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Emulation of Overspill Routing in Optical Networks

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Abstract *Overspill routing in optical networks, ORION, is a network architecture combining lower IP switching capacity requirements with high bandwidth efficiencies. We present results from an ORION emulation platform, which is fully compatible with GMPLS.*

Introduction

With the current progress in optical networking, the traditional problem, high transmission costs with relatively low switching costs, is somewhat reversing: transmission capacities keep increasing drastically, with ever reducing prices. In packet switched environments the bottleneck is thus moving towards the switching instead of the bandwidth.

In earlier work [1,2] we presented a network concept, ORION (Overspill Routing in Optical Networks), combining the lower IP switching demands of wavelength switching with the high utilization rate of full packet switching. These studies used simulation, and had to make simplifications. To validate these results we needed to build an ORION network as close to reality as possible. Thus, we developed an electronic router platform which mimics the behaviour of an optical ORION node on an electronic pc in every functional aspect. This allows for more accurate results and validation of earlier work, as well as quality measurements of live (multimedia) traffic (not discussed here) and proof of compatibility with GMPLS and RSVP-TE [3].

The ORION concept essentials

For a little more clarity, we summarize the essence of the developed concept here, referring to [2] for more detail. ORION is an architecture allowing full sharing of all wavelengths on a link, without huge amounts of electronic switching, or resorting to deflection routing like schemes, which can lead to inefficiencies.

We start from a reconfigurable wavelength switched network. This network can react to longer term traffic pattern changes of hours, or even days, by reconfiguring the wavelength paths in the network.

Then we add selective transparent insertion and removal of data on a wavelength path at any node it traverses. Thus, we can insert data on a wavelength path that normally would overshoot the destination node, but now we can extract it at any node. The data using this option, the "overspill" mode, can then be extracted before it actually overshoots its destination, leaving the path early. This ability results in a network that operates preferably like a wavelength switched network, but if necessary as a packet switched network. The idea is to send IP/MPLS packets as if operating a wavelength switched network, unless the provided wavelength paths are insufficient. In that case the data is sent in "overspill" mode, effectively operating the network in packet switched mode. By instantly switching between the operating modes operating we reduce switching load in the IP/MPLS routers, since most traffic can be sent through a direct wavelength path, but still allow maximal resource sharing since all wavelengths are still accessible if needed.

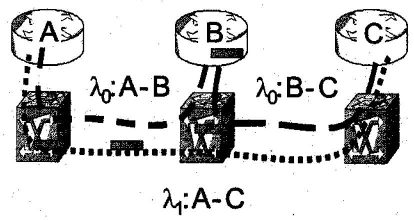

Figure 1: ORION at work: although λ_1 is a direct wavelength path from A to C, ORION can still use it to send packets to B by using the overspill mode

Fig. 1 illustrates how this principle works in practice. Suppose A – C on λ_1 is a direct wavelength path, as well as A – B and B – C on λ_0. All paths have a capacity of 10 Gb/s. Under normal conditions all traffic from A destined for C will pass B transparently. Now assume A has 12 Gb/s of traffic for B. In a simple wavelength switched network this would result in loss, as there is only 10 Gb/s available. In ORION, however, the remaining 2 Gb/s can also be serviced by sending the data in overspill mode over wavelength λ_1. Since overspill data behaves like a packet switched network, it will reach the IP router at destination B the next hop, instead of bypassing. This is also more bandwidth efficient than e.g. deflection routing. Special node architectures are required for ORION, examples are described in [2].

Building the emulator

In the emulator, an ORION node is represented by a linux based router, with ORION specific functionality implemented in Click instead of optics [4]. One ethernet cable corresponds to one wavelength. Also, each router encompasses both the electronic router and the OXC behaviour, supporting GMPLS and RSVP-TE [3] for path setup and teardown, in the manner described in [5]. The overspill detection, a hardware feature, was supported through usage of one of the experimental bits in MPLS.

Experimentation with the emulator

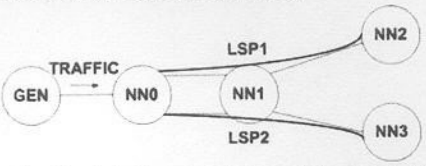

Figure 2: Emulated network topology used for the case study

As a simple case to study overspill behaviour in detail and test the emulator, we redid the simulation experiment from [6]. As Fig. 2 shows, nodes NN0 and NN2 are connected via a lightpath (always on λ_1), while NN0 and NN3 have a lightpath connection, always on λ_2, called LSP1 and LSP2 respectively. From an ORION perspective, the given topology means that LSP1 and LSP2 can use overspill on each others wavelengths on link NN0=>NN1, the studied link. Links NN1=>NN2 and NN1=>NN3 are configured to have ample capacity for the experiments. We then generated Poisson-like traffic of fixed packet size through both LSP1 and LSP2. The load of LSP1 was fixed at 66,6 % of its capacity while the load on LSP2 was gradually increased from 66,6% up to 150% (overload). During this experiment we measured throughput, and how traffic was transported.

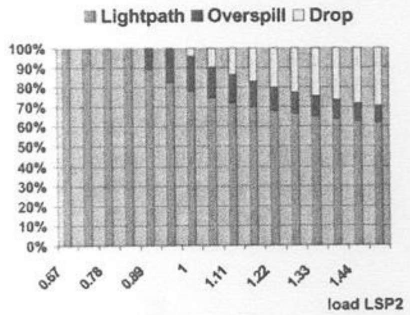

Figure 3 : Traffic statistics (throughput) for LSP2 on link NN0=>NN1

Fig. 3 shows the throughput of LSP2. Although there are some buffers present, the overspill mechanism already starts to work around load 0.85. This is due to the poisson-like traffic generation process, and traffic peaks being too long for the buffers to compensate. The overspill mechanism, however, captures the otherwise lost traffic and transports it over LSP1, which is lightly loaded. Once a severe overload scenario occurs however, overspill cannot prevent losses, even though on average there is capacity enough. It does, however, continue to function, allowing a higher throughput (+5%-+20%), by utilizing LSP1. Note that lightpath traffic on LSP1 always had zero loss, thus confirming the zero-impact behaviour of overspill. These results are similar to what was earlier obtained through simulation [6], although losses are a little higher (~10%). Buffering and ORION both help to overcome temporary overload. Since ORION can profit from its own buffers, apart from the classic one, this leads to 6 valid combinations (cfr. Fig .4). We compared those in the same setup as the previous experiment, results are shown in Fig. 4. Without buffering or ORION, there is a very high loss-rate. Adding a CB reduces loss. However, the NB scenario with ORION outperforms the scenario without ORION, even with CB. When CB is introduced with ORION, we see again a little decrease in loss, while the scenarios CB/OB and OB show almost the same loss. Thus, ideally, both a buffer and ORION are present. The buffer captures the very short peaks (bursts), while ORION can tolerate longer ones due to usage of spare capacity which cannot be reached otherwise. The OB buffer capacity is less powerful, but ideally both a CB and OB are present.

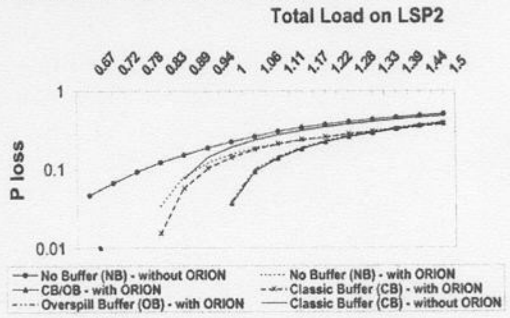

Figure 4 : Importance of buffering

Conclusion

ORION is a hybrid IP-Over-WDM network concept combining benefits from both packet switching and wavelength switching. We developed an emulator, using a standard GMPLS and RSVP-TE implementation as control plane. The presented case study in a real network confirms the results from earlier simulations, showing that ORION can indeed improve throughput significantly.

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