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Wavelength Conversion by using Multiple Fibres

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Abstract *We explain how wavelength conversion can be achieved by using multiple fibres, and show that multiple fibres reduce blocking probability in dynamic all-optical networks, whereby the need for conversion in all-optical networks will be limited.*

Introduction

The advantages of wavelength conversion in all-optical networks have been discussed extensively in the literature with the provisional conclusions that the effect is negligible in static wavelength routed optical networks [2], but significant in dynamic wavelength routed optical networks [4,6]. In [1,3] it is for a special case (random wavelength assignment, fixed routing) shown that limited-range wavelength conversion almost reduces the blocking to the level of full wavelength conversion. This is the first time the effect of multiple fibres is studied for fixed routing with many fibres and for adaptive unconstrained routing in general.

We first explain how multiple fibres correspond to limited-range wavelength conversion, and by simulations of dynamic wavelength routed optical networks we show that multiple fibres significantly reduces the blocking probability in the network.

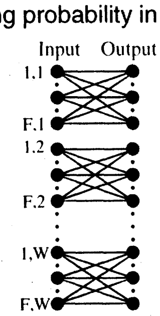

Fig. 1: Illustrates how limited wavelength conversion corresponds to multiple fibres. F fibres and W wavelengths on each fibre are shown. The number f,w to the left corresponds to the fibre and wavelength number.

With multiple fibres limited-range wavelength conversion is achieved in the nodes. Fig.1 illustrates how multiple fibres correspond to limited-range wavelength conversion. We assume an optical cross connect with any number of input and output links each with F fibres, and W wavelengths on each fibre. Then one wavelength, which has to be switched from an input link to a specific output link, has the choice of up to F available fibres. This situation corresponds to have one fibre on each link, and $F \cdot W$ wavelengths on each fibre, where the wavelengths can be converted freely in groups of F. In this case we define the degree of wavelength conversion to be F. A degree of 1 would correspond to no wavelength conversion and a degree of $F \cdot W$ would correspond to full wavelength conversion.

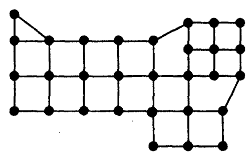

Fig.2: The NSF network, 30 nodes and 47 links.

We here assume all-optical networks where connections are set up and released as wavelengths, i.e. dynamic wavelength routed optical networks. With no wavelength conversion, a call is accepted if on all the links on its route there is at least one wavelength, which is simultaneously free on all the links of that route. This constraint is known as the wavelength continuity constraint. The offered traffic is uniformly distributed on all node pairs with Poisson arrival times and exponential holding times. We use fixed routing or adaptive unconstrained routing, both with the first-fit wavelength assignment method, the best known method, which only depends on local node information. In fixed routing the routing is fixed before simulation start with one path per node pair. For adaptive unconstrained routing any route with available capacity can be chosen when a traffic demand arises. The network used for simulation is shown in Fig. 2.

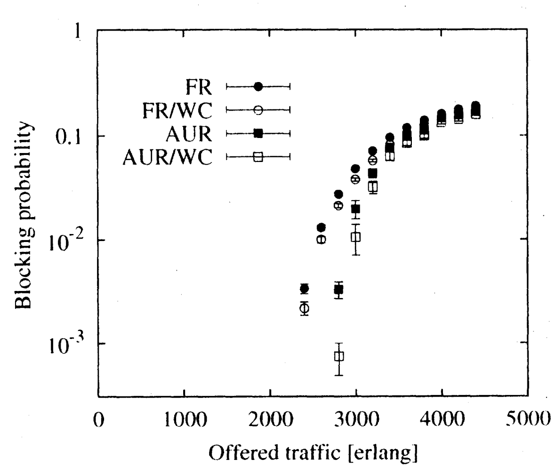

Fig.3: Displays the blocking probability of different routing principles as function of the offered load to the network.

By simulation we show that multiple fibres, which are assumed to be common in future broadband networks, reduce blocking probability in dynamic wavelength routed optical networks significantly and almost to the level of full wavelength conversion.

Results and Discussion

In Fig. 3 the blocking probability is plotted as function of the offered load for fixed routing (FR) and adaptive unconstrained routing (AUR) both without and with wavelength converters (WC). The bars illustrate the 95% confidence intervals. We find that wavelength converters clearly reduce the blocking, but also that using the more advanced routing method has an even larger effect on the blocking.

We have performed simulations with different combinations of wavelengths and fibres ranging from 1 to 256 fibres corresponding to 256 to 1 wavelengths for fixed routing in Fig. 4 and for adaptive unconstrained routing in Fig. 5, where the percentage gain in blocking probability by using the specified number of fibres and wavelengths as compared to using full wavelength conversion has been plotted. For each number of fibres we have made the plot for different values of offered traffic. In case of fixed routing then multiplying the number of fibres by four divides the gain of using wavelength conversion with more than two for almost every traffic load and combination of number of fibres / number of wavelengths. In case of adaptive unconstrained routing the effect of multiple fibres is even larger.

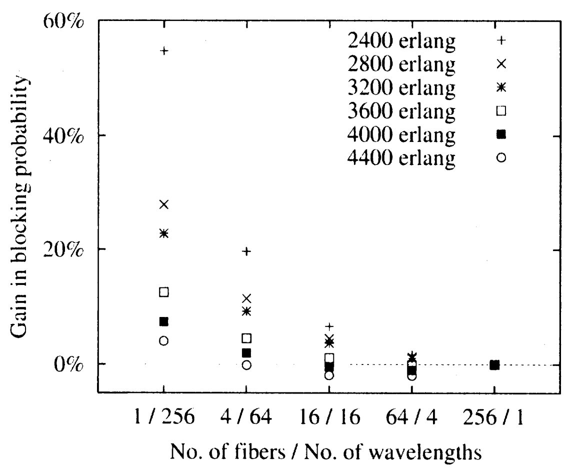

Fig.4: Gain in blocking probability using wavelength converters as function different ratios between fibres and wavelengths in the case of fixed routing.

The gain of wavelength converters is high for relative low networks load but approaches 0% as the load increases since the blocking probability, independently on routing principle, always approaches one for rising offered network load.

For a few combinations of traffic loads and number of fibres / number of wavelengths the gain is less than one, which means that adding conversion capability actually raises the blocking probability. This phenomenon has also been reported in [4,5]. That a network with wavelength conversion capability can have higher blocking than one without at the same level of offered traffic is caused by the formers higher ability to route longer paths, which take up more capacity than shorter paths. Thereby the equality in blocking probability between long and short connection is increased.

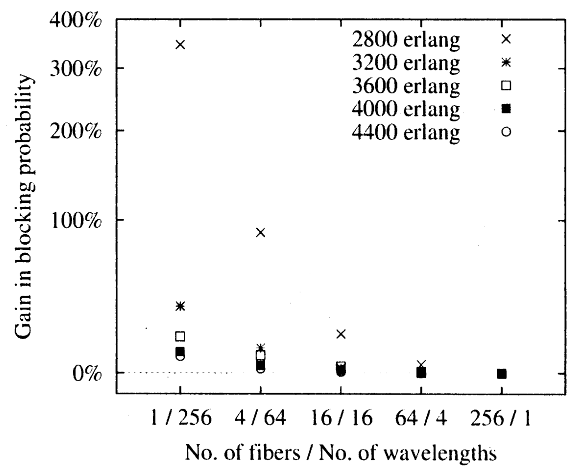

Fig.5: Gain in blocking probability using wavelength converters as function different ratios between fibres and wavelengths in the case of adaptive unconstrained routing.

Conclusion

We have shown how multiple fibres correspond to limited-range wavelength conversion. By simulation we find that multiple fibres reduce the blocking significantly and quickly to the level of full wavelength conversion both for fixed routing and unconstrained adaptive routing. Neither static nor dynamic wavelength routed networks will gain from wavelength conversion. Therefore neither limited-range nor full wavelength conversion will find any significant use in all-optical networks.

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