Available online at www.sciencedirect.com
ScienceDirect
Optik 121 (2010) 1295–1299
Optik Optics
www.elsevier.de/ijleo

Blocking and delay performance for differential output-ports choosing probability scheme applied optical burst switching network

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Received 11 September 2008; accepted 13 January 2009

Abstract

Differential output-ports choosing probability (DOCP) scheme is a novel traffic outputting model for core router in optical burst switching (OBS) network. In this paper, we provide an analytical model for studying the performance of traffic blocking and delay in DOCP-applied OBS network. We first evaluate blocking probabilities using DOCP and confirm it by simulation. Then, in optical buffer-equipped OBS core router, we consider the average delay time for buffered traffic and the average total traffic queueing length in core router. The knowledge of delay performance is useful for the optical buffer architecture configuration in differential traffic scenario. Several results indicate that, under the same load condition, the blocking probabilities and the delay time will change along with the changeable ports choosing probability and the ratio between different length bursts in the OBS system.

Keywords: Optical burst switching; Differential output-ports choosing probability; Blocking probabilities; Delay; Optical buffer

1. Introduction

Optical burst switching (OBS) technology has been proposed as a promising switching solution for the terabit bandwidth exploitation in next-generation wavelength division multiplexing (WDM) optical transport network [1–3].

In OBS network, edge router aggregates IP packets electronically into bursts, which are almost transparent and fully optical, and come through the core routers. Under the just-enough-time (JET) resource reservation protocol [4,5], burst and its burst control packet (BCP) use payload wavelength and separate control wavelength to transmit. BCP will precede its corresponding burst into OBS network and attempt to reserve the wavelength resource at each core router, so that the burst following its BCP need not wait for acknowledgment. In this case, if the wavelength resource requirement has been satisfied, burst will come through the core router successfully, otherwise it will be blocked and will be buffered on the condition that optical buffer is being equipped.

In the OBS core router, one issue should be noticed that if several output-ports could lead to the same destination, bursts will use large probability to choose the port leading to the short path for destination, and use small probability to choose the port leading to the long path for destination [6]. Thus, burst will use differential probabilities to choose the output-port; such a scheme has been described as "Differential Output-ports Choosing Probability (DOCP)" scheme, which has been mentioned in the previous work [7]. The short-path port could be written as "SPP" while the long-path port could be written as "LPP". DOCP is a novel scheme

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doi:10.1016/j.ijleo.2009.01.011

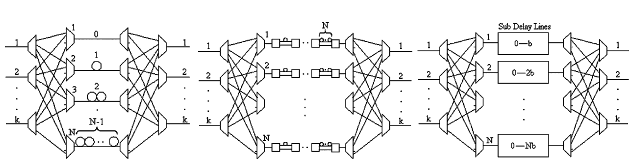
that is closer to the real network scenario. In the previous work, only the scheme has been mentioned. In this paper, we not only analyse the blocking performance based on the DOCP but also evaluate the delay performance in DOCP-applied core router to enhance the contention theory for the OBS network.

2. Several architectures of FDL buffers

In this section, we will discuss three architectures of fiber delay line (FDL)-based optical buffer. Fig. 1(a) shows a very commonly studied FDL buffer architecture [8–10], the buffer equipped with N FDL delay lines, and each delay line could provide a fixed delay time. k presents the wavelength number in input- or output-ports; this buffer could provide the minimal delay time $D_{\min}=0$, and the maximal delay time $D_{\max}=(N-1)b$, where b denotes the delay time by an FDL unit (a small circle in the figure). We may call this FDL buffer as Fixed Delay Buffer (FDB), which has a simple architecture but each delay line only provides a fixed delay time; thus, FDB is not an ideal FDL buffer architecture because it has bad agility. Fig. 1(b) shows an architecture of FDL buffer that could provide the variable delay time named Variable Delay Buffer (VDB), which also equipped with N delay lines, and each delay line could provide the delay time from the $D_{\min}=0$ to the $D_{\max}=(1+N)Nb/2$. But, VDB has a complex architecture; the figure shows that each delay line needs to be equipped with one 1×2, one 2×1 and $N-1$ 2×2 cross-connecters, and it makes the buffer architecture complex. In order to integrate the advantages of FDB and VDB, a novel architecture of FDL buffer named Hybrid Buffer (HB) has been emphasized as shown in Fig. 1(c) [10]. Compared to FDB, each delay line in HB is equipped with a sub-delay line, which could provide a variable delay time. Compared to VDB, each delay line in HB could provide the delay time from b to Nb, such architecture is simpler than VDB, which can only provide the same maximal delay time.

3. Delay performance included in the DOCP scheme

After introducing the concept of the DOCP scheme and several architectures of optical buffer, we will apply



(a) (b) (c)

Fig. 1. Several architectures of FDL buffers: (a) fixed delay buffer, (b) variable delay buffer and (c) hybrid buffer.

delay performance included in the DOCP scheme to the contention regarding the OBS system. In our discussion, all the referred output-ports can lead to the same destination but each of them has a different path distance. In the DOCP-applied OBS core router, when burst attempts to be outputted by SPP using large probability and one burst has already occupied this port, the former burst will be scheduled to the other LPP for transport. If all the output-ports have been occupied, contention will occur and the arriving burst will be blocked. In an optical buffer equipped core router, blocked bursts will be buffered. Suppose the delaying time provision capacity of the optical buffer is large enough for each contending burst, the contending burst will queue in the optical buffer and wait for the idleness of the output-port. When one port becomes idle, the buffered burst will be sent to that port for transmission, but if several ports are idle, control unit in core router will apply the DOCP scheme to schedule the buffered burst to the corresponding output-port for processing. The entire procedure could be illustrated by a flow chart as shown in Fig. 1.

4. Analytical model

In this section, we will give the analytical model for a DOCP-applied OBS core router. For simplicity but without losing generality, here we assume that core routers have two output-ports labeled No. 1 and No. 2, where No. 1 port is SPP and No. 2 port is LPP. We also assume that there are two types of length burst traffic in an OBS network, namely long-length burst and short-length burst. The "On–Off" model is applied, and let the on period of short-length burst and long-length burst have the means of $1/\mu_1$ and $1/\mu_2$ [11], respectively, and the off period have the means of $1/\lambda$ for both length bursts. We consider on and off periods to be negative exponential distributed and set $\mu_1>\mu_2$ here. In our discussion, wavelength conversion is unavailable, so the number of wavelength is equal to the number of fibers (Fig. 2).

Here, we use the Markov chain that has n states termed $State\_ij(i,j=0,1)$ and $State\_n$ for this OBS system [12,13], where i and j denote the number of bursts being served at No. 1 and No. 2 output-port, respectively, and n denotes the fact that there are $n-2$ bursts being buffered in FDLs. Let $P_{i,j}$ be the steady-state probability and the steady-state equations can be written as follows:

$$State\_00 : \lambda P_{0,0} = \mu_2 P_{0,1} + \mu_1 P_{1,0} \tag{1}$$

$$State\_01 : (\lambda + \mu_2) P_{0,1} = \mu_1 P_{1,1} + (1-\varphi)\lambda P_{0,0} \tag{2}$$

$$State\_10 : (\lambda + \mu_1) P_{1,0} = \mu_1 P_{1,1} + \varphi\lambda P_{0,0} \tag{3}$$