Active versus passive OPS architectures for metro rings: a network dimensioning point of view[†]

Chris Develder, Ruth Van Caenegem, Elise Baert, Mario Pickavet, Piet Demeester
Dept. of Information technology (INTEC), Ghent University – IMEC, Sint-Pietersnieuwstraat 41, 9000 Gent
email: chris.develder@intec.rug.ac.be

Abstract *Optical Packet Switching is a promising technology for metro environments. We discuss two ring architectures (with/without active components allowing for spatial reuse) and compare them in terms of resources required for a given traffic demand.*

Introduction

Next generation metro area networks (MANs) should provide high bandwidth in a flexible manner: they should efficiently exploit available resources, support multiple traffic types and offer rapid provisioning. Optical Packet Switching (OPS), with its packet-level granularity and hence efficient and flexible bandwidth sharing, fulfils these requirements very well [1].

In the European DAVID project [2], multiple MAN architectures are compared. Here, we outline the DAVID metro ring architecture and discuss two different MAN optical packet add/drop multiplexer (OPADM) designs: a Passive one, and an Active one. This paper focuses on the impact of these design choices on the resources needed to build a MAN network interconnecting a given set of nodes, with a given traffic demand from one node to another.

MAN ring architectures

In the DAVID concept, sketched in Fig. 1, the MAN comprises slotted WDM rings collecting traffic from several optical packet add/drop multiplexers (OPADMs). Rings are interconnected by a buffer-less Hub, which also provides access to a backbone (WAN). The rings constitute a shared medium, requiring a medium access control (MAC) protocol [3] to arbitrate access to the slotted channels. One wavelength, λ_c, is a dedicated control channel.

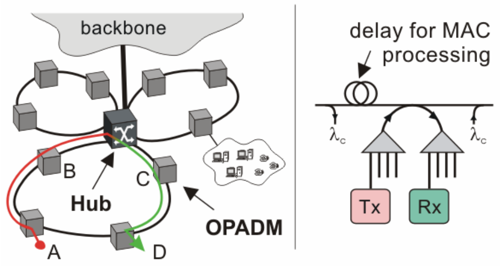

Fig. 1: Network architecture and *Passive* OPADM

DAVID proposes two OPADM architectures. The first one limits the use of advanced optical technologies, choosing commercial and mature ones instead [4]: it uses couplers and off-line filters to minimize physical cascadeability issues. The structure of this *Passive* OPADM is depicted in Fig. 1. The wavelength spectrum is separated for upstream (transmitters, Tx) and downstream (receivers, Rx): the Hub will perform conversion from Tx to Rx spectrum.

The second, *Active* OPADM proposal of Fig. 2 — considered as longer term approach— allows an incoming packet to be erased from the ring, and to replace it with a new one. Because of this erasing capability, there is no need for spectral separation of Rx and Tx signals. This also allows for spatial reuse: whenever the path from source to destination does not cover the whole ring, the same wavelength can be re-used, as for A-C and D-E in Fig. 2. To limit the tuneability range of the Rx/Tx elements, a waveband concept is introduced: a Rx/Tx board provides access to a set of only B wavelengths (with one Rx/Tx per band).

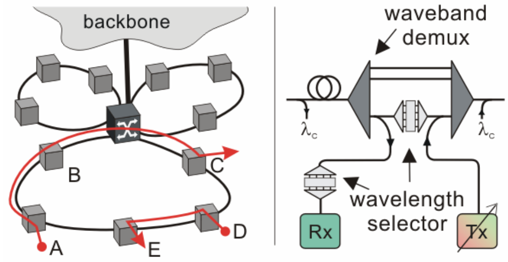

Fig. 2: Network architecture and *Active* OPADM

A network dimensioning point of view

The objective of this paper is to compare the architectures in terms of the amount of resources (which will to a great extent dominate the CAPEX) required to set-up a given demand between a given set of MAN nodes. Therefore, we developed a network planning algorithm starting from an ILP-formulation of the planning problem. Yet, the many degrees of freedom hamper the finding of ILP solutions within reasonable time. Hence, we provided heuristic solutions using a tabu-search approach to find the minimal number of resources needed to fulfil a given traffic demand.

The cost indicators used are the following: (i) *Rx/Tx capacity*: the total number of Rx/Tx elements used, summed over all OPADMs, (ii) *link capacity*: the number of wavelengths effectively used per link, summed over all physical links, (iii) *nr. of lambdas:*

[†] This work has been supported by the European Commission through the IST-project DAVID (IST-1999-11387), and by the Flemish Govern-ment through the IWT GBOU-project “Optical Networking and Node Architectures”. C. Develder is supported as a Research Assistant of the Fund for Scientific Research – Flanders (F.W.O.–Vl.), Belgium.

the number of wavelengths used per ring, summed over all rings. The first criterion is an indicator of the OPADM costs, while the last will impact the Hub dimension and thus its cost.

Note that this dimensioning study is only a single (but quite important) facet of an in-depth assessment of the pros and cons of Active and Passive architectures. This paper therefore is to be complemented with e.g. studies on the architectures' capabilities to deal with dynamic traffic in a network with given amount of resources, as eg. in [3].

Set-up of the case study

To assess the resource requirements of the OPADM architectures, we covered a wide range of demand patterns. The demand patterns are the following (where D[i,j] denotes the bandwidth required between OPADMs i and j): (i) *Uni*: a uniform demand pattern, where between each two OPADMs a bandwidth d needs to be set-up (D[i,j]=d); (ii) *Serv*: there is one server node s, which dominates the demand matrix (D[i,s]=D[s,i]=2d, other D[i,j]=d); (iii) *Neigh3*: each node only communicates to 3 other nodes (D[i,i+1]= D[i,i+2]=D[i,i+3]=d, rest is zero); (v) *David*: a demand matrix based on real-life traffic, provided by the operators participating in DAVID.

The impact of space reuse

The main difference between the active and passive architectures from a conceptual point of view is the space reuse capability of the Active structure. Fig. 3 presents dimensioning results of the dimensioning for Passive and Active with wavebands of a single wavelength. (Note that B=1 amounts to having no waveband concept; B>1 is discussed in the next section.)

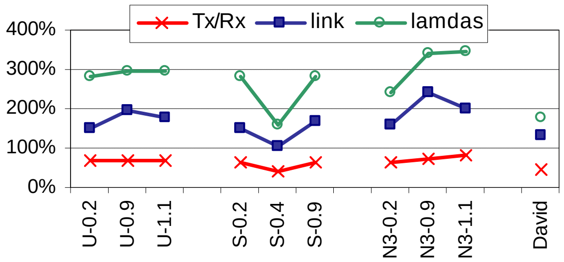

Fig. 3: Cost ratio Passive/Active; x-axis labels denote demand (U=Uni, S=Serv, N3=Neigh3; the number after the dash is the value of d)

From a Rx/Tx cost perspective, we conclude that the Active approach needs more Rx/Tx capacity. The reason is that to allow spatial reuse, the Rx and Tx have to be able to access the same wavelength, which sometimes requires an extra Rx/Tx (cf. B=1 means no tuneability).

The spatial reuse concept only proves useful when the CAPEX of the MAN is dominated by the link capacity, or the number of wavelengths per ring. This is due to the fact that there is no spectral separation for up- and downstream, and the spatial reuse capability allows for better sharing of the available bandwidth among different demands.

Wavelength bands

A second aspect in which the Active and Passive structures differ is the waveband concept. In the previous section, we used wavebands of a single wavelength (ie. no tuneability in the OPADMs). In this section we study the impact of introducing the waveband concept, again from a network dimensioning point of view. We compare the Active nodes with B=1 versus B=4 in Fig. 4.

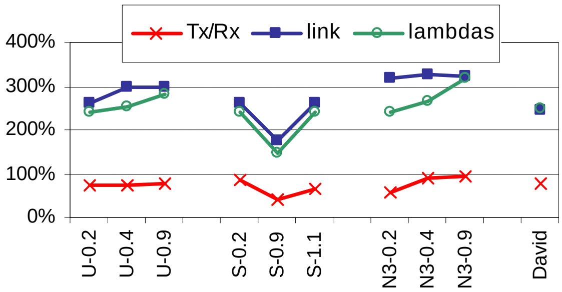

Fig. 4: Cost ratio (bands, B=4)/(no bands, B=1); x-axis labels denote demand

The advantage of the band concept is that Rx/Tx capacities can be somewhat reduced. Yet, when CAPEX is dominated by link capacities, the band concept is not useful, since it heavily increases the number of wavelengths used, indicating that spatial reuse opportunities within bands are limited. This stems from the fact that the architecture is assumed to allow only a single Rx/Tx per band per OPADM.

Conclusions

We have discussed two optical packet switched OPADM structures, and considered the impact of the architecture on the resources needed to fulfil a particular demand. Our results show that only when the amount of wavelengths used highly affects the network cost, the advanced active node structure should be deployed. In that case, a waveband concept does not seem to be appropriate if only a single Rx/Tx is allowed per OPADM per waveband.

References

1 S. Yao, et al., “All-optical packet switching for metropolitan area networks: opportunities and challenges”, IEEE Comm. Mag., 39(3), pp. 142–148.
2 L. Dittmann (ed.), et al., “The European IST project DAVID: a viable approach towards optical packet Switching”, to appear in JSAC.
3 A. Bianco, et al., “Access control protocols for interconnected WDM rings in the DAVID metro network”, in Proc. IWDC 2001.
4 N. LeSauze, et al., “A novel, low cost optical packet metropolitan ring architecture”, Proc. ECOC 2001.