www.ijecs.in
International Journal Of Engineering And Computer Science ISSN: 2319-7242
Volume 4 Issue 8 Aug 2015, Page No. 14022-14026

Analysis of Star, Tree and Mesh Optical Network Topologies for successive distance between nodes Using Optimized Raman-EDFA Hybrid Optical Amplifier

Rajpreet Singh[1], Dr. Sanjeev Dewra[2]

[1]Shaheed Bhagat Singh State Technical Campus, Punjab Technical University,
Ferozepur, Punjab
rajpreet.innovation@gmail.com

[2]Shaheed Bhagat Singh State Technical Campus, Punjab Technical University,
Ferozepur, Punjab
sanjeev_dewra@yahoo.com

Abstract: ***Analysis of the performance of star, tree and mesh topologies is made for successive distance between the nodes at the bit rate of 15 Gbps . The number of users supported at different distances is calculated in terms of Quality Factor and BER for the input signal power of -40dBm. An optimized Hybrid Raman-EDFA amplifier is used for post amplificion. Mach-Zehnder modulator at extinction ratio of 30dB with symmetry factor of -1 is used for the modulation of signals. The spacing between the channels is taken as 0.1 THz with the line width of 1 MHz. It is observed that Star topology is capable to support more users than other topologies for a distance of 6Km in terms of quality factor and BER.***

Keywords: Optical Star network topology, Optical tree network topology, optical mesh network topologies, Raman-EDFA hybrid optical amplifier.

1. Introduction

Optical Network Topologies are preferred these days in order to obtain huge bandwidth, security, reliability, low cost transmission and so on. WDM could be preferred for long distance transmission [1]. Data transmission takes place at high speed and long distances due to reduced noise in optical fibers over other guided or unguided medias. Addition of the optical amplifiers can make the optical network to perform better over the use of electrical amplifiers. In optical network optical, electrical or hybrid switching could be used [2]. An optical amplifier amplifies optical signals without conversion to electric forms and can be used for long distance transmission. A Carena et al. [3] by yielding a closed form analysis investigated on the optimal configuration of hybrid Raman-Edfa and revealed that Raman amplification can also be used to reduce nonlinearity of fiber. Ju Han Lee et al. [4] demonstrated performance of single pump dispersion compensating fiber based Raman-EDFA hybrid amplifier in the terms of static & dynamic properties for three different schemes and impact on system in which higher transient tolerance was observed in Raman amplifier over hybrid amplifiers. Seung Kwan Kim et al. [5] proposed the design of hybrid amplifier composed of a distributed Raman amplifier and EDFA. Raman-EDFA hybrid optical amplifier performs better in terms of high output power and reduced BER than in EDFA, SOA and hybrid EDFA-SOA [6]. Simranjeet Singh [7] revealed post amplifier scheme of Hybrid Raman-EDFA gives better results in terms of reduced BER and increased output power than in other schemes. Compensation in range loss and chromatic dispersion is balanced by Hybrid Raman-EDFA amplifier.

In star topology, nodes are coupled to a central hub. In active-star configuration, optical signal is firstly converted to electrical signal and then the distribution of the signals takes place whereas in passive configuration, distribution takes place without any conversion i.e. optical signals are distributed. In optical star topology, Transmission frequency is dedicated to users and receivers receives the signals through frequency matching [8]. Y.K. Chen [9] revealed the capability to support 64 users. Y. N. Singh [8] investigated the possibility of 4 users using SOAs at 1Gbps. Surinder Singh [10] revealed the possibility of 16 users for star topology using optimized SOAs at 10Gbps.

In tree topology, combination of bus and star topology takes place. In this topology, optical coupler acts as splitters to distribute the power among users. In a purely passive tree-net, the number of users supported is limited by split and distribution losses in star couplers. Scalability makes large number of users attachable to single node with the help of secondary nodes. Tree networks are used widely over globe. M.Gerla,et al [11] demonstrated that number of users over this network is product of branches and users per branch. Y.N. Singh [12], reported that tree network supports large number of users at 1 Gbps. Surinder Singh [10] revealed that tree network with optimized SOAs is low cost solution.

In Mesh Optical network, two arrangements i.e. full and partial takes place. In a full mesh topology, nodes are physically interconnected. Full mesh is used where there is a great need of fault tolerance for e.g telecommunications. In partial mesh topology, only some of the nodes follows full mesh scheme whereas others are connected to only one or two nodes in the network. Mesh networks in optical

communication provides good Quality-of-Service and dynamic services like bandwidth on the demand [13], scheduling of bandwidth, brokering of bandwidth, and virtual optical private networks [14] that opens new opportunities for service providers and their customers.

In this paper, we proposed star tree and mesh optical network topologies for successive distances between nodes at input signal power of -40dBm and bit rate of 15 Gbps. Optimized Raman-EDFA optical amplifier is used just before the receiver. The previous work [10], was carried out at for star topology using optimized SOA for -40dBm input signal power at bit rate of 10Gbps and in turn it was revealed that 16 users could be supported for distance of 1 Km between links i.e 5 Km between nodes. The work is extended here for 15 Gbps at input signal power of -40 dBm and is observed that star topology supports 16 users with an increased distance of 1.2 Km between links i.e. 6 Km between nodes using Raman-EDFA hybrid optical amplifier which compensates chromatic dispersion and range loss.

2. System Setup

2.1 Star Topology

In optical star network topology, information is made to pass through n x n coupler formed by 2X2 optical couplers [15]. Star topology through 2x2 couplers is shown in Figure 1. The Mach Zehnder modulated signals are transmitted through the transmitter and are made to pass through the matrix of the optical couplers placed at fixed distance through the single mode fibers. Before receiving at the receiver, the signals passes through the Hybrid Raman-EDFA amplifiers which are used as post amplifiers. The number of users carried out for successive distances is calculated in terms of Quality factor and BER as shown in Figure 4 and 5. It is observed that as the distance increases, Quality factor decreases and BER increases because of the different losses occurs during transmission. The limit of maximum transmission distance is given as [16]:

$$L = \frac{10}{a_f} log_{10}\left(\frac{P_{tx}}{P_{Rx}}\right) \quad (1)$$

Where P_{tx} is power transmitted by transmitter, P_{Rx} is minimum average power required to detect signal at bit rate B. a_f is the loss that occurs while transmission of signals. P_{Rx} can be further given as [16]:

$$P_{Rx} = \overline{N_P} h\nu B \quad (2)$$

Where $\overline{N_P}$ is number of photons/bits required by receiver, $h\nu$ is photon energy and B is bit rate. Eq. 1 and 2 shows the transmission distance will keep on decreasing with increase in bit rate. Pulse broadening and frequency chirping also limits the long distance transmission.

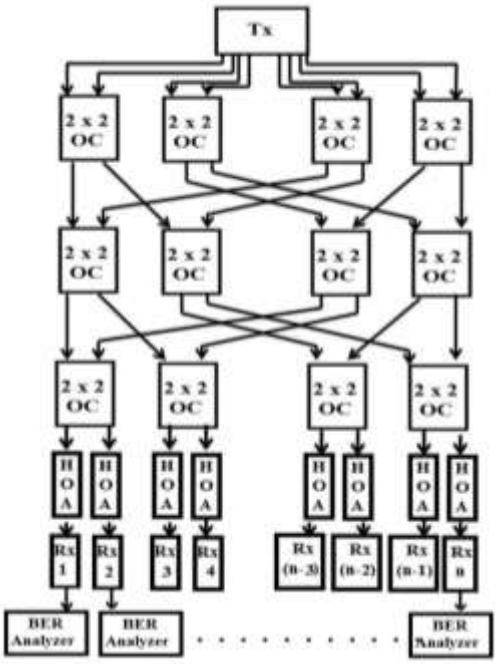

Figure 1: Optical Star Network Topology

2.2 Tree Topology

In tree topology, combination of bus and star topology takes place. In this topology, optical coupler acts as splitters to distribute the power among users as shown in Figure 2. Users supported in this topology are given by product of branches and users per branch. The mach zehnder modulated signals passes through the different couplers and power is finally splitted among the couplers. Signal is made to pass through Optical amplifier to compensate span loss and dispersion before it is received. In a purely passive tree-net, the number of users supported is limited by split and distribution losses in star couplers. The number of users carried out for successive distances is calculated in terms of Quality factor and BER as shown in Figure 6 and 7. It was observed that as the distance increases, Quality factor decreases and BER increases because of the different losses occurs during transmission.

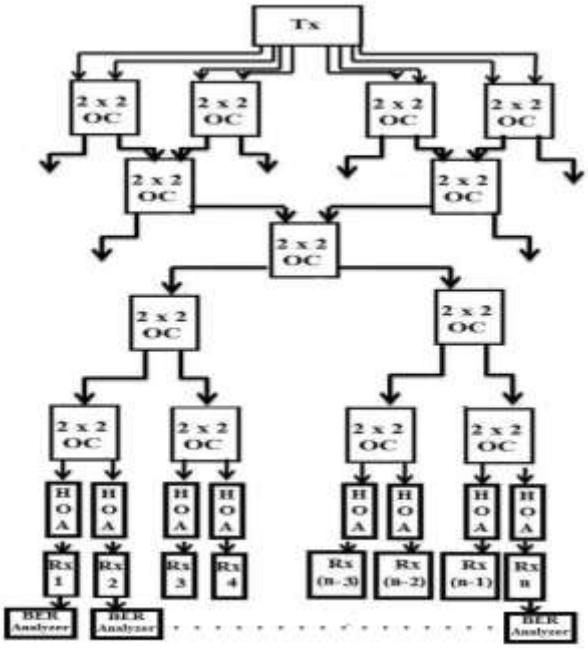

Figure 2: Optical Tree Network Topology

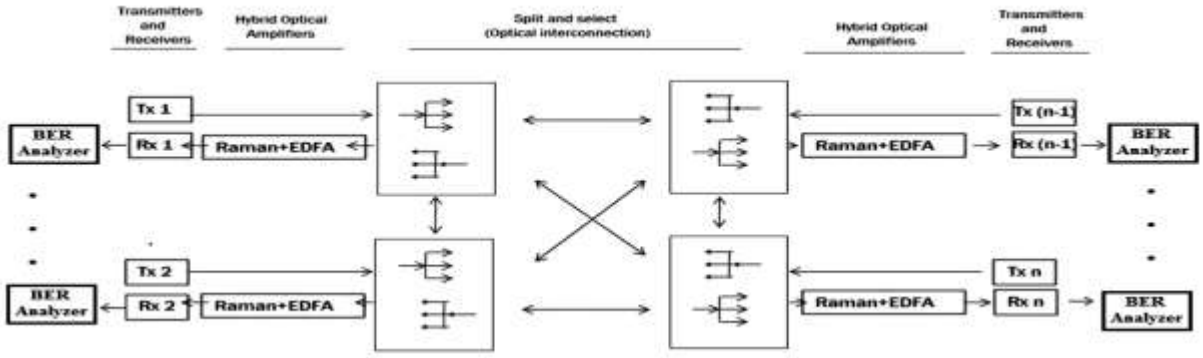

Figure 3: Optical Mesh Network Topology

2.3 Mesh Topology

In optical Mesh network, all the nodes are interconnected and for each splitter and combiner are used in order to make the nodes as transceiver as shown in Figure 3. The signal generated by transmitter passes through the splitters where the power is splitted in order to make it reachable to the other nodes. While receiving, the combiners combines the power received from other nodes and sends the signal to amplifier and finally received by receiver. The number of users carried out for successive distances is calculated in terms of Quality factor and BER as shown in Figure 8 and 9. It was observed that as the distance increases, Quality factor decreases and BER increases because of the different losses occurs during transmission.

3. Results & Discussions

Analysis based on performance of star, tree and mesh topology at successive distances between nodes is carried out in terms of quality factor and BER. Mach Zehnder modulated NRZ signals at input signal power of -40dBm with a bit rate of 15Gbps is taken as input signal.

Star topology for a distance between nodes of 2 Km supports 16 users within the acceptable Quality factor and BER range of 32.88-29.89 and 1.39755e-237–7.85559e-197 respectively. For distance of 4Km between nodes, 16 users are supported within acceptable Quality Factor and BER range of 14.51- 13.22and 1.65779e-048 – 2.14491e-040 respectively. At the distance of 6 km between nodes, 16 users are supported within the acceptable Quality factor and BER range of 7.64 - 7.30and 6.78921e-015–2.76098e-014.

Tree topology for a distance of 2 Km between nodes supports 16 users within the acceptable Quality factor and BER

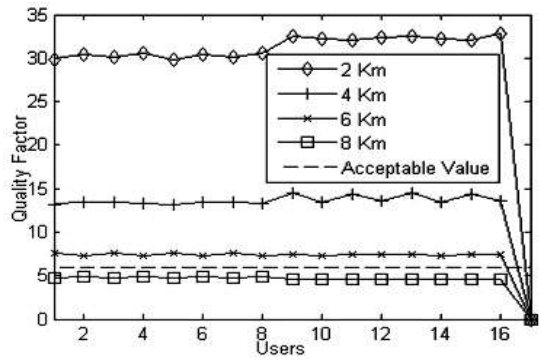

Figure 4: Quality Factor at different users for different distances using HOA in Optical Star Topology

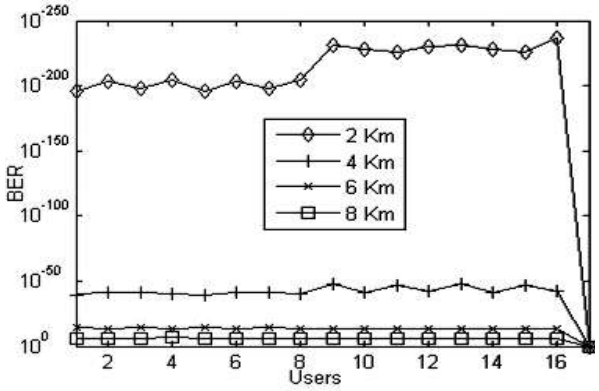

Figure 5: BER at different users for different distances using HOA in Optical Star Topology

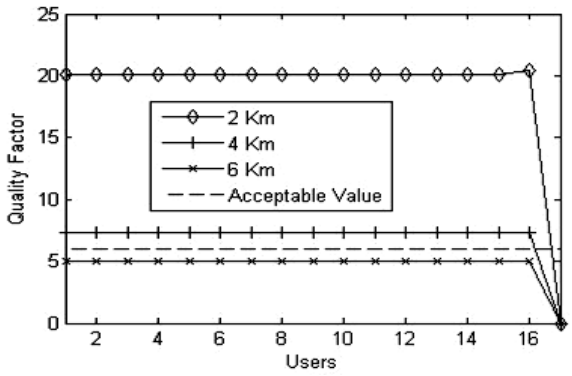

Figure 6: Quality Factor at different users for different distances using HOA in Optical Tree Topology

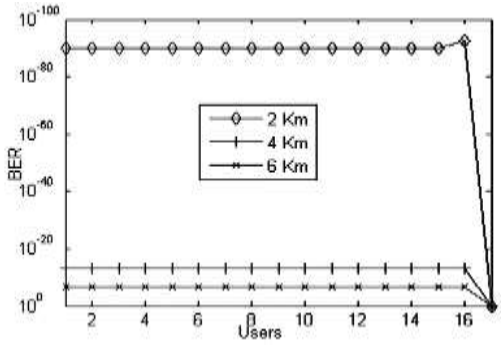

Figure 7: BER at different users for different distances using HOA in Optical Tree Topology

range of 20.39-20.12and 5.059e-093–1.25645e-090. For distance of 4Km between nodes, 16 users are supported within acceptable Quality Factor and BER range of 7.31-7.27 and 9.72632e-014–7.583e-014 respectively.

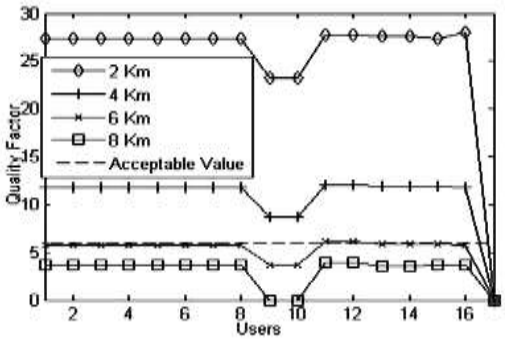

Figure 8: Quality Factor at different distances for Optical Mesh Topology using HOA.

Mesh Topology for a distance between nodes of 2 Km supports 16 users within the acceptable Quality factor and BER

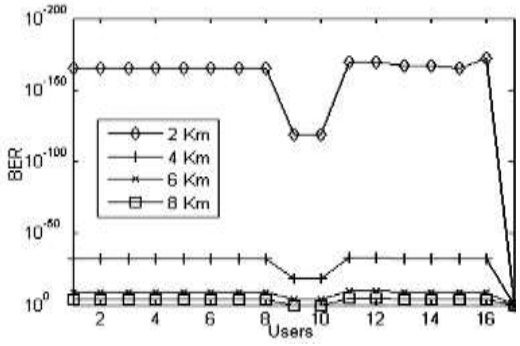

Figure 9: BER at different distances for Optical Mesh Topology using HOA.

range of 27.97-23.18 and 5.33802e-173–1.89506e-119 respectively. For distance of 4Km between nodes, 16 users are supported within acceptable Quality Factor and BER range of 11.90-8.72 and 9.8413e-034–7.58942e-019 respectively. At the distance of 6 km between nodes, 2 users are supported within the acceptable Quality factor and BER of 6.11 and 2.88755e-010.

4. Conclusion

It is concluded that optical star topology using MZ modulator is capable to cover long distance with high quality factor and low BER than Tree and Mesh optical Network Topologies at input signal power of -40dBm with bit rate of 15 Gbps. Optical star topology supports 16 users at a distance of 2 Km with the acceptable quality factor and BER range of 32.88- 29.89and 1.39755e-237–7.85559e-197 respectively. At 4 Km, 16 users with acceptable the acceptable quality factor and BER range of 14.51-13.22and 1.65779e-048–2.14491e-040 respectively. At the distance of 6 km between nodes, 16 users are supported within the acceptable Quality factor and BER range of 7.30-7.64 and 2.76098e-014 – 6.78921e-015.

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Author Profile

Rajpreet Singh received his B-Tech degree in Electronics & Communication Engineering from Punjab Technical University through Adesh Institute of Engineering & Technology, Faridkot. Presently he is Pursuing M-Tech from Punjab Technical University through Shaheed Bhahgat Singh State Technical Campus, Ferozepur. His research focuses on optical network design and optimizations.

Dr. Sanjeev Dewra received his B-Tech degree from Mahatma Gandhi Missions College of engineering & technology, Marathwada University, Aurangabad (M.S) in year 1993, An M.E. degree from GNDEC, Ludhiana in 2002 and A Ph.D. degree from Thapar University, Patiala (Punjab) in 2014. His field of interest is optical add drop multiplexer & optical cross connect for optical communication systems. He has published various research papers in international journals & conferences. Mr. Dewra is a life member of the Indian Society for Technical Education, Associate Member of Institution of Engineers (India). He has over 23 years of Education Experience. He served as lecturer at Saint Kabir Institute of Pharmaceutical & Technical Education, Fazilka from year 1994 to 1998. He then joined Lala Lajpat Rai Institute of Engineering & Technology, Moga as a lecturer in 1999. In 2000, he joined Giani Zail Singh College of Engineering & Technology, Bathinda (Punjab), as Lecturer in the Department of Electronics and Communication Engineering and continued till 2003. In 2003, he joined as a Lecturer in the Electronics and Communication Engineering Department at Shaheed Bhagat Singh College of Engineering and Technology, Ferozepur (Punjab) & turned a senior Lecturer in 2005. Presently he is working as an Associate Professor as well as M-Tech Co-ordinator at the same college.