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Investigation of wavelength division multiplexed hybrid ring-tree-star network topology to enhance the system capacity

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ABSTRACT

In this paper, we have investigated wavelength division multiplexed (WDM) hybrid (ring-tree-star) topology. Eight optical add/drop multiplexers (OADMs) are used to make ring structure. The single mode fiber and dispersion compensating fiber and semiconductor optical amplifier (SOA) are employed between each OADM to achieve a maximum. To increase the number of users each OADM node of ring network is connected to star and tree network topology which can accommodate more than 2048 users. Various system parameters (for different channel spacing, different input power signal, different data rates and the fiber length) are varied to investigate the system performance in the term of BER and Q factor.

1. Introduction

Optical networks are the revolution in technology because they deliver the increased bandwidth demanded by the information explosion. Optical networks are spreading outward from Internet backbones to cities, to corporations and even to the home [1]. Optical networks hold out the promise of meeting the high transmission quality and large bandwidth desired by end-user applications [2]. The passive optical network (PON) has been identified as one of the most promising solutions for next generation high-speed access and is being used more and more widely in both wired [3] and wireless optical [4,5] broadband access networks. The wavelength-division multiplexing (WDM) PON technologies that are cost-effective in core networks to support access and metro networks is expected to yield scalable and flexible networks [6].

In metropolitan network with different topologies which uses the link bandwidth efficiently and increases the capacity of the system [7,8]. Wen-Piao Lin et al. [9] proposed star-ring architecture with the cascade add/drop transceiver structure for subcarrier multiplexed PON with 118 optical network units (ONUs) at 2.2 km. The system consisting of a star network on the upper level and many concatenated ring subnets on the lower level with self healing capabilities. Josep Prat et al. [10] designed a ring-tree WDM/TDM-PON using 16 optical add/drop multiplexer (OADM) remote nodes performing the hybrid interface with 1024 ONU at 100 km. Chenwei Wu et al. [11] purposed a tree ring structure with the bit rate 1.25 Gbps at 27 km that protected the network at from either dual or single fiber failure and also crosstalk between uplink and downlink in fiber. Hehong Fan et al. [12] proposed a star-cross-bus topology architecture with 128 ONU a centrally controlled hybrid restoration mechanism. Although centrally controlled, single-distribution fiber at distance 10 km failure was restored.

Till now, we observed that the proposed architecture were limited to lesser data rates [11] and investigated at lesser transmission distance [9–12]. The original contribution of this paper is to provide a hybrid network with maximum number of users for future optical networks. In this paper we proposed a WDM network using ring-tree-star hybrid topology. This paper is organized into four sections. In Section 1, introduction to optical networks is described. In Section 2, the system setup for WDM network using hybrid ring-tree-star topology is described. In Section 3, results and discussion have been reported. Finally in Section 4, conclusion and future scope are made.

2. System setup

The schematic diagram of proposed WDM hybrid ring-tree-star topology architecture is shown in Fig. 1. An optical line terminal (OLT) and ONU device is installed at transmitter and receiver side, respectively. Fiber distribution is done using point to point architecture. In this architecture single mode fiber, dispersion compensating fiber with SOA amplifier is employed between each OADM node. Eight OADM nodes are used for establishment of com-

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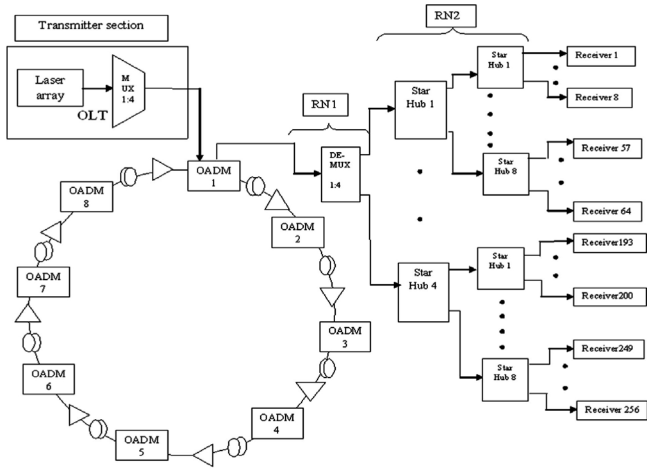

Fig. 1. Schematic diagram.

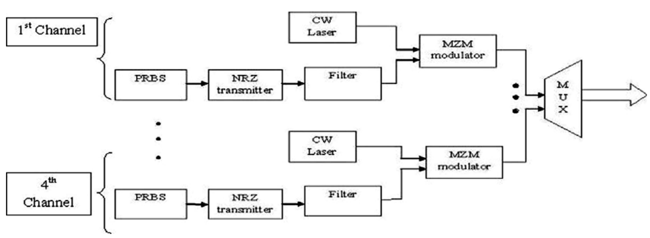

Fig. 2. Internal architecture of optical line terminal.

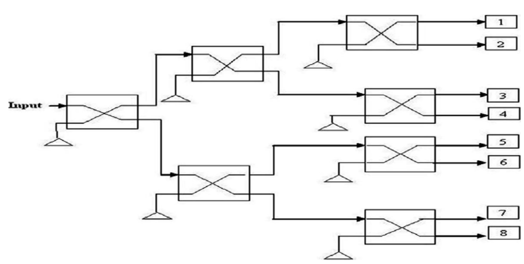

Fig. 3. Internal star hub structure.

munication between transmitter section to remote nodes (RN). To increase the transmission distance SOA with 5 dB gain is used. The architecture has investigated for different lengths, different data rates, with input power variation and channel spacing.

OLT is a device which serves as the service provider to end point of PON. It consists of WDM transmitter array with four wavelength channels to send the data to different users at 10 Gbps with 100 GHz channel spacing. The internal architecture for OLT is shown in Fig. 2. CW laser source with 10 MHz line width and data rate is generated by pseudo random binary sequence generator (PRBS) and is directly fed to non return to zero (NRZ) electrical driver which generates for each input bit, this electrical coded signal fed to rise time filter. The signals from data source and CW laser are fed to Mach–Zehnder modulator with 30 dB extinction ratio. The output from the Mach–Zehnder modulator is multiplexed by 4:1 multiplexer with 3 dB insertion loss then passed through the OADM.

At each OADM node, received signals are de-multiplexed by 1:4 de-multiplexer i.e. RN1. These channels with 100 GHz channel spacing is transmitted to star hub networks; which further distribute the signal to another star hub network. At RN2 the two cascaded 1:8 star hub are connected. The star hub consists of 2×2 cross couplers with coupling factor of 0.50 to combine or split the signals as shown in Fig. 3.

Fig. 4. Internal architecture for receiver end.

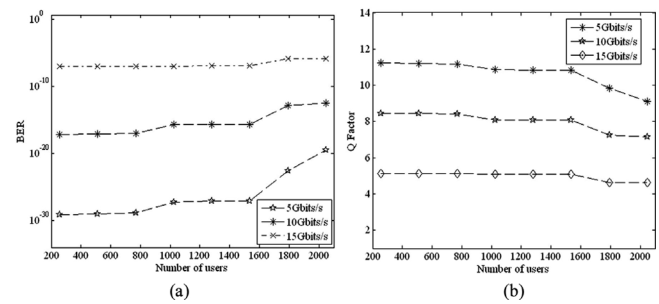

Fig. 5. (a) BER versus no. of users. (b) Q-factor versus no. of users.

The star hub output signals are received at receiver end. The receiver consists of re-sampler with 0.5 sample time, polarization filter, PIN photo-detector, low pass filter, signal analyzer as shown in Fig. 4.

Each OADM node is connected to another node by employing dispersion compensating fiber with different fiber length and SOA amplifier to boost up the transmitted signal. Then various simulation parameters are set to investigate the system setup such as by varying bit rate, channel spacing, input power and length of fiber. The various results at each node like BER and Q-factor are observed at signal analyzer.

3. Results and discussion

To evaluate the performance of the proposed system setup for hybrid ring-tree-star topology; each node consist of four channels with 100 GHz spacing and two RNs at receiver end as shown in Fig. 1. We have investigated this system with different data bit rate such as 5 Gbps, 10 Gbps and 15 Gbps. The graph between BER versus number of users at different data rates is shown in Fig. 5(a). It is seen that as the bit rate increases from 5 Gbps to 15 Gbps with the number of users, the degradation occurs due to continuous power loss in the signals. The 3.72×10^{-20} for 5 Gbps and 3.81×10^{-13} for 10 Gbps BER is observed.

As shown in Fig. 5(b) Q factor at different data rate with respect to the number of users is observed. The measured Q factor is 9.10 for 5 Gbps and 7.14 for 10 Gbps.

Fig. 6(a)–(c) shows the eye diagram at OADM node; with 5 Gbps, 10 Gbps and 15 Gbps at 150 km respectively. It is clearly shown that with the increase in data rate the signal start getting distorted.

We have also investigated the system under the variation of input power signal at each node. The graph for BER versus number of users is shown in Fig. 7(a). The input power variations are such as 0 dBm, 10 dBm and 20 dBm, respectively at each OADM node over 150 km with 10 Gbps. The better BER 9.17×10^{-18} is observed at −20 dBm.

The Q factor is also observed with the variation of input powers; the graph between Q factor and number of users is shown in Fig. 7(b). The acceptable Q factor is 8.80 at 20 dBm over 150 km distance between each node.

Fig. 8(a)–(c) shows the eye diagram at node; with 0 dBm, 10 dBm and 20 dBm input power variation. It is clearly shown that with the decrease in input power the signal start getting distorted.

To observe the BER and Q factor effect by variation of channel spacing, the graph between BER versus number of users as shown in Fig. 9(a). The BER is increased with the less channel spacing due