lines. The number of optical delay lines in the output buffer determines the number of incoming packets can be loaded simultaneously towards a required output. The length of the longest delay line determines the total output buffer capacity. Note that the number of parallel accesses determines the complexity of the optical buffer and it is independent of the optical buffer capacity, which is the longest delay line. No optical packet synchronizers are considered and all fibers only contain a single wavelength for shake of simplicity (no WDM).

Each fiber delay line in the subset can have an arbitrary length. Each delay line introduces a different time shift on the scheduled output time. Packets that contend simultaneously for the same output avoid collision using a different time shift path. Incoming packets are always routed to the shortest available delay lines. One delay line can accept an incoming packet when:

⑦ There is no other packet that is being loaded in the same delay line, and,

⑦ Packets loaded on other delay lines are not scheduled with the same output time.

The time shift model in Figure 1 summarizes all the available time shifts where incoming packets can be scheduled, one for each delay−line. According to this model, optical buffers with the same complexity (number of delay lines) can have different access distributions, i.e. different time shifting patterns. Figure 2 shows three possible configurations of an optical buffer, one with fixed steps, one with double fixed steps, and one with increasing step lengths.

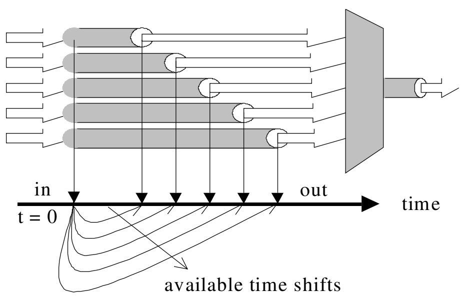
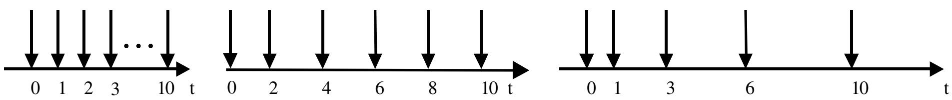


Figure 1: An optical buffer made up with 5 optical packets. The length of the longest delay line determines the total capacity of the optical buffer.

Figure2: Possible configurations of an optical buffer



TRAFFIC−DROP PRIORITY

When the number of incoming packets increases to the congestion point, some of theese packets will be lost. To determine which of them are going to be discarted, some traffic−drop priority settings have been defined. The traffic−drop priority scheme works as follows: if the network is not congested there is no difference in how the nodes treat each packet (e.g. no packet discard); and the packets are forwarded in the same order they are received. When congestion occurs best effort packets are discarded first, mitigating the congestion and leaving resources for the assured service packets. An example of how this strategy can be implemented is given in Figure 3.a. When a packet is received, the output port of the OPN node (and the associated queue) is determined. If the corresponding queue depth exceeds a given threshold T1 (congestion is imminent), best effort packets are discarded while assured packets are correctly sent into the queue.

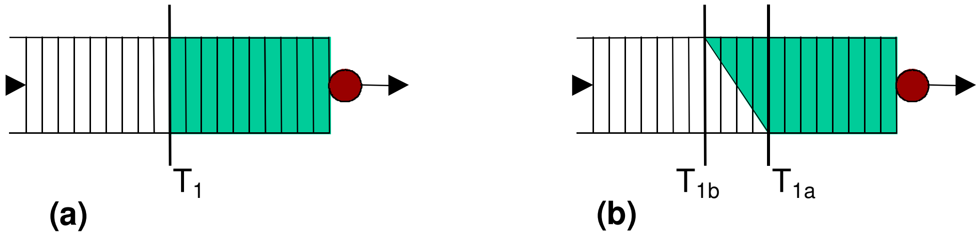


Figure 3: Output buffer with drop priority based on: (a) a threshold, (b) a RED policy.

This threshold mechanism can also be associated with a Random Early Discard (RED) strategy, providing a real advantage in the presence of optical packets carrying TCP/IP datagrams (Figure 3.b). When the buffer occupancy reaches the threshold T1a, the discard probability for a best effort packet begins to be more than zero and its value is increased to 1 when the buffer occupancy reaches the T1b value. In excess of this value only the assured quality packets can be buffered and all the best effort packets are discarded. It is worth noticing that in both cases (plain drop priority and RED) packets are discarded at the input of the OPN node: once packets have been entered the node, they undergo no scheduling modifications. This fits with the particular structure of optical buffers at OPN nodes, in which deleting a packet that has already entered the buffer is difficult and inadvisable.

TRAFFIC SOURCES

Three different types of traffic sources have been implemented [3] to feed the optical buffer. The first scheme is a synchronous and periodic source that is absolutely not realistic but can be very useful for the programmers to follow easily the packets inside the optical buffer, and to determine the accuracy of the implemented model. Another scheme implemented is a Poisson model for the packet arrivals, and even if it is not a realistic model for data network traffic, it has been used traditionally for traffic generation. A realistic model, based on the superposition of several Fractal Renewal Processes (FRP) is also implemented and characterized. For all the results presented in this paper, the latest model have been choosed.

Each packet is generated by the sources at a given time, according to the generation distribution selected, and with a given packet size. The packet sizes can be either fixed or with a distribution taken from real Ethernet traces.

TRAFFIC CHARACTERIZATION

Several simulations are carried out with different traffic sources and the traffic is characterized at the input sources and the output of the optical buffer. Results of the simulation using each generation model for the packet inter–arrivals and a packet size distribution from real Ethernet traces are presented in the following paragraphs. The generated traffic is analyzed. In the case of a Poisson process the mean and the variance of the traffic are related and correspond to the expectation defined by the number of packets per second generated. In the case of a self–similar (or fractal) process, a variable X is exactly self–similar with scaling parameter H (Hurst parameter), if for all levels of aggregation m,

$$X^{(m)} = m^{H-1} X$$

Where $X^{(m)}$ is the average of m consecutive values of the variable X.

The resulting linear log–log representation of $\mathbf{Var}(X^{(m)})$ versus m is called variance–time plot.

Intuitively, the critical characteristic of self–similar traffic is that there is no natural length of a "burst". At every time scale ranging from a few milliseconds to minutes and hours, similar–looking traffic bursts are evident. Aggregating streams of such traffic typically intensifies the self–similarity ("burstiness") instead of smoothing it.

The words fractal and self–similar must be read in this text as synonymous.

INPUT TRAFFIC TRACES

The figure 4 shows the incoming packets at the buffer input. The traffic generated to perform the simulations was obtained by the superposition of several Fractal Renewal Processes (FRP). The simulation time was 577 s., and the mean incoming bitrate was 5.1508 Mbit/s. In the figure the packets generations (carried out by 1 source) in the first 27ms (aprox.) of the simulation are represented.

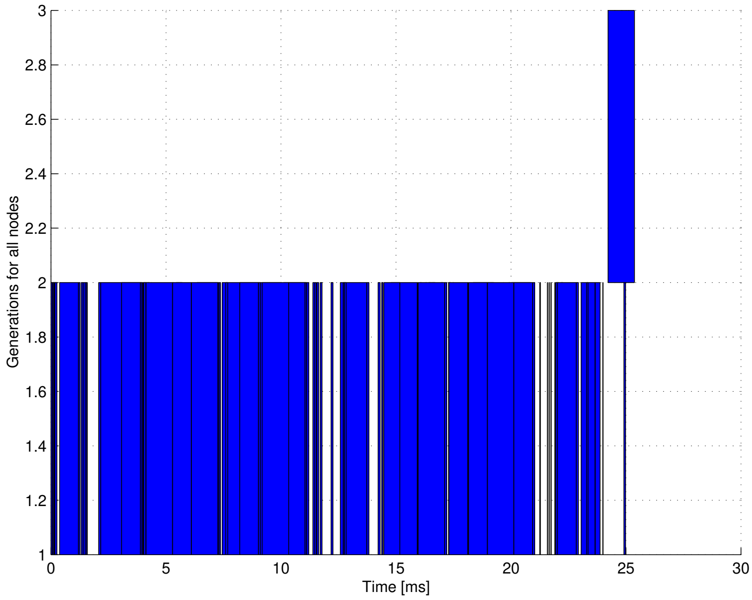


Figure 4: Visualize packets versus time (modulus 25 ms)

The characterization of the traffic generators in terms of their packet size distribution (figure 5) and their packet interarrivals probability (figure 6) is shown in the following graphics. In the simulations, the mean interarrival time for the sources was 0.5776 ms, with a mean packet size of 2.975 Kbits.

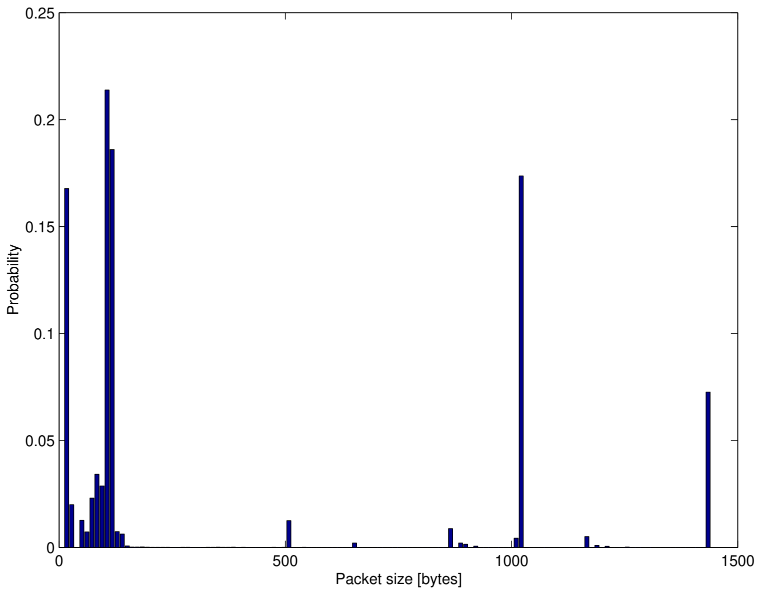


Figure 5: Probability of packet sizes

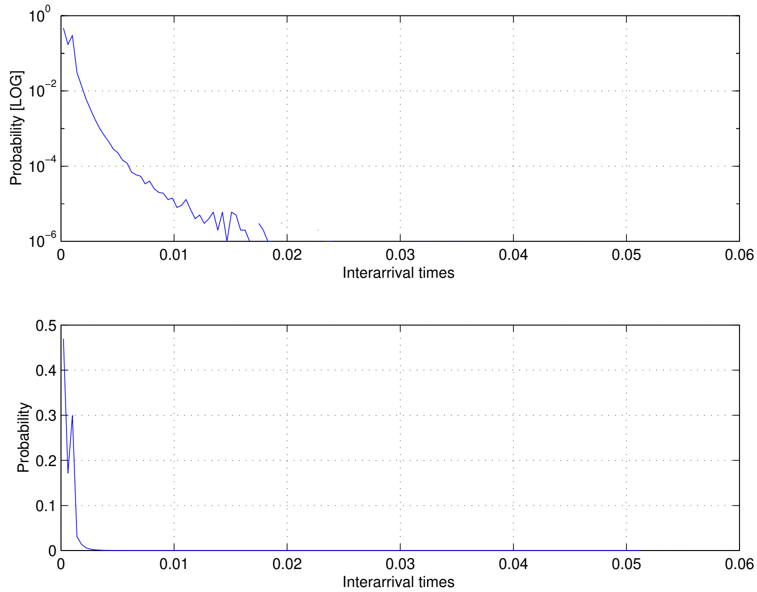


Figure 6: Probability of packet inter−arrivals with logarithmic and linear scales

The corresponding Variance−time plot is shown in the figure 7. The steep downward line to the left corresponds to the variance−time plot expected for Poisson traffic.

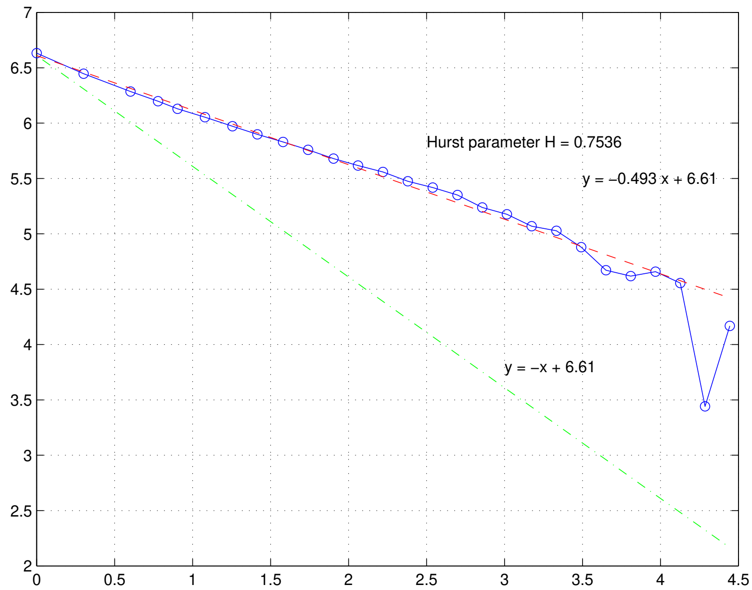


Figure 7: Variance−time plot of the traces. The steep downward line to the left corresponds to the variance−time plot expected for Poisson traffic

OUTPUT TRAFFIC TRACES

The caracterization of the output traffic at the buffer output is described in the following lines. To perform the simulations, the buffer was implemented with 5 delay lines, with delays going from 0.01s to 0.05s in steps of 0.01s. The discrimination criterium followed in case of congestion is described in the Traffic Drop Priority section, with 2 classes of service. The min−max size parameters were 4~5 for the first class, and 4~5 for the second one.

In the figure 8 we can see the visualization of the packets at the buffer output.

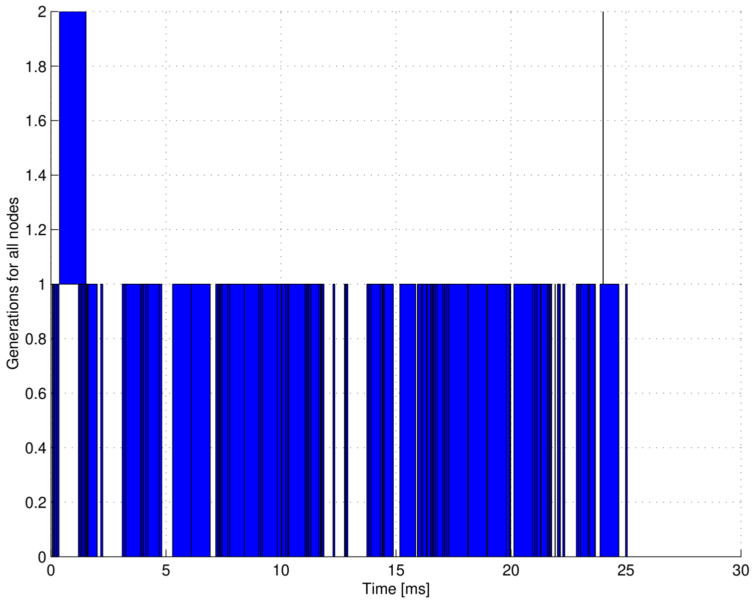


Figure 8:Visualize packets versus time (modulus 25 ms)

The characterization of the traffic generators in terms of their packet size distribution (figure 9) and their packet interarrivals probability (figure 10) is shown in the following graphics. In the simulations, the mean interarrival time for the sources and the mean packet size are almost the same of the values found at the input. The reason is that the traffic didn't arrive to the congestion point of this buffer, and the packet looses were minimal. Also the packet size distrubution was not so distorted by the buffer, since the discrimination (determinated by the packet size) had not notable effects.

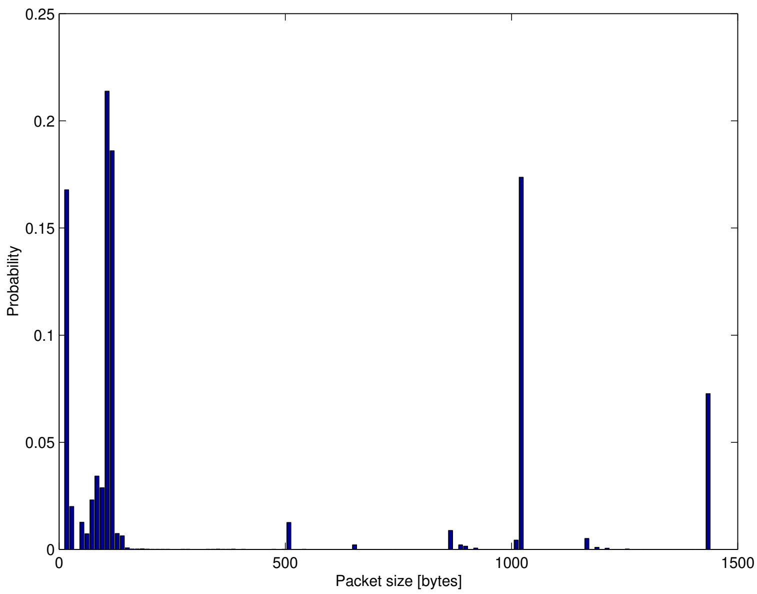


Figure 9: Probability of packet sizes

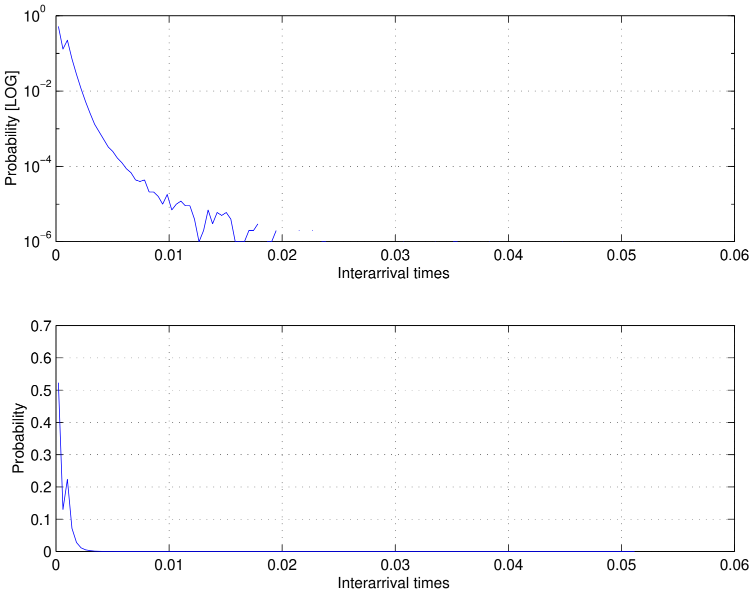


Figure 10: Probability of packet inter–arrivals with logarithmic and linear scales

The corresponding Variance–time plot for the output is shown in the figure 11.b. As we can see in this graphic, the similarity with the one at the input appears again.

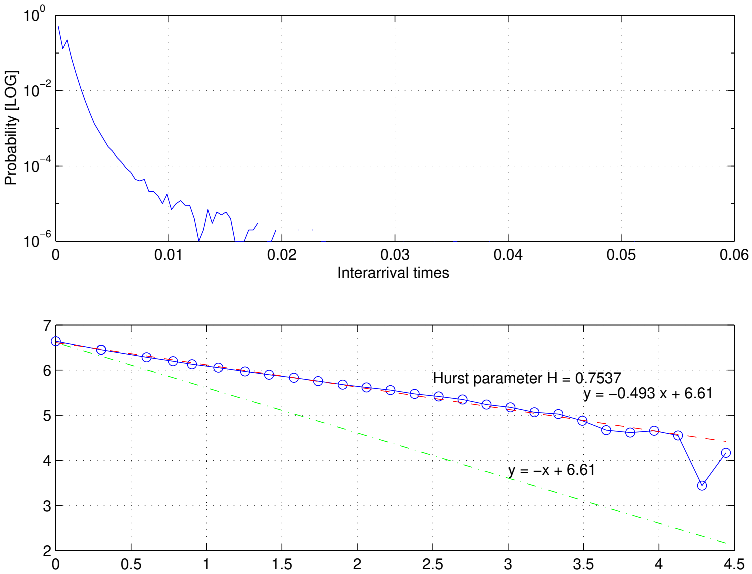


Figure 11: a)Probability of packet inter–arrivals with logarithmic scale. b)Variance–time plot of the traces. The steep downward line to the left corresponds to the variance–time plot expected for Poisson traffic.

CONCLUSIONS

A 5 delay line configuration has been presented in this work. An optical buffer has been simulated with three traffic sources types, with a 5 delay lines configuration. The results for the case of self–similar traffic have been shown.

The traffic generators are completely characterized in terms of their packet inter–arrivals probability and their packet size distribution. These sources fill the optical buffer queues and the output traffic has been analyzed.

In this case, the system has been evaluated in conditions of low traffic. Therefore the packet looses have not been notorious, and the statistical properties of the traffic at the output are very similar to the ones in the input. These properties would vary in case of traffic increase

The buffer delay lines have to be designed to be the optimum and a statistical study has to be carried out to find out the optimal values for these delay lines. A model of the optical for different Class of Services packets has to be created, and then exploited.

ACKNOWLEDGMENTS

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