A Metropolitan Optical Network with support for Multicasting in the Optical domain

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We present the FLAMINGO[1] network architecture, an all-optical wavelength-and-time-slotted Metropolitan Optical Network based on a multiple-ring topology. A couple of important aspects of this architecture include all-optical packet switching at intermediate nodes on a ring and the ability to put IP packets directly over WDM channels. The rings of the network are interconnected with intelligent bridges, architecture of which is presented. The network also enables all-optical multicasting at intermediate nodes, the architecture of which is also presented. Power budget calculations have also been dealt with and discussed in detail.

1. Introduction

Metropolitan Optical Networks (MONs) are characterised as networks that move traffic within the metropolitan area and into and out of the core network and customer access networks. These networks have increasingly gained importance from the operator's point of view for they bridge the gap between the core and the access networks.

Within the FLAMINGO project (see [1] and [2]) we have used optical wavelength and time slotting as the basis of realising a packet-switched network. The concept has been addressed also in other works, some of which include [3] and [4]. In this paper we focus on achieving optical multicasting within the FLAMINGO network and on its power budget implications in sections 3 and 4 respectively.

2. Network Architecture

The FLAMINGO network designed for interconnected city rings, as shown in figure 1, is based on an adaptation of the slotted ring concept to the multi-channel nature of WDM. Access to the slots is via the Access Points (APs) as shown in figure 1. In [1] we presented the FLAMINGO network that consists of a single ring supporting the APs. Here we go a step further in analysing interconnected rings, supporting multicasting in the network. As shown in the figure the rings are interconnected with intelligent bridges that will be studied in section 4.

The slotted ring concept of the FLAMINGO network has been treated in detail by us in [1] and [5]. To put it in brief, bandwidth of each channel is divided in the time domain into an equal and constant number of slots per wavelength that circulate around the ring. One of the WDM channels is reserved for carrying control information and header-slots. Slots on this channel are called control slots. The remaining slots on the other channels carry the payload (data-packets) and are called payload-slots. The header-slots contain the addresses of all destination APs on all corresponding payload slots. Furthermore, each AP on the ring is able to transmit and receive at any wavelength.

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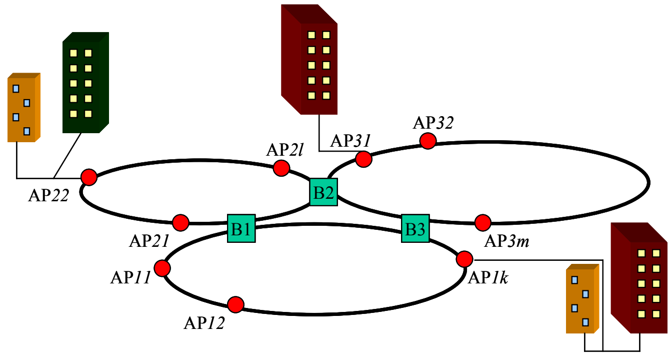

Figure 1: Interconnected City Rings,
AP= Access Point, B= Intelligent Bridge

3. Multicasting

The architecture of the AP is shown in figure 2. The functioning of the AP and the Header Processor has been described in some detail in [1], [2] and [5]. In this section we explain how the AP can be extended to support all-optical multicasting. This is achieved by introducing a 90:10 optical power coupler between the fiber delay line and the EDFA in figure 2. 10% of the dropped power at the coupler is then demultiplexed and fed into a receiver. The remaining 90% of the power goes to the 2x1 switch where it is either dropped and lost or allowed to pass through. In the event that it is dropped, new data packets may be added by the transmitter array at the corresponding wavelength.

It is important at this stage to mention that at the intelligent bridges (B, see fig. 1) we use buffers to transfer data from one ring to the other. The architecture of the bridge is structurally very similar to that of an AP and is shown in figure 3. Therefore, if in figure 1, AP11 wants to transmit data to one or more APs on it own ring and to one or more APs outside its own ring, then it generates 2 separate payload-slots (containing the same

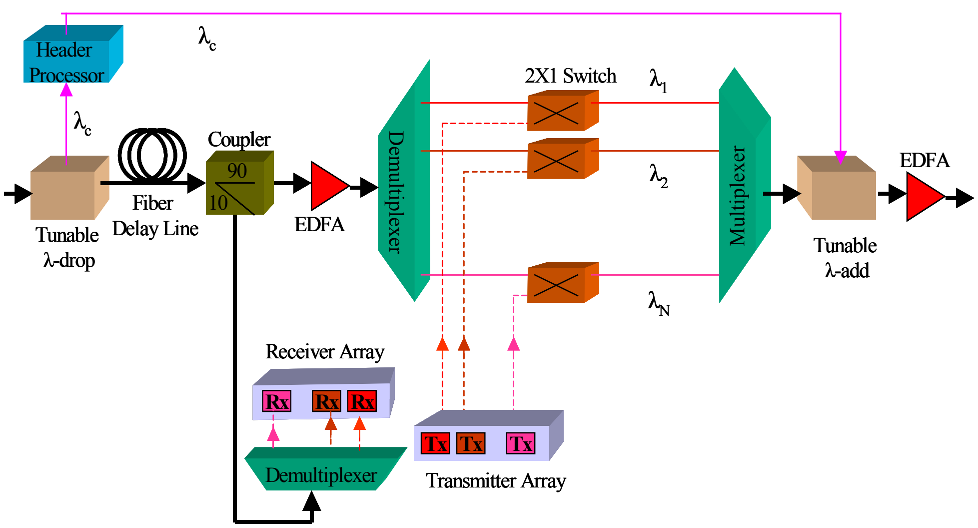

Figure 2: The Access Point

data-packet) at the source (that is, AP11), one for APs on its own ring and the other for APs outside its own ring. Suppose that the APs outside it own ring comprise of one or more APs on each of the other two rings in figure 1. Then bridge B2 or B3 (depending on the direction of the rings whichever comes first), with its knowledge of the topology generates two separate payload slots (containing the same data-packet) in the electronic domain. One such payload slot is for APs on its own ring and the other for APs outside its own ring. This way multicast trees are created.

A complete MAC including the creation of multicast trees is in the process of development within the FLAMINGO project. Parts of the MAC are available in [6].

4. Power Budget

The purpose of calculating the system's power-budget is to have an estimate of the power reaching the receiver so as to ensure reliable performance. Noise analysis is beyond the scope of this discussion and will be taken into account in future work. In calculating the power budget, the loss-values of the devices taken into consideration are their actual loss values under our laboratory conditions. Also the values include splice and connector losses. The average launch power, P_{Tx}, launched by the directly intensity-modulated laser is 0 dBm. If we assume L to be the total channel loss and P_{Rx} to be the APD receiver sensitivity then we have

$$P_{Tx} - L > P_{Rx} \qquad \text{......(a)}$$

Sensitivity of an APD receiver at a BER of 10^{-12} at 2.5 Gbps using a pseudo random 2^{23}-1 bit sequence at 1550 nm wavelength is roughly –34 dBm. For a more detailed

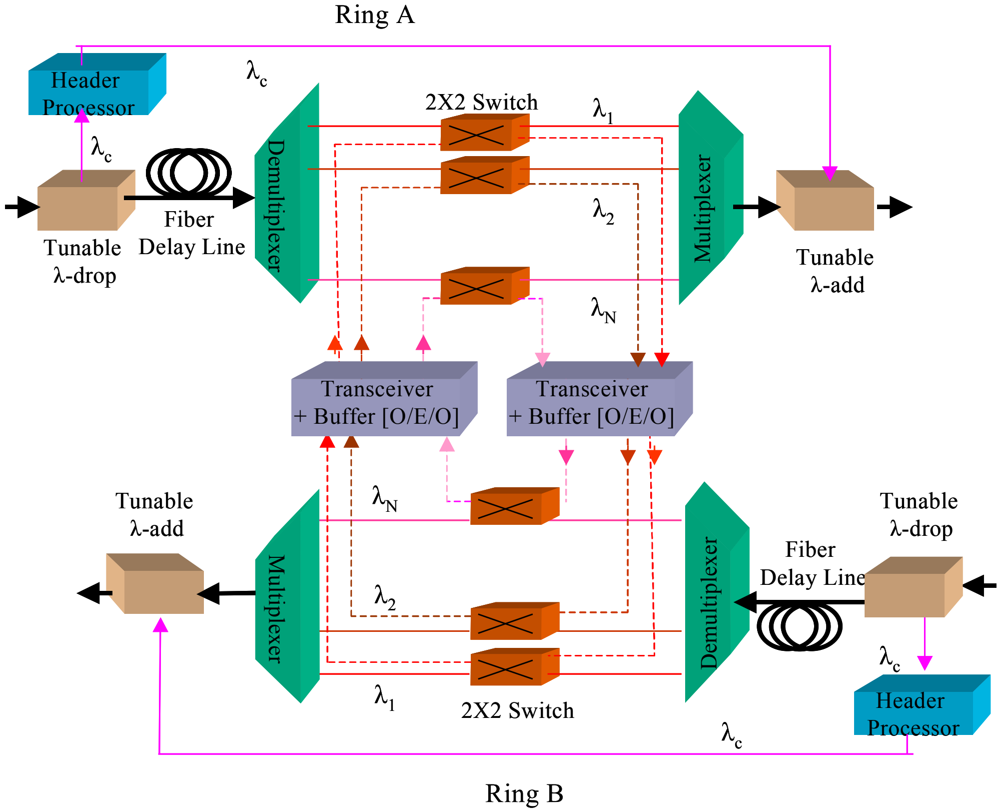

Figure 3: Intelligent Bridge

analysis refer to [7].

Assuming the device loss values as shown in table 1, and that the APs are separated by a maximum fiber length of 20 kilometres, we get at the input of the EDFA on the right (in figure 2) an input power of –17 dBm. The EDFAs used in our laboratory have the gain versus input signal power curve as shown in figure 4. Therefore at the input of the switches the power of each of the wavelength channels launched by the upstream AP is approximately 0 dBm, which equals the power launched by the transmitters.

At the output of the 90:10 coupler where the power is 10% we have signal strength of approximately –15 dBm implying that the power incident on the receivers is approximately –22 dBm. Thus equation (a) is satisfied.

Table 1

Devices	Insertion Loss
Phasar Multiplexer	7 dB
Phasar Demultiplexer	7 dB
Tunable λ-drop	6 dB
Tunable λ-add	6 dB
Switch	4 dB
Fiber Loss at 1550 nm	0.22 dB/km

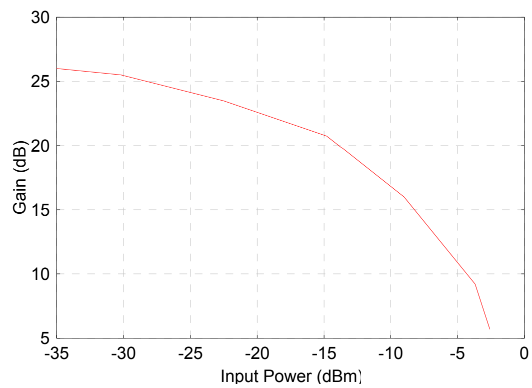

Figure 4: Amplifier Gain versus Input Power

5. Conclusion

In this paper we have shown how multicasting can be achieved within city rings using the slotted ring concept. We have also presented preliminary power budget calculations. Future work will address noise analysis and the maximum number of multicast sessions that can be supported based on it. Currently we are working on a demonstrator for the Access Point to verify a couple of concepts used in the network.

References

[1] D. Dey, A.M.J. Koonen, D. Geuzebroek, M.R. Salvador, "FLAMINGO: A Packet-switched IP over WDM Metro Optical Network", in *Proceedings of Networks and Optical Communications Conference (NOC)*, June 2001, pp 400-406.

[2] D. Dey, A. van Bochove, A. Koonen, D. Geuzebroek, M. Salvador, "FLAMINGO: A Packet-switched IP-over-WDM All-optical MAN", in *Proceedings of the 27th European Conference on Optical Communications (ECOC)*, September 30 – October 4, 2001, vol. 3, pp 480-481.

[3] I. Chlamtac, et al., "Scalable WDM Access Network Architecture based on photonic slot routing", *IEEE/ACM transactions on Networking*, vol. 7, no. 1, pp 1-9, 1999.

[4] C. –S. Kang, et al., "A broadband ring network: Multichannel optical slotted ring," *Computer networks and ISDN systems*, vol. 27, pp. 1377-1398, 1995.

[5] D. Dey, A.M.J. Koonen, M.R. Salvador, "Network Architecture of a Packet-switched WDM LAN/MAN", in *Proceedings of the IEEE/LEOS Symposium*, Benelux Chapter, October 30, 2000, pp 251-254.

[6] M. R. Salvador, S. H. de Groot, D. Dey, "An All-Optical WDM Packet-Switched Network Architecture with Support for Group Communication", in *Proceedings of IEEE International Conference on Networking (ICN)*, Colmar, France, July 2001, vol. 1, pp 326-335.

[7] R. Ramaswami and K. N. Sivarajan, "Optical Networks: A Practical Perspective", *Morgan Kaufmann Publishers, Inc.*, 1998, ch. 4, pp 186-195.