Abstract

The performance of bus, star, and tree network topologies is investigated for 10 Gbits/sec differential-phase-shift-keying signals in the presence of Erbium Doped Fiber Amplifiers (EDFA) and Semiconductor Optical Amplifiers (SOA). By considering the signal quality factor and received power, the maximum number of users supported is calculated for each network topology with the presence of EDFA and SOA amplifiers in each network scenario individually and a comparison is deduced. In addition to the above scenarios, analysis of the performance limitations of Single Mode Fiber (SMF) due to Self Phase Modulation (SPM) effect is discussed. With the aid of OptSim simulation software a DCF has been employed for each network scenario with proper variation in length of the transmission fiber to tackle the nonlinear effects in the transmission system.

1. Introduction

Multimedia networks are required today to carry large amounts of information such as real-time video services. Presently, almost all the trunk lines of existing networks are using optical fiber. Optical multiplexing and switching techniques are used to increase the capacity. The implementations of encoders/decoders and time multiplexers/de-multiplexers at terabits per second is very difficult, so optical network topologies reduce the complexity. A physical broadcast topology must have a minimum number of couplers, multiplexers and de-multiplexers, and optical amplifiers to reduce the cost in the large network. Also, minimum received power is required for a given bit error rate (BER) to maximize the number of users supported.

The bus topology supports very few users, typically. Due to amplified spontaneous emission (ASE) noise and gain saturation of SOAs, the number of users is limited, but compared to SOAs EDFAs performed well. The star topology distributes optical power equally to output ports. The number of users supported by the star is less than 64. The tree network topology provides large geographical area coverage, and the capacity of the network can be increased by use of a wavelength division network (WDM).

In this paper it is seen how the performance of a point to point communication system has been evaluated in presence of nonlinear effect SPM. The DCF compensating technique for the SPM effect in a SMF 10Gb/s transmission system over 100 km has been investigated. And this dispersion management scheme has been employed for long distance communication in optical network topologies. By incorporating this concept non-linear effect viz. Self Phase modulation is mitigated to a large extent for distance of 100Km. Finally a comparison is done to conclude the better performing topology which can accommodate maximum number of users with either SOA or EDFA for better received signal quality by estimating the BER and Q-Value of the signal.

2. Simulation Setup And Description

2.1 Bus Network Topology

Each user in the bus is connected through the optical splitter, every user is connected to every other user by single-mode fiber (SMF) and dispersion compensating fiber (DCF) through an amplifier.
The length of the DCF is chosen in accordance with the following concept:

$$L_2 = \frac{-D_1 L_1}{D_2} \text{ meter}$$

Where $L_1, L_2$ are the lengths of the SMF and DCF, respectively, and $D_1, D_2$ are the dispersion parameters for the SMF and DCF, respectively. The total minimum fiber link length is approximately 100 km. The placement of one amplifier is done at the start of each segment in order to continue broadcasting the information from transmitter users, i.e., segment $i-1$ shown in Fig. 1.

The performance of the bus network topology is shown in Fig. 2 and Fig. 3.

Please note that the figures include graphs and tables illustrating the BER values and Q-values for the bus topology with EDFA and SOA.
2.2 Star Network Topology

A Star Network model with single transmitter node and Four Receiver nodes is taken into consideration. Schematic setup for the broadcast star network topology shown below,

![Figure 4: Schematic setup for the Star network topology]

Two Scenarios are considered for this network
(i) With EDFA Amplifier
(ii) With SOA Amplifier

And for different inter-distance between user nodes viz.
   i) Distance between Transmitter and Hub. (S-H)
   ii) Distance between Hub and Receiver (H-R)

The BER and Q-value performance metrics have been analyzed.

The combination of SMF and DCF fibers for long distance scenario has been considered to mitigate the non-linear effects as shown in Fig.4

The performance of the star network topology is shown in Fig.5 and Fig.6

![Figure 5a: BER value of Bus topology with EDFA]

![Figure 5b: Q-Value metrics for Star topology with EDFA]

![Figure 6a: BER value of Bus topology with SOA]

![Figure 6b: Q-Value metrics for Star topology with SOA]
2.3 Tree Network Topology

A Tree Network model with a single transmitter node and receiver nodes with Three Stages is taken into consideration.

The Schematic setup for the broadcast Tree network topology is shown below.

Two Scenarios are considered for this network
(i) With a EDFA amplifier
(ii) With a SOA amplifier

For different inter-distance between user nodes viz. For 2nd and 3rd stages, The BER and Q-value performance metrics have been analyzed. The combination of SMF and DCF fibers for long distance scenario has been considered to mitigate the non-linear effects.

<table>
<thead>
<tr>
<th>Distance (S-H) in Km</th>
<th>Q Value (dB)</th>
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</thead>
<tbody>
<tr>
<td>25</td>
<td>18.29</td>
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<tr>
<td>50</td>
<td>15.36</td>
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<tr>
<td>75</td>
<td>11.83</td>
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<tr>
<td>100</td>
<td>6.68</td>
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<tr>
<td>100(with DCF)</td>
<td>17.99</td>
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Figure 8b. Q Value metrics for Tree topology with EDFA

<table>
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<tr>
<th>Distance (S-H) in Km</th>
<th>BER Value</th>
</tr>
</thead>
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<td>25</td>
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<tr>
<td>50</td>
<td>0.000213</td>
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<td>75</td>
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<td>100</td>
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<tr>
<td>100(with DCF)</td>
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</table>

Figure 8a. BER Value metrics for Tree topology with EDFA

<table>
<thead>
<tr>
<th>Distance (S-H) in Km</th>
<th>Q Value (dB)</th>
</tr>
</thead>
<tbody>
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<td>7.74</td>
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<tr>
<td>100(with DCF)</td>
<td>6.02</td>
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</table>

Figure 9b. Q Value metrics for Tree topology with SOA.

3. Performance Comparison Of Optical Network Topology

From the results obtained for the Bus, Star and Tree Network topologies, it can be observed that EDFA amplifier turns out to be better in terms of performance compared to SOA amplifier since for long distances its working is good. SOA amplifier turns out to be better for short distance communication between two nodes. But considering the network costs EDFA amplifier is more costlier than SOA and hence very high number of EDFA amplifiers in the network would mean high network costs. But considering...
the advantages it provides for good network performance compared to SOA cost aspect should be met judiciously by placement of EDFA amplifiers only at required locations in the network which are prone to high noise levels. On comparing the performance of the Network topologies it can be observed that,

BUS Network performance is good for short distance communication with only few User nodes. As the number of users increase the quality of the signal received at the receivers begins to fade. Hence it can support only a minimum number of users at a time for better network performance.

STAR Network is good compared to the Bus network since more number of user nodes can be accommodated. Here as inter distance between the Transmitter and the hub or Hub to receiver increases it results in poor network performance. As the inter distance increases the BER Value of the received signal also increases and Q-Value decreases.

TREE Network is the best of all the networks since maximum number of users can be accommodated. Hence it covers a large geographical area in terms of network distribution. Here to as the inter distance between the Nodes in Stage 1,2&3 results in increase in BER value and decrease in Q-Value.

4. Conclusion

Performance and Comparative Analysis of Optical Network topologies viz. Bus, Star and Tree with Erbium Doped Fiber Amplifier (EDFA) and Semiconductor Optical Amplifier(SOA) is implemented using Optsim Simulation tool. Simulation study of Dispersion Compensated fiber (DCF) in Single Mode Fiber(SMF) has been done using Optsim and its results have been applied to the proposed network topologies for long distance ranges.

This study is done to analyze which Optical Amplifier best suits for better performance of Optical Network topology taken into consideration and which topology serves better among the rest of the topologies, in terms of maximum number of users that can be accommodated without compromising on the received signal quality and within acceptable Bit Error Ratio (BER) limits.

The simulation results for Dispersion Compensated Fiber (DCF) compensated Single mode fiber (SMF) shows that for the combination of SMF with 80Km and DCF 20Km for a 100Km fiber length, the non-linear effects pertaining to Self Phase Modulation can be mitigated to a very large extent with better BER values and Quality of the signal is also retained to a large extent at the receiver end. By implementing this result in the proposed network topologies for distances ranging in 100Km fiber lengths optimum results have been realized. Of the three topologies taken into consideration, Tree Network with EDFA as the amplifier gives good results with maximum number of users accommodated for a large geographical area with each user node at the last stage receiving signals of acceptable BER values and high Q-Value.

5. Reference


