Stimulated Raman Scattering in Routing and Wavelength Assignment

W. S. Sim
Faculty of Computing and Informatics. Multimedia University
swssbaby@yahoo.com

S. C. Tan
Faculty of Computing and Informatics. Multimedia University
sctan1@mmu.edu.my

Zulfadzli Yusoff
Faculty of Engineering. Multimedia University
zulfadzli.yusoff@mmu.edu.my

ABSTRACT
In this paper, the implication of Stimulated Raman Scattering (SRS) in Routing and Wavelength Assignment (RWA) is investigated by analyzing the SRS parameters that related to RWA and its capabilities of influence the network performance. It then followed by identifying the necessary SRS parameters that must be followed in RWA to minimize the effect of SRS.

Key Words: Physical Impairment, Stimulated Raman Scattering, Routing and Wavelength Assignment, optical network.

INTRODUCTION
One of the strategic steps which will be undertaken during the Tenth plan period is putting in place world-class infrastructure for growth by significantly increasing broadband penetration, continuing to upgrade physical infrastructure to enhance access and connectivity and ensuring effective sourcing and delivery of energy.
The ever increasing growth in Internet Traffic is driving the demands for higher transmission capacity and higher processing speed. The processing capacity of electronic routers is rapidly approaching the electronic bottleneck few years ago. One possible solution to this limitation is to gradually move from electronic packet processing technology towards optical technology. Transparent optical networks based on wavelength division multiplexing (WDM) can exploit the huge capacity of optical fibers by dividing it among different wavelengths. As such they have been established as the enabling technology for today's high speed backbone networks, meeting consumer's ever-increasing bandwidth demands. One of the most important challenges in transparent optical network planning and provisioning is successfully solving the Routing and Wavelength Assignment (RWA) problem. In most of the RWA schemes, the optical layer is considered as a perfect transmission medium with no physical impairment. However, the actual performance of the system may not be acceptable for certain lightpaths. For this reason, the incorporation of physical layer impairments in transparent optical network planning

and operations has received attention from research communities. The physical layer impairments are either considered as constraints for the RWA decisions or the RWA decisions are made considering these impairments [1]. Thus, without physical-impairment awareness, a network layer RWA algorithm might provide a lightpath which cannot meet the signal quality requirement. Consequently, one challenge in designing all-optical networks is proposing a physical-impairment-aware RWA scheme such that physical-layer impairments are addressed and quality of service (QoS) guaranteed.
Generally, impairments can be classified into two categories, linear and nonlinear. Linear effects are independent of signal power and affect wavelengths individually. Nonlinearity is significantly more complex since they do not only generate dispersion on each channel, but also crosstalk between channels. These fiber nonlinearities are Four-Wave Mixing (FWM), Self-Phase Modulation (SPM), cross-phase modulation (XPM), Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS). There has been an intensive on-going research on physical impairments in RWA algorithm in Wavelength Division Multiplexing (WDM) optical networks [2][3][4]. Some physical impairments that has been studied include Polarization-mode Dispersion (PMD) [5], ASE[6], FWM[7] and SRS[8] and etc. There are various physical-impairment-aware RWA approaches proposed in the literature, but SRS-aware RWA approach has not been proposed. In [8-9], the work considers the crosstalk caused by SRS and the linear crosstalk introduced by the optical switches and demultiplexers while establishing lightpaths for arriving call requests using nonphysical aware RWA approach. In [9][10], the effect of SRS on IP traffic in WDM networks has been considered by talking into consideration the number of wavelengths, traffic loads and network size. In [11], the impact of SRS in RWA specifically to non-SRS-aware RWA scheme has been studied but a SRS-aware RWA scheme has yet to be proposed. The aim of this article is to investigate the implication of Stimulated Raman Scattering (SRS) in Routing and Wavelength Assignment (RWA) by analysing the SRS parameters that related to RWA in the network and its capabilities of influence the network performance. It then followed by identifying the necessary SRS parameters and sufficient rules that must be followed in RWA to minimize the effect of SRS.
This paper is organized as follows: Section 2 presents the implication of SRS in RWA and the discussion of the identified SRS parameters in RWA design. Finally, Section 3 concludes the paper.

STIMULATED RAMAN SCATTERING IMPLICATION IN RWA

In this section, SRS power depletion is calculated by analytical expression [12]. If in a WDM system the channels are N equally spaced in frequency separation Δf, the SRS induces power depletion in shortwave length channels and power amplification in long wavelength channels. The degradation caused by SRS effect will be most severe for the shortest wavelength channel. Thus we calculate signal degradation in the shortest wavelength channels as an indication of the whole system performance. The fractional power depletion of the shortest wavelength channel is given by [17]:

(1)

where λ_i and P_i are the wavelength and the injected peak power of the i- th channel, respectively.λ_s is the shortest wavelength of N channels. Le is the effective length of the fiber, $L_e = (1 - \exp(-\alpha L))/\alpha$, A_{eff} is the effective core area of the fiber with L the fiber length and α is the fiber loss coefficient. g_p is the peak Raman gain coefficient. All channels are set having the same input power $P_i = P_{in}$ and falling within the Raman gain profile. The masks and spaces are assumed occurring with equal probability in each channel and independently among N channels. m_i in Eq. (1) is the modulation factor in the i th channel where

= (2)

The factional nonlinear power attenuation of the shortest wavelength channel may be expressed as:

$P_{SRS} = \exp[-RP_{in}]$

(3)

where R is a random variable describing the statistics of SRS effect. In regenerated systems with optical amplifier, the ASE generated from different amplifier experiences different SRS effect since the ASE is added periodically through the transmission route. Thus, the optical signal to noise ratio
(OSNR) of the shortest wavelength channel is given by [13]:

[ ]

(4)

where K can be expressed as following:

(5)

where n_{sp} is the amplifier excess noise factor, hv the photon energy, B_0 the optical resolution bandwidth and L_a the amplifier spacing. The route along the path considers feasible must satisfies the requirement that imposed by SRS. The fiber parameters used are the same in all the experiments as follows: λ_s = 1550 nm, $g_p = 7 \times 10^{-14}$ m/W-1, $A_{eff} = 50 \times 10^{-11}$ m, L_a = 80 km, α = 0.22 dB/km,n_{sp}=2.3, B_0 = 12 Gbit/s, □f = 50 GHz, $c=3 \times 10^8$ m/s, $h=6.626 \times 10^{-34}$ joule/s.

Figure 1 shows the OSNR over input power under different setting of fiber length L for the channel capacity of 32. From the result in the diagram, OSNR increases when input power increase for all setting of fiber length L. However, OSNR is higher when L=40 compared to L=120.

Figure 1 Channel Capacity of 32

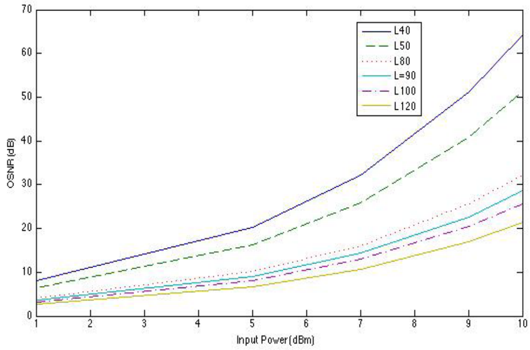
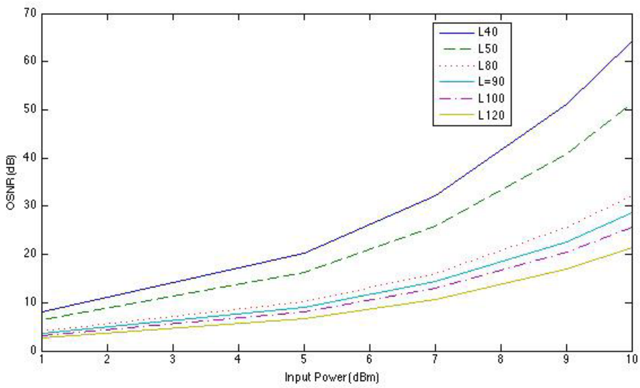


Figure 2 show the results of OSNR over input power under different setting of L for N=64. From the result in the diagram, OSNR increases when input power increase for all setting of fiber length L. However, OSNR is higher when L=40 compared to L=120.

Figure 2 Channel Capacity of 64



From the results shown in figure 1 and figure 2, when the fiber length is increased or channel capacity is increased, the OSNR is reduced. It is because more wavelength interference with shortest wavelength under higher channel. The factors such as the fiber length and the number of wavelength interference with shortest wavelength have high impact of SRS. Thus, these two factors must be taken into consideration in RWA design to minimize the effect of SRS.

CONCLUSION

The implication of Stimulated Raman Scattering (SRS) in Routing and Wavelength Assignment (RWA) is investigated and its capabilities of influence the network performance. Factors such as fiber length in connection and wavelength interference with shortest wavelength must be considered in RWA design to minimize the effect of SRS.

REFERENCES

A.R. Chraplyvy, Optical power limits in multi-channels wavelength-division multiplexed systems due to Stimulated Raman Scattering, Electron. Lett. 20 ,58–59(1984).

Azodolmolky, S., Klinkowski, M., Marin, E., Careglio, D., Pareta, J.S., Tomkos, I.,“A Survey on physical layer impairments aware routing and wavelength assignment algorithms in optical networks”, Computer Networks, vol.53, no. 7, pp. 926-944 (2009).

B. Ramamurthy, D. Datta, H. Feng, J. P. Heritage, and B. Mukherjee, “Impact of transmission impairments on the teletraffic performance of wavelength-routed optical networks, ” Journal of Lightwave Technology, vol. 17, pp. 1713-1723(1999).

Cerutti, A. Fumagalli, and M. J. Potasek, “Effect of chromatic dispersion and self-phase modulation in multihop multirate WDM rings,” IEEE Photon. Technol. Lett., vol. 14, no. 3, pp. 411-413(2002).

H. D. Kim, C. Lee, “Capacities of WDM transmission systems and networks limited by Stimulated Raman scattering”, IEEE Photon Technology letters, vol.13, pp.379-381 (2001).

I.E. Fonseca, R.C. Almeida, M.R.N. Ribeiro, H.Waldman,” Algorithms for FWM-aware routing and wavelength assignment,” Proceedings of the SBMO/IEEE MTT-S international microwave and Optoelectronics Conference, vol. 2, pp.707-712, 20-23(2003).

Jun He, Maïté Brandt-Pearce, and Suresh Subramaniam, “QoS-Aware Wavelength Assignment With BER and Latency Constraints for All-Optical Networks,” Journal of Lightwave Technology, vol. 27, no. 5,pp.462-474 (2009).

M. Ali, L. Tancevski, “Impact of Polarization-Mode Dispersion on the Design of Wavelength-Routed Networks,” Photonics Technology Letters, vol. 14, pp.720-722 (2002).

N. R. Das, S. Sarkar, “Probability of power depletion in SRS crosstalk and optimum detection threshold for minimum BER in a WDM Receiver ”pp.424-pp.430,vol. 47, no. 4,IEEE Journal of Quantum Electronics (2011).

S. C. Tan, F. M. Abbou, “The Effects of Stimulated Raman Scattering (SRS) in Routing and Wavelength Assignment in WDM Mesh and Ring topologies. International Journal for Light and Electron Optics, pp.1934-pp.1937, vol. 123(2012).

Tomkos, D. Vogiatzis. C. Mas, and I. Zacharopoulos, A. Tzanakako, E. Varvarigos, “Performance engineering of metropolitan area optical networks through impairment constraint routing,” IEEE Communications Magazine, vol. 42, no. 8, pp. 40-47 (2004).

X. Zhang, B. F. Jorgensen, F. Ebskamp, R. J. Pedersen,” Input power limit and maximum capacity in long-haul WDM lightwave systems due to stimulated Raman scattering”, Opt. Commun., vol.107, pp.358-360(1994).