Design of Reconfigurable Optical Add and Drop Multiplexer(ROADM) using Optisystem

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***Abstract*—** As bandwidth consumption continues to explode in a challenging economic environment, service providers and enterprises need to maximize their network's efficiency – deliver more with less. Effective use of Reconfigurable Optical Add Drop Multiplexers (ROADMs) is key to this strategy. Increasing the flexibility, scalability and remote configurability of a network lowers Operational Expenses (OPEX). Using ROADMs, a bandwidth provider can quickly turn up new services, alter networks as needed, protect his revenue stream and reduce truck rolls through remote management. However, the ROADM landscape is large and diverse, and all the available technologies and architectures can at times be confusing and potentially prevent operators from maximizing their networks' potential. Optical multiplexing is the key function of a WDM network and reliable method for data transport networks. WDM networks configured as rings/mesh along with Optical Add-Drop Multiplexers supports added flexibility, simplicity and augment the spectral efficiency. Further enhancement achieved with Reconfigurable OADM architectures, growing briskly along with automatic network management, let the transport network to acclimatize with dynamically varying environment and flexibly respond to the transport network changes. It permits single or many wavelengths to be added and/or dropped from a transport fiber without optical-to-electrical-to-optical domain translation. Presently ROADM technology has revolutionized optical networking and an inseparable part of modern optical communication offering huge bandwidth for data transport at minimum expense. In this view the article presents comprehensive study for numerous generations of ROADM and their architecture and persistent development.

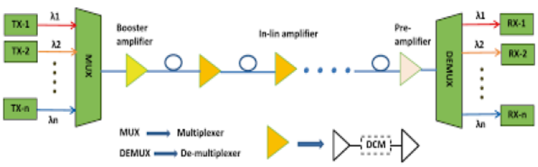
Keywords—**ROADM; WDM; DWDM; OTN; EON;OXC**

I. INTRODUCTION

Growth of the users' bandwidth demand has caused the fast and reliable provisioning of the optical paths to be a main objective of the optical communications service providers. DWDM technology, [1], emerged to help the service providers to handle the users' increasing traffic. Introduction of the new communication services like ehealth and e-gaming exacerbates the need of being equipped by a mechanism for remote and reliable provisioning of the optical paths. For this purpose, Reconfigurable Optical Add/Drop Multiplexers, ROADMs, provide various facilities for optical network managers to reconfigure the network, remotely. Some of the common optical modules that may exist in the ROADM structure are Optical Multiplexer/Demultiplexer, Optical Power Splitter/Coupler, Tuneable Optical Filter and Optical Switch. One major building block of some ROADMs is Wavelength Selective Switch, WSS, [2]. Using this module, any channel of any input port can be switched to any output port [2]. The existing ROADM architectures which are used in various applications have different characteristics. One ofthe properties of ROADMs is "Colourlessness". It means that any port of add/drop structure can add or drop anywavelength [3]. When a ROADM is "Directionless", any port of add/drop structure can add/drop a channel to/fromany degree of ROADM [3]. In "Contentionless" ROADMs, one can add/drop channels of the same wavelengths to/from any degree of ROADM [3]. "Multicast" means that a channel can also be routed to some output degrees, while it is dropped. It is called "drop and continue", also. "Scalability" is the ability to increase the number of ROADM degrees [4]."Modularity" is a key feature of ROADMs to provide the upgradability and reconfigurability [4]. Different ROADM architectures are investigated in literature [3-6]. One of the ROADM architectures is coloured in which the add/drop function is not colour blind [3]. It has one WSS in the output port of each degree. Other architecture is coloured with WSS in input and output port of each degree [4]. A colourless architecture with WSS in each degree is stated in [3]. The other ROADM structure is Colorless and Directionless, CD, in order to avoid a separate add/drop structure for each degree, [3]. A Colourless, Directionless and Contentionless, CDC, architecture is presented in [3] in which $m*n$ WSS module is used. Another CDC architecture, using Switch, Filter and Power Splitter is proposed in [3] because $m*n$ WSS is not available commercially. A CDC architecture is proposed in [5] that is designed based on (De)Multiplexer and Photonic Cross Connect, PXC, [7]. The other structure which is proposed in [6] is CDC that uses WSS in each output port and Coupler in input ports. One can use PXC and Coupler in output ports and WSS in input ports of ROADM, as presented in [5]. The other architecture is based on Coupler and WSS in both input and output ports to reduce the PXC size [5]. One important issue in ROADM-based DWDM networks is the network management in terms of add/drop of wavelengths in intermediate nodes of light paths. As we discuss later, add/drop of wavelengths in intermediate nodes can affect the quality of other channels passing through. Therefore, the network manager must deal with the wavelengths precisely to avoid the signal quality degradation. The rest of paper is organized as follows. In section 2, the proposed design of a ROADM-based DWDM network, including the design of proposed ROADM nodes and the derived DWDM network, is investigated. Section 3 presents the simulation and measurement results of the proposed ROADM-based DWDM network to address two issues of these kinds of networks. Ease of Use

II. DWDM ARCHITECTURE

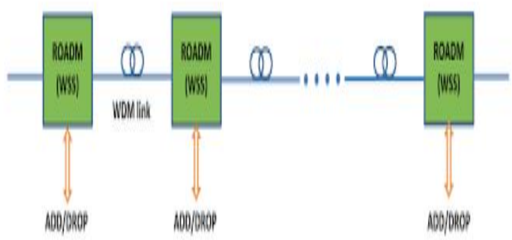
Before considering networks, we begin by describing point-to-point DWDM systems. Figure 2.2 shows the schematic of a point-to-point DWDM system, where multiple wavelength channels are generated in optical transmitters, each being modulated by a data signal and then combined by a WDM multiplexer. The composite DWDM signal is then transmitted over an optical fibre link with optical amplifiers to boost signal before transmission, to compensate fibre loss at each span as well as to improve receiver sensitivity. The in-line amplifiers are usually two stage amplifiers as shown in the inset in Fig. 2.2, where the Dispersion Compensation Module (DCM) is used in each span to compensate fibre chromatic dispersion. When using coherent technology, the fibre dispersion can be compensated in the coherent receivers instead. Hence the new DWDM networks are designed to be DCM-less to enable optimum performance for higher speed using coherent technology. At the receiving end, a DWDM de-multiplexer is used to separate the DWDM signal into individual channels and data signals are recovered in the optical receivers.



Schematic of a point-to-point DWDM system

DWDM technology provides an efficient way of increasing network capacity. Whilst the capacity is increased by the number of DWDM channels, the common network infrastructure, including optical fibre, optical amplifiers, DCMs. DWDM multiplexer, and de-multiplexer, is shared by all the DWDM channels. Thus the network cost is also shared, resulting in lower cost per channel. As traffic demand increases, network capacity can grow by adding extra transponders (i.e. transmitters and receivers) at the terminating points of the traffic. In addition. DWDM technology is transparent to the data signals carried by the wavelength channels. Therefore, new data rates and modulation formats can be introduced to further increase the network capacity.

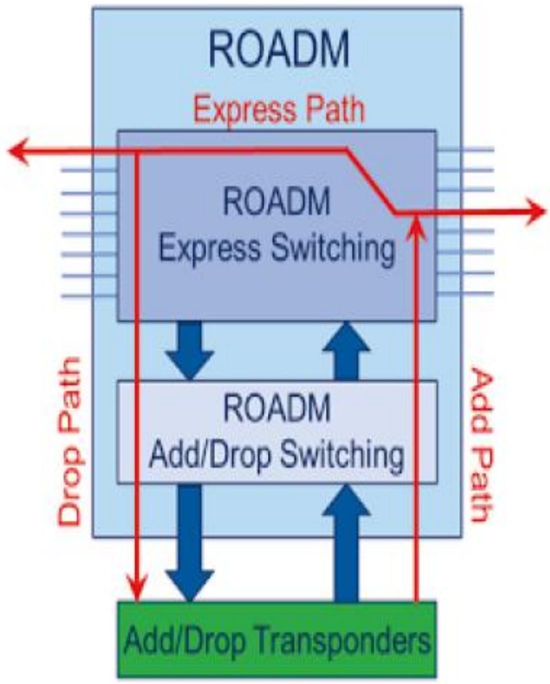
For commercial DWDM systems, the total fibre capacity has increased over the years from up to 0.24 Tb/s at a data rate of 2.5 Gb/s to a total of 9.6 Tb/s at the higher data rate of 100 Gb/s. It is worth mentioning that utilization of the optical fibre has also increased significantly as demonstrated by the improvement of the spectral efficiency from 0.05 to 2 bit/s/Hz when the data rate increases to 100 Gb/s. The spectral efficiency continues to improve as the data speed increases beyond KM) Gb/s, as well as when the network technology moves from fixed-grid DWDM to flexible grid networking, which will be covered in more detail in the following sections. In addition to increasing neuvork capacity as described above, DWDM technology has also evolved from point-to-point DWDM systems to DWDM networking with wavelength switching, initially with fixed wavelength Optical Add and Drop Multiplexers (OADM), and more recently with Reconfigurable OADM (ROADM), which can be configured remotely. Figure 2.3 illustrates a ROADM-based WDM network, where degree 2 ROADMs in WDM nodes route wavelength channels to different directions or to local ADD/DROP ports. Fixed- grid ROADMs using Wavelength Selective Switch (WSS) technology have now been widely deployed in WDM networks. ROADM nodes can have varying number of degrees, usually up to 8 degrees in the current WDM networks to enable meshes to be built. As bandwidth continues to increase and becomes more dynamic. ROADM-based WDM networks provide network operators more flexibility in adding new wavelengths or re-directing wavelengths, as well as restoration of traffic when a failure occurs. It also enables the monitoring, control, and management of power balancing among the WDM channels. All this can be carried out remotely via software or management configuration, resulting in significant operational cost reduction.



Schematic of a ROADM-based WDM network

2.2 ROADM Architectures

A ROADM is a network element that allows for dynamically adding or dropping of wavelengths at a network node. ROADM architectures are also able to switch DWDM wavelengths between the different express fibres. In the past. DWDM wavelengths were transmitted on a fixed 50 or 100 GHz bandwidth ITU grid. Hexgrid ROADMs have the additional advantage of being able to add and drop wave-lengths with both fixed and variable channel optical bandwidths.



Express and add/ drop functions of a ROADM

Some of the widely used components used today in both fixed and flex-grid ROADMs are:

- Wavelength Selective Switches (WSS)
- I x N and M x N All-Optical Switches (OXC)
- N x M Multicast Switches
- Optical Amplifiers (OA)
- Fixed and Tunable Filters
- Wave Blockers (WB)
- AWG Multiplexers
- Optical Splitters

Some of these components are intrinsically compatible with both fixed and flex- grid ROADMs. while others need to be adapted to work in flex-grid systems. Components, such as all-optical switches, splitters, circulators and optical amplifi-ers, are inherently flex-grid compatible since they are typically broadband devices that do not filter individual wavelengths. WSS devices do filter individual wavelengths but both fixed-grid and Ilex-grid versions are available.

MxN multicast switches combine multi-degree switching and filtering functions. They are used in the add/drop path to separate individual wavelengths from DWDM traffic on M fibres (M fibre degrees) and the individual wavelengths routed to N transponders. AWG filters are very popular mux/demux devices used to

separate out the individual wavelengths on DWDM fibres. AWGs are inherently fixed-grid devices that are not eompatible with flex-grid systems. While flex-grid all-optical wavelength multiplexers could be built, architects tend to prefer the flex- grid WSS that combines both filtering and switching in a single compact package.

Whilst WSS-based ROADM architectures have largely solved the problem of how to interchange wavelengths between different ROADM express fibres traversing a node, they have not resolved the issues with increasing add/drop flexibility. This flexibility has been addressed by Colourless Directionless Contentionless (C/D/C) ROADM designs:

- Colourless architectures allow any wavelength on an express fibre to be connected to any add/drop transponder associated with that fibre. In a colourless architecture the add/drop wavelengths on a single fibre share a group of transponders associated with that fibre.
- Colourless and Directionless ROADM architectures extend this concept to sharing a single group of transponders among all wavelengths from all express fibre directions.
- The word “Contentionless" was added to the definition because many proposed C/D architectures have some colour blocking and a way was needed to distinguish truly nonblocking from blocking architectures.

III.PROPOSED SYSTEM DESIGN AND METHODOLOGY

The proposed EON ROADM architecture employs a different set of four transmitter, receiver, wavelength splitter and an oadm switch in both directions to increase the network capacity as shown in Fig. 2. DWDM technology technique is used in proposed system because of following advantages:

1) Less fiber cores to transmit and receive high data.

2) A single core fiber cable could be divided into

multiple channels instead of using fiber core.

3) DWDM systems are capable of longer span lengths.

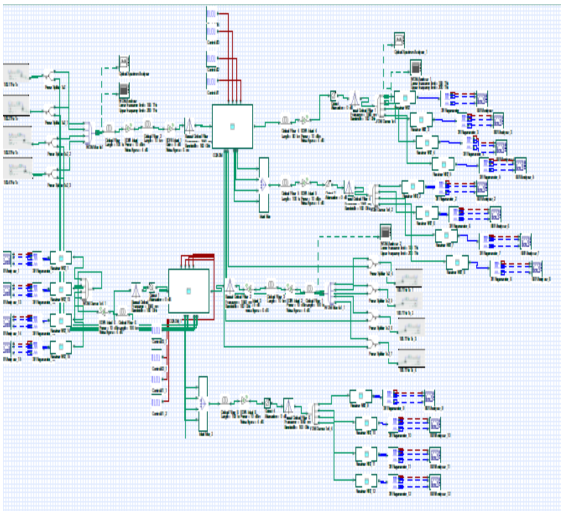


Fig. 2: Proposed Flexible Optical Network.

The optical transmitter is used to convert the electrical signal into optical form, and launch the ensuing optical signal into the optical fiber. The transmitter consists of the following components: an optical source, electrical pulse generator and an optical modulator. The key element of an optical receiver which converts light into electricity using the photoelectric effect is a photodetector,

An OADM consists of three stages: an optical de-multiplexer, an optical multiplexer and between them a way of reconfiguring the paths between the multiplexer, de-multiplexer and a pair of ports for adding and dropping signals. The de-multiplexer splits wavelengths in an input fiber onto ports. The reconfiguration can be accomplished by optical switches which govern the wavelengths to the multiplexer/drop ports. Then, the wavelength channels are multiplexed by the multiplexer that are to continue on from de-multiplexer ports with those from the add ports, onto a single output fiber.

IV .RESULTS AND DISCUSSION

OptiSystem version 7 software is used for simulating the proposed system design.

4.1 Q-FACTOR

The simulated Q-factor of the proposed system design can be seen in Fig. 3. Higher Q-factor means less loss and from the above figure, Q-factor is obtained approximately to 7.8 which is pretty high.

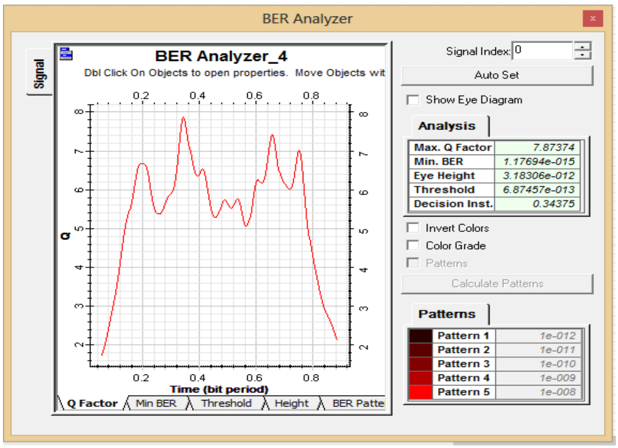


Fig. 3: Q-factor.

4.2 BIT ERROR RATE

Fig. 4 shows the BER (bit error rate) of the proposed network. It shows an error of approximately 1.2×10^{-15} which is satisfactory for optical communication compared to other networks.

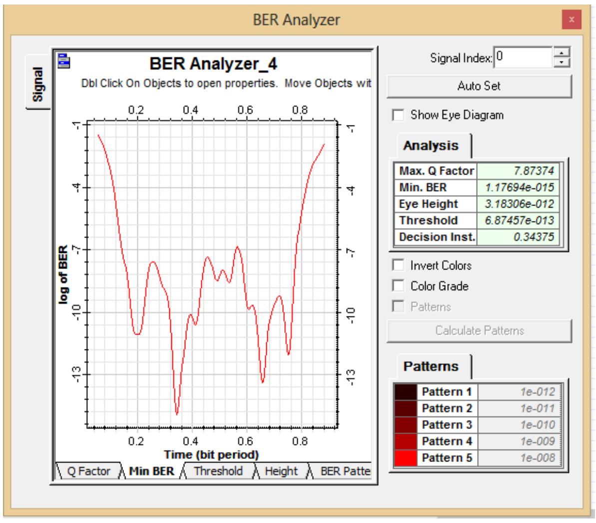


Fig. 4: BER Simulation Result.

4.3 BER PATTERN AND EYE HEIGHT

Fig. 5 displays the simulated BER pattern also known as "eye diagram" of the proposed design and Fig. 6 shows the eye height of the proposed network respectively. The eye height is the extra or additive noise in the signal and it is realized to be 3.18×10^{-12} which is sufficient for optical communication.

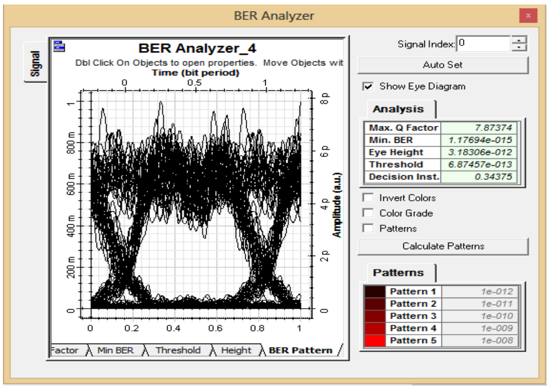


Fig. 5: BER Pattern.

4.4 SPECTRAL EFFICIENCY

The simulated power against the frequency is shown in Fig. 7. It shows that the power obtained at 193.2THz is -22.5dBm which is sufficient for optical communication.

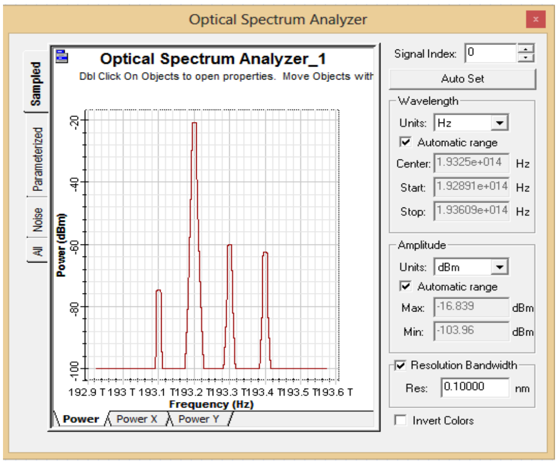


Fig. 7: Spectral Analyser.

V. CONCLUSION

This paper represents the design of a ROADM Optical Network using OptiSystem software. The Q-factor, BER (Bit error rate), Eye height, BER pattern and spectral efficiency have been calculated and from the simulation we have achieved the BER of this network is approx. $1.2x10^{-15}$, Q-factor is approx. 7.8, eye height is $3.8x10^{-12}$, the power obtained is -22.5dBm and from the following results it can be seen that the proposed design has a suitable affinityfootnote on the first page.

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