Offset Time Decision (OTD) Algorithm for Guaranteeing the Requested QoS of High Priority Traffic in OBS Networks

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ABSTRACT

In this paper, we propose the Offset Time Decision (OTD) algorithm for supporting the QoS in optical networks based on Optical Burst Switching (OBS), which is the new switching paradigm, and evaluate the performance of the OTD algorithm. The proposed algorithm can decide a reasonable offset time to guarantee the Burst Loss Rate (BLR) of high priority traffic by considering traffic load of network and the number of wavelengths. In order to design this effective OTD algorithm, firstly we illustrate the new burst loss formula, which includes the effect of offset time of high priority class. As the decision of offset time corresponding to the requested BLR, however, should use the reversed formula of new one, we are not able to use it without any changes. Thus, we define the Heuristic Loss Formula (HLF) that is based on the new burst loss formula and the proportional equation considering its characteristics. Finally we show the OTD algorithm to decide the reasonable offset time by using HLF. The simulation result shows that the requested BLR of high priority traffic is guaranteed under various traffic load.

Keywords: OBS, QoS, Optical switching, WDM, Internet

1. INTRODUCTION

With the beginning of new millennium, the explosive growth of Internet users and Internet-related services, such as broadband and real-time multimedia applications, actively promotes the research on the construction of broadband Optical Internet by using Wavelength Division Multiplexing (WDM), which can provide huge deliverable bandwidth. Thus, in recent years, many network approaches have been considered as the candidates of next generation Internet, e.g. IP over ATM over WDM, IP over SONET/SDH over WDM, and IP over WDM [1-3].

The ATM network and SONET/SDH provide the optimal solution to carry mixed traffics of different types and fast restoration capability in the event of fiber cut or the failure in an SONET/SDH node, respectively. However, conveying IP traffic to ATM demands high ATM cell tax and complex signaling protocols, and SONET/SDH networks are not suitable for accepting IP traffic that is asymmetric and also has a self-similar characteristics. Therefore, the IP over WDM, that is implementing IP directly over a WDM optical layer with a minimum electronics between these two, seems to be the best choice for future Optical Internet [4, 5].

Given that current IP provides only best effort service, supporting Quality of Service (QoS) becomes a crucial research issue in the Optical Internet since new applications, an increasing number of users, and growing commercial communication interest in this network services and the future integrated Internet will also demand differentiated services. For example, applications such as Internet telephony and video conferencing require a higher QoS than electronic mail and general web browsing. Thus, there is significant effort to include QoS mechanisms into the Internet by using IntServ and DiffServ approaches without the dependence of a transport network. However, if the QoS can be supported by the switching technology, it'll be very easy to service the applications requiring the QoS.

Recently, optical burst switching was proposed as a new switching paradigm for optical networks requiring less complex technology than optical packet switching, so many authors have been researching it as the candidate of reasonable transport layer offering most efficient support for IP traffic and specifically supporting QoS mechanisms. As a previous research considering OBS networks, extra-offset time based scheme to guarantee the QoS is suggested and

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this scheme takes advantage of an extra-offset time to isolate traffic instead of depending on the buffer, which consists of Fiber Delay Lines (FDLs). Thus, the high priority traffic with extra-offset can have better performance than low priority traffic in two-class system and is suitable for implementation in bufferless WDM networks [6]. However, this scheme is based on an assumption on which high priority traffic is completely isolated from low one by using long extra-offset time. Therefore, if there is the high priority traffic to require some level of QoS, such as the burst loss rate, we will not find a reasonable extra-offset time by using conventional method. And all high priority burst data should suffer the unnecessary delay in IP layer so as to support 100% class isolation before transmission of a burst on a WDM layer.

In this paper, we propose the offset time decision algorithm for supporting the QoS of high priority traffic when it requires some level of BLR in optical burst switching networks. For this goal, we first analyze the effect of offset time and describe the new burst loss formula considering it. However, in order to find the acceptable offset time for supporting the requested burst loss rate, we should still solve a problem that the new loss formula is not changed into reversed function for finding the offset time. Thus, we define the heuristic loss formula, which is made by various and sufficient analysis, and finally we propose the OTD algorithm to decide the offset time by using this HLF.

This paper is organized as follows. In Section 2, we analyze the effect of offset time and explain new burst loss formula. Section 3 presents the heuristic loss formula and describes the decision of reasonable offset time by proposed OTD algorithm. Section 4 shows the results from simulation, followed by the conclusion in Section 5.

2. BURST LOSS FORMULA CONSIDERING OFFSET TIME

In order to analyze the burst loss considering the extra-offset time of burst traffic, we assume that IP traffic in OBS based Optical Internet is classified as one of the following traffic classes, one is high priority traffic (class 1), which has an extra offset time, denoted by t_1^o, and the other is low priority one (class 0). For simplicity, we assume that the base offset is negligible as compared to the extra-offset time, and will refer to the latter as simply the offset time hereafter.

2.1 CLASS 0'S EFFECT ON LOSS OF HIGH PRIORITY CLASS

From the results of previous research, which refers to [6], we have known that the blocking of class 1's burst from class 0 can be avoided by using a large enough offset time. Thus, the blocking probability of high priority class was calculated by only considering class 1's offered load. However, if the offset time of high priority class is not so large, the burst loss rate of the high priority class P_1 must be calculated by considering the offered load ρ_1 of the high priority class and a fraction of the carried traffic of the low priority class. The reason of this case is that the length of a class 0's burst can be larger than the offset time of class 1's. Therefore, before illustrating the algorithm for decision of offset time to guarantee the QoS of high priority class, we should analyze the effect of class 0's burst on the loss of class 1's.

Usually, this loss effect fraction $\Delta(t_1^o)$ of low priority class is determined by three cases of offset time of high priority class, such as $t_1^o = 0$, ∞, and $0 < t_1^o < \infty$. Firstly, for the case of $t_1^o = 0$, class 1 and class 0 are not separated by offset time and class 0 always affect the loss of class 1's traffic to reserve the wavelength channel. Thus, $\Delta(t_1^o = 0)$ is the class 0's offered load ρ_0.

As a second case, we can think that t_1^o is ∞, but this case is the virtual one and we just apply it to analyze the effect of class 0. Fig. 1 describes the complete isolation of high priority class from low priority one when t_1^o is ∞ or very large in real. As shown in Fig. 1, the control packet of class 0 arrives at t_0^a, followed by one of class 1. When $t_1^a < t_0^a + l_0$, class 1's control packet would be blocked, if no offset time had been assigned to class 1. However, such a blocking can be avoided by using a large enough offset time so that the burst start time t_1^s of class 1 is $t_1^s = t_1^a + t_1^o > t_0^a + l_0$. Given that t_1^a may equal to $t_1^a + \varepsilon$, where $\varepsilon > 0$ can be very small, t_1^o needs to be larger than the maximum burst length over all bursts in class 0 in order for class 1's control packet to completely avoid being blocked by class 0. Thus, in this case, we can get $\Delta(t_1^o = \infty)$ is zero.

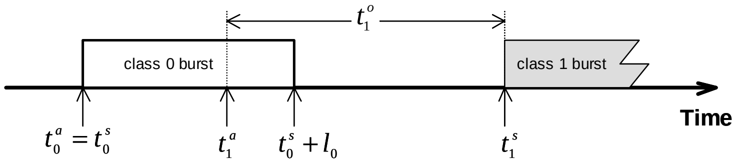


Fig. 1: Offset time for the complete isolation.

Finally, we can consider of $0 < t_1^o < \infty$. It, however, is difficult to calculate $\Delta(t_1^o)$ correctly, and we decide the maximum value $\Delta_{\max}(t_1^o)$ and minimum one $\Delta_{\min}(t_1^o)$ of $\Delta(t_1^o)$. Let us assume that the burst length is exponentially distributed with an average of L_{i-1} for a given class $i-1$. Then, the percentage $F(t)$ of bursts in class $i-1$ whose length is no longer than a given, *t*, is obtained by the following Probability Distribution Function (PDF).

$$F(t) = P[L \le t] = 1 - P[L > t] = 1 - e^{-(1/L_{i-1})t} \tag{1}$$

First, we can think the following Equation 2 as the maximum value or upper bound of $\Delta(t_1^o)$ when the offset time of high priority class is t_1^o.

$$\Delta_{\max}(t_1^o) = \rho_0(1 - P_0)(1 - F) \tag{2}$$

Where *F* notifies $F(t_1^o)$ and P_0 is the burst loss rate of class 0. In this equation, $\rho_0(1-P_0)$ is the carried traffic of low priority class at the time when the control packet of high priority class arrives. $1-F$ is the percentage of class 0 traffic which is larger than the offset time t_1^o. Thus, Equation 2 means that all of class 0 traffic that is larger than offset time and arrives before the control packet of class 1's without blocking, affects the loss of class 1. However, there are some of class 0 traffic not to affect the blocking of the high priority control packet, as shown in Fig. 2. Thus, Equation 2 is maximum effect of $\Delta(t_1^o)$.

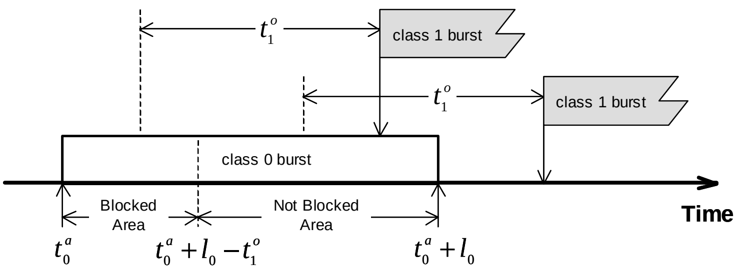


Fig. 2: Relationship of class 1's offset time and the length of class 0.

In Fig. 2, although a class 0 burst is larger than current offset time t_1^o given in class 1, if the high priority control packet arrives after $t_0^a + l_0 - t_1^o$, the class 1 burst will not be blocked by class 0 burst. But it is complex to calculate the "Not Blocked Area". Thus, we define the minimum value of $\Delta(t_1^o)$ as the following equation.

$$\Delta_{\min}(t_1^o) = \rho_0(1-F)\cdot\left((1-P_0)(1-F)\right) \tag{3}$$

In order to illustrate the minimum value, we consider the effect of $\rho_0(1-F)$ to the class 1's blocking instead of ρ_0 as shown in Equation 2. Thus, its effect is more than $(1-P_0)(1-F)$ that is considered in case of all class 0. Therefore Equation 3 means the lower bound of $\Delta(t_1^o)$ when the high priority control packet includes the offset time t_1^o to guarantee its some level of QoS.

From the Equation 2 and 3, we can notice that $\Delta(t_1^o)$ might be satisfied with the condition of $\Delta_{\min}(t_1^o) < \Delta(t_1^o) < \Delta_{\max}(t_1^o)$. In following section, we decide the burst loss rate for each case, maximum and minimum value, by using recursive method and average the sum of them as the finally burst loss rate of class 1 traffic.

2.2 BURST LOSS FORMULA

Assuming that there are *K* wavelengths on the output link, and the OBS router is capable of wavelength conversion, the burst loss rate in the classless case where the traffic is not differentiated is calculated using the following *Erlang's loss formula* (M/M/K/K), where ρ is offered load.

$$B(\rho, K) = \frac{\rho^K / K!}{\sum_{i=0}^{K} \rho^i / i!} \tag{4}$$

We now determine the burst loss probability of each class, denoted by P_i, where *i* = 0 or 1 for class 0 or class 1, respectively. In Section 2.1, we determine $\Delta(t_1^o)$ of class 0, and we can use the following equation to calculate the loss probability of high priority class. The offered load that we should consider is the sum of the offered load of class 1 and the fraction of class 0, which is dependent on the offset time of class 1.

$$P_1 = B(\rho_1 + \Delta(t_1^o), K) \tag{5}$$

When t_1^o is 0 or ∞, the effect $\Delta(t_1^o)$ of class 0 is ρ_0 or 0, respectively. Thus, the burst loss rate P_1 of class 1 is $B(\rho_1 + \rho_0, K)$ and $B(\rho_1, K)$, then we can also get the loss rate of low priority class by using *Conservation Law* as follows, where $\rho_{all} = \rho_0 + \rho_1$.

$$\rho_{all} P_{all} = \rho_0 P_0 + \rho_1 P_1 \tag{6}$$

However, when we consider the case of $0 < t_1^o < \infty$ we should use other method to find the burst loss rate of high priority class. When we accord to Equation 2, 3, and 5, there is a mutual dependency between P_0 and P_1. Therefore, we use the iteration solution in [5] for above formula.

We initialize the iteration with estimates for the loss probabilities of the high and low priority classes, $P_0^{(0)}$ and $P_1^{(0)}$, respectively. These zero order estimates can be derived from Equation 4 and 6.

$$\begin{aligned} P_1^{(0)} &= B(\rho_1, K) \\ P_0^{(0)} &= 1/\rho_0(\rho_{all} P_{all} - \rho_1 P_1^{(0)}) \end{aligned} \tag{7}$$

Therefore, the amount of carried low priority traffic is determined by Equation 2, 3, and 7.

$$\begin{aligned} \Delta_{\max}^{(0)}(t_1^o) &= \rho_0(1-P_0^{(0)})(1-F) \\ \Delta_{\min}^{(0)}(t_1^o) &= \rho_0(1-F)\left((1-P_0^{(0)})(1-F)\right) \end{aligned} \tag{8}$$

Then, these equations can be inserted in Equation 5 yielding first order results, $P_{1,\max}^{(1)}$ and $P_{1,\min}^{(1)}$ of high priority class. Iteration until some precision criterion is satisfied leads to $P_{1,\max}$ and $P_{1,\min}$. And we can get the loss probability of high priority class as follows when the offset time of high priority class is determined.

$$P_1 = \frac{P_{1,\min} + P_{1,\max}}{2} \tag{9}$$

As the final phase, the loss probability of the low priority class is also determined by using *Conservation Law.*

3. OFFSET TIME DECISION ALGORITHM

In the previous section, we analyze the burst loss rate by using Equation 5 and the iterative method when the offset time is determined. However, the decision of offset time for guaranteeing the requested BLR should be used by the reversed formula of Equation 5. Thus, it is very difficult to determine the reasonable offset time for corresponding the requested BLR. As a solution to overcome this problem, we show the *heuristic loss formula* (HLF) for calculating the loss probability of high priority class. First, before defining the HLF, we examine the characteristics of our new burst loss formula shown in Section 2. Fig. 3 shows the analysis result which is assumed K = 8, 32, and $\rho_{all} = 0.8$.

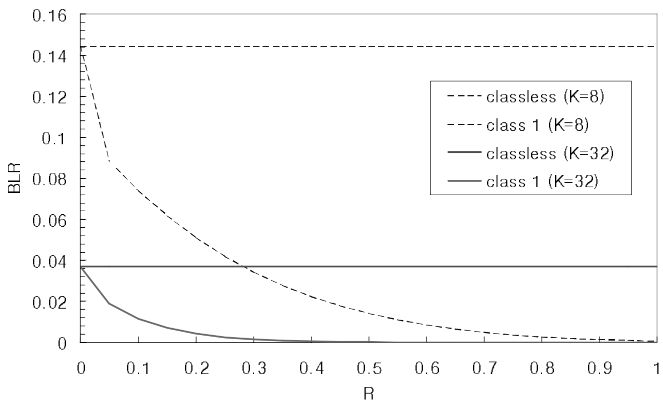


Fig. 3: Characteristics of class 1's burs loss rate.

From this analysis result, we define the following equation $G(\rho_1, K, R)$ that is the burst loss rate considering the offered load, the number of wavelength, and the offset time.

$$G(\rho_1, K, R) = X + Y(1-R)e^{-\beta R} \tag{10}$$

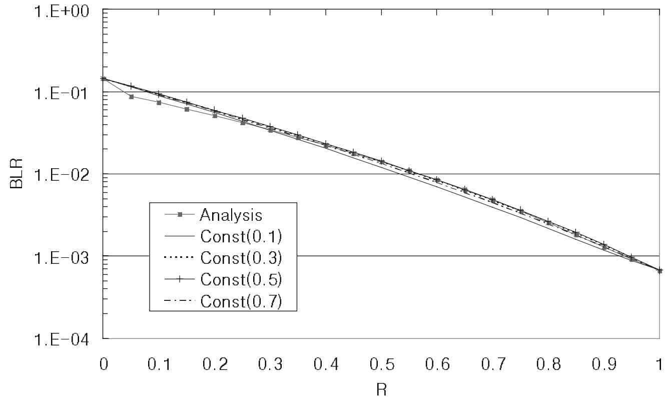
Where R is defined as $1-e^{-(1/L_0)t_1^o}$ and the range of $0 \le t_1^o \le \infty$ is mapped into $0 \le R \le 1$. Thus, we determine the t_1^o by using $t^o = -\ln(1-R)L_0$. To depict the characteristics of class 1 in Fig. 3, we define X and Y as $B(\rho_1, K)$ and $B(\rho_{all}, K) - B(\rho_1, K)$, respectively. And β is defined as a constant value according to ρ_1. If β in Equation 10 is determined as an acceptable value and K, ρ_1, and t_1^o are also applied, we get a result of this HLF equation which is similar to the analysis result from Equation 5.

In order to find a reasonable value of β, which is various when offered load, number of wavelengths, and offset time are changed, we first find the same burst loss rate by using Equation 5 and Equation 10. Therefore, we use an equation that $G(\rho_1, K, r)$ is equal to $B(\rho_1 + \Delta(-\ln(1-r)L_0), K)$. Thus, β is determined by Equation 11.

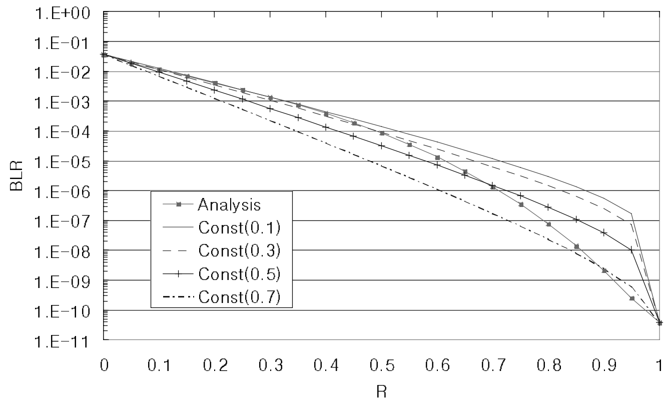
$$\beta = -\ln\left(\frac{B(\rho_1, Y(-\ln(1-r)L_0)) - X}{Y(1-r)}\right)\frac{1}{r} \tag{11}$$

Where the value of r can be selected from $0 \le r \le 1$ randomly. But we define r as $C + \rho_1 e^{\rho_1}$ considering the offered load of class 1. To decide the value of *C* reasonably, we use the numerical results of Equation 5 and HLF based on changing *C*.

Fig. 4 depicts the analysis result and the variable results of heuristic loss formula when *K*=8, 32 and *C* varies. In the result of left side in Fig. 4, we can see that results of Equation 5 and HLF are similar in spite of changing *C*. In case of *K*=32, however, we can see various results. From this result, we select the case of *C*=0.5 as a reasonable value because of the average. Thus, we define C as 0.5, and r is applied to above equation as $0.5 + \rho_1 e^{\rho_1}$.



(a) *K* = 8



(b) *K* = 32

Fig. 4: Variable results of HLF by changing *C*.

However, although Equation 10 is a acceptable equation for we define the heuristic loss formula to show similar results , the Equation 10 can not be used with its reversed formula. Thus, we redefine previous HLF as Equation 12.

$$\hat{G}(\rho_1, K, R) = X + Y(e^{-\beta \cdot R} - e^{-\beta}) \tag{12}$$

Where β is the value from Equation 10 and the difference of Equation 10 and 12 is $\left|Ye^{-\beta}(Re^{-\beta(R-1)} - 1)\right|$.

Therefore, we can decide *R* from Equation 12 when the requested BLR of high priority class is P_1^{req}. Then we also find the offset time for considering its QoS.

$$P_1^{req} = X + Y(e^{-\beta \cdot R} - e^{-\beta})$$

$$R = -\ln\left(\frac{P_1^{req} - X}{Y} + e^{-\beta}\right)\frac{1}{\beta} \tag{13}$$

$$\therefore \quad t_1^o = -\ln(1 - R) \cdot L_0$$

Now, we can find a reasonable offset time t_1^o of high priority class by following algorithm, when the number of wavelengths in output interface of OBS router and offered load of class 1 are K and A_1, respectively, and the BLR P_1^{req} of class 1 should be guaranteed is requested.

Offset Time Decision Algorithm by Heuristic Loss Formula (HLF)

(1) The request for the decision of reasonable offset time of high priority class to guarantee the BLR P_1^{req} arrives.

(2) If P_1^{req} is $B(\rho_1, K) \le P_1^{req} \le B(\rho_{all}, K)$, then go to next step, otherwise this request is rejected.

(3) Define r as $0.5 + \rho_1 e^{\rho_1}$ and β is determined by Equation 11.

(4) By Equation 13, *R* is decided.

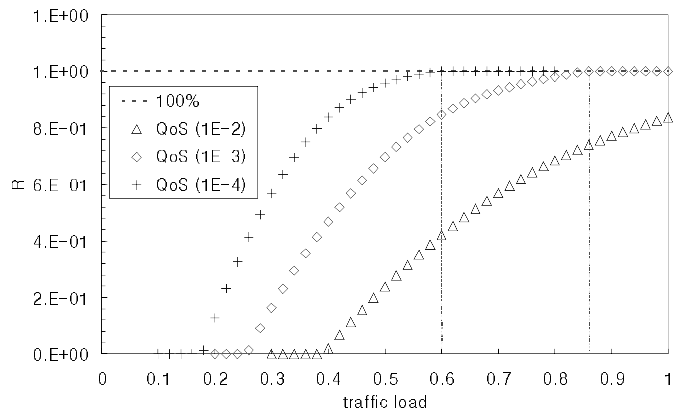
(5) If *R* is $R < 0$ or $R > 1$, then R = 0 or 0.999 (value very near to 1).

(6) Finally, we can decide t_1^o as $-\ln(1 - R) \cdot L_0$.

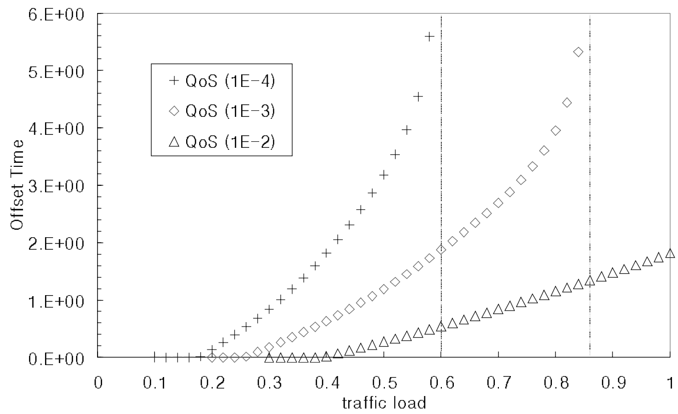
4. SIMULATION RESULTS

We use AweSim as a simulation tool to evaluate the performance of the proposed offset time decision algorithm. We assume that 8 wavelengths in output interface and the ratio of class 1 to total traffic load is 0.3. In addition, the burst length of class 1 and class 0 is distributed by exponential process with L_0 and the arrival process for burst data is Poisson distribution.

Fig. 5 shows *R* which are determined by the proposed OTD algorithm, when the requested BLR as QoS parameter is 10^{-2}, 10^{-3}, and 10^{-4}, and offset time of high priority class for corresponding to *R*. In Fig. 5(a), firstly, we can see the 100% dash line. That is the value of *R* for supporting the service differentiation by the conventional complete isolation method, and we can notice that the offset time of it is very large in Fig. 5(b). However, when we use OTD algorithm in consideration of changing offered load, we are able to find the dynamic changing of *R* and offset time in Fig. 5(b). That means our OTD algorithm provides the dynamic supporting for the requested BLR, which could not be done by the complete isolation scheme. Thus, the offset time of control packet for each QoS, such as 10^{-2}, 10^{-3}, and 10^{-4}, is different.



(a) R



(b) Offset time

Fig. 5: *R* and offset time of high priority class for guaranteeing its QoS.

Fig. 6 plots the burst loss rate of each class when we use OTD algorithm and the complete isolation. The top dot line and bottom bold line show the burst loss rate of class 0 and class 1, respectively, when it is separated with 100% isolation, while the burst loss rate of classless is curved between them and is evaluated by considering all of traffic load. To case of using OTD algorithm, the guaranteeing QoS for each requested BLR, such as 10^{-2}, 10^{-3}, and 10^{-4} is shown by using horizontal graph lines. Since we assume the number of wavelengths, *K*, is 8, the QoS for each case is guaranteed under the some range of offered load. That means that the burst loss rate of high priority class has upper bound and lower one on a given the number of wavelengths. The former is the performance of classless and the latter is class 1's, respectively. For example, in case of 10^{-4}, the OTD algorithm guarantees the BLR from 0.18 to 0.6 of total offered load. However, the case of 10^{-2}, the requested BLR is supported by our algorithm from 0.4. From these results, we can notice something as follows. First, when the offered load is low enough to support the QoS without any offset time the requested BLR is higher than the performance of class 1. This means that the number of wavelengths is sufficient and it might be reduced. However, when we use the OTD algorithm and the BLR of high priority class is requested with 10^{-2}, 10^{-3}, and 10^{-4}, the offset time is added to base offset from the point of 0.4, 0.26, and 0.18 of offered load in Fig. 5, respectively. Second, the small additional offset time is enough to keep the requested BLR while the offered load increases. This is why our OTD algorithm can calculate the reasonable offset time considering the offered load of high priority traffic. Finally, Fig. 6 shows that cases of 10^{-3} and 10^{-4} are not guaranteed though with very large offset time from 0.86 and 0.6, respectively. This means that the current number of wavelengths, 8, is not sufficient for supporting those QoS. Thus, to guarantee those QoS, we need to increase the number of wavelengths of output interface.

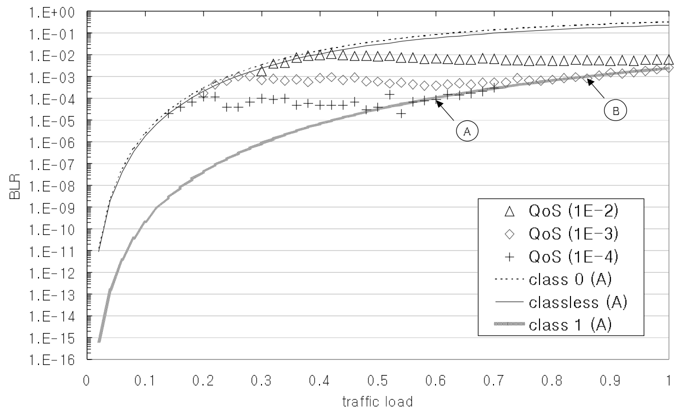


Fig. 6 Guaranteeing QoS by the reasonable offset time.

5. CONCLUSIONS

In this paper, a novel offset time decision algorithm has been proposed, which can decide the reasonable offset time according to the burst loss rate of high priority class. We first classify the IP traffic as one of high priority class and low priority one, which is based on the results of report by Internet Committee. In this classification, the high priority class request a level of QoS, such as burst loss rate, and it should be guaranteed by using offset time in OBS networks, while the low priority one is best effort traffic. We first considered the offset time of high priority and used it for our purpose. So we analyzed the loss effect of low priority class that is dependent on the offset time of high priority class and proposed a new burst loss formula. Then, by using this new formula and its characteristics of exponential function, we defined the heuristic loss formula, which can find the acceptable offset time for high priority class. Finally, we proposed offset time decision algorithm using this heuristic loss formula when the number of wavelengths and offered load is initialized and the request of high priority class for its QoS is arrived. By using this algorithm, the offset time, which is smaller than one determined by using conventional complete isolation method, was decided and we noticed that it is suitable for changing of offered load and its requested BLR. The other advantage of our OTD algorithm is that the bound of traffic load to guarantee the requested QoS is also calculated when we know the number of wavelengths. We think that this algorithm can be efficiently adapted to OBS based next generation Internet without optical buffer system.

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