Comparative Analysis of DWDM System Using OADM (Optical Add/Drop Multiplexer) At Different Data Rate, Distance and Channel Spacing

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Abstract - **In this paper, we have investigated dense wavelength division multiplexing (DWDM) system for fiber based on optical add/drop multiplexers (OADMs) at 1550 nm window. To perform circulator is employed with each OADM to boost for longer distance. A total distance of 800, 1200, 960, 1120, 1280, 1440 Km is achieved by using the proposed network. 8 channels with frequency 193.1THz at 100, 80, 40, 20GHz spacing are used to transmit data at various data rates i.e. 5, 10 and 15 Gbps. Various performance parameters such as different data rates, distance, channel spacing is varied to investigate the system performance in the term of BER and Q factor in eye diagram representation**.

1. Introduction

Due to the advancements in optical technology, the dense wavelength-division multiplexing (DWDM) not only can fully utilize the fiber bandwidth, but also can increase the capacity of the network and transmission distance of the fiber link [1]. In current optical fiber communication systems, DWDM transmission with 10 Gb/s wavelength channels at 50 GHz channel spacing was an International Telecommunication Union (ITU) standard adopted for long-haul and metropolitan networks [2,3].

DWDM System:

Dense wavelength division multiplexing, or DWDM for short, refers originally to optical signals multiplexed within the 1550 nm band so as to leverage the capabilities (and cost) of erbium doped fiber amplifiers (EDFAs), which are effective for wavelengths between approximately 1525-1565 nm (C band), or 1570-1610 nm (L band). EDFAs were originally developed to replace SONET/SDH optical-electrical-optical (OEO) regenerators, which they have made practically obsolete. EDFAs can amplify any optical signal in their operating range, regardless of the modulated bit rate. In terms of multi-wavelength signals, so long as the EDFA has enough pump energy available to it, it can amplify as many optical signals as can be multiplexed into its amplification band (though signal densities are limited by choice of modulation format). EDFAs therefore allow a single-channel optical link to be upgraded in bit rate by replacing only equipment at the ends of the link, while retaining the existing EDFA or series of EDFAs through a long haul route. Furthermore, single-wavelength links using EDFAs can similarly be upgraded to WDM links at reasonable cost. The EDFAs cost is thus leveraged across as many channels as can be multiplexed into the 1550 nm band.

Tasks in a DWDM / WDM Network

- Generating signals: Stable lightsource, with a narrow specific wavelength and the possibility of fast modulation [7].
- Combining signals: Merging all the different lightsources into one fibre [7].
- Transmission of signals: Controlling parameters as crosstalk and loss. Control over variables as channel spacing or input power. For long links: Amplification needed (flat gain amplifiers to amplify all used wavelengths together). It may further be necessary to remove or add certain wavelengths from the link, before they reach the end [7].
- Separating the received signals at the receiver end (demultiplexing) [7].
- Detecting the separated signals [7].

OADM:

A Optical add-drop multiplexer (OADM) is a device that can add, block, pass or redirect modulated infrared (IR) and visible light beams of various wavelengths in a fiber optic network. OADMs are used in systems that employ wavelength division multiplexing.

Before the development of optical multiplexing devices such as OADMs, signal routing in fiber optic networks was done by converting the IR or visible beams to electrical signals and routing those signals using conventional electronic switches. The electrical signals were then converted back into IR or visible beams.

In a conventional OADM, switching is accomplished without optical-to-electrical or electrical-to-optical conversion using three operations called add, drop and cut-through. An outgoing IR or visible beam can be generated (the add operation) or an incoming beam terminated (the drop operation). A beam can also be passed through the device without modification (the cut-through operation). In combination, these functions allow optical signal routing of considerable complexity. The configuration of the system can be changed remotely.

With the recent momentous advancement in wavelength routing devices and optical switches, OADMs will play a critical role in enabling greater connectivity and flexibility in DWDM networks for multi-wavelength signals locally transmitting/extraction (i.e., the add/drop operation) as well as signal routing and network (re)configuration (i.e., the cross-connect operation) at the HUB and access node (AN) [1,4]. Nevertheless, a single-fiber ring has been emerging to not only double the transmission capacity in the operating mode and provide the self-healing function without protection in the transmission path, but also reduce the required amount of optical fiber by half [3,5,6]. In this investigation, we have proposed DWDM system for fiber based on eight OADMs. A length of 150 Km distance of DCF is inserted between each OADM to achieve 800,960,1120,1200,1280,1440 Kms total distance of the proposed network. Eight channels with frequency 193.1THz at 100, 80, 40, 20GHz spacing are used to transmit data at various data rates i.e. 5, 10 and 15 Gbps.

2. System setup

The block diagram of proposed system setup of DWDM network using OADM is shown in Figure 3.1. Eight OADMs with centre frequency 193.1THz are installed to make a ring structure. The length between each OADM is kept 100 Km. SOA with 4 dB gain is also installed with all OADM to boost up the signals. OADM 3 is connected to 1:8 splitter and transmitter section. 1:8 splitter split the signal and given to optical network unit (ONU).

OADM 4 is also connected to 1:8 splitter and transmitter section.

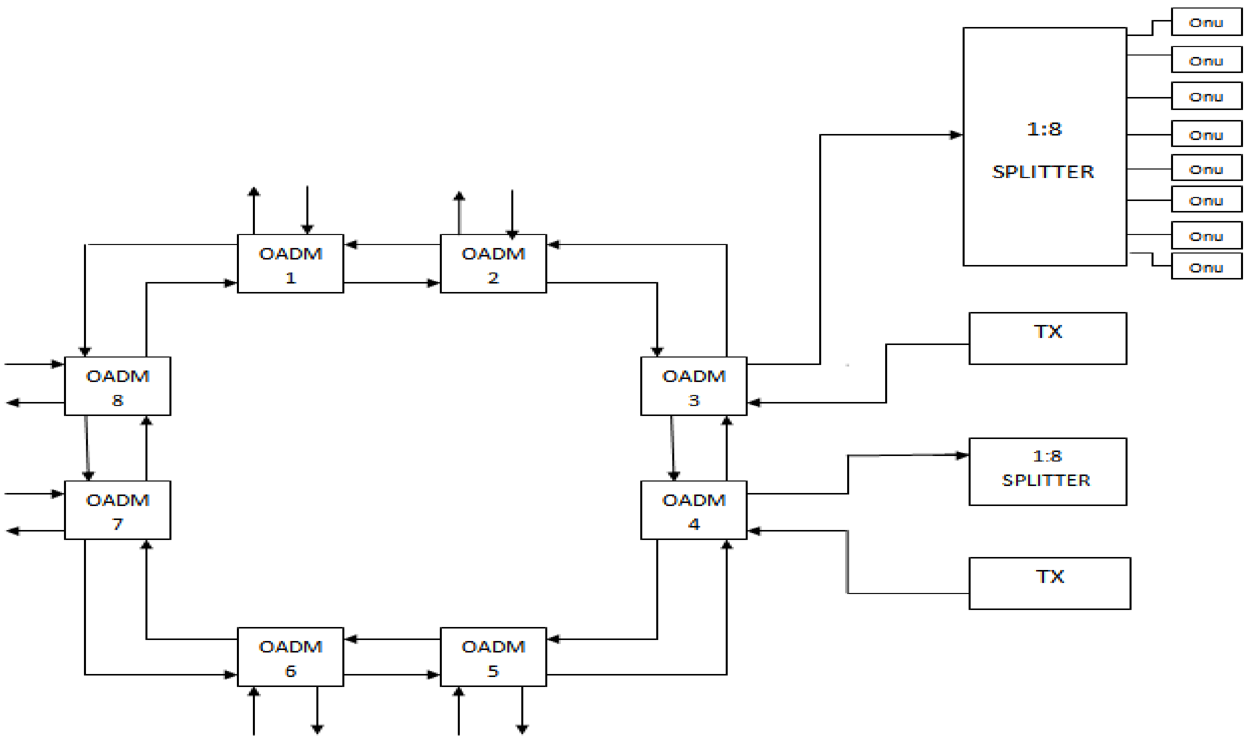

Figure 1- Block diagram of DWDM system using OADM

Each OADM consists of Transmitter array and Receiver array at input and output section. The internal structure of transmitter array is shown in Fig. 2.

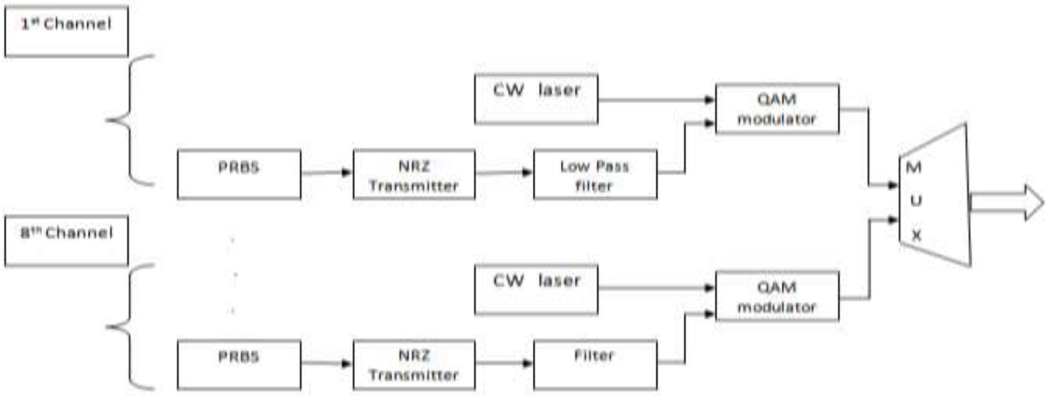

Figure 2- Internal structure of Transmitter section

It consists of eight wavelength channels to send the data to different users at 193.1 THz wavelength with spacing 100, 80, 40, 20GHz, data source, electrical driver, laser source, filter and modulator. CW laser source with 10 MHz line width and different data rates are generated by Pseudo Random Binary Sequence Generator (PRBS) and directly fed to non return to zero (NRZ) electrical driver which generates for each input bit, this electrical coded signal fed to low pass filter. The output from the Quadrature Amplitude Modulator is multiplexed by 8:1 multiplexer then passed through the OADM. The block diagram of receiver is shown in Fig. 3. To receive the data from OADM, the signal is passed through low pass filter to avoid the channel interference. PIN photodiode is used to detect the signal. Various result and performance analyzers are used to investigate the system performance. 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.

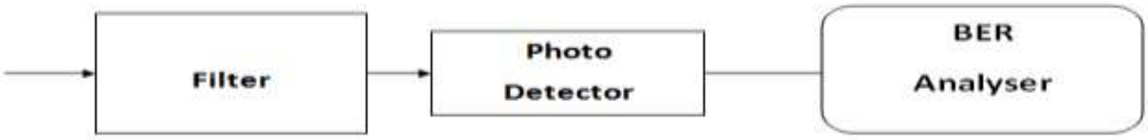

Figure 3- Receiver section

3. Results and discussion

In order to observe the performance of the proposed system, the setup is simulated for different data rates. Various result parameters like BER, Q factor at different data rates for added and dropped wavelengths at various OADM nodes are observed. The eye diagram of 5 Gbps of data rate at 1440 kms of distance is shown in Fig. 4.

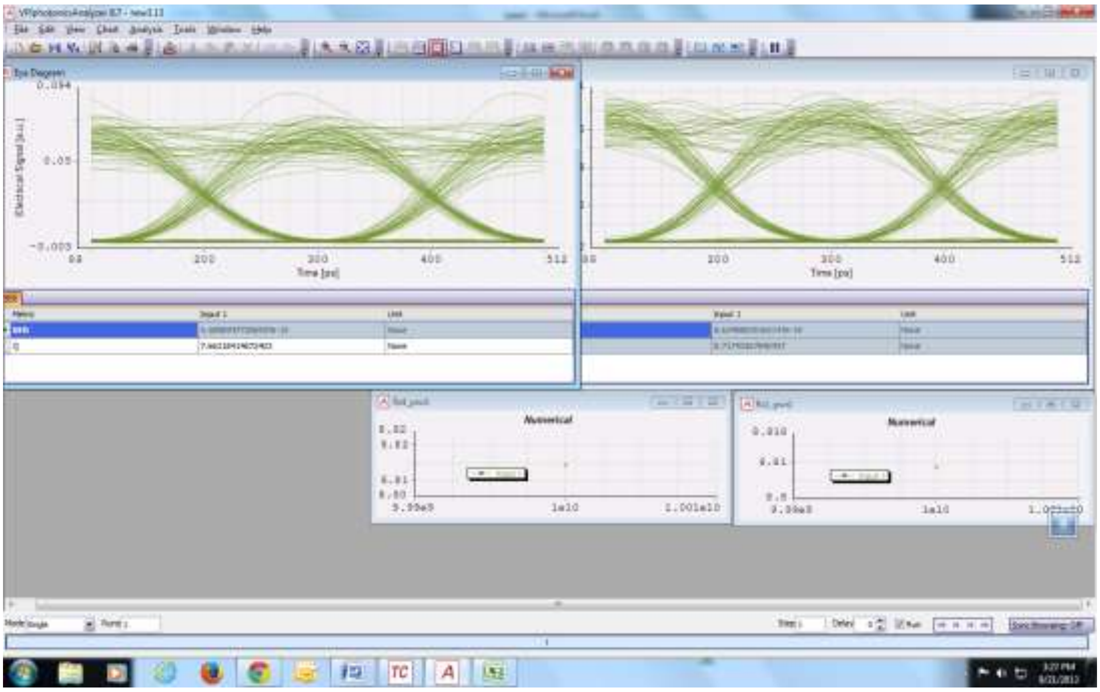

Figure 4- Eye diagram of 5 Gbps data rate at 1440 kms of distance

This figure shows the result at a 10 Gbps of data rate and fiber length of 1440 kms provided a bit error rate (BER) of 5.58989477206957e-15 and Q-factor of 7.66218414672403 at receiver 4 and BER of 8.8349029143437e-7 and Q-factor of 8.717435629437 at receiver 1.

Table 1- Comparison of Q-factor at different distance and data rate

Distance (kms)	5 Gbps	10 Gbps	15Gbps
800	4.65850835216055	9.99218179266199	4.73712693739615
1200	4.65850835216055	8.51288197404382	4.65850835216055
960	12.7762075727494	10.0546484813203	4.76142191483392
1120	12.8507835063992	9.55241927556298	4.90684589155493
1280	30.6846769934891	8.56057506112481	4.25747771100071
1440	8.7174356294371	30.6846769934891	3.77641960293133

Table 2- Comparison of Q-factor at different channel spacing and constant distance

Distance (kms)	100 Ghz	80 Ghz	40 Ghz	20 Ghz
800	8.89740197903864	9.11152401961236	7.51997119467457	0.241709805954364

Table 3- Comparison of Q-factor at different data rate and constant distance

Distance (kms)	5 Gbps	10 Gbps	15 Gbps
1200	9.828672805066428	9.828672805066428	4.6228136188323

Table 4- Comparison of Q-factor at different power level and constant distance

Distance (kms)	0 dbm	10 dbm	20dbm
1200	7.24899795386655	9.03256382622184	9.03256382622184

4. CONCLUSION & FUTURE SCOPE

We have investigated DWDM system at different data rate i.e. 5, 10, 15. Also the system is examined at different distance i.e. 800, 960, 1120, 1200, 1440 kms. Finally system is examined at different channel spacing of 20, 40, 80, 100GHz. Various performance parameters such as different data rates, distance, channel spacing is varied to investigate the system performance in the term of BER and Q factor. The comparison of output power at different channel spacing, distance and data rate has been made and improved eye diagram is observed at maximum distance of 1440 kms. The graph between different data rates at different distance has been shown below.

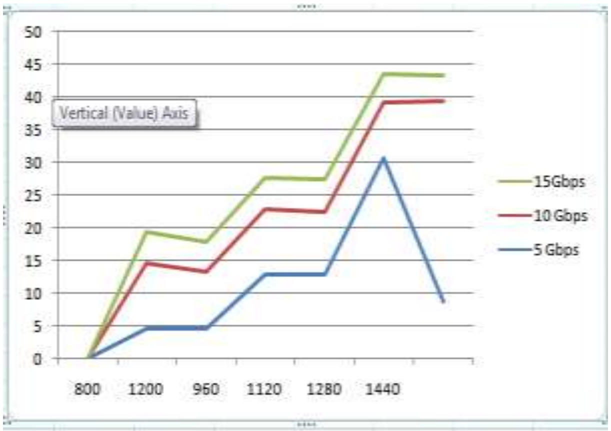

Figure 5- Graph between distance and data rate

Future Scope

It is predicted that, in the coming future, access based on the DWDM will be dominant. Primarily because this technology is maturing fast and it allows the total cost to be shared amongst a larger number of customers. In comparison with other access technologies such as DSL or Cable, FTTH offers much bigger bandwidth. It is certain that as a number of available HDTV channels grow even more bandwidth will be required. The introduction of a dense wavelength division multiplexing (DWDM) is evolution to increase its capacity. Further to reduce the system cost users can be increased and can investigate the systems for longer transmission distance. The fiber installation cost is a very important factor for designing of transmitter, receiver, splitters, combiners, multiplexers and de-multiplexers etc. for improving efficiency.

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