Network Protocols and Algorithms
ISSN 1943-3581
2018, Vol. 10, No. 3

A Retrial Queueing model with FDL at OBS core node

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Received: July 27, 2018 Accepted: October 27, 2018 Published: October 31, 2018

DOI: 10.5296/npa.v10i3.13431 URL: https:// doi.org/10.5296/npa.v10i3.13431

Abstract

Optical Burst Switching networks are considered as an important candidate for the future transport networks. Many analysis models of OBS node with FDLs have been proposed recently. In this paper, we propose a novel retrial queueing model at OBS core node architecture SPL - feed-forward. Blocking probability will be calculated based on Markov multi-dimensional models. Numerical solution values from the proposed analysis method are compared with simulation, as well as between these models.

Keywords: OBS, Blocking probability, Complete Wavelength Conversion (CWC), Share-Per- Link (SPL), Fiber Delay Lines (FDL), feed-forward, Retrial Queueing.

1,2							2α		μ	$-\mu-\gamma-2\alpha$	γ	
2,2								2α		2μ	$-2\mu-\gamma-2\alpha$	γ
3.2								$2\alpha(1-\theta_1)$			3μ	$-3\mu-2\alpha(1-\theta_1)$

and

$$Q_1^{(1)}=\begin{pmatrix}-\gamma-\alpha & \gamma & 0 & 0\\ \mu & -\mu-\gamma-\alpha & \gamma & 0\\ 0 & 2\mu & -2\mu-\gamma-\alpha & \gamma\\ 0 & 0 & 3\mu & -3\mu-\gamma_d\theta-\alpha(1-\theta_1)\end{pmatrix},$$

$$Q_1^{(2)}=\begin{pmatrix}-\gamma-2\alpha & \gamma & 0 & 0\\ \mu & -\mu-\gamma-2\alpha & \gamma & 0\\ 0 & 2\mu & -2\mu-\gamma-2\alpha & \gamma\\ 0 & 0 & 3\mu & -3\mu-2\alpha(1-\theta_1)\end{pmatrix},$$

$$Q_0^{(0)}=Q_0^{(1)}=\begin{pmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&\gamma_d\theta\end{pmatrix}\ ,\ Q_2^{(1)}=\begin{pmatrix}0&\alpha&0&0\\0&0&\alpha&0\\0&0&0&\alpha\\0&0&0&\alpha(1-\theta_1)\end{pmatrix},$$

$$Q_2^{(2)}=\begin{pmatrix}0&2\alpha&0&0\\0&0&2\alpha&0\\0&0&0&2\alpha\\0&0&0&2\alpha(1-\theta_1)\end{pmatrix}$$

$$Q=\begin{pmatrix}
-\gamma & \gamma & & & 0 & & & & & & & \\
\mu & -\mu-\gamma & \gamma & & & 0 & & & & & & \\
 & 2\mu & -2\mu-\gamma & \gamma & & & 0 & & & & & \\
 & & 3\mu & -3\mu-\gamma_d\theta & & & & \gamma_d\theta & & & & \\
0 & \alpha & & & -\gamma-\alpha & \gamma & & & 0 & & & \\
 & 0 & \alpha & & \mu & -\mu-\gamma-\alpha & \gamma & & & 0 & & \\
 & & 0 & \alpha & & 2\mu & -2\mu-\gamma-\alpha & \gamma & & & 0 & \\
 & & & \alpha(1-\theta_1) & & & 3\mu & -3\mu-\gamma_d\theta-\alpha(1-\theta_1) & & & & \gamma_d\theta \\
 & & & & 0 & 2\alpha & & & -\gamma-2\alpha & \gamma & & \\
 & & & & & 0 & 2\alpha & & \mu & -\mu-\gamma-2\alpha & \gamma & \\
 & & & & & & 0 & 2\alpha & & 2\mu & -2\mu-\gamma-2\alpha & \gamma \\
 & & & & & & & 2\alpha(1-\theta_1) & & & 3\mu & -3\mu-2\alpha(1-\theta_1)
\end{pmatrix}$$

Balance equations can be expressed as follows

$$\begin{cases} v_0 Q_1^{(0)} + v_1 Q_2^{(1)} = (0,0,0,0), \\ v_0 Q_0^{(0)} + v_1 Q_1^{(1)} + v_2 Q_2^{(2)} = (0,0,0,0) \\ v_1 Q_0^{(1)} + v_2 Q_1^{(2)} = (0,0,0,0). \end{cases}$$

$$\begin{cases} v_0 \times \begin{pmatrix} -\gamma & \gamma & 0 & 0 \\ \mu & -\mu-\gamma & \gamma & 0 \\ 0 & 2\mu & -2\mu-\gamma & \gamma \\ 0 & 0 & 3\mu & -3\mu-\gamma_d\theta \end{pmatrix} + v_1 \times \begin{pmatrix} 0 & \alpha & 0 & 0 \\ 0 & 0 & \alpha & 0 \\ 0 & 0 & 0 & \alpha \\ 0 & 0 & 0 & \alpha(1-\theta_1) \end{pmatrix} = (0,0,0,0), \\ v_0 \times \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \gamma_d\theta \end{pmatrix} + v_1 \times \begin{pmatrix} -\gamma-\alpha & \gamma & 0 & 0 \\ \mu & -\mu-\gamma-\alpha & \gamma & 0 \\ 0 & 2\mu & -2\mu-\gamma-\alpha & \gamma \\ 0 & 0 & 3\mu & -3\mu-\gamma_d\theta-\alpha(1-\theta_1) \end{pmatrix} + v_2 \times \begin{pmatrix} 0 & 2\alpha & 0 & 0 \\ 0 & 0 & 2\alpha & 0 \\ 0 & 0 & 0 & 2\alpha \\ 0 & 0 & 0 & 2\alpha(1-\theta_1) \end{pmatrix} = (0,0,0,0), \\ v_{1\times} \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \gamma_d\theta \end{pmatrix} + v_2 \times \begin{pmatrix} -\gamma-2\alpha & \gamma & 0 & 0 \\ \mu & -\mu-\gamma-2\alpha & \gamma & 0 \\ 0 & 2\mu & -2\mu-\gamma-\alpha 2 & \gamma \\ 0 & 0 & 3\mu & -3\mu-2\alpha(1-\theta_1) \end{pmatrix} = (0,0,0,0). \end{cases}$$

3. Numerical Results

Based on the blocking probability identified in the equation (8), (9), we proceed to graphically describe the change of the blocking probability depending on traffic load (ρ), the number of wavelengths (ω), and the number of FDL. System model with parameters as follows: $\omega = 16, L = 2,\ \mu = 0.020833,\ \theta = \theta_1 = 0.5$. Analysis results are also compared with simulation in some special cases. Similarly, the simulation parameters are used in [1], call $\beta = \rho/\omega$ is traffic load normalized per wavelength used at each output port (from 0.2 to 0.9 (Erl)).

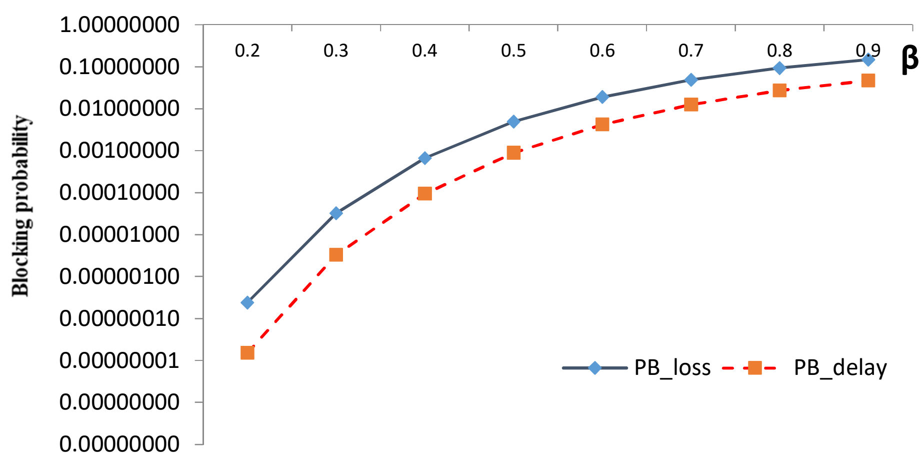


Figure 5. The blocking probabilities PB_{loss} and PB_{delay} vs β

Figure 5 shows the results of the blocking probability for the loss bursts and delay bursts $(\omega = 16, L = 2)$. In the analysis model, it is clear that the delay bursts have a smaller blocking probability due to delays in the FDL.

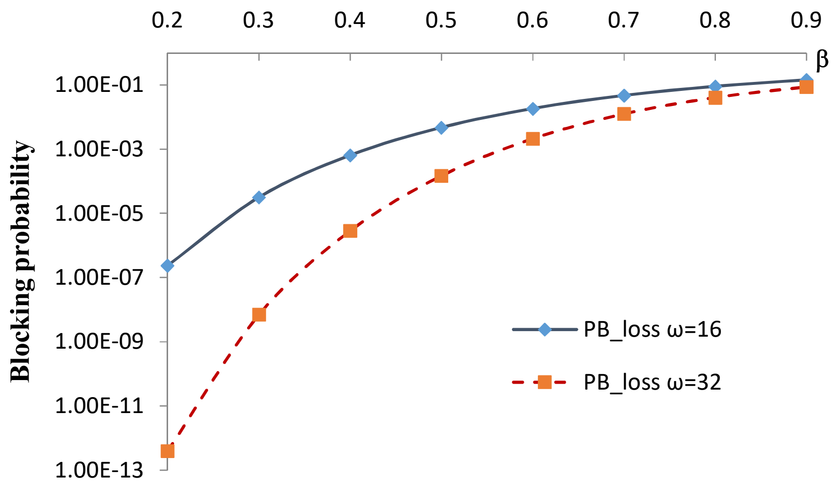


Figure 6a. The blocking probabilities PB_{loss} vs β

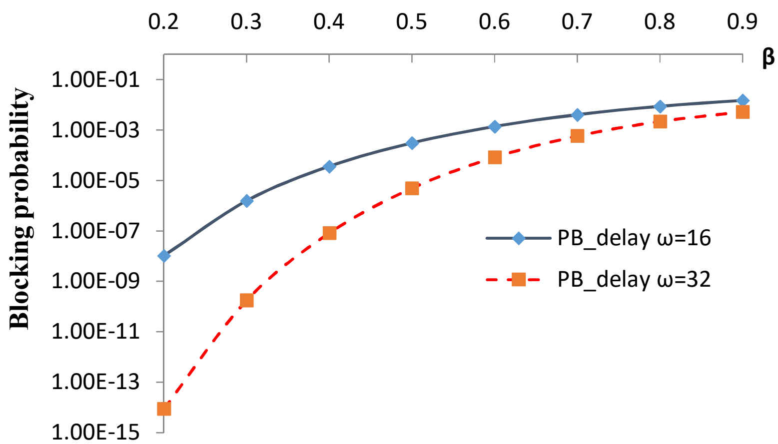


Figure 6b. The blocking probabilities PB_{delay} vs β

Figure 6a and Figure 6b show the blocking probability corresponding to the loss bursts and delay bursts of the Markov model with $\omega = 16, 32$; $L = 2$; $\rho_l = 0.3\rho$; $\rho_d = 0.7\rho$. Clearly, with a larger number of wavelengths, the blocking probability will be significantly improved, especially with low traffic loads.

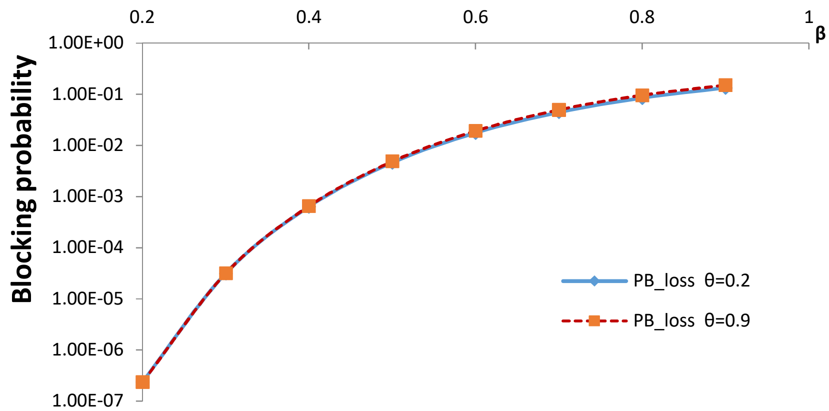


Figure 7a. The blocking probabilities PB_{loss} with $\theta = 0.2$ and $\theta = 0.9$

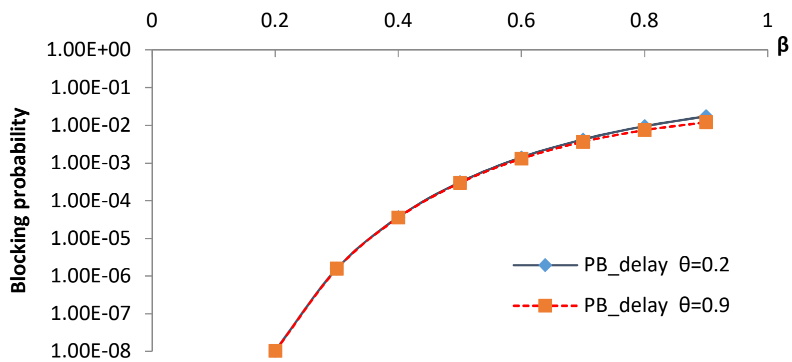


Figure 7b. The blocking probabilities PB_{delay} with $\theta = 0.2$ and $\theta = 0.9$

Figure 7a shows that the blocking probability PB_{loss} does not depend on the value θ. This is perfectly consistent with the model we built above because of loss bursts in congestion condition of the system independent of the parameters θ and θ_1. In contrast, with Figure 7b, when the value of β is in the range of 0.2 to 0.9, the probability retrial $\theta = 0.9$ is always better than the probability retrial $\theta = 0.2$.

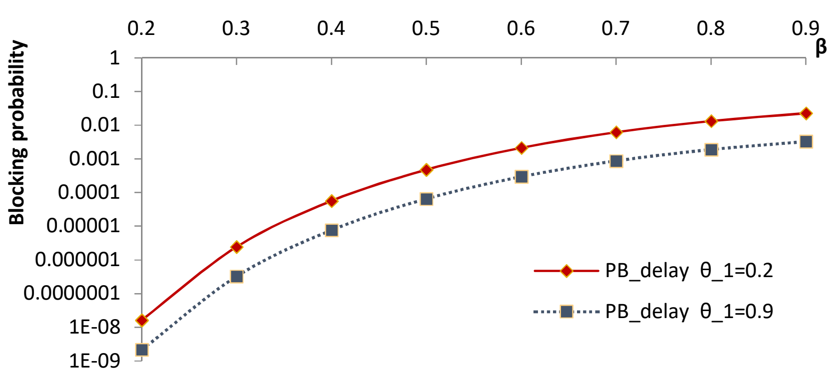


Figure 8a. The blocking probabilities PB_{delay} with $\theta_1 = 0.2$ and $\theta_1 = 0.9$

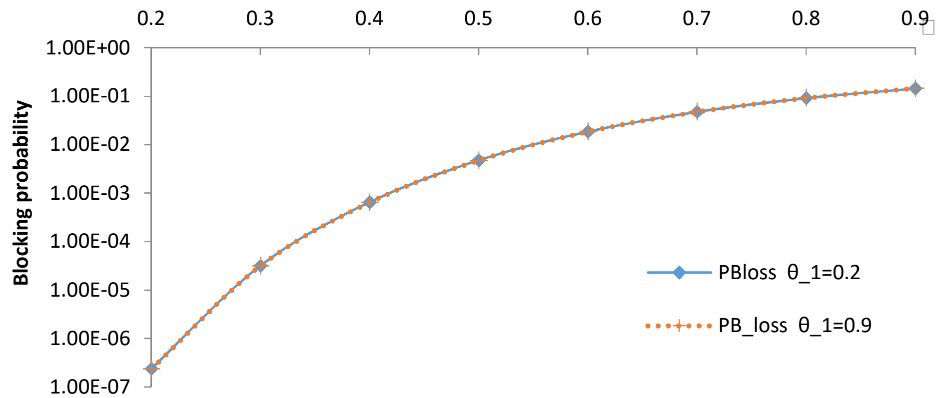


Figure 8b. The blocking probabilities PB_{loss} with $\theta_1 = 0.2$ and $\theta_1 = 0.9$

The similar, Figure 8a when the value of β is in the range of 0.2 to 0.9, then the retrial probability $\theta_1 = 0.9$ is always better than the retrial probability $\theta_1 = 0.2$. In contrast, Figure 8b shows that the congestion probability PB_{loss} does not depend on the value θ_1.

Figure 9 describes a comparison between the blocking probabilities of analytical model in this paper ($\theta = 1.0$, $\theta_1 = 0.9$) and the blocking probabilities of analytical model (i) in [1]. Clear that, our model in this paper has better results than in [1] due to using parameter θ_1.

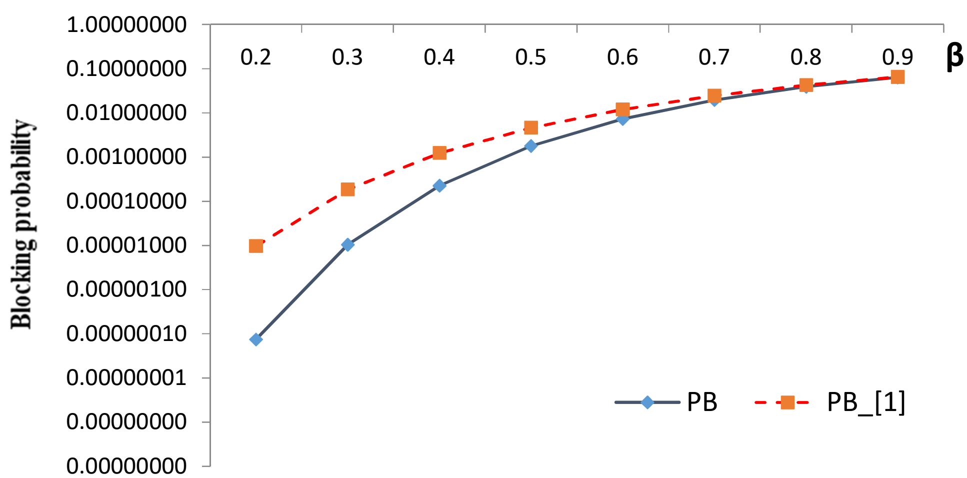
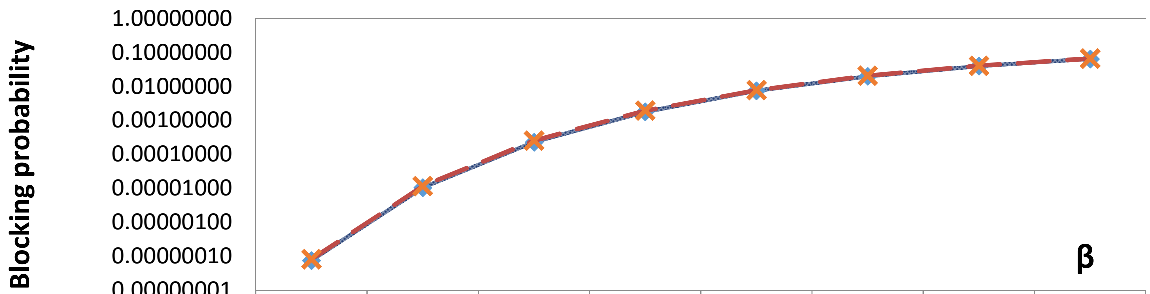


Figure 9. The blocking probabilities PB with $\theta = 1.0, \theta_1 = 0.9$ and PB_[1]

We also implement a special case of simulation on NS-2 (use the OBS-ns Simulator) [12], in order to compare analytical results with simulation. Figure 10 shows that there is a good match between the analysis results and simulation.



	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
PB_Analysis	0.000000	0.000010	0.000226	0.001773	0.007338	0.019731	0.039376	0.064021
PB_Simulation	0.000000	0.000011	0.000252	0.001947	0.007872	0.020683	0.040672	0.065846

Figure 10. Blocking probabilities in the analytical case ($\theta = \theta_1 = 0.5$) and simulation

4. Conclusion

The paper proposes a model to evaluate the performance of the SPL - feed-forward OBS architecture node with the retrial queuing model. Unlike previous studies [6], the proposed model considers the retrial factor for the FDL, i.e, considering that delayed traffic to FDL (orbit queue) with probability θ ($\theta \leq 1$) and retrial traffic (bursts come out from the FDL) when continuing the congestion at the output port can also re-circulate through one of the FDLs (2nd) with probability $\theta_1 (\theta_1 < 1)$. Numerical results show that the proposed continuous-time Markov chain can be efficiently used to compute the blocking probabilities. The numerical results illustrate that the blocking probability strongly depends on the traffic load density, the number of used wavelengths and variant abilities of retrial probability.

Our future research plan will propose a model of traffic prediction based admission control with QoS [13], which includes a statistical method of forecasting the arriving rate of bursts for flexible wavelength allocation and a mechanism of prioritizing more resources for high-priority bursts.

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