

Network Architecture of a Packet-switched WDM LAN/MAN

D. Dey^a, A.M.J. Koonen^b and M.R. Salvador^a

^a Centre for Telematics and Information Technology (CTIT), University of Twente, Netherlands

^b Bell Labs, Lucent Technologies, Huizen, Netherlands

E-mails: ^a{dey, salvador}@cs.utwente.nl; ^bkoonen@lucent.com

We propose a packet-switched WDM slotted ring network with destination release. The total bandwidth of each channel is divided into a fixed number of equal-sized slots. The nodes are equipped with fixed transmitters and tunable receivers. Control information, which is transmitted on a specific wavelength, is electronically processed at every node while the payload is kept in the optical domain. This reduces packet-delay and provides protocol and bit-rate transparencies. Among other issues involved in the design of such a network, we discuss a node architecture that takes into account multicasting and problems related to fiber dispersion.

1. Introduction

With the successful deployment of Wavelength Division Multiplexing (WDM) in core networks, access networks are the next bottleneck. The advantages of successful deployment of WDM accompanied by packet switching in local area networks (LANs) and metropolitan area networks (MANs) are incontrovertible. One very promising attribute is efficient usage of network resources. Time-slotting may be considered as one of the techniques useful in realizing a packet-switched network.

Conceptually time-slotting is similar to time-division multiplexing (TDM). In time-slotting bandwidth of each channel is split into equal number of time-slots of fixed length (duration). A lot of work has been done on similar architecture, some of which include [1], [2], [3] and [4].

In this paper we present architecture of a WDM LAN/MAN that goes beyond these works by incorporating aspects such as fault tolerance and multicasting. We also deliberate upon issues that need to be considered in the successful design of such a network.

2. Network Architecture

We consider a slotted multi-channel WDM network laid out as a ring. The nodes are interconnected with fiber carrying W channels. Bandwidth of each of the channels is divided in time domain into equal and constant number of *mini-slots* of fixed length that circulate around the ring. One of the W channels is reserved for carrying control information and the header. We call a mini-slot on the control/header channel a *header mini-slot*. The remaining $W-1$ channels are used to carry the payload (i.e., data). We call the mini-slots on these channels *payload mini-slots*.

The basic structure is as shown in figure 1a. The network consists of segment rings connected to a backbone ring via optical cross-connects (OXCs). Nodes in segment

rings are add-drop multiplexers (ADMs in figure 1a). Their function is either to drop a payload destined to it or to add a payload if a mini-slot is empty.

Each node on the ring is able to transmit on a fixed wavelength but is able to receive at any wavelength. This is shown in figure 1b. A fixed wavelength channel, λ_c , is reserved for transmitting the header and other control information. Except for the header mini-slot on λ_c , payload mini-slots on the other $W-1$ wavelength channels are synchronized such that they reach each node all at the same time. The header mini-slot is synchronized with the payload mini-slots such that the header mini-slot arrives a little ahead of the payload mini-slots.

The header mini-slot contains information about the payloads that are carried by the payload mini-slots on each wavelength. The header-information tells each node if the payload on any wavelength is or is not destined for that node. It also tells the node if the mini-slot on its transmitting wavelength is empty.

One of the major issues that we need to deal with in such a network is dispersion. As a result of dispersion, different channels may suffer from varied delay times. Thus, the mini-slots on the various channels may lose their synchronization. In the following section, we design a node that is capable of dealing with this issue and thereby maintain the required level of synchronization.

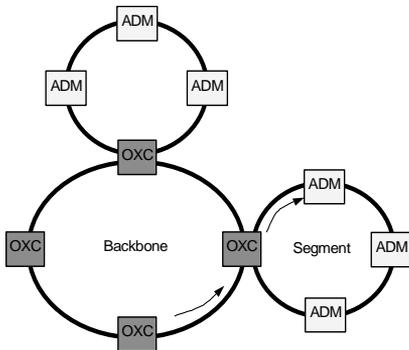


Figure 1a - Multi-ring WDM network

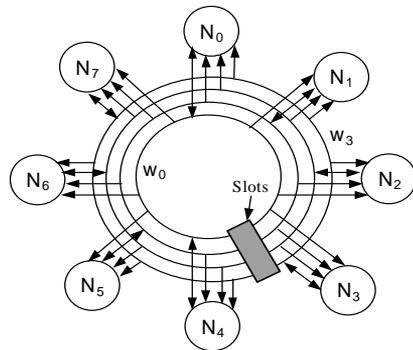


Figure 1b - Segment ring; W=4; N=8

3. Node Architecture

The node architecture is as shown in figure 2. The incoming data first goes through a slowly tunable λ -drop. This separates the header wavelength channel from the payload wavelength channels. The payload mini-slots are then delayed in a fiber delay line. This delay should equal the header processing time. The payload slots then go through a slowly tunable λ -drop, which selects the wavelength channel (λ_x in figure 2) that is to be used for transmitting data (provided the slot is already empty or will become empty at this node). The remaining wavelength channels are de-multiplexed. According to the information contained in the header, the tri-state switch (switch A in figure 2) is either in the bar, split or cross-states. The availability of switches operating in three states (cross, bar, split) enables all-optical multicasting of data-packets. The remaining wavelength channels are sent through a coupler, which drops 10% of the power to each of the

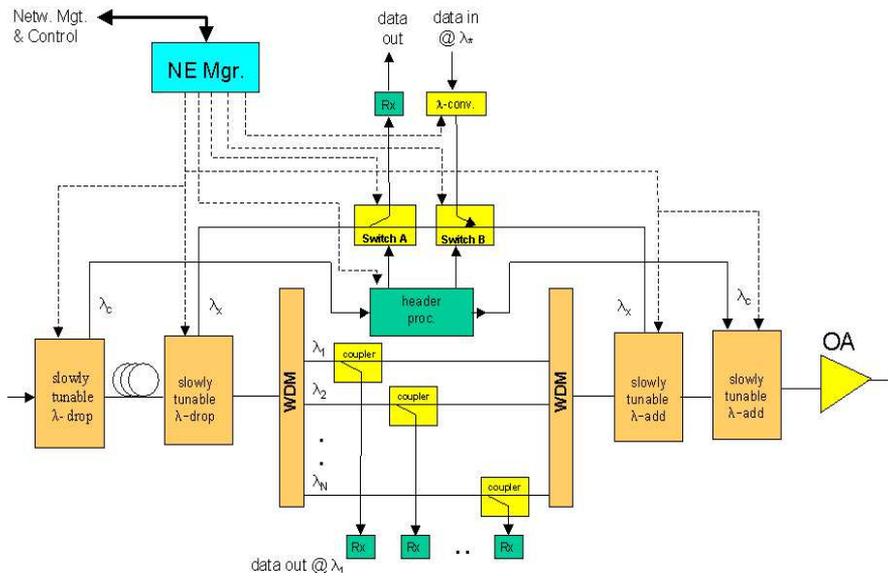


Figure 2. The node architecture

receivers. The remaining 90% of the power is allowed to pass through and the wavelength channels are then multiplexed. Based on the header information it is decided whether the 10% of the dropped power (at the couplers) is or is not meant for the node. If it is not it is simply discarded. The concept not only allows optical multicasting, but is also important for simultaneous reception of multiple wavelengths. The input wavelength channels and the header wavelength channel are then consecutively added using a slowly tunable λ -add.

As mentioned earlier the header mini-slot and the payload mini-slots are synchronized such that the header mini-slot is slightly ahead of the payload mini-slots. This is to take into account the switching time after the header information is processed. Here it is important to note that the switching time is different from the header-processing time. For the header-processing time we make use of fiber-delay lines, whereas, for the switching-time (that is required after the header is processed) we allow the header mini-slot to arrive at the node slightly ahead of the payload mini-slots.

As mentioned in section 2, one of the drawbacks of such a network is dispersion because of which the slots on different wavelength channels may lose synchronization. This is however taken care of in our node architecture. Every time a node generates data it sends a regenerated signal whose time of transmission can be controlled within a desired level of accuracy. Such regeneration occurs at least once in one complete revolution around the backbone ring. This is because destination-release leads to slot-reuse. The time of transmission of the new payload mini-slot can be controlled such that the new payload mini-slot is generated exactly some fixed amount of time after the header mini-slot is transmitted from the node.

It is important to realize that in the event of a failure of the transmitting wavelength channel of a node, the node is not able to communicate at all. Therefore, we need to take some measures to deal with this problem and to provide some fault tolerance. A close look at figure 2 indicates that the wavelength converter along with slowly tunable add-drops deal with this problem. The wavelength converter is able to match any incoming wavelength (carrying the data to be added in the node) to the specific add wavelength of this node. In the event of a failure of the wavelength channel λ_s , the wavelength-converter can convert to a reserved wavelength channel for transmitting data, in which case the slowly tunable λ -drop and λ -add can also tune to add or drop this newly selected wavelength channel. The other pair of slowly tunable add-drop takes care of a possible failure of the header channel, λ_c .

Conclusion

We have designed a packet-switched WDM LAN/MAN. The network is fault-tolerant in that it can switch to a reserved wavelength channel in the event of a failure in the control (header) channel or a channel at which a node is transmitting. We have also dealt with the problem of dispersion, which is a dominant factor in such types of networks. Our node architecture enables multicasting in the optical domain. The tri-state switch (switch A in figure 2) has to be fast enough to achieve high bit-rates. The payload is always kept in the optical domain. This is important in achieving bit-rate transparencies.

Acknowledgements

This research is supported by the Dutch Technology Foundation STW, applied science division of NWO and the technology program of the Ministry of Economic Affairs of the Netherlands.

References

- [1] J. Fransson, M. Johansson, M. Roughan, L. Andrew and M. Summerfield, "Design of a medium access control protocol for a WDMA/TDMA photonic ring network," *Proc. of Globecom '98*, (Sydney, Australia), pp. 307-312, November 1998.
- [2] I. Chlamtac, V. Elek, A. Fumagalli, and C. Szaba, "Scalable WDM access network architecture based on photonic slot routing," *IEEE/ACM Transactions on Networking*, vol. 7, no. 1, pp. 1-9, 1999.
- [3] S. M. Gemelos, K. Shrikhande, D. Wonglumsom, I. White, T. Ono, and L. G. Kazovsky, "HORNET: A packet-switched WDM metropolitan area network," *Proc. CNIT '99* (Portofino, Italy), pp.260-276, 1999.
- [4] C. -S. Kang, B. -S. Park, J. -D. shin, and J. -M. Jeong, "A broadband ring network: Multichannel optical slotted ring," *Computer Networks and ISDN systems*, vol. 27, pp. 1377-1398, 1995.