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Performance of Contention Resolution Strategies in OBS Network Scenarios

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***Abstract*–This paper presents a comprehensive study of the efficiency of wavelength conversion, fiber delay line buffers and deflection routing for contention resolution in optical burst switching (OBS) in two reference network scenarios.**

I. INTRODUCTION

Optical Burst Switching (OBS) has the potential to become an efficient and flexible switching paradigm for a highly dynamic future optical data plane [1]. In most OBS approaches, bursts are sent without an acknowledgement of successful path set-up (one-pass reservation) and thus burst loss can occur in case of contention. Thus, efficient contention resolution in OBS core nodes is essential in order to achieve a low burst blocking probability as required in transport networks despite one-pass reservation strategy and statistical multiplexing.

II. CONTENTION RESOLUTION IN OBS

In principle, contention resolution in OBS networks can be performed in one of the three physical domains wavelength, space and time (c. f. [2] for a more detailed discussion). In this paper, following basic strategies and further assumptions are considered (acronyms in parentheses):

- wavelength conversion; no limitations regarding number or tuning range (*Conv*)
- deflection routing based on the shortest path in each node (*Defl*); no limitations apply regarding the number of deflections, the number of alternative paths and even loops (improvements and penalties were marginal as long as a reasonable amount of flexibility was allowed)
- buffering uses a shared feedback fiber delay line (FDL) buffer with a single FDL employing WDM (*FDL*).

Apart from these basic strategies, also combinations of them can be applied. As the order in which these schemes are applied is essential, they are named by a concatenation of their acronyms. E. g., *ConvFDLDefl* refers to a scheme which tries conversion first, only if this fails it tries to buffer in an FDL and only if this also fails it tries deflection routing. Previous work [2] showed that when combining full wavelength conversion and FDL buffers conversion should always be used first. Thus, we only compare schemes which apply wavelength conversion first.

So far, OBS research on contention resolution has concentrated either on isolated nodes or on network topologies with uniform traffic and uniform link dimensioning. Especially, deflection routing is commonly evaluated in regular interconnection networks like torus topologies, i. e., in networks with a large number of equal length alternative paths. However, as topology and link dimensioning determine the performance of wavelength conversion and deflection routing, irregular networks which are dimensioned tight should be used for a more realistic analysis. In [3], a thorough comparison of different basic and combined contention resolution schemes has been performed for Optical Packet Switching in an irregular, uniform link capacity network under a uniform demand matrix and with IP traffic characteristics.

In this paper, in contrast, we use tightly dimensioned Pan-European and German reference networks (Fig. 1 and 2) for our evaluation. Also, we incorporate the specifics of OBS, e. g., FDL buffer and output wavelength are both reserved according to just-enough-time (JET) *before* the burst enters the buffer which prioritizes buffered bursts over newly arriving bursts—this is called *PriorRes* in [5]. We show how the different strategies can be optimally combined in order to achieve low burst loss probabilities and to overcome the reduced flexibility of the optical layer compared to the electronic layer like the lack of cheap random access memory.

Fig. 1: Pan-European Network Scenario [4]
total traffic = 1 Tbps,
mean number of λs/link = 5.43

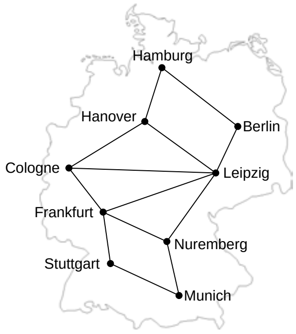

Fig. 2: Germany Network Scenario
total traffic = 1 Tbps (large: 4 Tbps),
mean number of λs/link = 5.43 (large: 27.15)

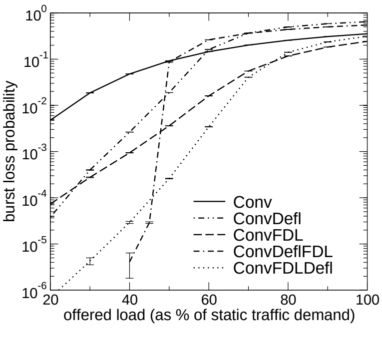

Fig. 3: Results for Pan-European Network

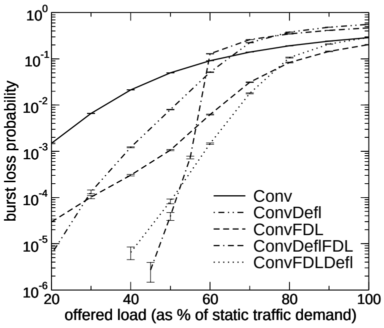

Fig. 4: Results for Germany Network

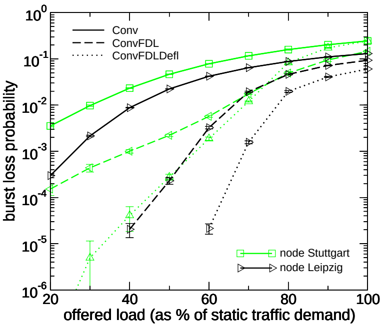

Fig. 5: Results for nodes Stuttgart and Leipzig in Germany Network

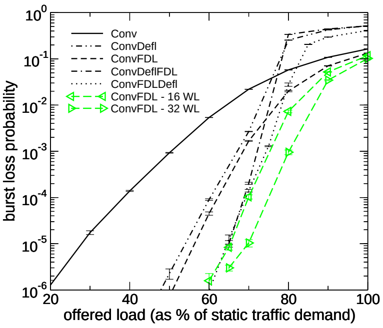

Fig. 6: Results for Germany Network (large) with different FDL buffer dimensioning

III. Performance Evaluation

Performance of the different basic and combined schemes is evaluated by event-driven simulation. Bursts are generated based on a Poisson process and burst length is exponentially distributed with mean 100 kbit, i. e., a mean burst duration of $h = 10\,\mu s$ for 10 Gbps line-rate.

The number of add/drop ports in OBS nodes is not limited and the delay for burst control packet processing is compensated by a short extra FDL of appropriate length at the input of the node. Thus offset violation due to excessive deflections is no issue. The delay of the buffer FDLs is $2h = 20\,\mu s$ and unless stated differently there are 8 wavelengths in the FDL.

Link capacities in both networks are dimensioned according to a static traffic demand matrix obtained from a population model based on shortest path routing such that blocking probabilities on all links are equal in the Erlang model [6]. In order to allow for a systematic analysis, fiber length on all links is 200 km which translates into a propagation delay of 1 ms. Thus, FDL delay is small compared to link delay which is realistic in WAN scenarios [7].

Principle Behavior

Fig. 3 and 4 depict burst loss probability versus relative offered load for both networks. It can be seen that the results are very similar for both scenarios. For high loads, the schemes employing deflection routing after conversion are inefficient as they produce additional load in an already highly loaded network. For medium loads *ConvDefl* outperforms *Conv* and *ConvDeflFDL* which are all outperformed by *ConvFDL* and *ConvFDLDefl*. For low loads, loss probability of *ConvDeflFDL* drops rapidly as enough network capacity becomes available. *ConvFDL* does not decrease as fast as all other schemes. For the Germany network, this can be explained by comparing the loss probabilities in Fig. 4 and 5: the node Stuttgart dominates the network performance for low loads as it is attached to the link to Munich with only 2 wavelengths which only yields minimal multiplexing gain. This effect can be avoided by deflection routing (*ConvFDLDefl*) due to an alternative route.

Fig. 5 also shows how the node Leipzig which is connected to 5 neighbor nodes by links with several wavelengths greatly benefits from the FDL buffer and additional deflection routing for low to medium loads. This could motivate the application of different schemes for different nodes depending on topology, link dimensioning and node degree.

Impact of Network Capacity

In order to further analyze this impact of network capacity, a second Germany network is used which is dimensioned such that it can carry four times the traffic as before (Fig. 6). Here, the curves for all combined strategies significantly outperform *Conv* except for very high load. Also, *ConvDefl* and *ConvFDL* as well as *ConvDeflFDL* and *ConvFDLDefl* yield almost identical performance for medium loads respectively. The fact that these curves all have comparable slope indicates that there is no extreme bottleneck link anymore that dominates performance.

Impact of FDL Buffer Dimensioning

While we have scaled the link dimensioning in the previous section we have not scaled the FDL buffer dimensioning. For *ConvFDL*, Fig. 6 also depicts the impact of the number of wavelengths in the buffer FDL on burst loss probability. It can be seen that increasing this parameter from 8 to 16 and from 16 to 32 can reduce burst losses by up to an order of magnitude for medium to high load values and again make buffering significantly more efficient than deflection routing. This same increase has only marginal effect for the first Germany network dimensioning (graphs are left out due to space restrictions).

Concluding, the performance of contention resolution schemes is sensitive to both network and buffer dimensioning which should be considered in their analysis. Combination of conversion with FDL buffers yields lower losses than conversion with deflection routing in most cases, however at the cost of the additional buffer.

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