Evaluation of Packet Loss Rate in Optical Burst Switching equipped with Optic Delay Lines Buffer

Hoang-Linh To, Dang-Quang Bui and Won-Joo Hwang
Dept. of Information and Communications Engineering, HSV-TRC, Inje University

Abstract

High packet loss rate and impatience of messages passing through optical switches are essential characteristics in Optical Burst Switching system equipped with Optic Delay Lines buffer, which have not been solved efficiently yet by current existing models. In order to capture both effects, this paper introduces an analytical model from the viewpoint of classical queuing theory with impatient customers. We then apply it to evaluate and compare two wavelength-sharing cases, (1) all delay lines share a common wavelength resource and (2) each wavelength is associated with a number of delay lines. Our numerical results suggest to implement the first case because of lower packet loss rate for a fairly broad range of traffic load.

1. Introduction

Optical Burst Switching (OBS) has been proposed to meet the fast increasing of Internet traffic. In OBS, contention issue often arises whenever two or more incoming optical bursts contend to the same output switch ports at the same time and leads to high packet loss rate [1]. This problem can be reduced by adding buffer at the output. Unlike electronic buffer case with random access memory (RAMs), optical RAMs are not feasible today. Instead, we can use Optic Delay Lines (ODLs) as alternative to resolve contention [2].

Another important characteristic in such systems is impatience of messages passing through ODLs. In queuing literature, an impatient customer is one who leaves the queue if not be served before a certain deadline [3]. Similarly, optical packets only wait in the ODLs for a specified period τ, otherwise auto-discard.

This paper presents a queuing model for OBS network equipped with ODLs buffer to capture both impatience of messages and high packet-loss rate characteristics in Section 2. We then use it to evaluate performance of two common sharing-wavelength cases which are different in the aspects of cost and implementation complexity in Section 3.

2. Mathematical model

a. Assumptions.

Our model is based on following assumptions, which are commonly used and accepted in the literature [3-5].

- Packet inter-arrival times and packet lengths are random variables, follow Poisson and exponentially distribution, with arrival rate λ and service rate μ, respectively (Fig.1).
- A finite number ODLs is denoted as d. An arriving packet which finds all service lines busy and ODLs occupied is considered lost.
- Each entering packet can wait in ODLs for a specified time τ for start service. If waiting time exceeds τ, the packet is also considered lost.
- Packets are served by First-In-First-Out (FIFO) discipline.

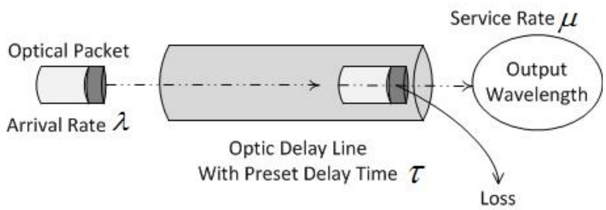

Fig.1. Operation model of OBS with ODLs buffer.

b. Queuing Model with Impatient Features.

Our approach here is to extend the classical queue model $M/M/s/k$ by adding impatient features: reneging and balking situation. We propose a Markov model through the following equations. This is a birth-death process type with state-transition diagram in Fig.2.

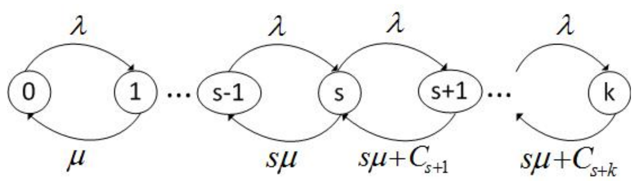

Fig.2. State-transition-diagram.

$\lambda_i = \lambda,\quad \text{for } 0 \le i \le k-1;$

$\mu_i = i\mu,\quad \text{for } 1 \le i \le s;$

$\mu_{s+i} = s\mu + C_{s+i},\quad \text{for } s+1 \le s+i \le k;$

$$C_{s+i} = \frac{\tau^{j-1}e^{-s\mu\tau}}{\int_0^\tau t^{i-1}e^{-s\mu t}dt},\quad (1)$$

where C_{s+i} is the long-run rate of reneging situation from state $s+i$.

Equation (1) is a reneging formula, which was first proposed by Barrer [4] and then verified by Rajabi [5]. Such a system assures ergodicity condition. Let p_k denote probability of system being at state k. Applying relation equations of p_k and p_0, we calculate probabilities for every state as below:

$$p_j = p_0\left(\frac{\lambda}{\mu}\right)^j \frac{1}{j!},\qquad 1 \le j \le s,$$

$$p_0 = \left(\sum_{j=0}^{s}\frac{\rho^j}{j!} + \frac{\rho^s}{s!}\sum_{j=1}^{k-s}\frac{\lambda^j}{\prod_{i=0}^{j-1}(s\mu + C_{s+j-i})}\right)^{-1},$$

$$p_{s+j} = p_0\left(\frac{\lambda}{\mu}\right)^s \frac{1}{s!}\frac{\lambda}{\prod_{i=0}^{j-1}(s\mu + C_{s+j-i})},\qquad \text{for } s \le s+j \le k,$$

where $\rho = \lambda/\mu$ is input traffic load to system.

Balking situation happens when packets find buffer is already full (at k^{th} state). Reneging happens when waiting time exceeds preset time period. Both situations lead to packet loss. Let L_B, L_R and L_T denote long-run rates of packet loss due to balking, reneging and total, respectively. We have $L_T = L_B + L_R$,where $L_B = \lambda p_k$ and $L_R = \sum_{j=1}^{k-s} C_{s+j}p_{s+j}$.

Let PLR denote the total packet loss rate. We have:

$$PLR = \frac{L_T}{\lambda} = p_k + \frac{\sum_{j=1}^{k-s} C_{s+j}p_{s+j}}{\lambda}.$$

3. Numerical result

Now, we use our model to evaluate performance of two sharing-wavelength cases. First, each output link can transfer up to s wavelengths and d delay lines are associated with the link, which can be modeled as $M/M/s/s+d$. In the other one, d delay lines are divided equally between s wavelengths, and form subsystems with d/s buffers, which can be interpreted as $M/M/1/(1+d/s)$. The first one results in complexity of scheduling and wavelength-sharing control algorithm, but a burst can choose any free wavelengths. On contrary, the second case results in a simpler and cheaper switches, however, it may not effectively utilize available resources of optical switches. Hereafter, we analyze both cases by simulating in Matlab.

Input parameters are same for both cases. Number of wavelengths $s = 4$, number of optic delay lines $d = 20$. Mean service rate of each wavelength $\mu = 1$ and preset delay of each ODLs $\tau = 0.5$(sec). Our numerical in Fig.3 shows the accuracy level of proposed model compared to simulation results. It also suggests us that case 1 with more free-wavelengths should be considered for implementation because of lower packet loss in a broad traffic-load range $\rho = 0.5$ to $\rho = 5$.

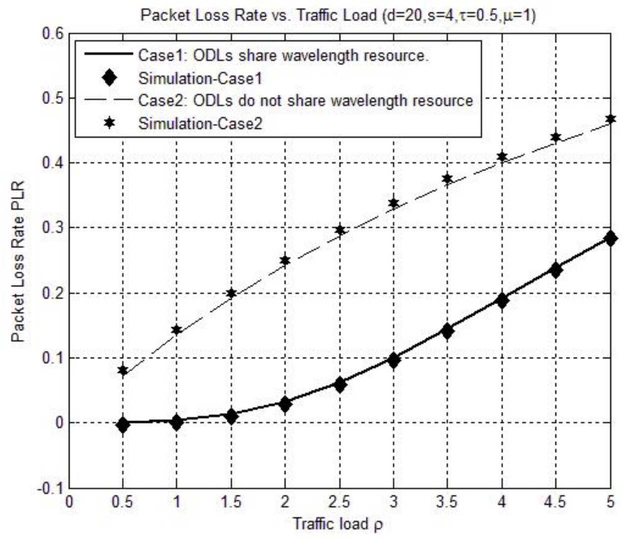

Fig.3. Packet loss rate vs. traffic load ($d = 20, s = 4, \mu = 1, \tau = 0.5$).

4. Conclusion

We have evaluated performance of OBS network using ODLs to resolve burst contention. Our model captures impatience of messages characteristic, which has not been met by existing models for delay lines. Future research should consider to minimize packet loss rate subject to a finite number of optic delay lines buffers.

References

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