Blocking Probability Evaluation and Traffic Management of Bufferless OPS/OBS Networks

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Abstract
We present here a new method for the estimation of blocking probabilities in OPS/OBS networks, validate its accuracy by simulation, demonstrate various performance effects, and provide useful insight into efficient and stable packet/burst deflection techniques.

Introduction
As Internet traffic increases, the capacity of the networks that transport this traffic must also increase. Future all-optical networks are seen as a way to meet this growing demand [1], [2]. However, for all-optical networks to be economically feasible, improved methods of network dimensioning are required. A key component of network dimensioning is the accurate estimation of blocking probability in the network links [3]–[5]. In this paper, we present a new method for the estimation of blocking probabilities in all-optical packet switched (OPS) [2] and all-optical burst switched (OBS) [1] networks. The words packet and burst are interchangeable here. Our new method is based on a recently published technique for estimation of blocking probabilities in general overflow loss networks [6]–[8]. The network model that we consider is sufficiently general to include a number of techniques shown to reduce blocking in all-optical networks. We include deflection routing [9], [10] and full wavelength conversion [11]. In addition, we include trunk reservation to account for some of the instability introduced by deflection routing [10], [12]. We focus on a model of a bufferless optical switched network [13]. The study of a bufferless optical switched network is important because although there have been some improvements in optical buffering technologies [1], there remain significant size and energy consumption limitations [14]. On the other hand, the alternative of electronic buffering suffers from the drawback of energy intensive optical-to-electrical and electrical-to-optical conversion [14].

Deflections and Reservations
In a buffereless OPS/OBS network, a packet may arrive at a switch but cannot be forwarded to its destination because all the links in the trunk towards the destination are busy. In such a case, the packet can be deflected to another switch or dumped. If a large number of packets are repeatedly deflected, the carried traffic drops and instability occurs [10], [12]. A method known to be effective to avoid instability, is the so-called *wavelength reservation* [10], [12]. In a network with wavelength channel reservation, some of the capacity on each trunk is reserved for packets that have not been deflected [10], [12]. When we say 90% reservation, we mean that 10% of the trunk capacity is reserved for undeflected packets. Moreover, to avoid congestion during heavy traffic periods, we set what we call the *maximum number of deflections* to limit the number of times a packet can be deflected. If, for example, the maximum number of deflections is 3, then if after three times the packet is deflected, it reaches a switch where the trunk towards its destination is fully busy, then the packet is dumped.

Blocking Probability Approximations
We consider two approaches. The first is the well known Erlang Fixed-Point approximation (EFPA) [3]-[5]. The second is the Overflow Priority Classification Approximation (OPCA) [6],[7]. The accuracy of the approximations will be considered in three regions: low traffic, high traffic, very high traffic. **Low traffic**: OPCA is accurate, while EFPA usually underestimates the blocking probability. OPCA captures well the dependency and occurrances of occasional congestion [6], while EFPA suffers from errors due to the Poisson and independence assumptions. **High traffic**: overflow traffic dominates, links are used inefficiently because bursts take longer paths using more links, and carried traffic drops causing instabilitity in EFPA [10]. OPCA considers a surrogate system that gives preemption priority to primary traffic, so primary traffic dominates when in fact the overflow traffic dominates in the real system. Therefore OPCA is stable but underestimates the blocking in this region. **Very High Traffic:** EFPA is now stable. It does not consider priorities, so it captures the excess overflows and predicts higher blocking probabilities than OPCA. This is demonstrated in Fig. 1 for a 6-node fully meshed network and gives rise to the max(EFPA,OPCA) approximation which appears to be reasonably accurate for a wide range of parameters. Although as the case is with approximations, there may potentially be scenarios where max(EFPA,OPCA) is inaccurate.

Utilization
We can use our approximation to evaluate the utilization achievable by an OBS/OPS network with reservation and deflection and learn the effect of the maximal

allowable number of deflections on the achievable utilization. In Fig. 2 we consider a 6-node fully meshed network with reservation threshold of 90%. We aim for a target blocking probability of 1/1000 (blocking here includes only events where the packet is blocked and cleared out of the system and not only deflected). We vary the maximal number of deflections between 0 – 6 for the cases where the number of wavelength channels (links) per trunk is 10, 50 and 100. We clearly observe a reduced marginal benefit of increasing the maximal number of deflections. When this number reaches 4, the benefit in terms of the achievable utilization is negligible. We also observe that for cases where the number of links per trunk is low (10) deflections can lead to significant improvement.

Conclusions

We have developed a new method for blocking probability evaluation of OPS/OBS networks with deflections and reservation. The new method enables us to study the performance of OPS/OBS networks and to make decisions on design and dimensioning.

References

1. C. Qiao and M. Yoo, "Optical burst switching (OBS) - a new paradigm for an optical internet," J. High Speed Netw., vol. 8, no. 1, pp. 4468–4492, 1999.

2. S. J. B. Yoo, "Optical packet and burst switching technologies for the future photonic internet," J. Lightw. Technol., vol. 24, no. 12, pp. 4468–4492, Dec. 2006.

3. S.-P. Chung, A. Kashper, and K. W. Ross, "Computing approximate blocking probabilities for large loss networks with state-dependent routing," IEEE/ACM Trans. Netw., vol. 1, pp. 105–115, 1993.

4. R. Cooper and S. Katz, "Analysis of alternate routing networks with account taken of nonrandomness of overflow traffic," Bell Telephone Lab. Memo., Tech. Rep., 1964.

5. F. P. Kelly, "Blocking probabilities in large circuit-switched networks," Adv. in Appl. Probab., vol. 18, pp. 473–505, 1986.

6. E. W. M. Wong, A. Zalesky, Z. Rosberg, and M. Zukerman, "A new method for approximating blocking probability in overflow loss networks," Comput. Netw., vol. 51, no. 11, pp. 2958–2975, 2007.

7. E. W. M. Wong, M. Y. M. Chiu, M. Zukerman, Z. Rosberg, S. Chan, and A. Zalesky, "A novel method for modeling and analysis of distributed video on demand systems," in Proc. IEEE International Conference on Communications 2005 (ICC'05), May 2005, pp. 88–92.

8. G. Raskutti, A. Zalesky, E. W. M. Wong, and M. Zukerman, "Blocking probability estimation for trunk reservation networks," in Proc. IEEE International Conference on Communications 2007 (ICC'07), June 2007, pp. 223–228.

9. A. Zalesky, H. L. Vu, Z. Rosberg, E. W. M. Wong, and M. Zukerman, "OBS contention resolution performance," Perform. Eval., vol. 64, no. 4, pp. 357–373, 2007.

10. . A. Zalesky, H. L. Vu, Z. Rosberg, E. W. M. Wong, and M. Zukerman,, "Stabilizing deflection routing in optical burst switched networks," IEEE J. Sel. Areas Commun., vol. 25, no. 6, pp. 3–19, Aug. 2007.

11. E. Ciaramella, G. Contestabile, F. Curti, and A. D'ottavi, "Fast tunable wavelength conversion for all-optical packet switching," IEEE Photon. Technol. Lett., vol. 12, no. 10, pp. 1361–1363, Oct. 2000.

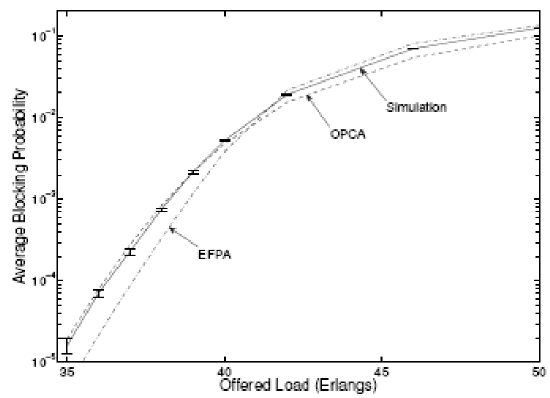

Fig. 1. Blocking probability comparison of OPCA vs. EFPA for a 6-node fully meshed topology with 90% reservation threshold.

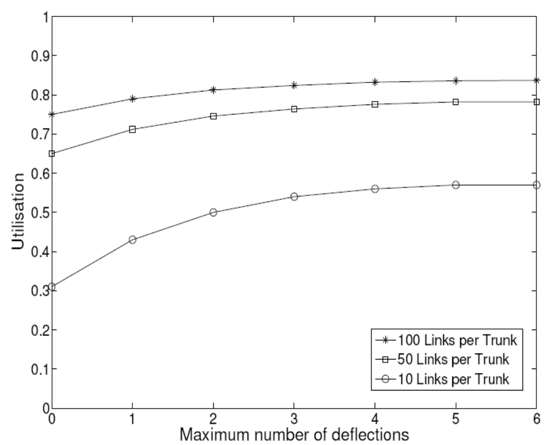

Fig. 2. The utilisation of a 6-node fully meshed network with reservation threshold of 90%, target blocking probability of 1/1000 and maximal deflections between 0 – 6 when the number of links per trunk is 10, 50 and 100 network.

12. J. Baliga, E. M. W. Wong, and M. Zukerman, "A new deflection method for OBS/OPS networks," submitted to IEEE Commun. Lett., 2009.

13. V. Eramo and M. Listanti, "Packet loss in a bufferless optical WDM switch employing sharedtunable wavelength converters," J. Lightw. Technol., vol. 18, no. 12, pp. 1818–1833, Dec. 2000.

14. R. S. Tucker, "The role of optics and electronics in high-capacity routers," J. Lightw. Technol., vol. 24, no. 12, pp. 4655–4673, 2006.