Performance of Wavelength Translation in All-Optical Cross-connected Networks

G. A. Castanon, O. K. Tonguz and A. Bononi[1].

Abstract— The teletraffic performance of regular two connected multi-hop datagram optical networks in uniform traffic under a combination of wavelength translation routing and hot-potato routing is presented. Manhattan Street (MS) Network and ShuffleNet (SN) are compared in terms of average propagation delay and throughput.

I. INTRODUCTION

This paper analyzes the steady-state behavior of two connected mesh *packet-switched* optical networks under wavelength translation. We present the limit of operation based on a uniform traffic scenario. We introduce an optimized wavelength translation routing algorithm that minimizes the probability of packet deflection. We analyze wavelength translation assuming that packets in transit have translation priority over new locally generated packets. Packets are wavelength translated in the case of local conflict to an available slot in an output wavelength to avoid deflection, otherwise packets will transparently traverse the node. In case of local conflict, but no available alternative slots, one packet is randomly chosen for deflection instead of being dropped.

The teletraffic performance of *circuit-switched* all optical [1], [2] and electronic (regenerative) [3] wavelength translation has recently been reported. However, the teletraffic performance of *packet-switched* wavelength translation with deflection routing has not been reported yet.

II. NODE STRUCTURE

The node is composed of a stack of submodules, one per wavelength. Fig. 1 shows the architecture of the wavelength translation node. All the submodules are interconnected and there is a central control unit which decides absorption, translation, injection of a new packet, and routing operations. The wavelengths from the input fibers are spatially demultiplexed and sent to the appropriate submodule. Packets from the submodules are finally re-multiplexed onto the output fibers. The logical flow of submodule operations is *absorption*, *translation* to a receiving wavelength, electronic *translation/injection* of a new generated packet, and *routing*.

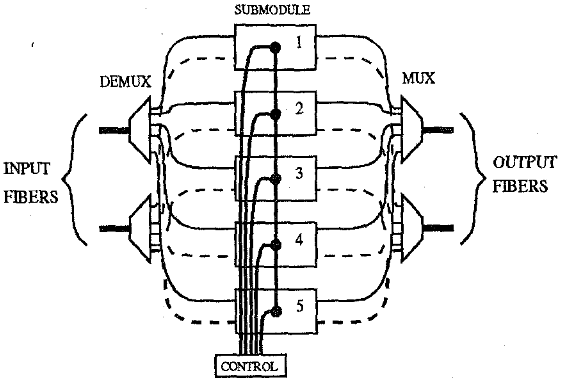

Figure 1: Architecture of the wavelength translation node. All the submodules are interconnected and there is a central control unit which decides transmission operations.

III. RESULTS

Fig. 2 shows propagation delay H in number of hops versus number of channels n for ShuffleNet (SN) and Manhattan Street (MS) networks with 64 nodes. Observe that propagation delay for hot-potato, single-buffer [4], and ideal store-and-forward (S&F [5]) keep constant because channels are independent of each other whereas propagation delay for wavelength translation routing improves with the number of channels. The reason for this is that packets in conflict have the possibility of being translated to an available non-conflictive slot. The probability of deflection then decreases and the propagation delay improves. Simulations use uniform traffic conditions for each channel. Full load (probability of packet generation $g = 1$) is used for each channel in the network, corresponding to the case of a saturated infinite shared input queue at the transmitters ($TX's$) [6]. SN64 network performs better than MS64 due to the fact that SN has less traffic congestion because the link load is lower and the packet absorption probability is higher. Simulation statistics were collected for 30,000 clock cycles, after discarding 10,000 initial cycles to allow for transients to die out. Observe the good match between an approximate analytical model and the simulation results in Fig. 2 for MS (at g=1, 0.5) and for SN (at g=1). The discrepancies in results for MS and SN between theory and simulation are in the range of 0 to 0.08.

Figs. 3a and 4a show results (for MS and SN respectively) of the average propagation delay H ver-

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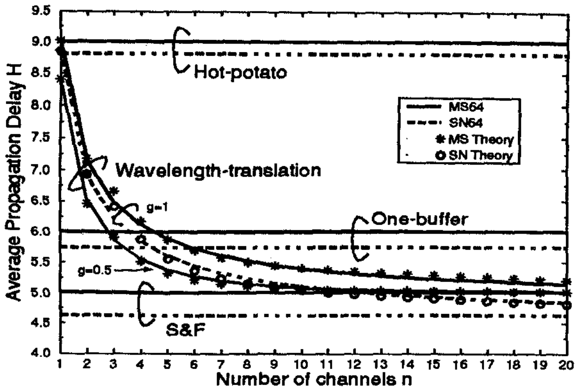
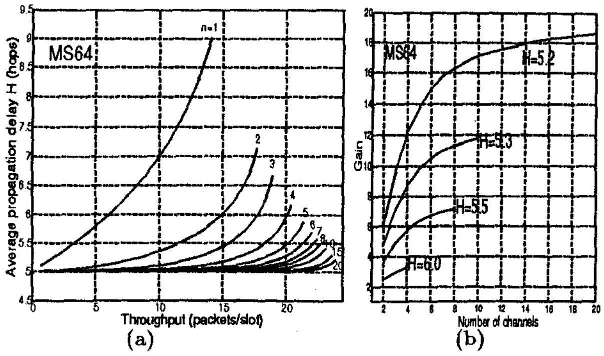
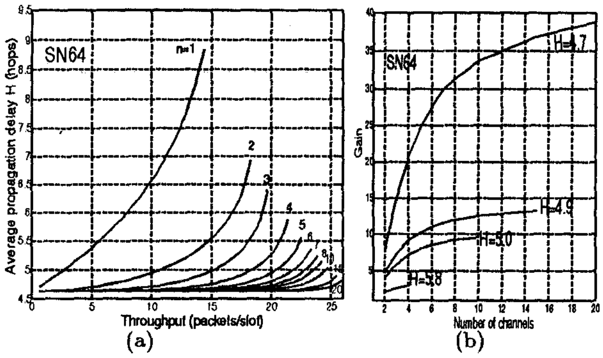


Figure 2: Results of average propagation delay H in number of hops versus number of channels n for hot-potato, single-buffer, store-and-forward (S&F) and wavelength translation at g=1. Results are for ShuffleNet (SN64) and Manhattan Street (MS64) networks with 64 nodes.



(a) (b)

Figure 3: a) Results of average propagation delay H versus throughput for MS b) Results of Gain versus number of channels n for values of H=5.2, 5.3, 5.5, 6.0



(a) (b)

Figure 4: a) Results of average propagation delay H versus throughput for SN b) Results of Gain versus number of channels n for values of H=4.7, 4.9, 5.0, 5.8

sus throughput per channel S. Where throughput is the average number of packets inserted/absorbed per slot. Observe that the throughput and propagation delay improve depending on the number of channels used. As a measure of the benefit of wavelength translation for packet switching, define the *Gain* as the increase in throughput for the same average propagation delay. Then *Gain* is

$$Gain = \left|\frac{S(n>1)}{S(n=1)}\right|_{H,g>0} \tag{1}$$

where $S(n = 1)$ represent the throughput per channel of a network without wavelength translation, and $S(n > 1)$ represent the throughput per channel of a network with wavelength translation. Figs. 3b and 4b show curves of *Gain* for fixed values of H =5.2, 5.3, 5.5, 6.0 for MS, and H =4.7, 4.9, 5.0, 5.8 for SN. As H decreases the *Gain* increases depending on the number of channels used, however this *Gain* comes at the expense of increased hardware.

In summary, the benefits of wavelength translation for two-connected packet switching networks increase with the number of wavelengths used due to the fact that the probability of deflection decreases, therefore average propagation delay decreases, throughput per channel increases, and thus *Gain* increases.

IV. CONCLUSIONS

Wavelength translation in *packet switching* networks with deflection routing has the feature of decreasing the probability of deflection, i.e. improving the throughput and propagation delay depending on the number of channels used in the network. In this paper an optimized wavelength translation routing algorithm has been used that minimizes the probability of packet deflection. The results show that, on the average, SN has higher throughput and lower propagation delay than MS when wavelength translation is used due to the fact that SN has less traffic congestion. The effectiveness of wavelength translation is quantified. It is verified that under uniform traffic, the use of wavelength translation recovers more than 60% of the propagation delay loss of hot-potato with respect to store-and-forward when five or more channels are used in the network.

References

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