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ORIGINAL ARTICLES

Theoretical Analysis of OXADM Restoration Scheme in Ring metropolitan Network: Failure Possibility Analysis

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ABSTRACT

This paper will discuss on the survivability features offered by OXADM for ring optical network. It started with the development of OXADM symbol and subsequent review failure locations that occurs in a network with the introduction of appropriate protection mechanisms to be activated. Consequently, a theoretical analysis is conducted to identify if there are any limitations there is in OXADM device.

Key words:

Introduction

Add Value to Existing Device:

In the redundancy system used today is comprised into two major types of protection strategies which are dedicated protection and shared protection. Shared protection is then classified into two main types of coverage which are multiplexed signal shared protection and optical channel shared protection (Acterna, 2005).

Dedicated protection scheme uses two transmission line consisting of two groups of wavelengths in the working line and protection line. Protection mechanisms used in the dedicated protection scheme is linear protection where the transmitted signals will be transferred to protection line in case of failure occurs at working line connected at each node. Typically nodes based on optical cross-connect switching make this protection mechanism as the main protection strategies. The devices are OXC, OXN and OCCS (Tsushima *et al.,* 1998; Shiragaki *et al.,* 1998; Mutafungwa, 2001). OXADM device is also capable of carrying out the mechanism by directing the signals into the device to one of the output. In normal circumstances, the protection line can be used as data transmission line and thus increase data transmission capacity. If the two lines operated by different wavelengths, OXADM provide multiplex protection to collect all of the input signal to an output path in the event of failure occurs to one of the working line. Node-based on optical add drop switching uses the function drop and re-add to operate the linear protection as practice in tunable ring node (TRN) (Eldada and Nunen, 2000).

Shared protection uses two transmission lines consisting of four groups of wavelengths. Each transmission line consists of working groups and protection group. For example in a transmission line, group A ($\Lambda 1$) is a working group and group B ($\Lambda 2$) is a protection group. While in the second transmission line, the group B ($\Lambda 2$) is a working group and group A ($\Lambda 1$) I protection line. The technique that used wavelength group makes this system capable of carrying bidirectional data transmission and performing a ring protection scheme (the signal is reflected back to the second input terminal). Usually optical node based on add drop switching use this protection scheme as a main survivability strategies such as in OADM and TRN (Eldada and Nunen, 2000). The echanism of protection be used is complicated because it involves drop and add signal operations. In addition, an additional circuit to direct the signal path to the particular add port when protection mechanisms activated are also needed have make the system more complex and bulky. But in architecture of OXADM, the signals will be turned in 'U' directly by activating a switch to E without involving the add and drop operation, without need the additional circuits as well. However, the protection bandwidth for each of the terminals is still needed because during the formation of new rings spiral path, all signals will propagate in the same channel (Eldada and Nunen, 2000). Therefore all the bandwidth used will be allocated as the data and bandwidth protection. In addition, during the ring protection mechanism activated the linear protection mechanism can be also run simultaneously making it more flexible. Optical node using optical cross-connect switching architecture is also not capable of performing ring protection mechanisms as practice in OXADM, OADM and TRN.

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OXADM is a device that combines optical switching techniques in crosslinking and the loss add drop signal, so it can carry out both types of protection (linear and ring protection) simultaneously on one device architecture. It will be activated according to the type of failure, whether breakdown occurs at single line or two lines or damage to the optical distribution node. OXADM controlled by a microprocessor system to detect any failure and damage and identifies and activate an effective protection mechanism. In addition all OXADM protection mechanisms that can run directly without involving the operation of drop and re-add. Therefore OXADM is said to be complementary to the existing system currently.

Brief Research on OXADM:

Urvivability System in MAN and FTTH Network:

OXADM introduced two schemes for the protection of the MAN ring network by means of Linear protection/Multiplex and Ring protection. Perlindunga linear (main line is used) and Multiplex cover (both main and protection line used) is activated if failure occurs on one transmission line (Ab-Rahman, 2008; Rahman and Shaari, 2007; Ab-Rahman and Shaari, 2006; Ab-Rahman *et al.,* 2007). Studies have been carried out by simulation and experimental. This protection was extended to FTTH-PON and FTTH-WDM with rebranding the protection scheme which are Linear protection and Shared protection (Ab-Rahman, 2010; Ab-Rahman *et al.,* 2006; Ab-Rahman and Jumari, 2009; Ab-Rahman *et al.,* 2009; Ab-Rahman, 2011). OXADM also proposed as an OLT in this FTTH network. Studies described above were carried out by simulation. In point to point network, several studies carried out on achievable distance, total loss, performance in different transmission rates and the number of devices cascaded. (Ab-Rahman *et al.,* 2006; Ab-Rahman, 2008; Ab-Rahman, 2011; Ab-Rahman, 2011; Ab-Rahman *et al.,* 2010). They can be achieved by using simulation, experiments and analytical modeling.

Multifunctional Device:

OXADM has also shown potential as a multifunctional device. With different configurations OXADM can serve as demultiplexer, multiplexer, coupler WDM, OADM, OXC and WRB. It has proven to be simulated in a previous publication (Ab-Rahman, 2011; Ab-Rahman and Wahab, 2008; Ab-Rahman, 2011).

Topology Migration:

OXADM also ensure the cost effectiveness of the optical network need to be expanded such as Migration from ring topology to mesh topology. Since OXADM has OADM and OXC features so it can function as optical nodes in both topologies without involving the network restructure due to migration process. It has proven to be simulated in a previous publication (Ab-Rahman *et al.,* 2011; Ab-Rahman *et al.,* 2006).

OXADM Hybrid Recovery Mechanism:

This section describes the survivable mechanism in optical ring network proposed by using OXADM as the optical security node. There are basically two types of protection can be handled by the OXADM which are linear protection and ring protection. Multiplex protection is used to replace the linear protection for the network use both line as the transmission media. Activation mechanisms of the protection depends on several factors which are the direction of signal propagation, type of signal on both line whether the same or different wavelength and location of failure. This section will list all network recovery mechanisms at all possible locations of failure by using OXADM. OXADM hybrid restoration mechanism will activate the appropriate protection scheme depends on the type and level of the failure occurred. It involves the nodes near the failure without affecting the other nodes. OXADM hybrid restoration mechanism refers to the node OXADM used for bidirectional data transmission and operated at different wavelengths for the first line (working line) and the second line (protection line). The difference carrier signal shows clearly in red (clear line) and blue (dashed line) used as the signal flow. Linear/Multiplex protection scheme is enabled for dedication protection while ring protection is enabled for the shared protection scheme.

Network Failure Category:

This section will explain how OXADM works as a node in the event of failure at different locations in the metropolitan ring network. OXADM node will be controlled by a microprocessor system that interfaced with the failure detector subsystem. When there is any failure occurs in certain classes, then this sensor will send an emergency signal to a node near the damage. Then the signal would be sent to the nodes by the node nearby to inform the class of failure and the recovery mechanism will be determined immediately. All the sensors will be handled by the microprocessor system in the electrical domain. For that, we must know the classes of possible failure in a metropolitan ring network. Failure classes can be categorized into three main parts and repair mechanisms will depend on the class of such failure. Table 1 shows the classes of failure, type of failure and protection scheme used for the recovery. To demonstrate the flexibility of order OXADM position in a optical network, OXADM nodes are organized in a face to face connection.

Table 1: Kategori kerosakan yang kemungkinan berlaku dalam sesuatu rangkaian cincin serta mekanisme pembaikpulihan boleh digunakan.

Classes	Failure Type	Node Position	Architecture	Protection Scheme
Class IA	Breakdown occurs at any transmission line (working line or protection line)	Back to Back	1:1 and 1+1 for unidirectional and bidirectional	Linear/Multiplex Protection
Class IB	Breakdown occurs at any transmission line (working line or protection line)	Face to Face	1:1 and 1+1 for unidirectional and bidirectional	Linear/Multiplex Protection
Class IC	Breakdown occurs at any transmission line (working line or protection line)	Face to Back	Odd Node Number	Linear/Multiplex Protection
Class IIA	Breakdown at both lines	Back to Back	Even Node Number	Ring Protection
Class IIB	Breakdown at both lines	Face to Face	Odd Node Number	Ring Protection
Class III	Node Breakdown	All Position	1:1 for unidirectional and bidirectional	Ring Protection

OXADM Node Symbol:

In designing a metropolitan ring network and analyze the mechanism for failure recovery, it is important to design a symbol that distinguishes OXADM node with other optical nodes. Since the face and back OXADM node has a different architecture (asymmetric) make order of the nodes in the network OXADM ring may also be different from the order of the other optical nodes (device symmetry), so the symbol nodes is important in explaining OXADM mechanisms that occur. Figure 1 shows the symbol OXADM node that will be used and explanations for each distribution area in the node.

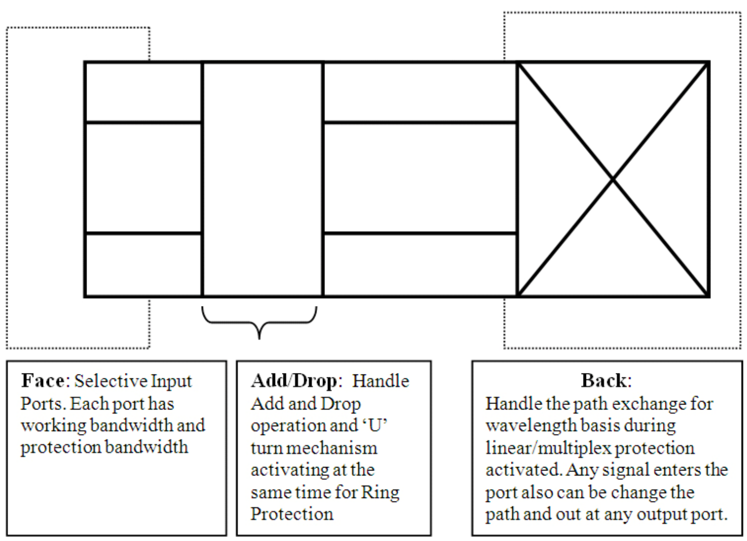

Fig. 1: OXADM node symbol and classification based on the function and mechanism.

Even Nodes Number:

Case 1: Failure Class IA:

Recovery: Linear/Multiplex Protection:

In the event of an emergency and the type of failure is identified, the signal will be sent to Node 1 to activate the emergency switch. Depending on the direction of the signal the node before the line is responsible to activate the emergency switch to turn on the path change switch. The other nodes work as normal because the signal through the first node after the breakdown will be separated into their own path and this is an advantage in the OXADM ring network architecture (Figure 2).

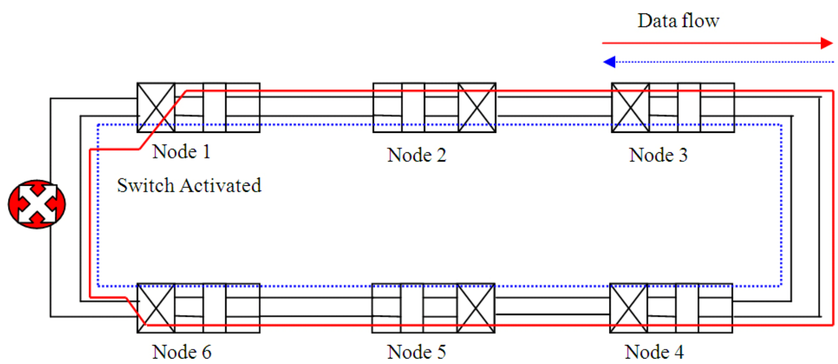

Fig. 2: Network recovery for the case of failure occurs at the working line by using linear/multiplex protection. Node 1 and Node 6 activate path change switch when received emergency signal from the nearest node to the failure area.

Case 2: Failure Class IB:

Recovery: Linear/Multiplex Protection:

Breakdown to a single line on the face to face configuration can also be restored through linear protection mechanism (as in Figure 3). Due to OXADM able to direct the signal path in bidirectional, therefore any failure that involve only one line can be recovered through this mechanism (Figure 3). Function add/drop can operate as usual, especially at Node 3 and Node 4.

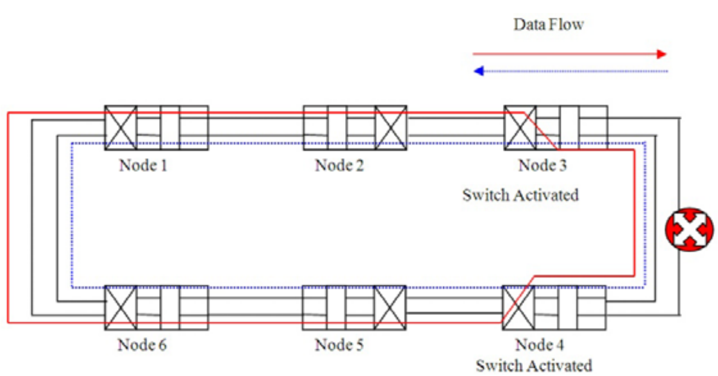

Fig. 3: Network recovery for the case of failure occurs at the working line by using linear/multiplex protection. Node 3 and Node 4 activate path change switch when received emergency signal from the nearest node to the failure.

c. *Case 3: Failure Class IIA:*

i. *Recovery: Ring Protection:*

If both working and protection lines are fails, a ring protection will be activated involving the node before and after the breakdown. Other nodes are working as normal. Figure 4 shows a ring protection mechanism used to ensure signal flow continuously. Node 1 and Node 6 will remain with emergency switching until the signal indicates the recovery has been improved and the flow will be changed to normal. Quick and effective protection ring will ensure no damage on the signal in the event of failure to both lines.

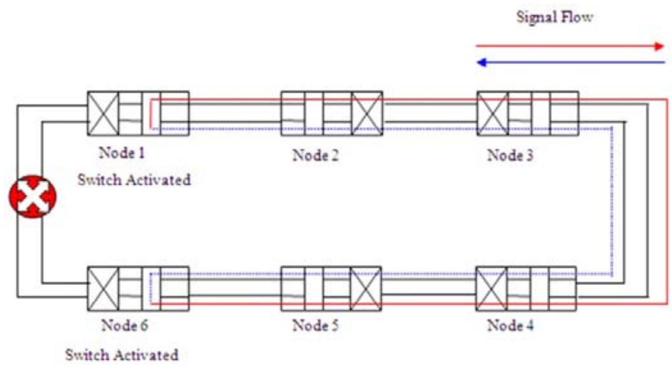

Fig. 4: Network recovery for the case of failure occurs at the both lines by using ring protection. Node 1 and Node 6 activate 'U' turn switch when received emergency signal from the nearest node to the failure area.

Case 4: Failure Class III:

Recovery: Ring Protection:

Damage Class III refers to damage to the optical node which requires activation of a ring protection mechanism for quarantining the damage area of the data transmission network. Data will flow in its original condition when the node has completed repairs. The quarantine process requires an activation switch E at nodes adjacent to the damaged node (Figure 5). Signals will propagate in one pass using the bandwidth of working and protection bandwidth. Quarantining in OXADM protection mechanisms only apply to the damage without affecting the other nodes and different as practiced in a OADM and OXC ring network.

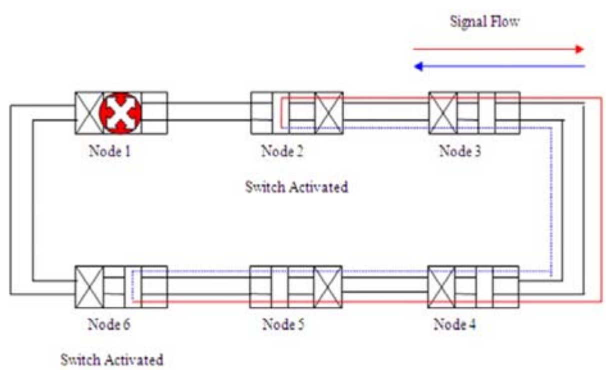

Fig. 5: Ring protection mechanism is activated to quarantine the failure/node area from the working area by rebuilding the new ring network.

Odd Nodes Number:

Case 1: Failure Class II B:

Recovery: Ring Protection:

In the metropolitan ring network with an odd number of nodes, a ring protection is selected to restore the transmission network in the event of damage to both the transmission line. This recovery mechanism will ensure that the data can be sent continuously without involving the process of data extraction and delivery in the form of a new wavelength that causes the time delay on the signals sent and complicate the data transmission network. Recovery mechanism for this network is shown in Figure 6.

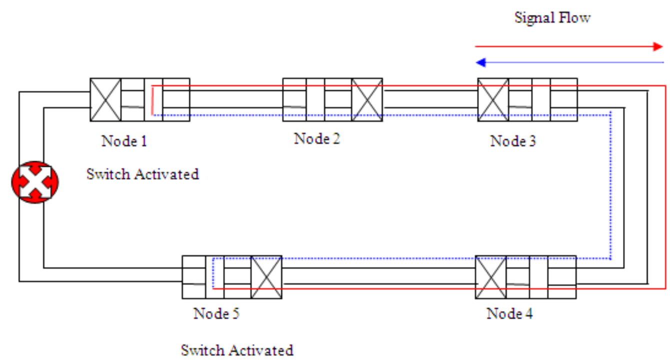

Fig. 6: Ring protection mechanism is also used for recovery for odd number of nodes in optical ring network when both lines fail.

Case 2: Failure Class IC:

Recovery: Linear/Multiplex Protection:

Figure 7 shows the activation of linear protection mechanisms for the recovery of failure in a single line in the face to back configuration in an odd number of nodes ring network. It is similar to linear protection mechanism described in Figure 2 where the change in path (multiplex protection) is done at the first node before the damage (Node 5). However, the signal will be switched back to the original route bypassed the damage as soon as the next node (Node 1).

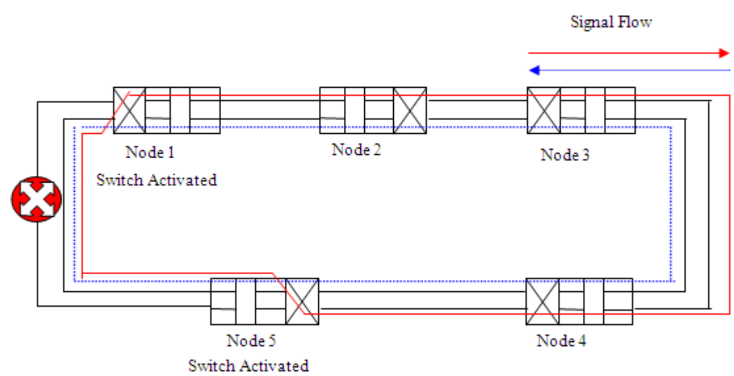

Fig. 7: Linear/Multiplex protection mechanism is also used for recovery for odd number of nodes in optical ring network when one of the lines fail.

Conclusion:

Although OXADM is asymmetrical optical device, it is capable of recovery failure to the transmission network with the most appropriate protection mechanism depend to the types of failure for all types configuration such as Face to Face, Face to Back, Back to Back connection. This shows OXADM device does not depend on the position and order in a ring and mesh networks as well as the number of optical nodes in the network (either completed or odd). The breakdown involves only one transmission line will activate the OXADM linear protection mechanism while breakdown to both lines or optical distribution node will be activated OXADM ring protection mechanisms. OXADM ring protection technique generally used for cases of failure that cannot be recovered by the linear protection. OXADM Hybrid is the first reported which integrate three protection mechanisms in one network and will be activated based on the level and type of failure as well as signal processing is done in the full optical domain.

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