Protection and evaluation of bus and ring topologies using hybrid RAMAN-EDFA amplifier

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In this paper, we investigated the number of nodes supported in optical system at different crosstalks with minimum optical input power for Ring, bus topologies using optical cross connect and with protection schemes in these topologies at 10 Gb/s in the presence of hybrid optical amplifier. It is found that in ring topology, more than 20 nodes are supported at -10 dBm signal input power and 8 nodes are supported at -20dBm signal input power for -30dB crosstalk. In bus topology, 16 nodes are supported at -10 dBm signal input power and 4 nodes are supported at -20dBm signal input power for -30dB crosstalk. The number of nodes supported in case of -50 dB and -70 dB crosstalks are more than 20 in both the bus and ring topology.

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1. Introduction

In dense wavelength-division-multiplexing (DWDM) networks, optical add–drop multiplexers (OADMs) and Optical cross-connects (OXCs) plays an important role for enabling greater connectivity and flexibility [1]. OADM's allow the network nodes to access a subset of the wavelengths in the network, reducing the hardware requirements and allowing the network to scale to terabits-per-second data rates. The larger the OADM the larger the number of crosstalk terms resulting in a larger electrical noise floor [2]. Optical cross-connect (OXC) is a path switching element in an optical transport network that establishes routed paths for optical channels by locally connecting an optical channel from an input port (fiber) to an output port (fiber) on the switch element [3,4]. Optical DWDM ring and bus networks are becoming important because they have the potential to dramatically increase total network capacity, improve reliability and simplify network management compared with optoelectronically regenerated networks [5]. In a protection scheme whenever a link failure occurs, the signal will be switched to the alternative routes. The affected node will switch the signals to protection route [6]. Protection is achieved by optical cross connect switches by choosing a path between redundant transmitters and receivers. In this way, the failure of transmitters and receivers as well as other optical components is protected [7]. Rajneesh Randhawa et al. [8] investigated and compared the various network topologies comprising of various nodes and concluded that in ring topology there is no appreciable signal degradation and in bus topology the Quality of signal goes on decreasing with increase in the number of nodes. Rachna asthana et al. [9] reviewed protection and restoration schemes. In optical layer protection schemes, the path protection schemes provide better resource utilization at the cost of more computational complexity whereas link protection can be provided once and for all. The physical level failure are to be recovered in the optical layer schemes to avoid the severe problem of fault multiplication in the higher layer. Higher layer schemes can be used to recover higher layer node failures or single link failure in the high layers. Willner et al. [10] reported that a ring network can accommodate 25 nodes using erbium-doped fiber amplifiers (EDFAs) and a novel narrowband channel dropping filter at a bit rate of 2.5 Gbits/s. Emma Lazzeri et al. [11] presented new concept for all Optical add and drop multiplexing (OADM) node for hybrid network topology. The node was meant to act as gateway node between optical network segments that exhibit diverse properties in terms of multiplexing systems, granularity and modulation format.

Till now, the work reported for a less number of nodes [8]. There is less work reported for a large number of nodes supported considering the impact of crosstalk at low signal input power. In Section II, the System Set up for bus and ring topologies using optical cross connects with hybrid optical amplifier are presented. In Section III, the results are discussed in terms of number of nodes supported. Finally conclusion is made in Section IV.

2. System set up

The schematic set up for the bus network topology is shown in Figure 1. The bus network consists of twenty nodes. Each user is connected to bus through the optical cross connects. Every node is connected to each other by

SMF of 30 km length. The placement of one hybrid optical amplifier is done in the start of each segment in order to continue broadcasting the information from transmitter users. In bus network topology, hybrid optical amplifiers are used after required number of nodes. The first hybrid optical amplifier is used after first node and further placement of hybrid optical amplifiers is done after four nodes. The hybrid optical amplifier consists of Raman and EDFA amplifier. The Raman amplifier is operating at a temperature of 300K with single pumping and consists of counter-propagating Raman pump unit with pump power 20 dB, pump frequency 206.35 THz, pump wavelength 1451.77nm and pump attenuation of 1.2 dB/Km. The EDFA has flat Gain shape and noise figure with a fixed Gain of 25 dB. Further, the node is composed of transmitter (TX1), receiver (RX1) and an Optical cross connect (OXC). The optical cross connect add new channels at different wavelengths and also drop the previous channel. The dropped channel is the channel added at the previous node. Each transmitter section consists of a data source, a laser source, an electrical driver and an optical modulator. The data source is in non-return-to-zero (NRZ) format at 10 Gbits/s. The electrical driver converts the binary sequence into the electrical signal. Continuous wave Lorentzian (CW) laser source is used to convert data into optical. Modulation driver is used to generate data format of the type NRZ rectangular. The pulses are then modulated using $\sin^2$ Mach–Zehnder modulator. The simulation is performed with a simulation bandwidth of 2.3 THz and a center frequency of 193.35THz. The analysis of results is made by means of measurement blocks i.e. electrical scope and optical power meter attached to each node.

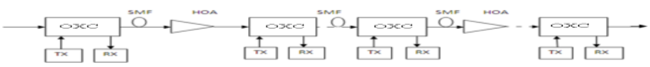

Fig. 1. Schematic setup for the bus network topology using Hybrid optical amplifiers

The ring network consisting of twenty nodes using optical cross connects as shown in Fig.2. The placement of first hybrid optical amplifier is done after first node and further placement of hybrid optical amplifiers is done after four nodes and so on. The analysis of results is made at the nodes by means of measurement blocks i.e. electrical scope and optical power meter. Further, the node is composed of transmitter, receiver and an Optical cross connect (OXC). At the twenty nodes the used frequencies are f1, f2, f3, f4, f5, f11,----f20. All these frequencies are used in circular fashion in the ring i.e. at the node1 the frequency f1 is added and frequency f20 is dropped. At the node 2 the frequency f2 is added and frequency f1 is dropped and so on. The simulation of the ring optical network is done with the center frequency of 193.4THz and the reference bit rate of 10Gb/s.

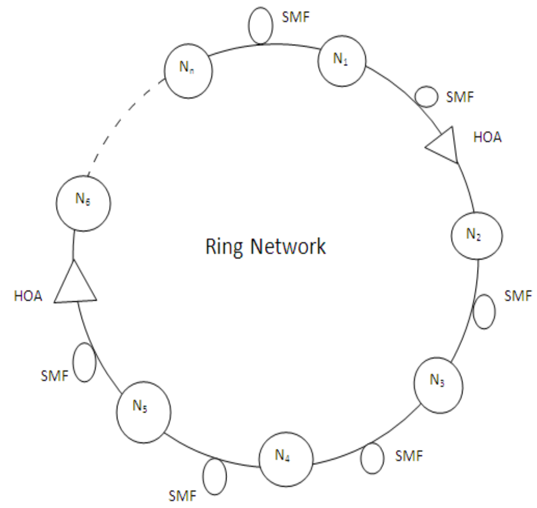

Fig. 2. Schematic setup for the ring network topology using Hybrid optical amplifiers

The schematic set up for the bus network topology using linear protection scheme is shown in Fig. 3. In a bus topology, 1+1 is a type of network protection technique. Under 1+1, signal is transmitted respectively on a working and a protection channel. At the receiver side, the receiver can make a decision to accept which copy of signal based on the signal quality. The Schematic setup for the ring network topology using ring protection scheme is shown in Fig. 4.

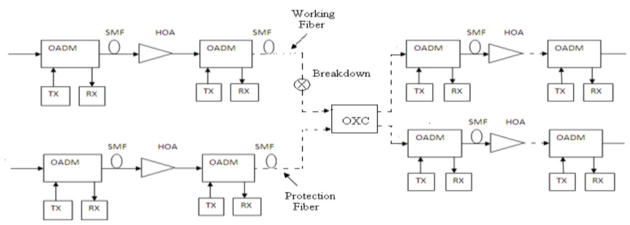

Fig. 3. Schematic setup for the bus network topology using protection scheme

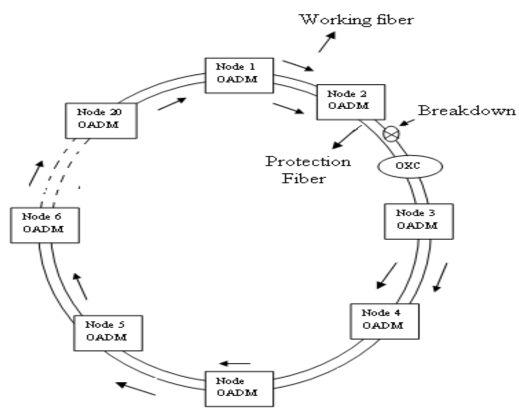

Fig. 4. Schematic setup for the ring network topology using protection scheme

In 1+1 architecture, a single protection path is used to protect the signal. In this case the bridge at the head of the path is permanent. It is at the tail end where the switching occurs. In this architecture traffic is sent over two parallel routes and the destination or the receiving end selects the better of these two signals. In case of any failure, the destination switches onto the protection path.

3. Results and discussion

For the bus network topology with twenty nodes, the simulation is performed for different crosstalks and low signal input powers by using hybrid optical amplifiers. The Quality factor vs. number of nodes supported at -10dBm signal input power for different crosstalks is as shown in Fig. 5. The maximum number of nodes supported is more than 20 for -50dB and -70dB crosstalks. But at -30dB crosstalk 16 nodes are supported. Fig. 6 depicts the Quality factor vs. number of nodes supported for the bus network at -20dBm signal input power. The number of nodes supported is 4 at -30dB crosstalk and more than 20 nodes are supported in case of -50dB and -70dB crosstalk. The quality of the signal decreases with a decrease in the signal input power. This is due to the increase in ASE noise power which reduces the quality of the received signal. At -10 dBm signal input power, the effect of ASE noise power is less.

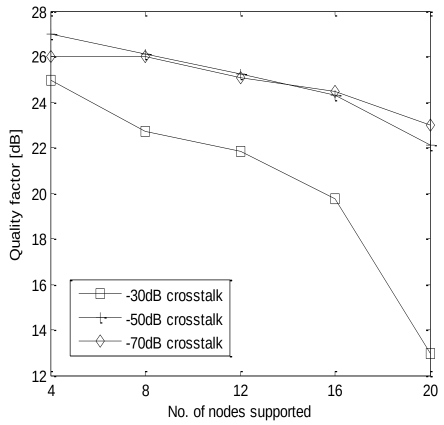

Fig. 5. Quality factor vs. number of nodes supported for the bus network at -10dBm signal input power

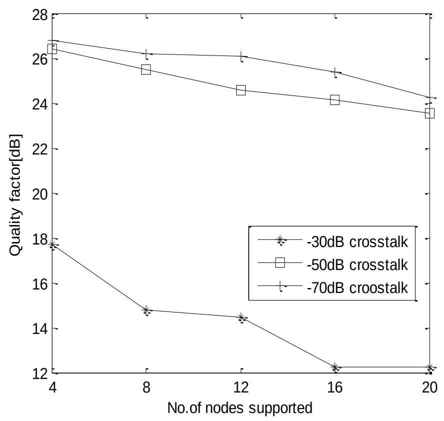

Fig. 6. Quality factor vs. number of nodes supported for the bus network at -20dBm signal input power

Fig. 7 shows the quality of signal as a function of number of nodes supported at -10dBm signal input power for ring network. It is observed that more than 20 nodes are supported at different crosstalks.

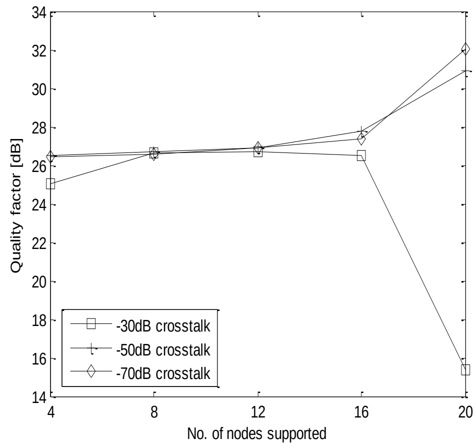

Fig. 7. Quality factor vs. number of nodes supported for the ring network at -10dBm signal input power

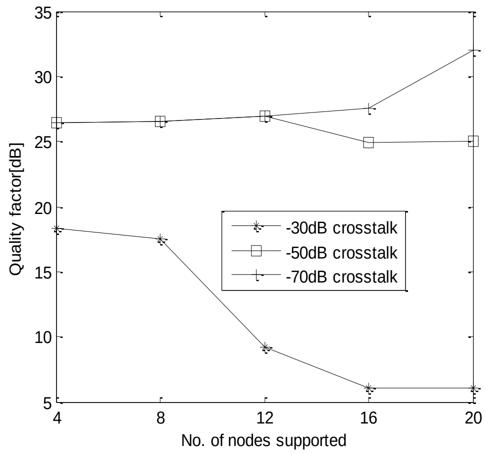

Fig. 8. Quality factor vs. number of nodes supported for the ring network at -20dBm signal input power

The quality factor vs. number of nodes supported for ring network at -20dB signal input power is shown in Fig. 8. The maximum number of nodes supported is 8 at -30 dB crosstalk. In case of -50dB & -70dB crosstalk more than 20 nodes are supported. This result shows an improvement over the results reported in [8].

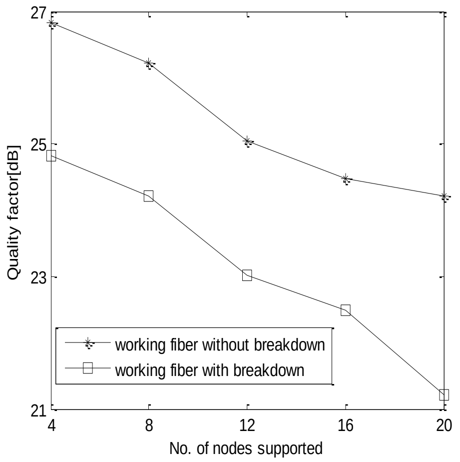

Fig. 9. Quality factor vs. no. of nodes supported with protection scheme for bus topology

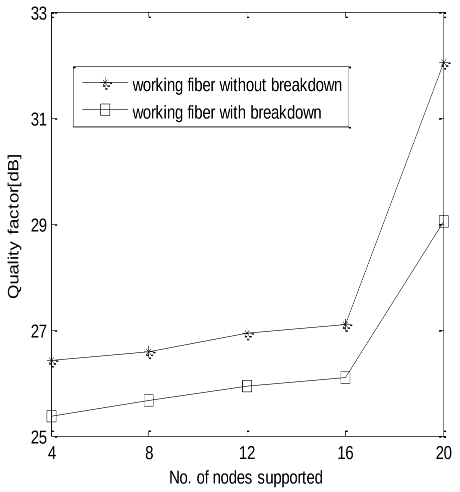

Fig. 10. Quality factor vs. no. of nodes supported with protection scheme for ring topology

Fig. 9 & 10 shows the Quality factor vs. no. of nodes supported with protection scheme for bus and Ring topology at -70dB crosstalk with 30 km fiber length between two nodes for working and dedication protection condition. Few changes in quality factor were observed which shows no degradation in the quality factor with and without breakdown.

4. Conlcusion

This paper concludes the simulation of twenty nodes of bus and Ring topology. In ring topology, 8 nodes are supported and in bus topology 4 nodes are supported at -20dBm signal input power for -30dB crosstalks The number of nodes supported in case of -50 dB and -70 dB crosstalks are more than 20 in both the bus and ring topology. If breakdown occurs in working fiber, optical cross connect switches the affected over to the protection path. The switching performed within the optical layer will be able to achieve high speed restoration against the failure/degradation of cables, fibers and optical amplifiers.

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