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Design and Performance Analysis of OBS Network Using Hybrid Contention Resolution Technique

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ABSTRACT—Optical burst switching (OBS) is a promising switching technology for realization of terabit optical network because it offers a very high bit-rate transport service that is potentially bandwidth-efficient and cost-effective in terms of network infrastructure. However, the lack of optical processing capability of OBS technology results in increased blocking probability and limits the network performance. Efficient contention resolution is therefore necessary. OBS networks are usually implemented using different contention resolution protocols but in particular, the analysis of wavelength conversion schemes and fibre delay line (FDLs), is required more attention as these two are easily realizable contention resolution components. Wavelength conversion is the process of converting a wavelength on an incoming channel to another wavelength on the outgoing channel. FDLs can be used to delay bursts until the contention situation is resolved and the original destination wavelength becomes available. Performance of wavelength converters may be restricted by number of available wavelength converters, sharing strategy and degree of conversion. Theoretically a burst may recirculate multiple times through FDL bank, although signal degradation issues may limit the number of recirculations. Hence it difficult to achieve desired contention resolution performance by using any one type of the conventional technique. In this paper a hybrid contention resolution scheme for OBS network has been proposed with the combination of wavelength converters and FDLs to achieve better contention resolution performance. Appropriate mathematical models have been developed to calculate the gain and blocking probability of the proposed scheme. Results are validated through proper simulations.

1. Introduction

Optical burst switching (OBS) network has the advantages of both optical circuit switching and optical packet switching networks, while avoiding their shortcomings. OBS networks provide connection-less transport, so the bursts may contend with one another at the intermediate nodes. Burst loss due to contention is a major source of concern in OBS networks. Such contention losses which are temporary in nature can degrade the performance at the higher layers. Contention among two bursts occurs due to the overlap of two bursts (in time) arriving simultaneously on two different links or wavelengths and requesting the same wavelength at a given time. In electronic packet switching networks, contention is handled by buffering. However optical buffers are difficult to implement and also there is no optical equivalent of random access memory. The conventional techniques used to resolve contention for an incoming wavelength signal at the core nodes are discussed below [1-3].

Wavelength domain: This strategy of contention resolution is implemented by means of wavelength conversion, where the burst can be sent on a different wavelength channel to the designated output line.

Time domain: The contention can also be resolved by utilizing a fiber delay lines (FDLs) buffer, where a burst can be delayed until the contending situation is resolved. In contrast to buffers in the electronic domain, FDLs in optical domain provide a fixed delay and maintain the order of the data transmitting through the FDLs.

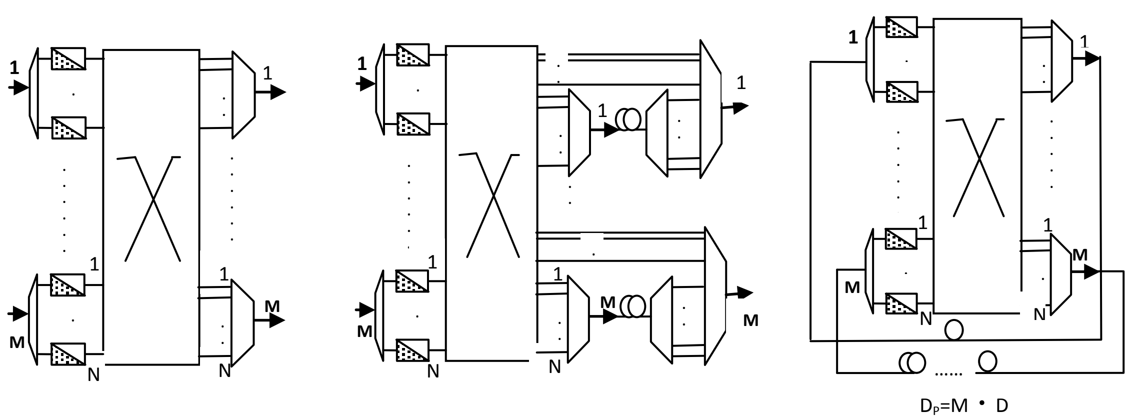
Space domain: Space domain contention resolution can be obtained by using deflection routing. In deflection routing, a burst is sent to a different output link of the node and consequently on a different route towards its destination node. Space domain can be exploited differently in case where several fibers are attached to an output line. A burst can also be transmitted on a different fiber of the designated output line without wavelength conversion in order to avoid network overload through traffic management policies.

Burst Segmentation: In burst segmentation, a portion of the burst which overlaps with another burst is segmented instead of dropping the entire burst. When two optical bursts contend for the same wavelength, either the head of the contending burst, or the tail of the other burst is segmented and dropped. Therefore segmentation can be classified into head dropping or tail dropping. The remaining segment of the burst is transmitted successfully to the destination thereby increasing the packet delivery ratio.

Although the above mentioned contention resolution schemes perform well in case of OBS networks, but they have inherent problems such as; that deflection routing makes setting the time lag between a burst header packet and the corresponding data burst i.e. offset time at the edge node is a hard problem because the exact transmission path of the burst is not known, and the scheme usually sets the offset time under the worst case; that fiber delay line technology will increase data latency and also introduce complexity for the network, optical burst segmentation is not easy to carry out in the physical layer now a days; and that the control scheme increases the complexity of implementation too much. The addition of wavelength converters to the switch reduces contention at output ports by enabling a burst arriving on one wavelength channel to be directed to a different wavelength channel at the output. In performance evaluation studies, there may be assumed restrictions on the number of available wavelength converters [4] and on the sharing strategy, for example, a pool of converters may be shared amongst all output ports at the switch or each output port may have a dedicated pool. Additionally, there may be restrictions on the range of conversion between one wavelength and another, and limitations on physical properties of the conversion devices [5]. The addition of FDLs to the switch can also achieve a substantial reduction in burst loss (by orders of magnitude) [6] by selectively delaying bursts in order to reduce contention for outgoing wavelengths. Full wavelength conversion is the most efficient way to solve the burst contention problem but full wavelength converters are expensive and complex devices at present. Hence there should be an analysis depending on the combinations of different contention resolution techniques in order to achieve the best possible performance of the network. In the present paper we have considered a hybrid contention resolution technique which is consisted of the combinational effect of two different contention resolution techniques, namely FDLs and wavelength conversion.

2. Architecture of the Optical Switches

An OBS network can be designed with wavelength converters and FDLs in tandem, in order to resolve the contention problem more efficiently. Optical switches can be variously configured with full, partial or no wavelength conversion and with or without a bank of single/multiple wavelength channel FDL buffers, arranged in feed-forward or feedback schemes (Fig.1) [7].In feed-forward architecture (Fig. 1(b)) each of M output ports have a dedicated FDL. The cross connect switch may redirect an incoming packet to one of N available channels in an FDL, in order to avoid a contention. With wavelength converters present at input ports, any available FDL channel may be selected. Having beendelayed in the FDL, the packet is transmitted on the samewavelength at the output port. If it is not possible to selecta wavelength that is available both in the FDL and the output port then the packet mustbe dropped. Although further efficiency could be gainedby introducing additional wavelength converters between the FDL and the output port, this arrangement would incursignificant addition hardware costs.



1 (a) No FDLs   1 (b) Feed-forward FDLs   1 (c) Feed-back FDLs

Fig. 1 OBS switches with tunable wavelength converters on all input channels and different FDL arrangements

In feed-back architecture [Fig. 1(c)] all output ports share a bank of MFDLs of different delay times m・D where m=1 . . . M and D is the delay granularity. With wavelength converters at input channels, a contending packet may be directed to any free channel in a chosen FDL. With wavelength converters at input channels, a contending packet may be directed to any free channel in a chosen FDL. The number of channels in an FDL may be less than the number of channels at the input port, allowing the FDL ports to be scaled according to cost/performance trade-offs. It is theoretically possible that a packet may recirculate multiple times through the switch and FDL bank, although signal degradation issues may limit the number of recirculations in practice and there are diminishing performance gains as FDL resource usage per packet increases with each recirculation [8].

3.Mathematical Model for the Analysis of Gain

In order to evaluate the performance of the proposed hybrid contention resolution scheme for OBS network we need to derive the probabilistic evaluation of the network configurations shown in fig (1). Contain M number of output channels and assuming that a queue is used to hold all request calls which cannot be immediately assigned a channel. The expression for call delayed formula is given by

$$P_c[\mathit{Call\ Delayed}] = \frac{\rho^M}{\rho^M + M!(1-\frac{\rho}{M})\sum_{i=0}^{M}\frac{\rho^i}{i!}} \tag{1}$$

and the blocking probability is given by

$$P_b = \frac{\rho^M}{\rho^M + M!(1-\frac{\rho}{M})\sum_{i=0}^{M}\frac{\rho^i}{i!}} * \exp\frac{-(M-\rho)}{t_d}t \quad . \tag{2}$$

where, 'ρ' is the incoming traffic , 't' is the delay time and' t_d' is the average duration of the call.

As shown in [9-10] a measure of the benefit of wavelength converters can be expressed in terms of the increase in the gain of the network for the same blocking probability. Gain of a network can be defined as the ratio of the achievable utilization for a given blocking probability in networks with wavelength converters and without converters. Increase in the utilization G can be written as

$$G = \frac{[1-(1-\frac{\rho^M}{\rho^M + M!(1-\frac{\rho}{M})\sum_{i=0}^{M}\frac{\rho^i}{i!}} * \exp\frac{-(M-\rho)}{H}t)^{1/H}]^{1/w}}{1-(1-(\frac{\rho^M}{\rho^M + M!(1-\frac{\rho}{M})\sum_{i=0}^{M}\frac{\rho^i}{i!}} * \exp\frac{-(M-\rho)}{H}t)^{1/w})^{1/H}} \tag{3}$$

$$G \approx H^{[1-(1/w)]}\frac{(\frac{\rho^M}{\rho^M + M!(1-\frac{\rho}{M})\sum_{i=0}^{M}\frac{\rho^i}{i!}} * \exp\frac{-(M-\rho)}{H}t)^{1/w}}{-\ln[1-(\frac{\rho^M}{\rho^M + M!(1-\frac{\rho}{M})\sum_{i=0}^{M}\frac{\rho^i}{i!}} * \exp\frac{-(M-\rho)}{H}t)^{1/w}]} \tag{4}$$

Here M is the number of output; H is the number of hops available in the network, w is the number of wavelengths available at each output port.

If there is no concept of wavelength converters, any session must continue using same wavelength on all the hops, throughout the entire path. Hence, a request is considered only if a free wavelength exist i.e. any wavelength which is not being uses on each and every hop. It makes sense that any network containing wavelength converters is more flexible compared to the same network without any of them. Also, the former network has a lesser blocking probability over the latter. Hence, extensive research on wavelength converters implementation in a network has been done.

4. General Model for the Analysis of Blocking Probability

The main function of a wavelength router is to transparently switch optical channels from its input fiber to the output fibers. We assume for simplicity that each node has Mincoming and Moutgoing unidirectional fibers the number of wavelengths per fiber w will also be considered the same for all the fibers, and so a wavelength router node will have a theoretical maximum capacity C = M·w optical channels or connections. Here we suppose that the optical switch is a M·w by M·w crossbar-like switching fabric and is non-blocking from a space-switching point of view. The realistic wavelength converters only have the capability of limited wavelength conversion. Moreover, low conversion degree is likely to be far easier to realize in practice than higher degree conversion. Assume that a limited wavelength converter has conversion degree d (for some integer d, $1 \le d \le w$) if an input wavelength can be converted to d −1 different output wavelengths in addition to the input wavelength itself. We refer to these d output wavelengths as the set of available wavelengths of input wavelength λ_i. Apparently, the case of d = 1 is the no conversion, and the case of d = w is the full conversion. For a node with limited wavelength conversion of degree three (d= 3), incoming wavelength λ_i[11-13].
We need to consider three cases in the following:

A. No Wavelength Conversion d = 1

No wavelength conversion is one of the extreme cases for the node model. In the absence of wavelength converters, different wavelengths do not interact with each other. The blocking probability P_b for this case is the probability that each wavelength is used either on the source link or on the destination link and can be written as

$$P_b = \{\{2\rho(1-\frac{1}{N}) - [\rho(1-\frac{1}{N})]^2\}^w - \{2[\rho(1-\frac{1}{N})]^w - [\rho(1-\frac{1}{N})]^{2w}\}\}/\{1-[\rho(1-\frac{1}{N})]^w\}^2 \quad ....(5)$$

B. Limited Conversion 2 ≤ d ≤w－1
A connection request commencing on wavelength λ_i is blocked either if input λ_i itself is being used, or if all the available output wavelengths of λ_i are occupied. Accordingly, we can get

$$P_b = \frac{[8(19\rho/20)^5(1-(19\rho/20))^2]}{[1-(19\rho/20)^4]^2} \quad for \quad d=2 \quad ......(6)$$

$$P_b = \frac{[4(19\rho/20)^6(1-(19\rho/20))^2]}{[1-(19\rho/20)^4]^2} \quad for \quad d=3 \quad .....(7)$$

C. Full Wavelength Conversion d = w
A connection request is blocked when all w wavelengths on the source link or on the destination link are being used, that is P_b=0. Therefore in terms of internal blocking probability, a node with full wavelength conversion capability is always non-blocking. The above equations have been used in blocking probability and gain calculation for different network parameters in the MATLAB environment under the appropriate node and traffic assumptions.

5. Simulation and Results
The simulations are carried out for a general optical switching configuration for a generic traffic with specific node architecture, having variable traffic routing factor. Here we have analyzed the network performance for various configurations viz, with full, partial or no wavelength conversion and with or without a bank of single/multiple wavelength channel FDL buffers, arranged in feed-forward or feedback schemes. The performance of the networks are measured with the help of parameters like network gain, number of hops, number of available wavelengths per channel, blocking probability, utilization probability and degree of conversion. The variation of gain with different number of available wavelengths is depicted in fig. 2(a), 2(b) and 2(c) for network with no FDL, network with feed-forward FDLs and network with feed-back FDLs. Here we see that the gain of the network increases with number of available wavelengths for all different values of H (no. of available hops). This trend in gain increment is significant upto a certain value of number of wavelengths and after that the gain becomes almost saturated and in fact the gain reduces little bit for higher value of number of wavelengths. The possible reason behind this nature is that initially as the number of wavelengths is increasing, more amount of incoming traffic can be carried out. At higher wavelength values the network becomes more complex and the data handling capability of the network switch reaches its

optimum value. So the amount of carried traffic will no longer increase and as a result the gain of the network will also remain almost unchanged.

Fig. 2(a) shows that the maximum gain offered by the network is almost equal to 3, 6, 9 and 11 for H=5, 10, 15 and 20 respectively when the network in not equipped with FDLs. It can be seen from fig. 2(b) and 2(c) that the overall gain increases if we include FDLs with tunable wavelength converters (TWC). The qualitative nature of gain variation is almost similar in both the cases but with different quantitative values. This result proves the superiority of the hybrid combination than the simple network having only wavelength conversion facility. Now if we compare fig. 2(b) and 2(c) it can be inferred that the network with feed-back (FB) FDLs shows better result than the network with feed-forward (FF) FDLs. The FB configurations generally outperform the FF configuration, even when the total number of FB FDL channels is less than the number of FF channels. This improvement is accounted for by the fact that two wavelength conversions may be performed in the FB case allowing independent wavelengths to be selected in the FDL and the output port.

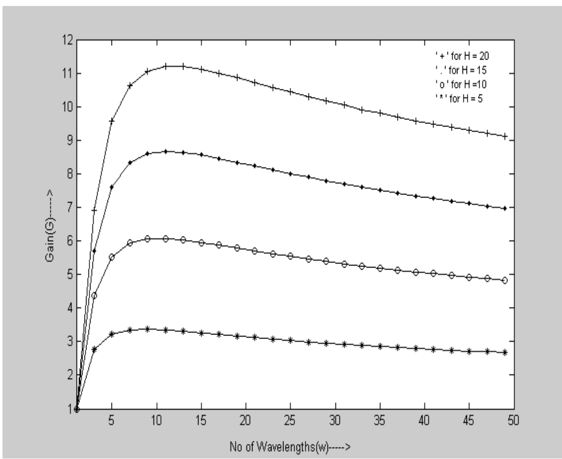


Fig. 2(a): Network Gain vs No. of wavelengths for no FDLs

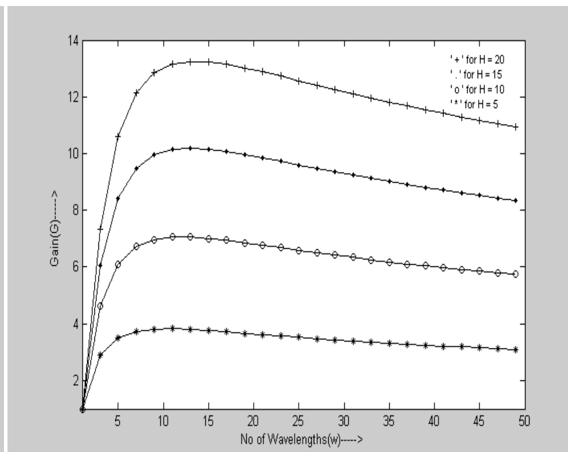


Fig. 2(b): Network Gain vs No. of wavelengths for feed forward FDLs

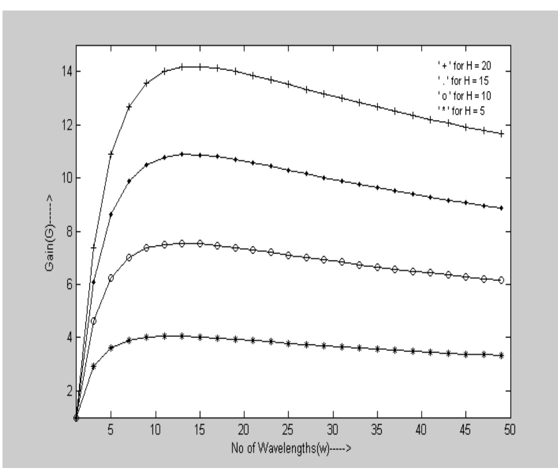


Fig. 2(c): Network Gain vs No. of wavelengths for feed-back FDLs

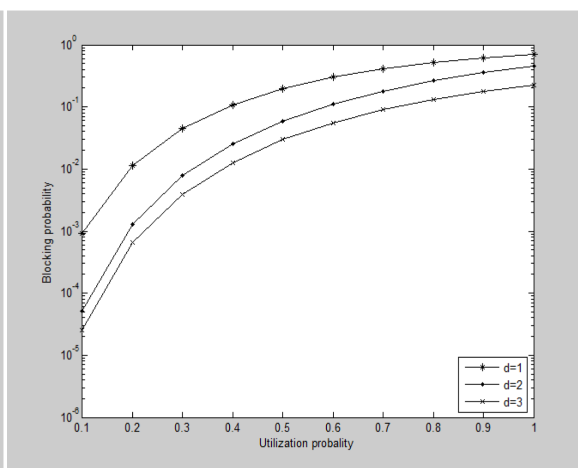


Fig.2 (d): Blocking Probability vs Utilization Probability for different degree of conversion

Fig.2 (d) shows the Blocking Probability vs Utilization Probability for different degree of conversion. The simulation results reveals that as the conversion degree increases, the wavelength correlations become greater, thus leads to the inaccuracy of the model. Also, as is evident from the plots, with the same value of network utilization, blocking probability reduces as conversion degree increases for a given number of wavelengths 'w' per link.

In summary, the overall gain performance of a network increases significantly with the number of available hops. Similar gain improvement is noticed as the number of wavelengths per output channel is increased. The qualitative nature of gain enhancement continues if the network switch is equipped with hybrid contention resolution techniques. From the simulation result it is inferred that the network switch which is designed with both TWC and FDLs offer better output performance which is quite obvious.

6. Conclusions

In this paper a hybrid contention resolution technique consisted of FDLs and wavelength converter has been proposed. The OBS network has been analyzed for various configurations viz, with full, partial or no wavelength conversion and with or without a bank of single/multiple wavelength channel FDL buffers, arranged in feed-forward or feedback schemes. Appropriate mathematical models are developed for the same. The performance of the networks are verified with the help of parameters like network gain, number of hops, number of available wavelengths per channel, blocking probability, utilization probability and degree of conversion under MATLAB environment considering the appropriate node and traffic assumptions. Simulation result reveals that the network switch equipped with both TWC and FDLs offer better contention resolution and output performance.

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7. References

[1] Z. Rosberg, A. Zalesky, H. L. Vu, M. Zukerman, “Analysis of OBS Networks With Limited Wavelength Conversion,” IEEE/ACM Transactions on Networking, vol. 14, no.5, pp. 1118-1127, October 2006.

[2] Reviriego, A. M. Guidotti, C. Raffaelli, J. Aracil, “Blocking models of optical burst switches with shared wavelength converters: exact formulations and analytical approximations,” Photonic Network Communications, vol. 16, no.1, 2008.

[3] ConorMcArdle, Daniele Tafani, Liam P. Barry, Anthony Holohan and Thomas Curran, “Simplified Overflow Analysis of an Optical Burst Switch with Fibre Delay Lines”, Published in: Sixth International Conference on Broadband Communications, Networks, and Systems, BROADNETS 2009.

[4] Z. Rosberg, A. Zalesky, H. L. Vu, M. Zukerman, "Analysis of OBS Networks With Limited Wavelength Conversion," IEEE/ACM Transactionson Networking, vol. 14, no. 5, pp. 1118-1127, October 2006.

[5] G. I. Papadimitriou, C. Papazoglou, A. S. Pomportsis, Optical Switching, Wiley-Interscience, 2007.

[6] X. Lu, B. L. Mark, "Performance Modeling of Optical-Burst Switching With Fiber Delay Lines," IEEE Transactions on Communications, vol.52, n. 12, December 2004.

[7] C. M. Gauger, H. Buchta, E Patzak, “Integrated Evaluation of Performance and Technology Throughput of Optical Burst Switching Nodes Under Dynamic Traffic,” Journalof Lightwave Technology, vol. 26, n. 13, pp. 1969-1979, July 2008.

[8] ConorMcArdle, Daniele Tafani and Liam P. Barry, “Analysis of a Buffered Optical Switch with General Inter arrival Times”, Journal of Networks, Vol. 6, No. 4, April 2011.

[9] [9] Richard, B.A., Pierre, H.A., “Models of blocking probability in all-optical networks with and without wavelength changers”, IEEE Journal on Selected Areas in Communications 14(5) (June 1996).

[10] Chunyong Yang, Deming Liu, Wei Li, Jun He, “Blocking Probability Analysis of the Node in WRON”,Department of Optoelectronics Engineering, Huazhong University of Science and Technology, Wuhan 430074,People’s Republic of China.

[11] X. D. Qin, Y. Y. Yang, "Optical cross connect architectures for wavelength routed WDM networks", Optical Networks Magazine (2003) July/August 50-62.

[12] [12] Chunyong Yang, Deming Liu, Shaojing Wu, Wei Li and Dexiu Huang, "A Node-Level Blocking Probability Analysis for WRONsPhotonic Network Communications" Volume 10, Number 2 (2005), 215-223, DOI: 10.1007/s11107-005-2485-1.

[13] R. A. Barry and P. A. Humblet, "Models of blocking probability in all-optical networks with and without wavelength changer", IEEE Journal on Selected Areas in Communications 14 (6) (1996) June 858-867.