ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.11

Implementation of Transmitter & Receiver for Flexible Optical Networks

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Abstract:
Elastic optical networking has emerged as a promising technology to accommodate high-capacity and dynamic bandwidth demands of next-generation wireless networks. However, the nonlinear impairments affect the network performance in terms of system reach distance, spectral efficiency and network utilization. The nonlinear impairments are currently assigned a fixed reference margin based on a worst case estimation which results in sub-optimal spectrum utilization. Therefore, in this paper, we propose a novel load-aware nonlinearity estimation model which is more accurate compared to the fixed reference margin and is shown to reduce request blocking ratio. We further present a routing, modulation and spectrum assignment (RMSA) solution using the proposed nonlinearity model. 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

Keywords: DWDM, EON, PON, Laser Diode, *Optical add/drop multiplexer*

I. INTRODUCTION

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. Hex grid ROADMs have the additional advantage of being able to add and drop wave-lengths with both fixed and variable channel optical bandwidths.

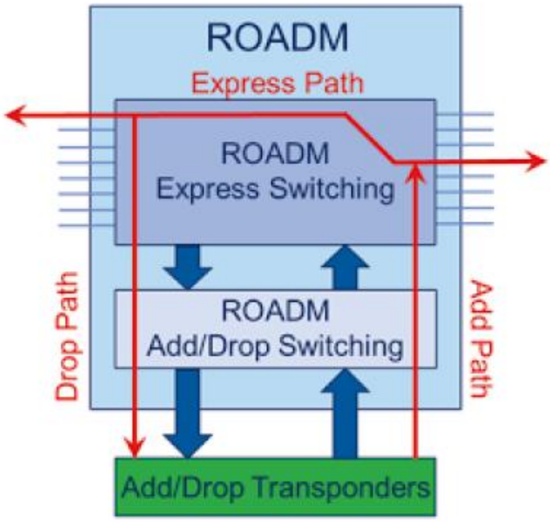


Figure.1. Express and add/ drop functions of a ROADM

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 amplifiers, 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 func-tions. 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 “Contention less" was added to the definition because many proposed C/D architectures have some color blocking and a way was needed to distinguish truly no blocking from blocking architectures

II. LITERATURE REVIEW

The authors propose four regenerator placement algorithms based on network topology and traffic prediction. Then, given sparse regenerator placement, they address the problem of wavelength routing by incorporating two regenerator allocation strategies with heuristic wavelength routing algorithms. They consider wavelength routing under the DLE scheme and try to minimize blocking probability. They use the bit error rate (BER) to evaluate the signal quality and as a criterion for generating the regeneration demands. Therefore, a number LNmax, which denotes that a transparent optical signal can traverse at most LNmax links without having its BER exceed the BER threshold, is determined for each 12 topology. LNmax is used in heuristic wavelength routing algorithms in order to assign route and wavelength to each demand without violating physical impairment constraints. The authors also show that compared to their opaque counterparts, translucent networks with a slightly compromised performance in terms of blocking probability save up to 76% and 88% network cost for regenerators under light and heavy traffic loads, respectively. This indicates once again why translucent networks are one of the most promising solutions to reduce CAPEX and OPEX of the optical networks. Ezzahdi et al. present a heuristic for routing and wavelength assignment with regenerator placement taking into account physical layer impairments. The suggested algorithm, LERP, minimizes the light path demands rejection ratio and the number of required regenerators under the SLE scheme. The authors develop in their previous work a BER-Predictor tool which is used to predict, for any light path, the BER value at intermediates nodes. By using this tool, they evaluate the signal quality as a criterion for generating the regeneration site. BER-Predictor takes into account the simultaneous effect of the four impairments, namely, CD, PMD, ASE and non-linear phase shift. In addition to that, RWA and RPP are not easily solved concurrently. Therefore, LERP decomposes problem into two parts, RWA and RPP. Firstly, RWA is performed.

Then, regenerator sites are determined. As we have done in this thesis, this work tries to minimize the number of regenerator sites rather than amount of regenerator modules at nodes. After, regenerator sites are minimized, they assume that sufficient regenerator modules are located at each regenerator site. Klinkowski et al. investigate the offline problem of RWA and RP in translucent networks, by minimizing the light path blocking and number of regenerator module. The authors present two variants of the problem, which correspond to two different types of QoT estimators, called linear and nonlinear. In the linear QoT, the effects of the nonlinear impairments are overestimated and accumulated to the rest of the impairments in the QoT calculation. As a result, the QoT estimation of a light path solely depends on its route. In a nonlinear QoT, nonlinear impairments like crosstalk or cross-phase modulation, which account for the interferences from neighboring light paths in the network, 13 are explicitly computed. Then, the QoT estimated for a light path depends on the routes of other light paths in the network. For the linear case, the authors suggest an ILP model and two heuristics, LS and Three-Step Heuristic. For the nonlinear case, the authors propose a heuristic iterative regenerator placement algorithm (IRP). Both Three-Step Heuristic and IRP are designed to guarantee no light path blocking due to signal degradation and wavelength conversion requirements. The authors compare LS and Three-Step Heuristic with LERP, algorithm in [15], in terms of computation time, blocking probability and average number of utilized regenerator modules. These algorithms perform much better than LERP in every aspect. As a contribution of this paper, the relation between the number of regenerator modules and network size is also examined. Same topologies are tested after lengths of their links are multiplied by constant numbers. So the authors obtain the conclusion that as network sizes become larger, the number of required regenerator modules also increases inevitably

III. COMPONENT DESCRIPTION

3.1 WSS stands for Wavelength Selective Switch. WSS has become the central heart of modern DWDM reconfigurable Agile Optical Network (AOC). WSS can dynamically route, block and attenuate all DWDM wavelengths within a network node. The following figure shows WSS’s functionality.

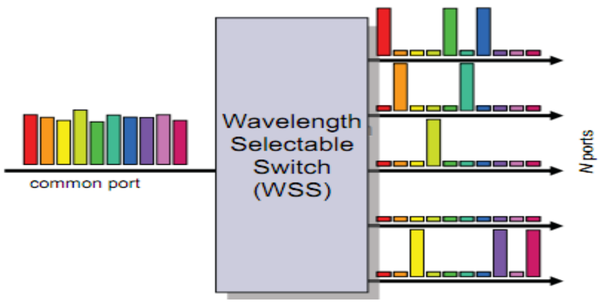


Figure. 2. WSS Switch

The above figure shows that a WSS consists of a single common optical port and N opposing multi-wavelength ports where each DWDM wavelength input from the common port can be switched (routed) to any one of the N multi-wavelength ports, independent of how all other wavelength channels are routed. This wavelength switching (routing) process can be dynamically changed through a electronic communication control interface on the WSS. So in essence, WSS switches DWDM channels or wavelengths. There is also variable attenuation mechanism in WSS for each wavelength. So each wavelength can be independently attenuated for channel power control and equalization.

3.2 Optical OXC

All optical OXC The whole idea behind fiber optics, in general, is to make the light stay in the fiber. How can light waves be induced to change fiber without changing the light into electricity? This is what the all-optical cross-connect does. All optical, or photonic OXCs, as the name indicates, don’t need expensive Optical – Electrical – Optical (OEO) conversion, but the signal stays in photonic domain through the switching. This is the first requirement for transparent operation. Photonic OXCs can be divided to free space optical switching devices, optical solid-state devices and electromechanical mirror-based devices. Among the most promising switches with many input ports to many output ports is the generalized Mach-Zehnder WGR. In this device, a given wavelength at any input port appears at a specified output port this type of free space optical switching is also known as wavelength routing.

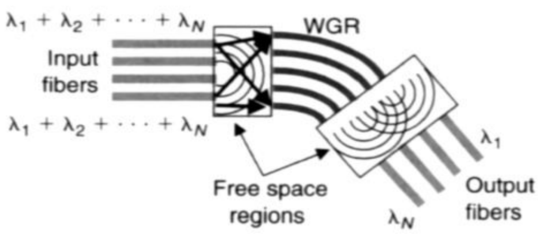


Figure. 3. Mach-Zehnder WGR

3.3 Optical amplifier

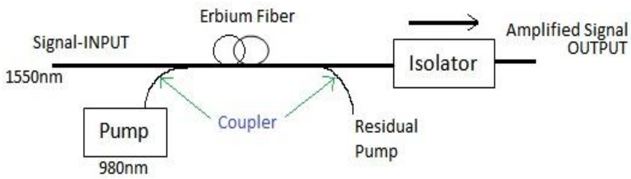
It is the device which increases the strength of the optical signal. Typical fiber cable has loss of about 0.2dB per km for 1.5 micro-meter light signal. Hence if the signal occurs loss of about 20dB if it travels a distance of 100km. The signal needs to be amplified in order to compensate for the losses at the regular intervals and to maintain SNR (or BER). Usually optical amplification is carried out by converting signal from optical to electrical and later signal is converted back to optical form. Erbium Doped Fiber Amplifier (EDFA) has made it possible to amplify the signal in the optical form without being converted to the electrical form avoiding costly high speed electronic devices needed for such conversions at frequency of more than 10GHz. An optical amplifier is usually characterized by parameters such as gain, gain efficiency, gain bandwidth, gain saturation etc. The same is described below.

- Gain = ratio of output power by input power. It is measured in Decibel (dB).
- Gain taken as function of the input power is referred as gain efficiency.
- Bandwidth refers to range of wavelengths over which amplifier functions effectively and provides maximum gain.
- Gain saturation refers to the max. Output optical amplifier can deliver. Above this limit amplification is not possible.

1) Types of Optical Amplifier

The main types of amplifiers are EDFA (Earth Doped Fiber Amplifier), Semiconductor Optical Amplifiers (SOA) and Raman Amplifier. Rare Earth Doped Fiber Amplifiers are of two types EDFA (Erbium Doped) and PDFA (Praseodymium Doped). EDFA works in 1500-1600nm band. PDFA works in 1300nm band. SOA works in 400-2000nm band.

2) EDFA (Erbium Doped Fiber Amplifier)



When the stimulated emission gets dominated over spontaneous emission, efficient amplification can be obtained. As we know that light gets absorbed when it propagates through the medium. If the population at higher state of energy is more than that at lower state, light will be amplified when it travels from one end of fiber amplifier to the other end. Usually 980 nm pump is preferred due to its low noise amplification characteristics over 1480nm pump. But at 1480 nm wavelength silica fiber incur low loss and hence pump can also propagate along with the input signal to be amplified. Pump can also be placed remotely.

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