IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 3, March 2016

Design of High Capacity, Reliable and Efficient Core WAN Network using DWDM

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Abstract: This paper deals about the use of DWDM technique and its design. The DWDM technique refers to optical signals multiplexed in the range of 1550nm. It works effectively in the range of C-Band which has the wavelength from 1530-1565 nm. This technique enables us to increase the throughput by decreasing the usage of the medium which is the optical fibre. It deals with the twin concept of Optical transport network and Wavelength division multiplexing. By implementing in DWDM, the network gets optimised to have extended coverage area and maximization of bandwidth. DWDM terms like throughput, latency, Bit Error Rate, Optical Signal to Noise ratio are analysed by this technique.

Index Terms: DWDM (Dense Wavelength Division Multiplexing), multiplex, throughput, Optical transport network, Wavelength division multiplexing, latency, Bit error rate, Optical signal to noise ratio.

I. INTRODUCTION

The concept of combining many signals of different wavelength in a single optical fibre is called as the Wavelength Division Multiplexing. It has different types in it such as Broad WDM, Coarse WDM, and Dense WDM. Of which the Dense WDM has the major advantage in today's data needs by transmitting signals over long distance at higher data rate. It multiplexes number of optical signals from different transmitters and transmits it through a single fibre. In the receiver end, all the different signals are split from the multiplexed signals. The major advantage of this technique is that it requires a single optical fibre medium instead of one fibre for a transmitter. This technique is protocol independent. This system provides greater bandwidth over any other existing optical system. This technique allows having a single fibre medium instead of handful of fibre for transmission of signals over long distance. It uses the Raman/ EDFA (Erbium Doped Fibre Amplifier) which gives the advantage that it does not require any regenerator for boosting the power of the signal frequently. The signal transmitted by this technique is 4 to 8 times better than the TDM (Time Division Multiplexing) signal and without regeneration it can be transmitted for about 300 Km. DWDM is well adaptive and can transmit variety of data which may differ in wavelength by bits in parallel or by character in serial manner.

The emergence of this technique is an important phenomenon for optical transmission technology. It created the revolution by increasing the embedded fibre capacity. Networking industries faced the major issue of tremendous need for bandwidth. The development of optical networks along with the DWDM technique created the new network evolution. The existing system of SDH (Synchronous Digital Hierarchy) and TDM (Time Division Multiplexing) can be opted for voice traffic and not the high speed data traffic. In order to support this need, very intelligent all-optical network device should be developed which will combine the features of SDH and the bandwidth increasing property of DWDM. The concept of optical fibre switching, loss control, packet switching and network topologies and synchronization has major role in the measure of throughput of the network.

Wideband WDM has its evolution in the late 1980s with the widely spaced wavelength in 1310 nm and 1550nm. The second generation WDM, also called as the Narrowband WDM has its evolution in early 1990s.It supports two to eight channels in the interval of 400GHz in 1550nm wavelength range. By mid 1990s DWDM technique emerged which supports 16-20 channels with the interval of 100-200 GHz spacing. By late 1990s DWDM evolved to support 64 to 160 parallel channels in the interval spacing of 50 or 25 GHz.

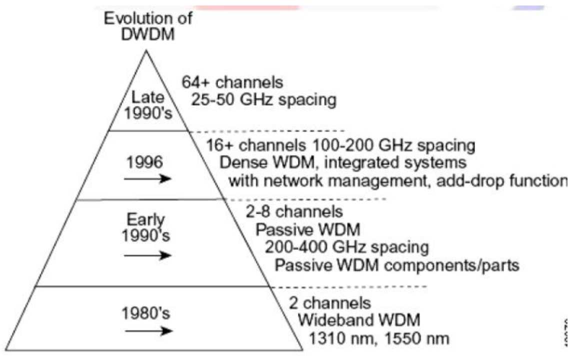

Fig 1: Evolution of DWDM technique

II. KEY CHARCTERISTICS OF DWDM

Here, we discuss the most important characteristics of the DWDM networks.

- Component reliability, system availability and system margin is obtained by well- engineered devices.
- An optical amplifier has two important components: the optical fibre with Erbium doped and an amplifier. When laser is used to energize the erbium, it acts as the

DOI 10.17148/IJARCCE.2016.5355

IJARCCE
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gain medium which amplifies the signal. The use of connector instead of medium results in the accumulation of dust which causes damage to the connector.

- When a channel gets added or removed from the fibre, optical amplifier should be automatically adjusted for optimal performance. When a signal with high power is transmitted, degradation in performance occurs whereas for low power, it is insufficient to provide enough gain for amplifier.
- Silicon based optical amplifiers works similar as fluoride based optical amplifiers at the range of 1530 to 1565 nm. However fluoride based amplifier is costlier to implement.
- With the application of high power and additional signal to noise ratio it is possible to upgrade the system.

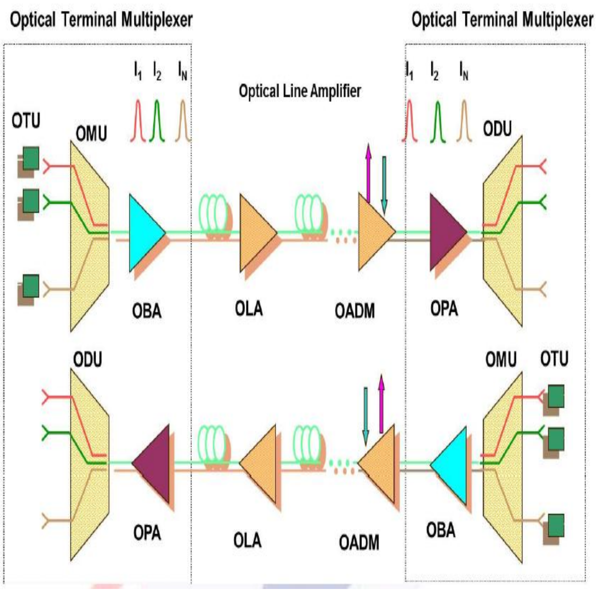

Fig 2: Typical DWDM system

III. DWDM SYSTEM COMPONENTS

The figure shows the typical DWDM networking components. The major components include:

- Optical Terminal Multiplexer(OTM)
- Optical Add Drop Multiplexer(OADM)
- Optical Line Amplifier(OLA)
- Optical Cross Connect(OXC)

A. Optical Terminal Multiplexer
It consists of

- Optical Transponder Unit (OTU)
- Optical Multiplexer Unit (OMU)
- Optical De-multiplexer Unit (ODU)
- Optical Amplifier (OA)
- Common Control Cards (NCP,OHP, OSC, LACT)

B. Optical Amplifiers
It amplifies the optical signals directly without need for the signal to be converted in to electrical form. It does not allow performing the OEO (Optical- Electrical- Optical) conversion. It increases the strength of the signal with addition of little amount of noise. It is an analog device which performs the amplification process with addition of some unwanted signals. IT is used to compensate the attenuation losses in the signal passing through the fibre.

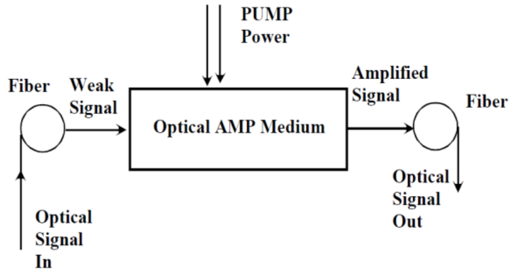

Fig 3: Optical Amplifier Unit

We can use either EDFA (Erbium Doped Fibre Amplifier) or Raman Amplifier. Erbium doped Fibre Amplifier is the widely used optical amplifier for long range fibre optic communication. It amplifies light in 1.5μm wavelength region efficiently. This is of great importance to Telecom industry where they acquire minimum loss. Its application includes the boosting of the data transmitter power with EDFA amplifier for long distance fibre cable or for the fibre optic splitter which has maximum loss. Eg: Traditional Cable TV system now used, which transmits to several fibre using a single transmitter. Raman amplifier is now mostly attracted because of its smaller noise figure and cheaper than EDFA amplifier.

C. Optical Add Drop Multiplexer
It is a device which is used to drop or add some wavelength while passing the remaining wavelength signal. It does not require any OEO (Optical- Electrical-Optical) conversion. We have fixed OADM as well as new generation OADM called ROADM (Reconfigurable Optical Add Drop Multiplexer). As per the situation ROADM can be configured using the software from remote station.

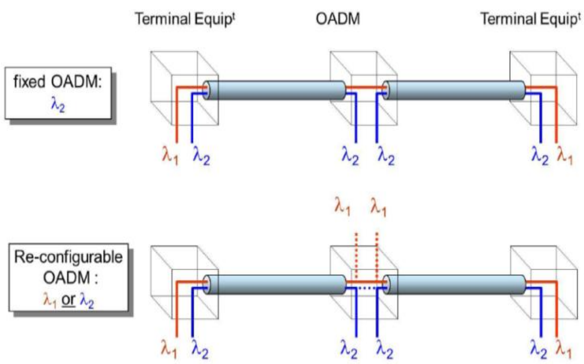

Fig 4: Optical Add Drop Multiplexer

D. Optical Cross Connect
It is widely used in Telecommunication Industry for switching high speed optical signal into optical cables. Today's OXC are very popular as it converts the optical data streams into electrical using Electronic cross connect

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and vice versa. This type is called as Hybrid or Opaque OXC. Another method of realising an OXC is switching the optical signals in all the optical devices. This type is called as Transparent or Photonic cross connect.

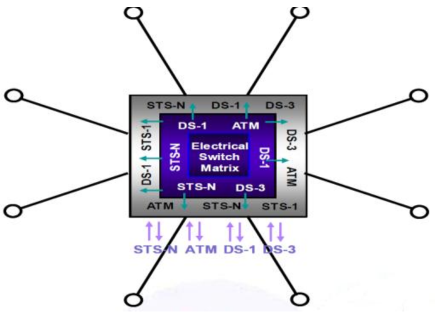


Fig 5: OEO –OXC

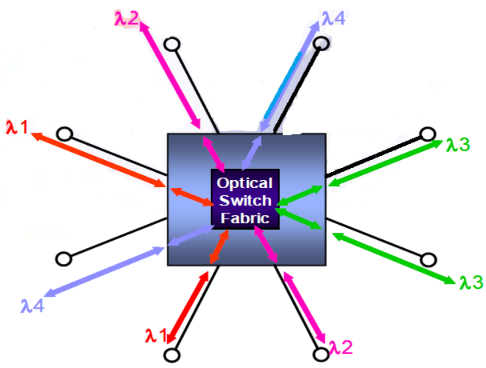
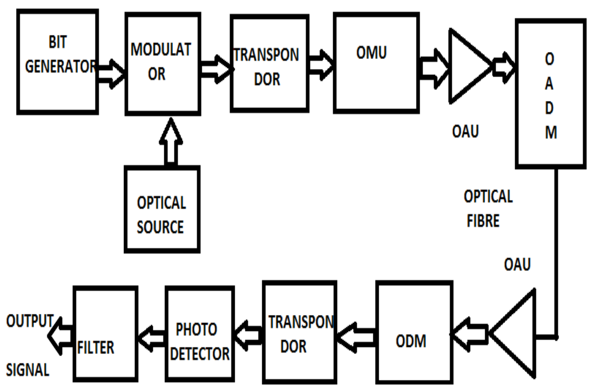


Fig 6: OXC-OOO (Photonic Cross connect)

IV. BLOCK DIAGRAM

Here, the block diagram for the DWDM system is discussed. It contains two parts. One is the transmitter part, and other is the receiver part connected by means of the medium, optical fibre.



V. IMPLEMENTATION

The implementation of this technique in simulation is done by the software named Opti-system developed by Optiwave. This tool allows us to design, plan and test our optical network for different elements. This tool has variety of devices of about twenty testing instruments, twenty two Lasers for input to the system, more than 50 modulation techniques. Based on our requirement of the optical network design we can make avail of the devices from the software. It is the comprehensive design software suite allows us to design, plan, and test and simulate modern optical network in transmission layer of the network. The design of a DWDM network can be made effective by observing the parameters like Bit Error rate, latency, throughput, reliability. We use the test instrument tools like BER analyser, WDM analyser, Power meter, Spectrum Analyser for our design. The power meter is used to measure the average power of the optical signal transmitted. The spectrum analyser is used to plot the wave of magnitude of the input signal and frequency. The WDM analyser used to measure the values like Signal to noise ratio, Signal power and noise power.

VI. DESIGN

Here, we have designed a network of DWDM technique for different input wavelengths. The design goal is to achieve the transmission power and receive power of about +18±3 dB. The design has three sections, first is the transmitter part (OTM), then Add drop multiplexer, and the receiver part (OTM). The communication is through the optical fibre with the length of 60 Km and with insertion loss of 0.3dB.

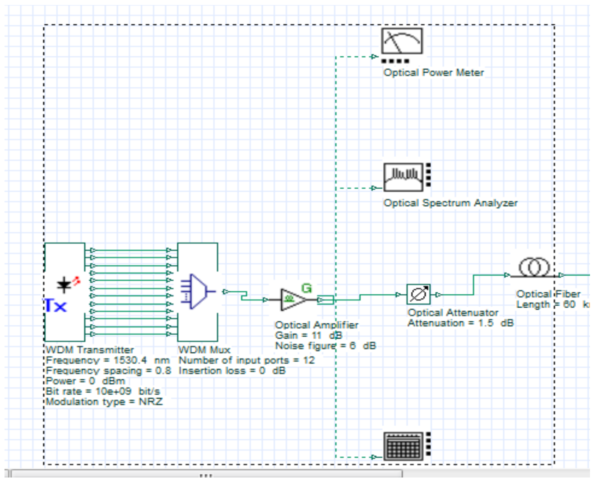


FIG 7: Design of Transmitter part (OTM)

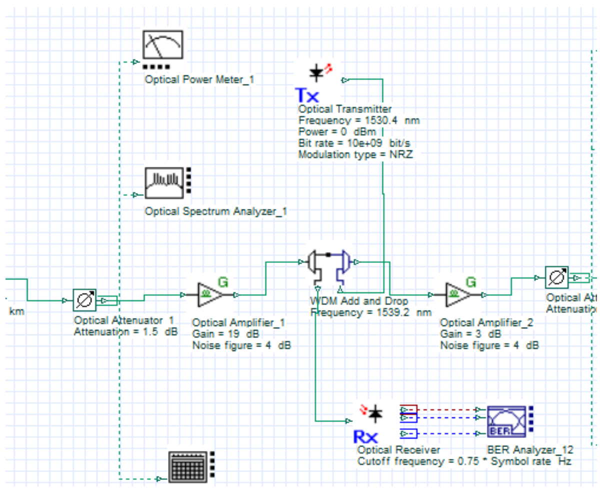


FIG 8: Design of ADD Drop multiplexer

IJARCCE

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The relative output for the three sections are measured using the power meter, WDM analyser, Spectrum analyser.

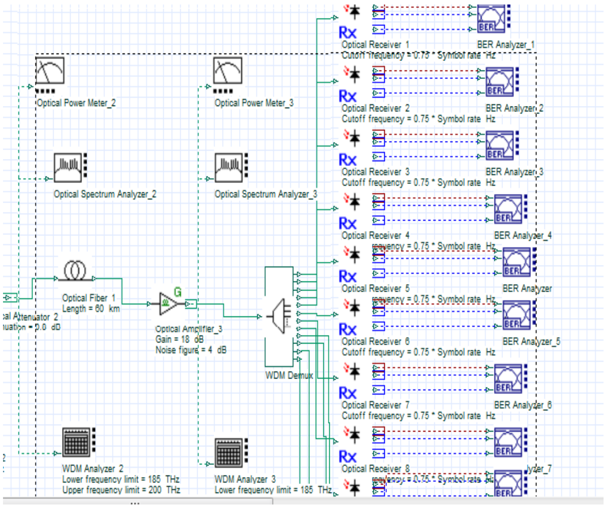

FIG 9: Design of Receiver (OTM)

VII. RESULT ANALYSIS

The output of the design measured using the power metre and spectrum analyser are discussed here.

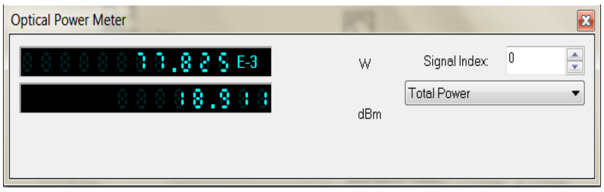

FIG 10: Transmitter power (OTM)

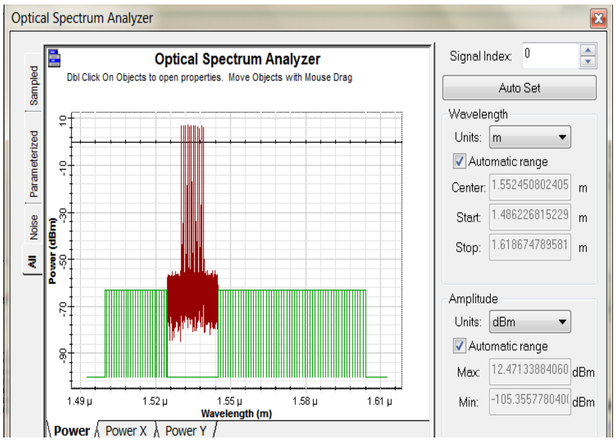

FIG 11: Spectrum analyser at ADD drop multiplexer

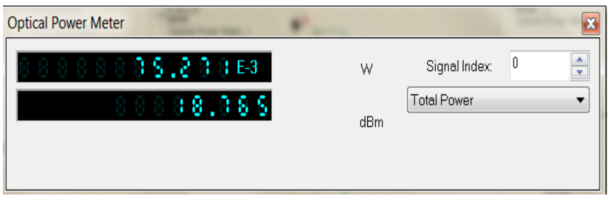

FIG 12: Power at Add drop multiplexer

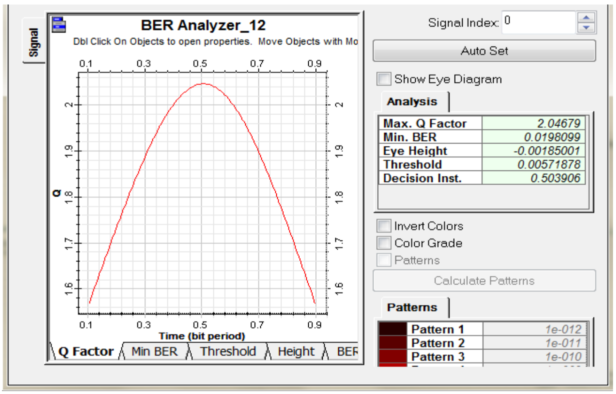

FIG 13: BER at Add drop multiplexer

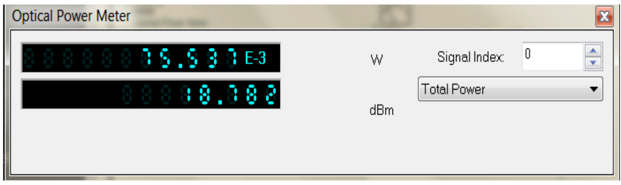

FIG 14: Power at receiver (OTM)

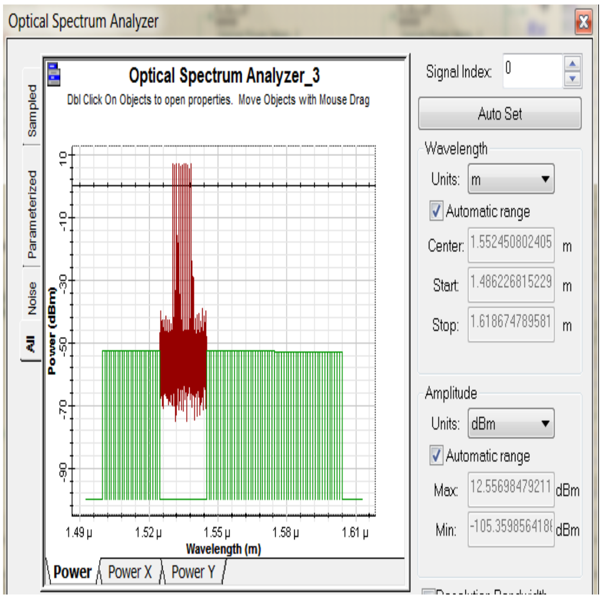

FIG 15: Spectrum analyser at receiver (OTM)

VIII. ADVANTAGES OF DWDM

In this section the advantages of implementing the system are discussed.

- It increases the bandwidth in terms of both speed and distance.
- There is no need for update or replacement of the existing system.
- It allows less fibre cores to be used for transmission of high capacity of signals.
- Allows using a single fibre core to have a maximum number of channels for transmission.
- It provides easy expansion of network as a single fibre can be used for transmission; there is no need for extra cables to be laid.

- Low cost of expense as it uses the existing cable.
- It has capacity to satisfy next generation data rate with high speed.

IX. CONCLUSION

This paper gives the brief discussion about the DWDM technique, its components and design of the network with efficient transmission of power. The Bit error ratio is also analysed. Since there is a very big need for huge data rate, this technique with enormous number advantage and application act as the base for the future communication needs. As stated above, this technique along with the current technique of SDH will have a absolute effective network formation to handle the increasing data rate. This technique will have some of the losses which may occur due to the dispersion of signal, splice loss, connector loss, insertion loss due to multiplexing number of wavelengths. Thus, DWDM technique is the most important milestone for the communication background in order to meet the huge demand of data rate.

ACKNOWLEDGEMENT

The authors would like to thank **Mr. Vetrivel** and **Mrs. P. Nalini** for their guidance in preparation of this article and the issues we faced in the design.

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