Performance Analysis for Prioritized Multi-classes in Optical Burst Switching Networks

Sungchang Kim, Jin Seek Choi, *Member, IEEE* and Minho Kang, *Senior Member, IEEE*
Optical Internet Research Center, Information and Communications University,
e-mail : {pluto, jin, mhkang}@icu.ac.kr

Abstract **— In this paper, we analyze blocking probabilities for prioritized multi-classes in optical burst switching (OBS) networks. The blocking probability of each traffic class can be analytically evaluated by means of class aggregation and iteration method. The analytic results show the good agreement with simulation results.**

Index Terms **— Optical Burst Switching, QoS, Blocking Probability**

I. INTRODUCTION

The performance analysis addressed in this paper is developed based on the concept of the optical burst switching (OBS) networks. Everyone agrees that current optical circuit switching eventually evolves optical packet switching. However, until today, optical component technologies do not support the optical buffer. In the mean time, OBS is considered as a promising solution for optical packet switching since OBS switches do not require optical buffering at intermediate nodes, and its delay reservation (DR) scheme increases the wavelength utilization through burst multiplexing [1]. However, in order to implement practical OBS network, there are a lot of challenging issues to be solved. Sophisticated quality of service (QoS) mechanism is one of the essential parts to support diverse user requirements.

Recently, the offset-time-based QoS scheme was proposed by Yoo and Qiao [2]. In this scheme, OBS brings about two offset times. One is basic offset time that is required to make up processing delay of control packet in intermediate nodes. Second is QoS offset time that is required to isolate traffic classes instead of buffer. For multiple QoS classes, different QoS offset time will be assigned to each traffic class to provide different QoS services.

As shown in Fig 1(a), the high priority class 2 can be perfectly isolated from low priority class 1, if QoS offset time, $t^2_{QoS\_offset}$ is greater than the message length of priority class 1, l^1. However, the high priority class 2 can be blocked by the low priority class 1 if l^1 is greater than $t^2_{QoS\_offset}$ as shown in Fig 1(b). Here, we didn't concern about basic offset time which was independent of QoS performance.

Nevertheless, the authors assume that the high priority class can be perfectly isolated from low priority class if the QoS offset time of high class is 3~5 times larger than low class burst length in [2]. However, perfect isolation is impossible to achieve since the burst length has exponential distribution. The assumption of perfect isolation greatly approximates the performance estimation unless the QoS offset time is infinite.

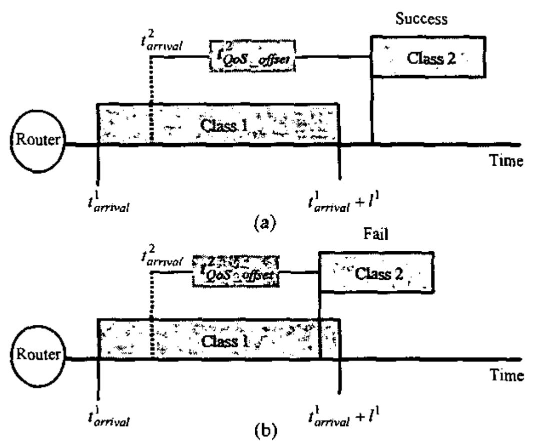


Fig 1. Basic concept of QoS offset time, where $t^1_{arrival}$ and $t^2_{arrival}$ represent the control packet arrival time of class 1 and 2 at intermediate node, and $t^2_{QoS\_offset}$ represents extra QoS offset time in class 2, and l^1 indicates the burst length of class 1 respectively.

In [3], the blocking probability is exactly evaluated for n class case. However, the evaluation model has the approximation that the burst length of each class is bounded by predefined maximum length. Usually, this truncated burst size model is not considered as a general OBS model. In [4], the authors propose an analytic model for arbitrary QoS offset time which releases the approximation of perfect isolation in [2]. However, this paper only concern about blocking probability of two class case.

In this paper, blocking probabilities of multi-classes was evaluated without the approximation of perfect isolation. The main focus of this paper is on analysis of blocking probabilities for general n class (n>2) case with exponential distributed burst size and Poisson arrival environment using class aggregation and iteration method.

II. PERFORMANCE ANALYSIS

In this section, we present an analysis of the blocking probabilities in just-enough-time (JET) based OBS network that distinguishes n classes, thus class n has the highest priority and class 1 has the lowest priority. Under the assumption that control packet of class m ($1<m<n$) arrive Poisson stream with rate λ_m and data burst length has exponential distribution. Let t^{burst}_m be a mean data burst transmission time of class m, and then ρ_m be an offered load which can be simply calculated by $\lambda_m t^{burst}_m$. Based on this assumption, we can use Erlang B formula for the

blocking probability of M/G/k/k system. In this system, k represents the number of wavelengths used at each output port.

In order to evaluate the blocking probability of n class case, we first evaluate three classes case. For our analysis, we assume that the basic offset time of each class is same that means basic offset time does not affect class isolation. Therefore we assume that the basic offset time of each class is 0. Furthermore, we define $\delta_{i|j}$ which indicates the QoS offset time difference between class i and j $(i < j)$.

The overall burst blocking probability P_{all} in multi-class OBS node can be obtained by using Erlang B formula as mentioned above [5].

$$P_{all} = B(\rho_{all}, k) = \frac{\rho_{all}^{k} / k!}{\sum_{i=0}^{k} \rho_{all}^{i} / i!} \qquad (1)$$

In order to calculate the blocking probability of highest priority class P_3, we should concern about effective loads to affect the blocking probability. In Fig 2 (a), if we assume that the offset time difference $\delta_{1|2}$ and $\delta_{2|3}$ are arbitrary small value, traffic class 3 is not completely isolated from traffic class 2 and 1. Therefore, P_3 can be represented by

$$P_3 = B(\rho_3 + Y_2(\delta_{2|3}) + Y_1(\delta_{1|3}), k) \qquad (2)$$

$$Y_i(\delta_{i|j}) = \rho_i(1 - P_i)(1 - R(\delta_{i|j})) \qquad (3)$$

where, $Y_i(\delta_{i|j})$ is the effective loads of low priority class i affecting blocking probability of high priority class j. Within this equation, $\rho_i(1-P_i)$ represents the carried loads of class i and $(1 - R(\delta_{i|j}))$ represents the probability which data burst lengths in class i are larger than the offset time difference $\delta_{i|j}$ where $R(\delta_{i|j})$ is the isolation rate between class i and j which can be represented by

$$R(\delta_{i|j}) = (1 - \exp(-\delta_{i|j} / t_i^{burst})) \qquad (4)$$

Since the memoryless property of exponential distribution in data burst lengths, the residual service time of i class data burst is same regardless of arrival time of j class data burst. Therefore, the approximation of $Y_i(\delta_{i|j})$ is independent of j class arrival time.

Now we drive blocking probability of class 2. In order to obtain P_2, we define aggregated state which consists of class 3 and class 2 as shown in Fig. 2 (b). The blocking probability of aggregated state which is mixed loads of class 3 and 2 can be represented by

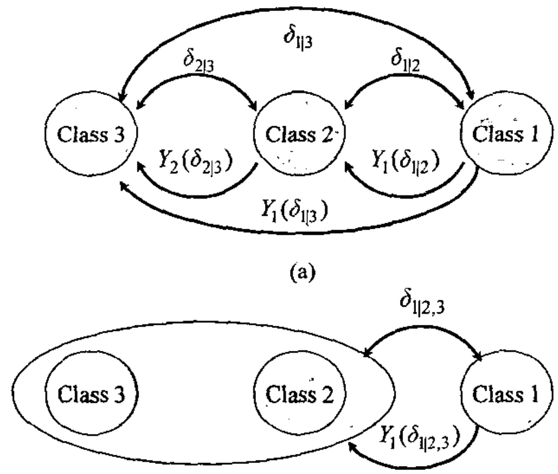
$$P_{2,3} = B(\rho_{2,3} + Y_1(\delta_{1|2,3}), k) \qquad (5)$$

where, $\rho_{2,3} = \sum_{i=2}^{3} \rho_i$ and $\delta_{1|2,3} = (\delta_{1|2} + \delta_{1|3})/2$. Once you calculate $P_{2,3}$, the blocking probability of class 2 can be obtained by well known conservation law.

$$\rho_{2,3} P_{2,3} = \rho_2 P_2 + \rho_3 P_3 \qquad (6)$$

Once we obtain P_3 and P_2, the blocking probability P_1 is also calculated by conservation law.

However, the blocking probability of each class is dependant each other. For example, in order to calculate P_3 in eq.(2), we have to know P_2 and P_1 in advance. Therefore, iterative solution is required.



(b)

Fig 2. (a) Relationship between two different classes according to offset time difference and effective load (b) Class aggregation model

For the zero[th] order blocking probabilities, we assume that the P_3 and $P_{2,3}$ are completely isolated from lower priority classes such as $P_3^0 = B(\rho_3, k)$ and $P_{2,3}^0 = B(\rho_{2,3}, k)$. Then we can obtain zero[th] order blocking probability of each class P^0 and effective loads $Y^0(\delta_{i|j})$. Next, first order blocking probabilities can be obtained when effective loads $Y^0(\delta_{i|j})$ values plug into eq. (2) and (5). Iteration procedure continues until blocking probability of each class converges at certain level.

In general n class case, the blocking probability of each class can be calculated by following iteration.

$$P_n^l = B(\rho_n + \sum_{i=1}^{n-1} Y_i^{l-1}(\delta_{i|n}), k) \qquad (7a)$$

$$P_{m,m+1,\ldots,n}^l = B(\rho_{m,n} + \sum_{i=1}^{m-1} Y_i^{l-1}(\delta_{i|m,n+1,\ldots,n}), k) \qquad (7b)$$

$$\delta_{i|m,m+1,\ldots,n} = (\sum_{j=m}^{n} \delta_{i|j})/(n-m+1), \ (1 < m < n) \qquad (7c)$$

$$P_m^l = (\rho_{m,n} \cdot P_{m,m+1,\ldots,n}^l - \rho_{m+1,n} \cdot P_{m+1,m+2,\ldots,n}^l)/\rho_m \qquad (7d)$$

III. SIMULATION AND RESULTS

In this section, we present our analytical results driven by eq. (7) and compare with simulation results. The simulations model is assumed that each node has 8×8 ports and each port has $10Gbps$ transmission rate. The traffics are classified by three different priorities such as class 1, class 2 and class 3. Class 3 is the highest priority class and the class 1 is the lowest one and offered load of each class is equally distributed. The burst length is exponentially distributed with average value of $20Kbyte$ according to assumption that several tens of IP packets have been assembled into one burst. Also, we assume that the channel number k is 16 and the offset time differences between successive classes are set to average burst length.

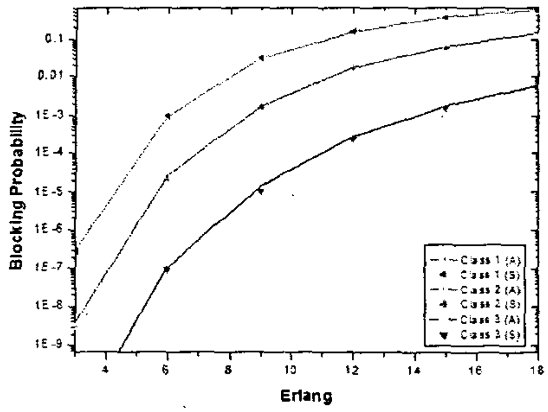


Fig 3. Blocking probabilities of analysis and simulation results when QoS offset time is set to average burst length ($\delta = t^{burst}$). ((A) Analysis, (S) Simulation)

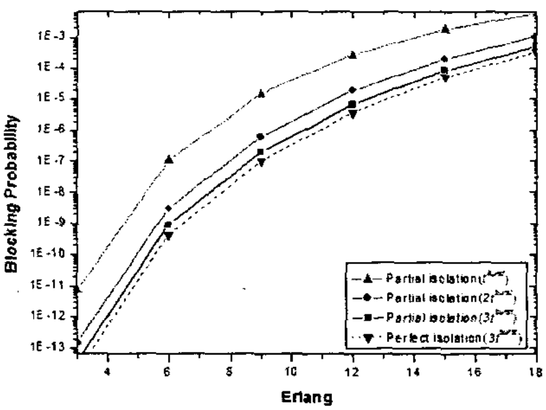


Fig 4. Blocking probabilities of class 3 when we assume that the class 3 isolated from low priority classes either partially or perfectly in the case of $\delta = t^{burst}, 2t^{burst}$, and $3t^{burst}$

In Fig 3, we show the blocking probabilities of each priority class versus offered load. As can be observed by comparing the blocking probabilities obtained from our analysis and simulation, our analytic results are in good agreement with those from the simulation. It can be seen that iteration procedure may compensate the mixed load approximation error. Using this analytical model, we can obtain blocking probabilities of n classes in the case of not only perfect but also partial service isolation.

In Fig 4, we show that the assumption of perfect isolation is not valid even if QoS offset time is three times lager than the mean burst length. As decrease the QoS offset time from $3t^{burst}$ to t^{burst} , performance difference between partial and perfect isolation model caused by under-estimation of perfect isolation is getting bigger.

IV. CONCLUSION

In this paper, we analyzed the blocking probabilities for prioritized multi-classes in optical burst switching networks using class aggregation and iteration method. Furthermore, we have used the simulation to validate our analytic results. Since our general n class analysis covers variable QoS offset time, we can determine the point of suitable isolation between classes as an optimal way.

ACKNOWLEDGEMENT

This work was supported in part by the Korea Science and Engineering Foundation (KOSEF) through OIRC project.

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