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Flexible Topology Migration in Optical Cross Add and Drop Multiplexer Metropolitan Ring Network: The Next Proposal

Mohammad Syuhaimi Ab-Rahman, Aswir Premadi, Hamimi Fadziati and Sahbudin Shaari
Research Group (SPECTECH) Spectrum Technology, Department of Electrical,
Electronics and Systems Engineering, Faculty of Engineering and Built Environment,
Institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia,
43600 UKM Bangi, Selangor, Malaysia

Abstract: This study introduces the next generation of the Optical Cross Add and Drop Multiplexer (OXADM) for optical networks device particularly of the metropolitan ring and mesh configurations. OXADM is able to provide survivability through restoration against failures by means of linear, multiplex and ring protection to both configurations. Hybrid restoration technique with OXADM enables the linear, ring and multiplex protection mechanism to be integrated in single optical network which will be activated according to the degree and types of failure. Present simulation study has shown the topology migration can be implemented by using OXADM without any node restructuring and reinstallation. Any loss due to link extension can be compensated with the amplifier gain. The minimum gain required in the mesh is equal to the value in ring topology if the span is remain unchanged.

Key words: OXADM, hybrid, protection, optical networks, migration

INTRODUCTION

Wavelength Division Multiplexing (WDM) offers an attractive means for satisfying the high capacity transmission requirement in fiber optic networks. A key element for the realization of WDM networks is the wavelength-reconfigurable devices such as Optical Add Drop Multiplexer (OADM) and Optical Cross Connect (OXC) (Tzanakaki *et al*., 2003). Both devices have different structure, function and application but if both functions could be integrated, the applications of optical network will be tremendously widened (Rahman *et al*., 2006a). In this study, we propose a new device called Optical Cross Add-Drop Multiplexer (OXADM) which combines the operational concepts of OXC and OADM. It enables the operating wavelengths on two different optical trunks to be switched into each other while implementing add-drop function simultaneously. The operating wavelengths can then be reused again as a carrier of new data stream. The wavelength transfer between two different cores of fiber will increase the flexibility, survivability and efficiency of the network structure. To ensure efficient operation, Micro-Electromechanical Systems (MEMS) switches are used to control the mechanism of operations, such as wavelength add-drop and routing. The switching performed within the optical layer will enable high-speed restoration against failure/degradation of cables, fibers and optical amplifiers. Three restoration schemes are proposed to provide survivability in ring and mesh metro networks; which are, by means of linear, multiplex and ring protection (Rahman and Shaari, 2007; Rahman, 2008). Topology migration can be carried out in a more convenient way because the installation of new nodes is no longer necessary due to the fact that OXADM is applicable to both types of topologies, as well as providing efficiency, reliability and survivability to the network. Previously we proposed also another migration technique using OXADM but with both bandwidths are actively after migration and the capacity double after the migration. (Rahman *et al*., 2006a; Ab-Rahman *et al*., 2007). In this study, we propose and experimentally demonstrate flexible topology migration using OXADM to prevent the occurrence of fiber failure. The performance of the output power and Bit Error Rate (BER) performance have also been analyzed.

OPTICAL HYBRID DEVICE

OXADM is an element that provides the capabilities of add/drop function, as well as cross-connecting traffic

Corresponding Author: Mohammad Syuhaimi Ab-Rahman, Research Group (SPECTECH) Spectrum Technology, Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

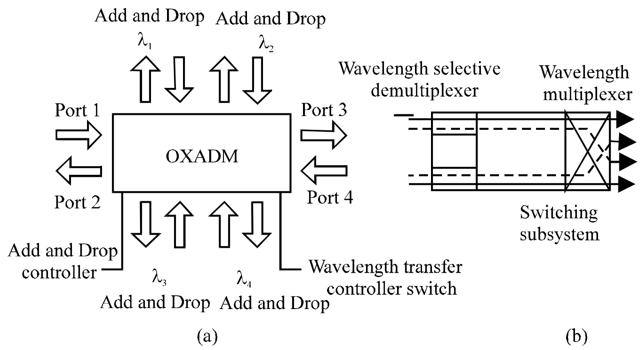

Fig. 1: The diagram of Optical Cross Add and Drop Multiplexing (OXADM) (a) block (b) signal routing path

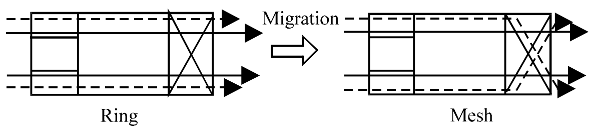

Fig. 2: Signal routing in ring and mesh topology. Both wavelengths are activity used in both topologies

Table 1: OXADM functional characteristics in ring and mesh networks

Signal	Ring Network	Mesh Network
λ1a and λ2a	Working Bandwidth	Working Bandwidth
λ3b and λ4b	Protection Bandwidth	Protection Bandwidth
λ3a and λ4a	Working Bandwidth	Working Bandwidth
λ1b and λ2b	Protection Bandwidth	Protection Bandwidth

in the network, similar to as provided by OADM and OXC, respectively (Rahman *et al*., 2006b). An OXADM node consists of three main subsystem; a wavelength-selective de-multiplexer, a switching subsystem and a wavelength multiplexer are shown in Fig. 1. Each OXADM is expected to handle at least two distinct wavelength channels (Table 1) each with a coarse granularity of 2.5 Gbps or higher (signals with finer granularities are handled by logical switch nodes such as SDH/SONET digital cross connects or ATM switches) (Tsushima *et al*., 1998). The device has two input and two output ports which are connected to the optical trunks. The 4-channel OXADM design is expected to have a maximum operational loss of 0.6 dB for each channel when the components of the device are in ideal condition. By taking into account the component's loss at every channel, the maximum insertion loss is 6 dB. In a transmission using SMF-28 fiber with transmitter power of 0 dBm and sensitivity -22.8 dBm at a point-to-point configuration with safety margin, the required transmission length is 71 km with OXADM.

Figure 2 represents the topology migration from ring topology to mesh topology using the OXADM architecture which is use different signal in both ports. In a ring network configuration, 50% of the ring capacity is dedicated for protection purposes which allows the protection capacity to be pooled and shared amongst the different wavelength demands routed on the ring. The working channels in one fiber are protected by the protection channels in the other fiber, traveling in the same direction around the ring. Signals of the working bandwidth will be diverted to the protection bandwidth which is activated according to the condition of failure, when a breakdown occurs at the transmission line or node. OXADM is the first device that integrates the linear, ring and multiplex protection into a single device.

In mesh configuration the protection channels are also used as the working channels. OXADM enables the operating wavelength on two different optical trunks into be switched to each other in bidirectional way while implementing add-drop function simultaneously, similar to OXC functions. MEMS switches are used to control the mechanism of operation to ensure efficiency.

TOPOLOGY MIGRATION USING OXADM

Figure 3 shows the migration process from ring topology to mesh topology network which used OXADM nodes. The traffic flows in mesh network is depicted in Fig. 4 and will be used as reference in present simulation next. The network specification for span 70 and 80 km is shown in Table 2 and 3, respectively. The objective of the simulation is to study the influence of span to the output power and BER performance. The suitable amplifier gain for the network is also determined for both configurations.

ORIGINAL RING NETWORK

Figure 5 shows the output power measured at every node in the original ring network. The span between

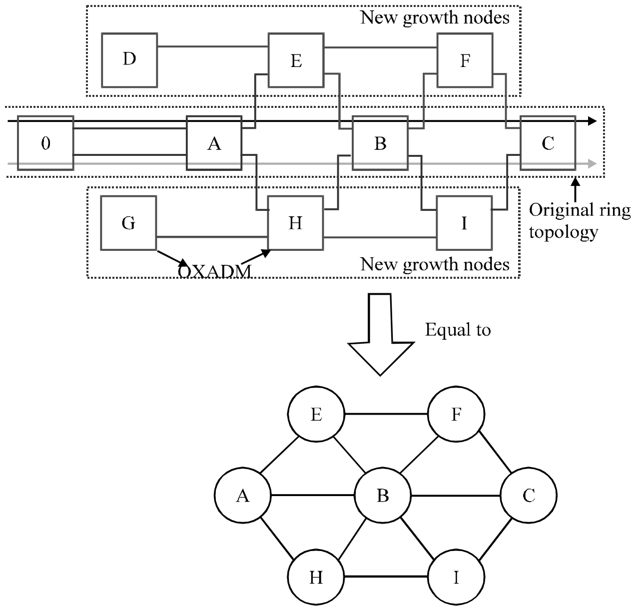

Fig. 3: Topology migration from ring to mesh configuration using OXADM. The OXADM uses half of the bandwidth capacity to ring and mesh network

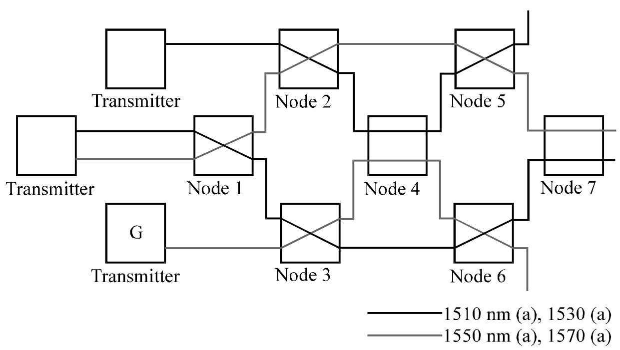

Fig. 4: Signal propagation path in mesh network using OAXDM. The simulation next will refer to this path

Table 2: The simulation parameters for mesh network at span 70 km

Specification	Value
Span	70 km
Pre-Amplifier Gain (from transmitter)	3 dB
Post-Amplifier Gain	22 dB
Pre-Amplifier Gain (Second and Forth)	7 dB
Data Transmission Rate	OC-48
Photodetector Sensitivity	-25 dBm at 1530 nm (2.5 GHz)

two nodes is 70 km and the total amplifier's gain is 33 dB. The output power is also below the dynamic range of 25 dB. Therefore the sensitivity of the receiver used meets the standard which is -30 dBm after considering safety margin. While Fig. 6 represents BER performance that undergone performance test at 2.5 Gbps (OC-48) with BER less than 10^{-9} (without error rate).

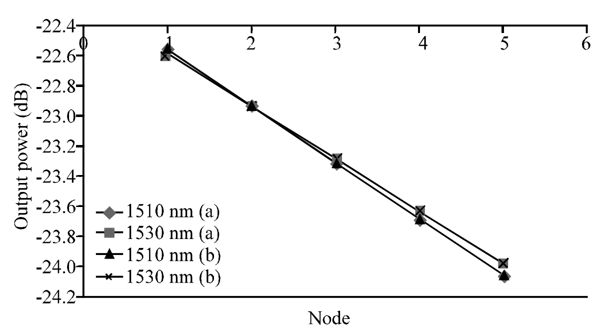

Fig. 5: Output power measured in original ring mode. The signal injected at both OXADM input port are the same

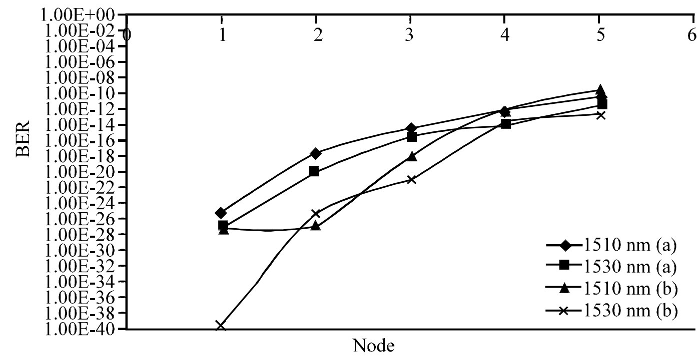

Fig. 6: BER performance measured in original ring mode. The five nodes give the accepted value which is below than 10^{-9}

MIGRATED MESH NETWORK

Figure 7 shows the output power measured at every node in mesh network at span 70 km. Due to random arrangement in mesh network, the received power at every node is higher compare to the node in serial ring arrangement. BER performance measured also in accepted value (1×10^{-9}). The BER performance is shown in Fig. 8 which is the output power for every node is observed in stable value and give the better performance of BER (in this case, the maximum BER is about 1×10^{-09}. The value of gain used in every span is similar to the load line.

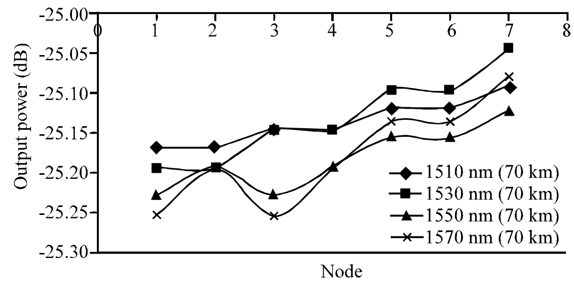

Fig. 7: The output power measured in mesh network at 70 km span

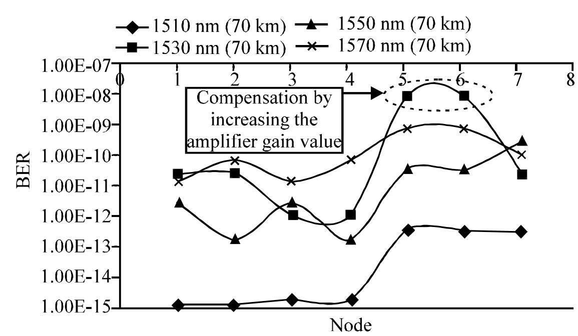

Fig. 8: BER performance measured in mesh network at 70 km span

SPAN ANALYSIS

If the span is extended to 80 km with the gain value unchanged, the output power measured at every nodes starts to degrade and the BER performance become worse. This happen because the load line is bigger than the gain used. The effect of the span increment on the output power and BER performance is depicted in Fig. 9 and 10, respectively. The degradation occurs at every node with 1.2377 dBm dB^{-1}. The BER performance degraded at every nodes and the maximum value achieved at node 5. To compensate the BER performance, the amplifier gain used for every node should be increased. The effect of gain increment (from 29 to 32 dB) can be seen as Figure 11 and Fig. 12. The suitable gain at 70 km span is 29 dB and 80 km span is 32 dB. It can be seen the output power become improved with similar happen to the BER performance. Therefore, the minimum gain value required for mesh metropolitan network is:

$$\text{Minimum Gain required (mesh metropolitan)} = \text{Load Line (dB)} + \text{Operational Loss (dB)} \quad (1)$$

Table 3: The simulation parameters for mesh network at span 80 km

Specification	Value
Span	80 km
Preamplifier gain (from transmitter)	6 dB
Postamplifier gain	25 dB
Preamplifier gain (second and forth)	7 dB
Data transmission rate	OC-48
Photodetector sensitivity	-25 dBm at 1530 nm (2.5 GHz)

The minimum gain required in mesh network is equal to minimum gain value for ring network to show when the migration occurs at a certain span the gain required also similar to after migration.

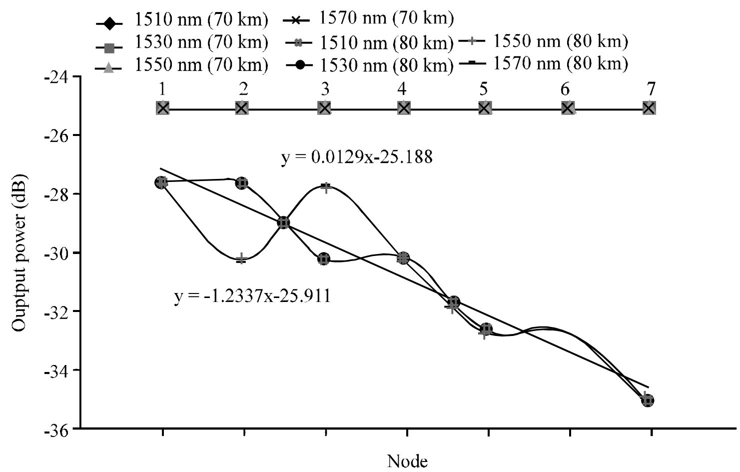

Fig. 9: Comparison of output power measured at span 70 and 80 km with the gain value. The gain value equal to the load line value at 70 km span

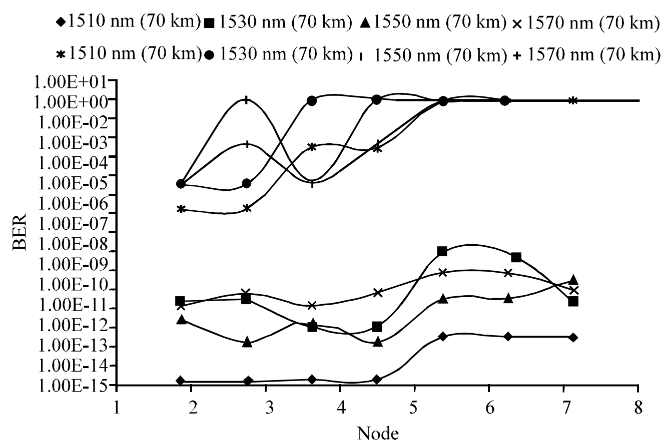

Fig. 10: Comparison of BER performance measured at span 70 and 80 km. The gain value used in the network is suitable to load line value at 70 km span

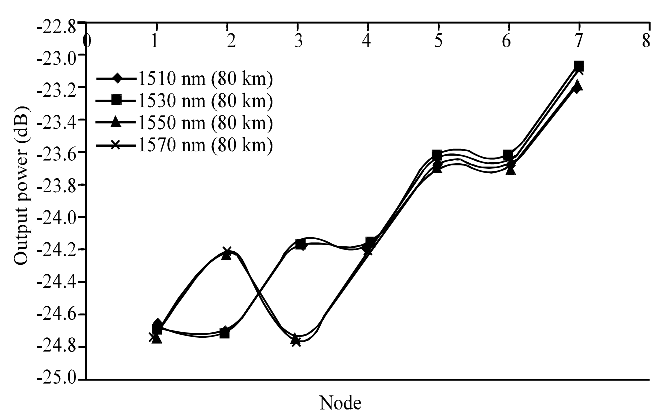

Fig. 11: The output power measured in mesh network at 50 km span

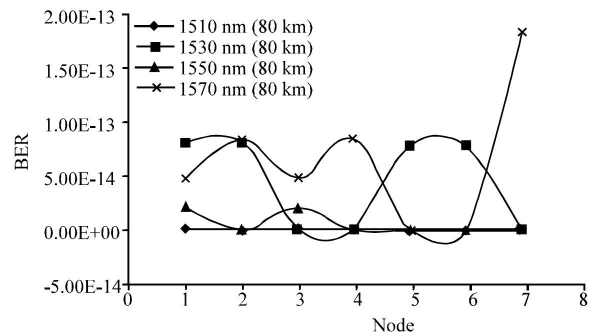

Fig. 12: BER performance measured in mesh network at 80 km span

DISCUSSION

This simulation study has shown the topology migration can be implemented by using OXADM. Any loss due to link extension can be comensated with the amplifier gain. The minimum gain required in the mesh is equal to the value in ring topology. We evaluate the performance of the proposed restoration scheme, the BER characteristics were measured at 1 Gbps and no degradation was observed in linear protection as confirmed by a comparison of the simulation results with those obtained from systems without restoration mechanisms and span are also studied analytically and the result has verified the simulation result obtained by using OptiSystem simulation.

CONCLUSION

OXADM is a new device which is able to function as a node in both ring and mesh topologies. Besides conveniently enabling topology migration (ring-to-mesh, vice-versa) OXADM can also provide three protection schemes to the networks. Thus OXADM is expected to increase the flexibility and survivability to the existing networks today.

This study describes our recent work on advanced ring metropolitan network through the development of an OXADM. The OXADM focuses on providing survivability through restoration against failure by means of linear/multiplex and shared protection, activated according to the conditions of failure. The BER characteristics are measured to be 2.5 Gbps (OC-48) and minor degradation was observed, as confirmed by a comparison of the simulation results with those obtained from systems without restoration element. Restoration scheme in OXADM node is more reliable and efficient compared to conventional devices due to the internal routing mechanism which requires no 'drop and re-add' function to route the signal to alternative path when failure occurs in the working path.

As a result, present simulation shows that the proposed topology migration can be implemented by using OXADM. The performance analysis of the output power and BER performance have also discussed and reported.

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