

Design and analysis of active node based multi-channel optical add/drop networks

ABID KARIM, ARIF ALI REHMAN, ALEEM KHALID ALVI^a

Bahria University (Karachi Campus), National Stadium Road Karachi, Pakistan

^aComputer Engineering Department, College of Computer Sciences and Engineering, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia

Thousands of channels can be transmitted through a single mode fiber using different multiplexing techniques. These multi-channel optical systems provide saving in cost of installing and upgrading of lightwave networks. Also they can easily be implemented on existing optical fiber networks. The use of active or intelligent node rather a passive node can further increase the capacity of multi-channel optical networks. In this paper, multi-channel optical add/drop networks are investigated with respect to passive and active nodes. Results show the use of active node in an optical network increases the system capacity and improves the performance of a system.

(Received November 23, 2007; accepted after revision June 30, 2008)

Keywords: Optical networks, Add/drop optical networks, Multi-channel optical network, Active node optical networks

1. Introduction

Although, most optical networks in practical use are based on point-to-point techniques, however, continuous main bus system, in which nodes are connected simply by tapping-off photons from the main bus or by coupling photons from a local optical source onto the main bus is of particular interest [1-4]. These types of systems may be termed as passive bus optical systems. One of the major disadvantages associated with passive bus optical network is that the photons which are tapped-off at each node are lost and the accumulation of these losses grows quickly to a limit where the required bit rate error (BER) cannot be maintained to a pre-specified level unless the signals are regenerated. In order to overcome this problem, a monolithic optoelectronic integrated circuit (OEIC), which would consist of necessary electronic and optical devices, can be used at each node; thus making it an active or intelligent node. Incorporation of an OEIC at each node would result in an active bus optical add/drop system which would consist of cascaded OEICs to compensate for passive component losses incurred in passive bus optical network. Here, results for passive and active node based

optical add/drop network (OADN) are compared with respect to number of users (which can be connected to a network) and the rate of data transmission.

2. Theoretical background

Fig. 1 gives schematic representation of a passive bus OADN (PBOADN). Suppose P_t is the input power coupled into the bus and P_r is the received power at N_{th} node in fig. 1. P_r can be given as [5]:

$$P_r = 4 P_t N^{-2} \left[\frac{N-2}{N} \right]^{N-2} 10^{-N\alpha/10} \quad (1)$$

where α is the total access loss per node. N is the number of nodes. For a large number of N , eq. (1) can be approximated as:

$$P_r = 4 P_t N^{-2} e^{-2} 10^{-N\alpha/10} \quad (2)$$

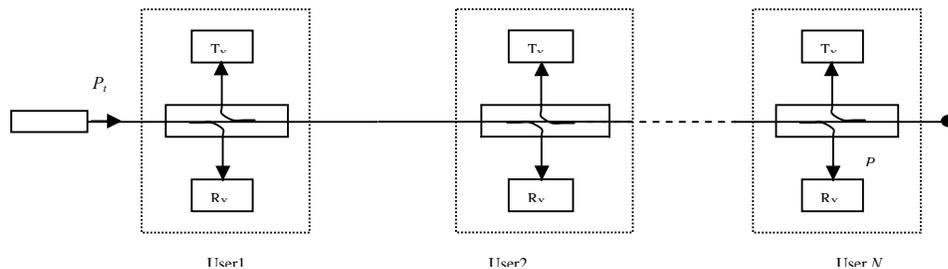


Fig. 1. Schematic representation of passive bus OADN.

An active bus OADN is schematically shown in Fig. 2. From node of user 1 to node of user N , each OEIC

would consist of a semiconductor laser amplifier (SLA). Therefore, the active network model can be treated as a

combined model of the cascaded optical amplifiers for the compensation of the optical losses incurred during the transmission. The maximum number of cascaded amplifiers, j , in a compensated repeater network can be achieved when the last amplifier is utilized as a preamplifier rather than in-line repeater amplifier [6]. Power received at last node P_o can be given as:

$$P_o = G \left[G P_r - (P_r + \alpha_a) \sum_{j=0}^{N-1} (G_j + 1) \right] \quad (3)$$

here P_r is the power received by the each node, G is the gain at each active node, G_j is the gain of j th amplifier and α_a is the excess loss at each node.

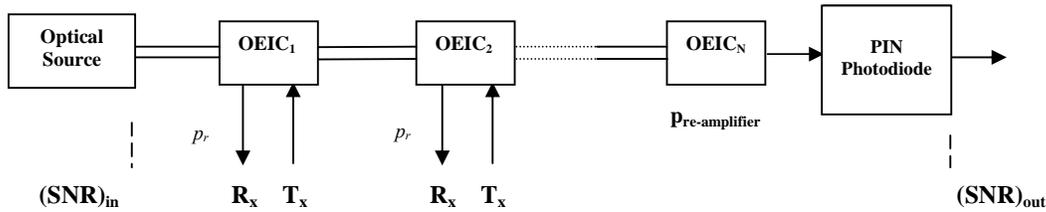


Fig. 2. Application of OEIC in ABOADN.

3. Results and discussion

The main aim of the work reported in this paper was to examine how the different parameters of passive and active bus networks (PBOADN and ABOADN) would affect the maximum number of users connected to the network, the rate of data transmission with respect to loss/gain at each node and to compare the overall performance of both types of bus networks.

3.1. Loss/gain at a node and number of users

The first parameter considered here is the optical loss or gain at each node (excess loss/gain per node). The effect of excess loss/gain per node is shown in Fig. 3 at a bit rate of 100 Mb/s for both types of networks. Bit rate of 100 Mb/sec is chosen to avoid crosstalk [8]. Fig. 3 shows how the coupler excess loss can limit the number of users, N to a very low value in the case of PBOADN, especially, when it is greater than a few dBs. On the other hand, the number of users has increased in the case of ABOADN as compared with PBOADN due to the use of active nodes in place of passive nodes. However, as the gain per node increases, the number of users, which can be connected to the active network, goes down due to locally generated and amplified spontaneous emission (ASE) at each active node.

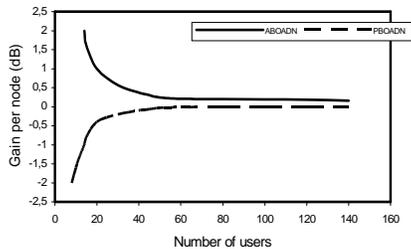


Fig. 3. Number of user versus coupler excess loss/gain for PBOADN and ABOADN at a data transmission rate of 100Mb/s.

3.2 Effect of rate of data transmission on the number of users

Fig. 4 shows the rate of data transmission with respect to the number of users for PBOADN and ABOADN for a typical loss/gain of 1dB/node. It is clear from fig. 4 that as the bit rate increases, the number of users able to share the network with the required level of performance rapidly decreases for a typical PBOADN. One of the important reasons is that at higher bit rates, the contribution of the thermal and the shot noise terms becomes significantly high as they require higher transmission bandwidth. This overwhelms the SNR and as a result BER of the network suffer. Whereas in case of ABOADN, the number of users increases with the rate of data transmission. The reason behind this effect is that the total losses at each node are compensated by the attached OEIC. This is exactly opposite to the results of PBOADN where each node has particular value of loss, which grows as the number of user increase. As it can also be seen from fig. 3 that as the gain of cascaded OEICs increases, the maximum number of users connected to the network decreases. Therefore, the use of amplifiers with a lower gain would be required. This would also reduce the effect of ASE and hence would allow the higher number of users to be connected with a network.

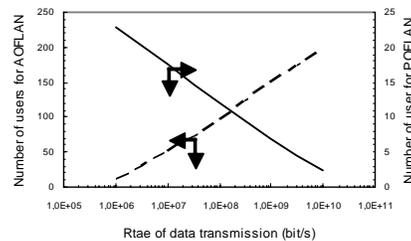


Fig. 4. Number of users versus rate for rate of data transmission for PBOADN and ABOADN.

3.3 Comparison between PBOADN and ABOADN_v

The main disadvantage of a passive bus network (PBOADN) is that the maximum number of the users connected to the network is limited due the excess loss at each node. The use of an OEIC at each node would not only overcome the inherited losses of a passive node but would also provide the extra gain, hence making it an active node. This also affects the data transmission rate. Figure 4 shows an inverse relationship between the number of users and the rate of data transmission in PBOADN. But due to the use of OEIC at each node, the number of users is directly proportional to the rate of data transmission in ABOADN. It can be concluded here that the problems encountered in PBOADN can be removed by the use of ABOADN, however, the generation and amplification of spontaneous emission in cascaded OEICs is a major problem in ABOADN which does not appear in PBOADN.

4. Conclusion

In this paper, a comparative study between passive and active bus networks has been carried out. It was found that the main limiting factor in PBOADN was the excess loss at each node. Not only this limitation of a PBOADN was overcome, but also a significant improvement in the

number of users and the rate of data transmission was achieved in ABOADN.

References

- [1] M. M. Nasseki, F. A. Tobagi, M. E. Marhic, IEEE J. Selected Areas in Commun. **3**, 941 (1985).
- [2] Y. W. Leung, G. X. Xiao, K. W. Hung, IEEE Trans. on Commun. **50**, 135 (2002).
- [3] J. J. He, D. Simeonidou, Photonic Network Commun. **3**, 49 (2001).
- [4] J. P. Wang, Y. Dong, W. S. Cai, J. J. Yan, Y. H. MA, X. D. Jia, M. Y. Zou, and S. H. Xie, Optic Commun. **200**, 153 (2001).
- [5] S. S. Wagner, IEEE Trans. on Commun. **35**, 419 (1987).
- [6] Y. Yamamoto, T. Mukai, Optical and Quantum Electronic **21**, S1 (1989).
- [7] D. G. Baker, Monomode Fiber-optic design, Van Nostrand Reinhold Company, New York (1987).
- [8] S. Singh, R. S. Kaler, Optics Communications **274**, 105 (2007).

*Corresponding author: abid@bimes.edu.pk,
akarimpk@yahoo.com