ROUTING OF DYNAMIC POISSON AND NON-POISSON TRAFFIC IN WDM NETWORKS WITH LIMITED WAVELENGTH CONVERSION

Jan Späth, Stefan Bodamer

Institute of Communication Networks and Computer Engineering (IND), University of Stuttgart
Pfaffenwaldring 47, 70569 Stuttgart, Germany
Tel.: +49 711 685 7990, Fax: +49 711 685 7983, e-mail: {spaeth, bodamer}@ind.uni-stuttgart.de

Abstract: The paper presents the influence of different traffic characteristics (Poisson and non-Poisson) on WDM network performance under dynamic traffic conditions. The complex impact of limited wavelength conversion on the performance of routing strategies is shown.

Introduction

WDM cross-connect networks able to route single wavelength paths are widely expected to build the basis of the future wide area broadband telecommunications infrastructure /3/. A lot of work reported in literature deals with the design and optimisation of such networks to achieve efficient network solutions /1/. Most of these considerations are made by using static traffic assumptions (i.e. a given demand between all source-destination pairs).

During operation however, the network has to deal with dynamic traffic conditions out of several reasons as for example restoration mechanisms, load variations, or the provisioning of leased wavelength services. Former investigations show that a network planned for a certain static traffic demand will suffer blocking if this network has to carry dynamic traffic /4/. Although the dynamic over time in an optical transport layer will be relatively small, the importance of single blocking events within the optical layer is increasing due to the higher bitrates.

The above described traffic dynamic requires an establishment and release of wavelength channels over time. This comprises routing of these channels through the network which has to consider physical aspects (e.g. power considerations) as well as networking aspects (e.g. blocking probabilities). This paper will focus on the latter point.

Routing in a WDM network has many things in common with classical circuit switched (CS) networks for which many routing strategies are known /2/. We concentrate on the following strategies. *Fixed Source Routing* (*FSR*) accepts only the shortest path used for planning, *Sequential Office Control* (*SOC*) allows a selection between multiple alternatives in all nodes, but only for *SOC with crankback* (*SOCc*) this control can be given back to a predecessor node in case a node finds no path for the next hop.

Apart from many analogies between photonic and classical networks there are also various differences such as path length limitations (e.g. due to dispersion accumulation). Another difference is the additional degree of freedom for routing strategies by using the wavelength domain including the possibility of wavelength conversion /5/. A very important but yet unclear point is the characteristic of future transport network traffic, i.e. how the parameters for the description of wavelength channel behaviour will look like. Most of the work reported in literature uses Poisson traffic. We present an approach to evaluate how the network will behave under certain different traffic characteristics.

Problem Parameters and Modelling Approach

The problem of wavelength channel routing has many input parameters which influence the results:

- network topology and dimensioning
- wavelength conversion capability and other technology aspects (e.g. number of wavelength channels per fibre)
- offered load (i.e. traffic demands for the network)
- traffic characteristic (e.g. distribution types)
- routing strategies and searching strategies for resource allocation
- QoS parameters for wavelength path requests
- priority scheduling for other routing parameters (e.g., does the routing method try to minimise either the path lengths or the number of converters used)

Each parameter presents a degree of freedom for the evaluation process. Our modelling approach shortly described here allows us to consider all these parameters (for more details of the model and of the simulation tool see /4/, /5/). We approximate the total traffic (i.e. all wavelength channels) between a source-destination node pair with a single generator in our discrete event simulation model. We characterise the traffic behaviour with distribution functions for the interarrival time between two wavelength channel requests and for the service time (i.e. the time a wavelength channel remains established). Both distribution functions are parameterised by their mean value and their coefficient of variation (*CoV*), respectively. This allows us to generate Poisson traffic ($CoV = 1$) as well as smoother traffic ($CoV < 1$) or traffic with higher variance ($CoV > 1$).

Since it is much too complex to vary all parameters simultaneously, we keep several of them fixed and concentrate on the influence of the available conversion capability and on the influence of different traffic characteristics. All results are derived for a possible German long-distance network with nine cross-connect nodes and 8 wavelength channels per fibre. It was dimensioned for a certain so-called *static traffic demand*.

Influence of limited Wavelength Conversion

Previously published results show that there is a difference in achievable performance for WP networks (no converters) and VWP networks (full converter equipment). This difference can be relatively small with an appropriate strategy /4/, /5/. We looked at partial wavelength conversion considering two different strategies. They are compared in Figure 1 for different routing methods (FSR, SOC, SOCc) and a load equalling 80% of the static traffic demand.

The solid lines show the total network blocking versus the number of converters per fibre (0 converters equals the WP, 8 converters equals the VWP concept) using a strategy looking for paths with a minimum number of converters while accepting longer routes. As expected from prior studies /4/, already a relatively small number of converters reduces blocking significantly while further increasing this number results in nearly no improvements.

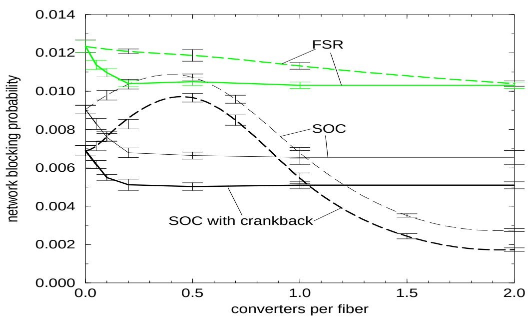
The dashed lines represent the results for a routing strategy that tries to minimise the path length (according to the routing method) and uses as much converters as required. Here, two basic effects determine the network behaviour:

- More converters allow in principle a better utilisation of network resources (fibres). This increases success for routing along shorter paths and therefore network blocking decreases. This effect dominates for higher converter equipment and leads to even lower blocking compared to the strategy described above.
- Converters are also used on relatively short paths (although there may exist short “detours” which require fewer converters). Thus, converters may become a bottleneck if only a few converters are available. Therefore, increasing the number of converters even leads to higher blocking within a certain range.

For both strategies, blocking decrease is neglectable for more than 2 converters per fibre which equals only 25% conversion of the VWP case.[1]

As a conclusion, we can say that routing strategies have to be selected very carefully taking the available conversion capabilities into account.

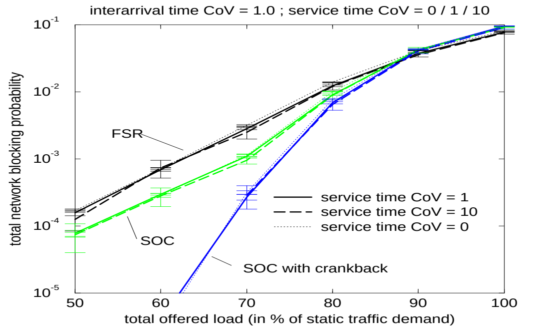
Figure 1: Limited wavelength conversion



Influence of Traffic Characteristics

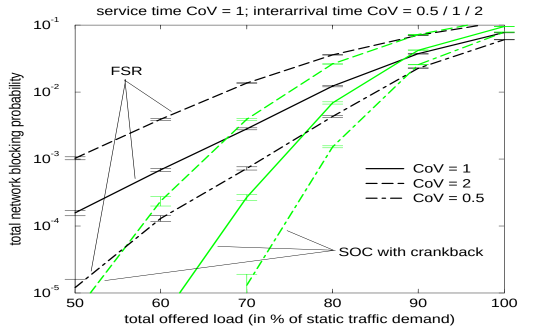
In the following, we look at the influence of different traffic characteristics on network performance by pointing out some general trends using the above described traffic model. First, we keep the interarrival time negative-exponentially distributed but vary the variance of the service time. Figure 2 shows the result very astonishing at the first glance: network blocking probability is nearly independent from the service time distribution if the call arrivals follow a Poisson process. In Figure 2, we see that this holds for the WP concept for all routing methods over the full load range. We observed this effect also for many other configurations (network topologies, routing strategies, ordering principles for resource allocations, VWP concept).

Figure 2: Influence of service time characteristics



This changes completely if the interarrival times are non-Poisson, even in the case of negative-exponentially distributed service times (Figure 3). Here we see that with a higher CoV, blocking increases while with a lower CoV blocking decreases. Again, this effect was observed for many other configurations. (Similar effects could be shown for non-Poisson behaviour of both, interarrival *and* service times.)

Figure 3: Influence of interarrival time characteristics



Conclusions and Outlook

We have shown that limited wavelength conversion has a complex impact on the performance of routing strategies. The influence of traffic characteristics on network performance showed that blocking depends strongly on the type of interarrival time distributions. Further work will consider additional routing strategies and the influence of other problem parameters (e.g. other network topologies).

References

/1/ R. Cruz, G. Hill, et al., (editors) “Optical networks”, special issue of the IEEE Journal on Selected Areas in Communications, Vol. 14, No. 5, June 1996

/2/ A. Girard, “Routing and dimensioning in circuit-switched networks”, Addison-Wesley, 1990.

/3/ R. Ramaswami, K. Sivarajan, “Optical networks - a practical perspective”, Morgan Kaufmann Publ., 1998.

/4/ J. Späth, S. Bodamer, “Performance evaluation of photonic networks under dynamic traffic conditions”, 2nd IFIC TC6 Working-Conf. on Optical Network Design and Modelling, Rome, Feb. 1998, pp. 15–19.

/5/ J. Späth, S. Bodamer, “Routing strategies for photonic networks under dynamic traffic conditions”, Proceedings of the NOC '98.

[1] Similar results are already well-known for static network design problems focusing on an efficient use of resources.