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An optical interconnection network with wavelength time slot routing

Ireneusz SZCZEŚNIAK and Roman WYRZYKOWSKI

Institute of Computer and Information Sciences
Częstochowa University of Technology, Poland

Introduction

Interconnection networks connect computing and storage nodes, chips on motherboards, and components on a chip. It is generally agreed that interconnection networks in the long term should become more optical and less electronic to increase performance and reliability, and to decrease power consumption [1]. Intel and IBM already demonstrated working prototypes of optical interconnects [2, 3].

We propose a novel idea of *wavelength time slot routing* (WTSR) for interconnection networks. WTSR is time slot routing augmented with wavelength-division multiplexing (WDM). Time slot routing (TSR), in turn, is a form of time-division multiplexing (TDM) that is used in communication networks to share a transmission link, but we devised TSR as a simple and efficient means of routing packets in an interconnection network.

Architecture

The network interconnects N client nodes. Each of the nodes can send at most W packets every time slot, where W is the number of wavelengths a client uses.

Figure 1 presents the architecture of the interconnection network, where only the AWG and a space switch are used.

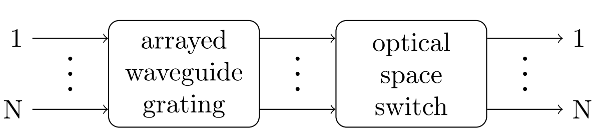


Figure 1: Interconnection network architecture.

The AWG distributes the packets encoded on different wavelengths to the inputs of the space switch. The configuration of the space switch changes every time slot according to the permutations of inputs to outputs that change periodically. There are $(N-1)$ permutations required. Figure 2 shows sample required permutations for a 4×4 network. Figure 3 shows a sample configuration of Beneš network for permutation P1.

P1	P2	P3
$1 \to 2$	$1 \to 3$	$1 \to 4$
$2 \to 3$	$2 \to 4$	$2 \to 1$
$3 \to 4$	$3 \to 1$	$3 \to 2$
$4 \to 1$	$4 \to 2$	$4 \to 3$

Figure 2: Sample required permutations for a 4×4 network.

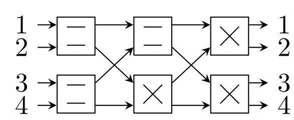


Figure 3: A sample configuration of the 4×4 Beneš network for permutation P1.

Destination node n_{wtsr} of a packet sent from node n is determined by wavelength number w and time slot number t as given by (1), where $s = N/W$ is a parameter of the AWG.

$$\begin{aligned} n_{wtsr} &= (n_{tsr} + sw) \bmod N \\ n_{tsr} &= (n + 1 + t \bmod (N-1)) \bmod N \end{aligned} \tag{1}$$

Simulation results

The comparison of WTSR and store-and-forward routing (SAFR) is presented in Figures 4 and 5 for the cases without and with acknowledgments. In each of the figures, the subfigures (a) are for $W = 1$, (b) for $W = 4$, and (c) for $W = 16$.

The results for traffic without ACKs for WTSR are shown with the bullets (•), and for SAFR are shown with the pluses (+) for the buffers of size 1, with the crosses (×) for the buffers of size 2, and with the circles (∘) for the buffers of size 3.

The results for traffic with ACKs for WTSR are shown with the solid lines, and for SAFR are shown with the dashed lines for buffers of size 1, with the dash-dot lines for the buffers of size 2, and with the dotted lines for buffers of size 3.

Conclusion

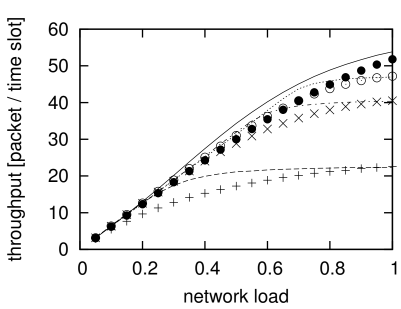
Wavelength time slot routing can be used for optical interconnects in computing and storage centers, but also in networks on chip (NoC). Wavelength time slot routing allows for a simple network design without buffers and header processing. The proposed routing compares favorably with store-and-forward routing.

References

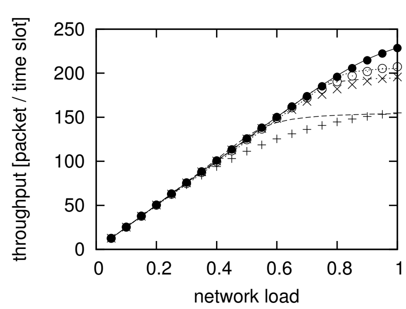
[1] "International technology roadmap for semiconductors: interconnect chapter," 2011. [Online]. Available: www.itrs.net

[2] M. Taubenblatt, "Optical interconnects for high-performance computing," *Journal of Lightwave Technology*, vol. 30, no. 4, pp. 448–457, February 2012.

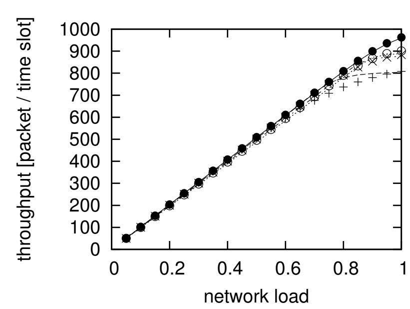
[3] R. Leheny, "Molecular engineering to computer science: the role of photonics in the convergence of communications and computing," *Proceedings of the IEEE*, vol. 100, pp. 1475–1485, 2012.



(a) One wavelength

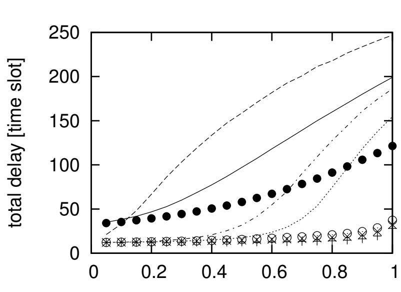


(b) Four wavelengths

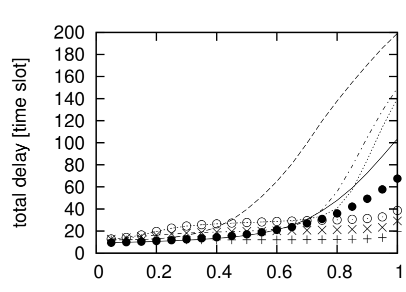


(c) Sixteen wavelengths

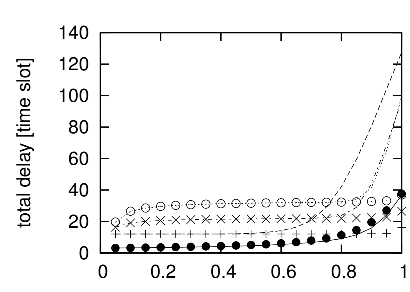
Figure 4: Comparison of the mean network throughput for the network with 64 nodes.



(a) One wavelength



(b) Four wavelengths



(c) Sixteen wavelengths

Figure 5: Comparison of the mean total packet delay for the network with 64 nodes.