Advances in Natural and Applied Sciences, 5(6): 517-523, 2011
ISSN 1995-0772

This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLE

Analytical Analysis on Comparison of OXADM and OXC Device in Optical Network

Mohammad Syuhaimi Ab-Rahman

Spectrum Technology Research Division (SPECTECH), Computer and Network Security Research Group, Department of Electrical, Electronic & Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Mohammad Syuhaimi Ab-Rahman; Analytical Analysis on Comparison of OXADM and OXC Device in Optical Network

ABSTRACT

OXADM is a new designed device which is fabricated after considering the drawbacks found in the existing device such as OADM and OXC. OXADM has shown its multifunctional device in survivable optical switch in Ring and mesh optical network and customer access network FTTH-PON. OXADM can also perform flexibly node in network migration. However in term of scalability OXC shows better in OSNR and power penalty. The number of cascaded OXC is two times greater than OXADM. This paper reveals this comparison between OXADM and OXC which covers the application, limitation and scalability performance. The analytical modeling is used to achieve the objectives.

Key words:

OXADM versus OXC:

OXADMs are elements which provide the capabilities of add and drop function and cross connecting traffic in the network, similar to OADM and OXC (Ab-Rahman, M.S., *et al*., 2006; Ab-Rahman, M.S., 2004; Ab-Rahman, M.S., S. Shaari, 2006; Ab-Rahman, M.S., 2011a; Ab-Rahman, M.S., 2011b). OXADM consists of three main subsystem; a wavelength selective demultiplexer, a switching subsystem and a wavelength multiplexer. Each OXADM is expected to handle at least two distinct wavelength channels each with a coarse granularity of 2.5 Gbps of higher (signals with finer granularities are handled by logical switch node such as SDH/SONET digital cross connects or ATM switches. There are eight ports for add and drop functions, which are controlled by four lines of MEMs switch. The other four lines of MEMs switches are used to control the wavelength routing function between two different paths (see Fig. 1).

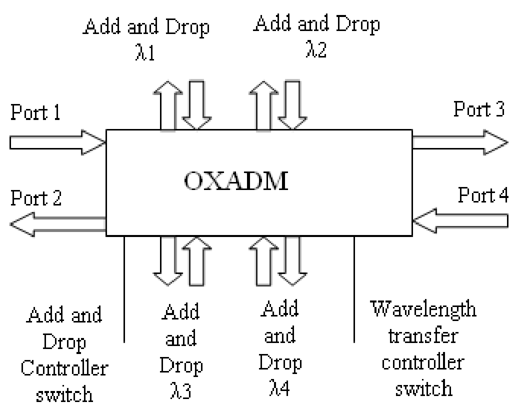


Fig. 1: The block diagram of Optical Cross Add and Drop Multiplexing (OXADM).

Corresponding Author: Mohammad Syuhaimi Ab-Rahman, Spectrum Technology Research Division (SPECTECH), Computer and Network Security Research Group, Department of Electrical, Electronic & Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.
E-mail: syuhaimi@vlsi.eng.ukm.my

The functions of OXADM include node termination, drop and add, routing, multiplexing and also providing mechanism of restoration for point-to-point, ring and mesh metropolitan and also customer access network in FTTH. With the setting of the MEMs optical switch configuration, the device can be programmed to function as another optical device such as multiplexer, demultiplexer, coupler, wavelength selective coupler, OADM, WRB an etc for the single application. The designed 4-channel OXADM device is expected to have maximum operational loss of 0.06 dB for each channel when device components are in ideal condition (Ab-Rahman, M.S., H. Husin, 2006). The maximum insertion loss when considering the component loss at every channel is less than 6 dB. In the transmission using SMF-28 fiber, with the transmitter power of 0 dBm and sensitivity –22.8 dBm at a point-to-point configuration with safety margin, the required transmission is 71 km with OXADM (Ab-Rahman, M.S., H. Husin, 2006). The asymmetrical OXADM architecture consists of 3 parts; selective port, add/drop operation, and path routing. Selective port permits only the interest wavelength going through and acts as filter. With the switch configuration, add and drop function can be activated in second part of OXADM architecture. The signals are then re-routing to any port of output. The signals can also be accumulated on one path and exit at any output port (Ab-Rahman, M.S., 2011a).

OXC:

An optical cross-connect (OXC) is a device used by telecommunications carriers to switch high-speed optical signals in a fiber optic network, such as an optical mesh network (Keiser, G., 2000; Palais, J.C., 2005; Tsushima, H., 1998). Due to OXC is an architecture that can be developed, particularly in the conversion from ring to mesh topology without involving the exchange of new optical nodes, so OXC also have a security system that can be used in both cases. Security system is on the 'accumulation of signals on one path. This feature allows all signals entering the input terminal multiplexed together on one optical path in the event of failure/damage to one output line. As OXC operates in both lines input and this feature is also supplied with then it becomes a weakness to the existing OXC devices. This is because if both the transmission line is used, the damage occurs on one line in use result in a broken transmission path in which the input data from the database could not be submitted where any part of its output. Figure 2 below shows the damage on the second line phenomenon which causes the data on the second input is blocked and cannot be sent. In the event of damage to the two lines or even damage to the optical nodes near the network ring causes the data cannot be delivered directly.

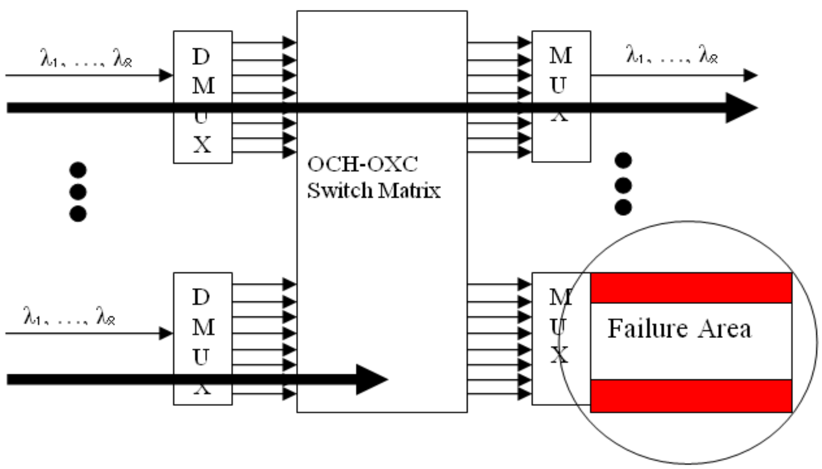


Fig. 2: Failure at one of transmission line cause the disconnection of the line and affect the traffic send to the users. This case happens to the network configuration which has two fiber connection (e.g ring and mesh).

The necessary security features is a ring of protection schemes used in OMS-spring. This ring of protection involving signals at the first input terminal is turned on 'U' and exit at the second input terminal allows the segmentation, the damage done. However, this feature is not provided in the security architecture of OXC. In a ring network architecture using optical OXC node, in the event of damage cases involving two or all of the line or even damage to the nodes, the nodes are near the damage will be used as a node and signals the termination of all signals to be dropped or navigate to a new path which would involve large areas segmentation will also involve nodes in good condition. This condition has caused a defect in the optical communication system called resistant and able to recover against any possible damage. Figure 3 shows the process of segmentation or quarantine the area of damage in a ring network using OXC node.

Adv. in Nat. Appl. Sci., 5(6): 517-523, 2011

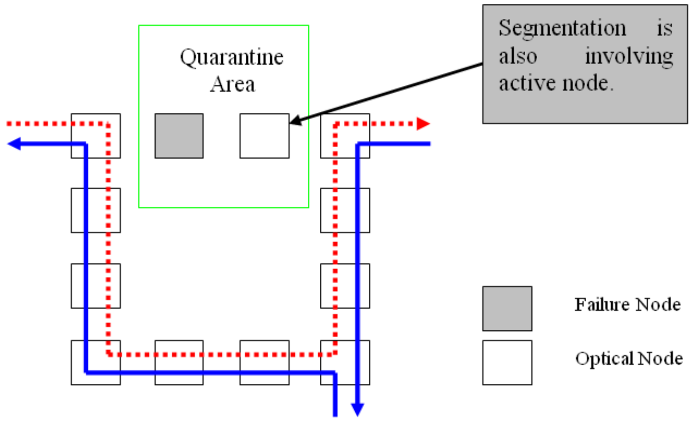


Fig. 3: Segmentation process has to be activated in ring network prior to the network repairing and installation.

Device Comparison:

The OXADM device will be compared with two existing switching devices; directional coupler (DC) switch and optical cross connect (OXC).

The non-selective directional coupler switch has two states and one control element. It has fixed number of input and output port which is two. The wide bandwidth signal comes from the input port will be switched to either one of the output ports. It works bi-directional with symmetrical function (Keiser, G., 2000; Palais, J.C., 2005).

Figure 4 shows the mechanism of switching for directional coupler switch in normal (a) and active condition (b) & (c). The application of DC switch is to control the signal path in WDM network and optical storage; and can also perform the function of OADM in optical distributed network

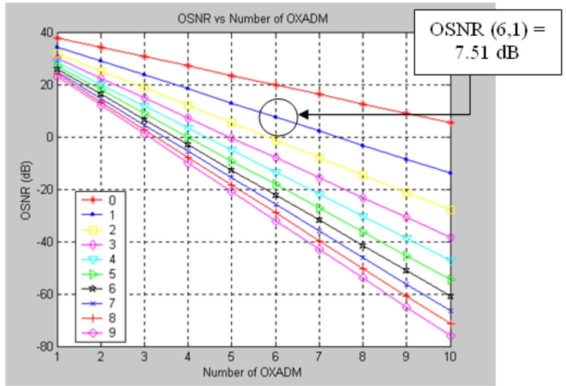
OXC is the directional coupler witch but with many ports. The functional of OXC is cross-connecting between output and input port (Figure 5) (Ab-Rahman, M.S., S. Shaari, 2004). Same with OXADM, the OXC is selective device but it does not have accumulation function. In contrast with OXADM, OXC works bi-directional with symmetrical function. The application of OXC is as a switching device in mesh network configuration and also in optical storage (Stevens, 2005). Table 1 summarizes the differences of OXADM with DC and OXC.

Table 1: Comparison between OXADM, DC and OXC.

Features	OXADM	DC	OXC
Selective	Yes	No	Yes
Accumulation	Yes	No	No
Scalability	Yes	No	Yes
Symmetrical function	No	Yes	Yes

Distance between Two Nodes (SPAN):

Figure 4 shows the relationship of OSNR at a distance of data transmission across the 10 nodes with the distance between two different nodes. Inclusion of optical amplifiers is to compensate dissipation that occurs and the distance between the two amplifiers is 70 km. Entry of a new optical amplifier is in-line amplifier (in-line amplifier). Observed in the graph is the entry of the amplifier unit (increasing the distance between two nodes two times) causes OSNR value decreases. OSNR degradation rate also decreased by polynomials and the relationship shown in Figure 5. The increase in the rate of this decline to the inclusion of optical amplifiers shows the distance between two nodes play an important role with respect to perimeter of ring network. However, an increase in distance between two nodes will increase the perimeters of a ring network. Observations made in Figure 4 for OSNR values at 700 km transmission distance is the OSNR for 700 km (2 nodes + 9 amplifier) is 8.12 dB and 1.77 dB for 700 km (11 nodes). The difference of 10.31 dB has shown OSNR for the same transmission distance for different number of nodes is different and larger value for the network using a small number of nodes although the rate of decline in OSNR for 700 km (2 nodes + 9 amplifier) and 700 km (11 nodes) differ, respectively -11.02 dB / unit node and -3.61 dB / unit node



y = -3.61x + 41.52 (A=0)
y = -5.37x + 39.76 (A=1)
y = -6.62x + 38.51 (A=2)
y = -7.59x + 37.54 (A=3)
y = -8.38x + 36.75 (A=4)
y = -9.05x + 36.08 (A=5)
y = -9.63x + 35.50 (A=6)
y = -10.15x + 35 (A=7)
y = -10.60x + 34.53 (A=8)
y = -11.02x + 34.12 (A=9)

Fig. 4: OSNR measured at each OXADM node by increasing the span (with application of amplifier) in ring optical network.

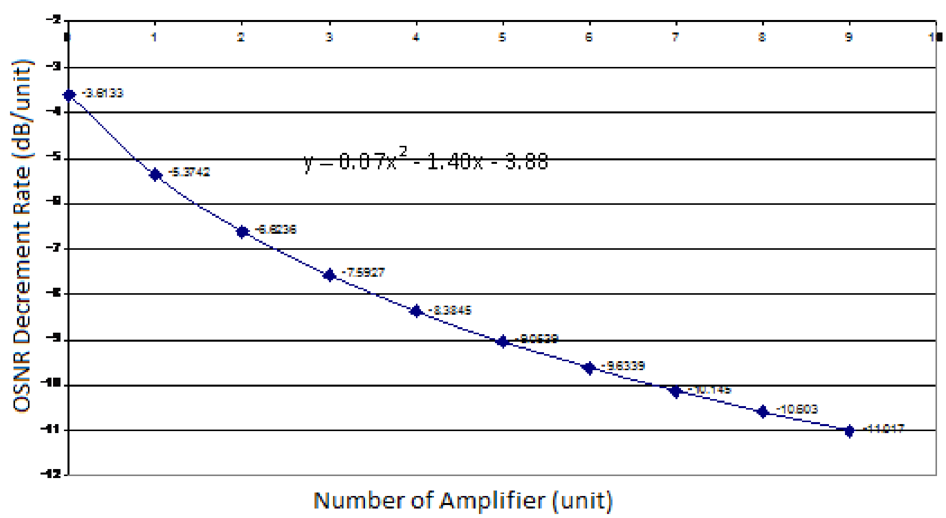


Fig. 5: OSNR decrement rate with the number of amplifier insertion for ring optical network.

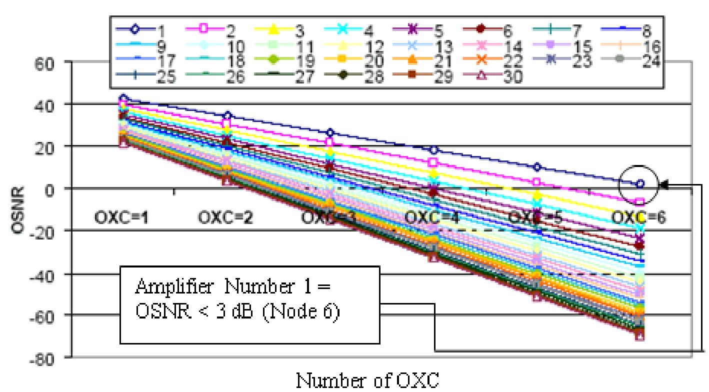


Fig. 6: OSNR measured at each OXC node by increasing the span (with application of amplifier) in ring optical network (Stevens, 2005).

Adv. in Nat. Appl. Sci., 5(6): 517-523, 2011

Figure 6 shows the OSNR performance of a ring network OXC (M = 8, N = 4) for different distances between the nodes (with the inclusion of optical amplifiers every 70 km). The sensitivity of photodetector used in the network is -46 dBm (OC-48). Comparison has been made on OSNR performance in OXADM ring network as depicted Figure 4. When single optical amplifier unit used (the distance between two nodes 140 km) the OSNR at node-6 is less than 3 dB for the OXC ring network (Stevens, 2005). In contrast to the OXADM ring network (M = 2, N = 2), for the same number of amplifiers produce OSNR equal to 7.51 dB at node-6. As the number of carriers and the number of OXC is greater than OXADM, it is relatively OXC ring network has the OSNR value greater than OXADM ring network. This is because the optical switch in OXADM architecture consists of a single form for each channel path, then the elements that contribute to the crosstalk phenomenon is minimized. Thus, at the same time they increase the value of the OSNR. But because of the nature of OXADM capable of collecting all the signals in one path has produced a maximum value of autocovarian, Max (σ2RIN) = ε x (NM-1). This causes the noise resulting from the interferometric noise intensity also larger than other devices. As a result the OSNR in OXADM ring network reduced. As a conclusion, OXADM performance in the ring network is less good than OXC. The maximum value of OXC autocovarian is, Max (σ2RIN) = ε x (N + M-2) (Stevens, 2005; Kirihara, T., 1993).

Power Penalty:

Figure 7 shows the power penalty of the 2x2 OXADM device cascaded on the number of different carriers of 2, 4, 6 and 8 channels at each port. Meanwhile, Figure 8 shows on the cascaded 4x4 OXC devices for the number of carrier 8 and 16 channels for each base. Comparison is done by comparing two points on the graphs. The first point is the power penalty of the node 6 of OXADM for M = 8 while the second point is on the power penalty of the node-6 of OXC for M = 8. We found the OXADM power penalty is greater than OXC device that shows loss generated by crosstalk phenomenon OXADM larger than OXC.

Figure 9 and Figure 10 shows the comparison of power penalty of OXADM and OXC devices to the number of port changes, while the number of designated carriers is remain unchanged. Comparison is made to measure the power penalty at the node-6 for (M = 2 and N = 4) for OXADM and (M = 16 and N = 4) for the OXC. Power penalty for OXADM is 0.59 dB while OXC was less than 1.5 dB. Relatively the power penalty of OXADM will increase with increasing number of carriers and this value would in theory more than 1.5 dB (for M = 8 and N = 2, fines for OXADM power node to-6 is 1.5755 dB (Figure 4.26)), this showing power penalty of OXC is lower than OXADM. The greater power penalty is the major disadvantage of the OXADM device compared with OXC devices. This occurs due to the ability to bring together OXADM signal on a path (multiplex) causes the maximum autocovarian value of OXADM, Max (σ2RIN) = ε x (NM-1) and this value is greater than with other devices such as OXC with maximum autocovarian value, Max (σ2RIN) = ε x (N + M-2). Therefore, the noise resulting from the noise intensity for OXADM interferometrics is greater than the other devices.

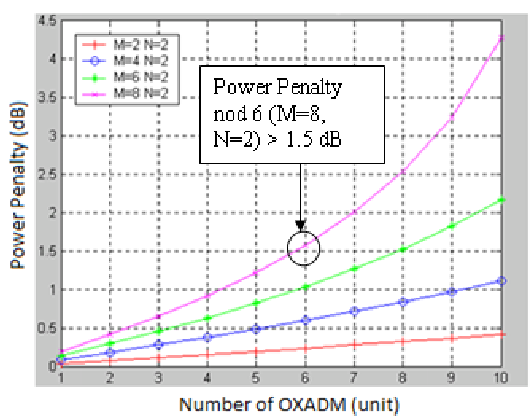


Fig. 7: Powe penalty at different cascaded OXADM number with different number of carrier in ring optical network (number of ports = 2).

Figure 11 shows a linear relationship between OSNR and the distance between two nodes in the point to point OXADM network at 2.5 Gbps as a method of simulation and analytical calculations. Small deviation of 1.4 dB with the same slope (m =- 0.5) shows the two characterization methods give the same accuracy of measurement. The OSNR reduction rate of is 0.25 dB/km (1510 nm, 1530 nm and 1570 nm) and 0.5 dB/km (1550 nm) using DCF fiber. The gain of the amplifier used is 24 dB with noise figure, NF = 4 dB. Sensitivity of photodetector was set at -25 dBm. Optical power ratio of each crosstalk contribution is, ε = 41 dB (7.9432 x 10-5).

Adv. in Nat. Appl. Sci., 5(6): 517-523, 2011

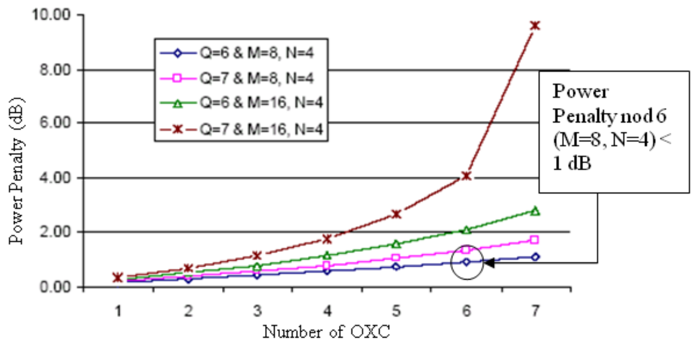


Fig. 8: Powe penalty at different cascaded OXADM number with different number of carrier in ring optical network (number of ports = 4) (Saleh, B.E.A., M.C. Teich, 1991).

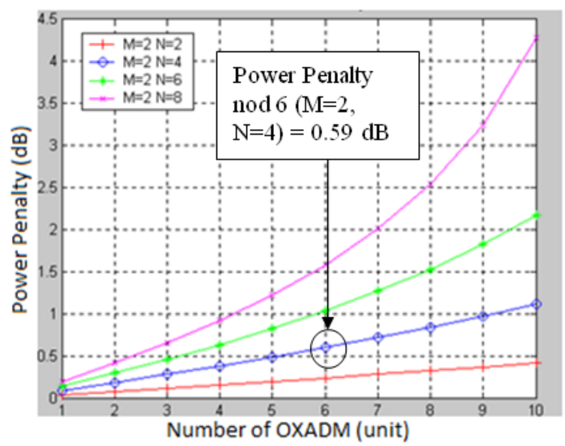


Fig. 9: Powe penalty at different cascaded OXADM number with different number of port in ring optical network (number of carrier = 2).

Analytical modeling of single OXADM devices and OXADM ring network was shown in Ab-Rahman, M.S., H. Husin, (2006). From the results obtained can be concluded that the OXADM device has a weakness in scaling with (MN-1) L <174 (Ab-Rahman, M.S., 2009). However, this weakness can be improved practically by the use of MEMS-based optical switches. The use of micro mirrors to reflect optical signals to a particular route gives the percentage distribution of the ratio up to 99.9%. A small percentage of the leaked signal reduces the loss cause by phenomenon of crosstalk and further reduces the value of power penalty. The small power penalty ensures a high OSNR values, thus allowing the network can be developed OXADM ring and scaled (to the number of carriers and the number of bases).

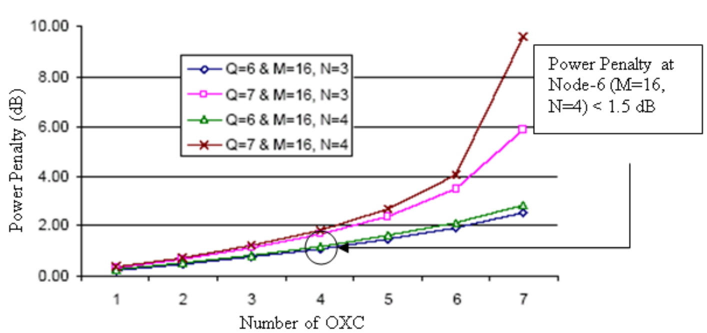
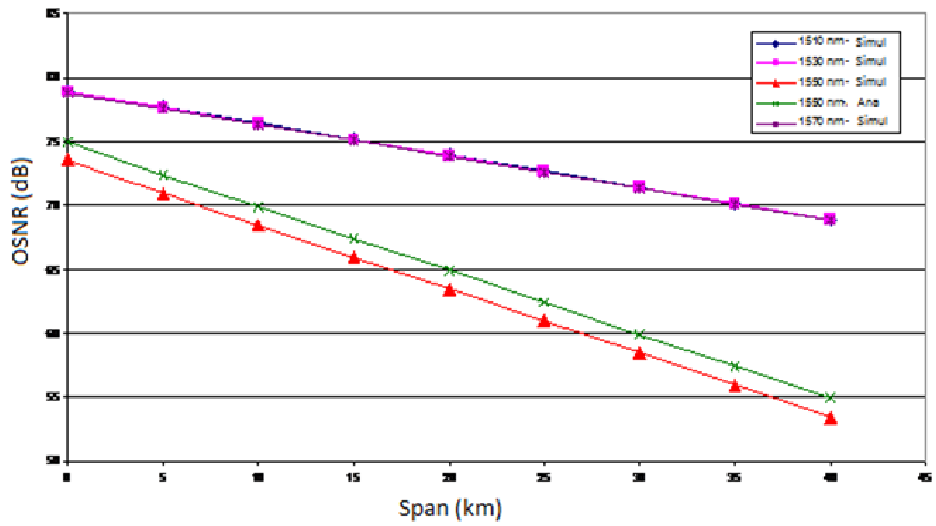


Fig. 10: Powe penalty at different cascaded OXC number with different number of port in ring optical network (number of carrier = 2) (Saleh, B.E.A., M.C. Teich, 1991).



y = -0.2504x + 78.953 (1510 nm - Simulation)
y = -0.2503x + 78.894 (1530 nm - Simulation)
y = -0.5015x + 73.491 (1550 nm - Simulation)
y = -0.5x + 74.924 (1550 nm – Analytical)
y = -0.25x + 78.836 (1570 nm - Simulation)

Fig. 11: OSNR measurement at different span by simulation and analytical study for OXADM point-to-point network at 2.5 GHz.

References

Ab-Rahman, M.S., A.A. Ehsan, S. Shaari, 2006. Mesh upgraded ring in metropolitan network using OXADM. *Proceeding of the 5th International Conference on Optical Communications and Networks & the 2nd International Symposium on Advances and Trends in Fiber.*

Ab-Rahman, M.S., S. Shaari, 2004. Modeling of planar lightwave circuit OADM for CWDM. *Proceeding 2004 Postgraduate Conference*, 116-120.

Ab-Rahman, M.S., S. Shaari, 2006. OXADM restoration scheme: Approach to optical ring network protection. *IEEE International Conference on Networks*, 371-376.

Ab-Rahman, M.S., 2011a. *Determination of Internal Gain in Optical Cross Add and Drop Multiplexer (OXADM) Device*. Journal of Applied Sciences Research. In-press.

Ab-Rahman, M.S., 2011b. *Analysis of Gain Profile in Optical Ring Network*. Journal of Applied Sciences Research. In-press.

Ab-Rahman, M.S., H. Husin, A.A. Ehsan, S. Shaari, 2006. Analytical modeling of optical cross add and drop multiplexing switch", *Proceeding 2006 IEEE International Conference on Semiconductor* Electronics, pub. IEEE Malaysia Section, 290-293.

Ab-Rahman, M.S., M.K.A.M. Nor and M.N. Dollah, 2009. *Analytical Analysis of Limited Power Penalty on Optical Cross Add and Drop Multiplexer (OXADM) – with OXC Comparison*. Journal of Optical Communication, JOC (German), 30(3): 179-185.

Eldada, L., J.V. Nunen, 2000. Architecture and performance requirements of optical metro ring nodes in implementing optical add/drop and protection functions. *Telephotonics Review.*

Keiser, G., 2000. Optical fiber communications: Singapore: McGraw-Hill.

Kirihara, T., M. Ogawa, H. Inoue and K. Ishida, 1993. Lossless and low-crosstalk characteristics in an InP-based 2x2 Optical switch. *IEEE Photonics Technology Letter*, 5(9): 1059-1061.

Mutafungwa, E., 2000. An improved wavelength-selective all fiber cross-connect node. *IEEE Journal of Applied Optics*, 63-69.

Palais, J.C., 2005. *Fiber optic communication*. New Jersey: Prentice Hall.

Saleh, B.E.A., M.C. Teich, 1991. Fundamentals of Photonics (Wiley Series in Pure and Applied Optics.

Stevens, 2005. *Impact of Routing Optimization Strategy on the Transmission Performance of Wavelength Routed Transparent Optical Network*. http://cui.phy.stevens-tech.edu/lab2005/pdf/thesis/YH-thesis.pdf.

Tzanakaki, A., I. Zacharopoulus, I. Tomkos, 2003. Optical add/drop multiplexers and optical cross-connects for wavelength routed network, *ICTON*, 41-46.

Tsushima, H., S. Hanatani, T. Kanetake, J.A. Fee, S.K. Liu, 1998. Optical Cross-Connect System for Survivable Optical Layer Networks. Hitachi Review, 47(2): 85-90.