Australian Journal of Basic and Applied Sciences, 4(12): 6260-6268, 2010
ISSN 1991-8178

Protection for Tree-Based EPON-FTTH Architecture Using Combination ACS and OXADM

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Abstracts: Ethernet Passive Optical Network (EPON) was proposed to overcome the bandwidth bottleneck at the Access Network due to its simplicity, cost effectiveness and wide spread deployment. A failure in access networks can cause serious problem, because access network transmit aggregated high-speed traffic from hundreds of subscribers. Protection and restoration mechanisms have been applied in backbone networks, but access networks are not considered significantly in the scope of survivability. Towards that, this paper describes our recent approach toward advanced customer access network through the development of an access control system (ACS). The ACS focuses on providing survivability through the OXADM restoration scheme against failure by means of dedicated and shared protection that is applied in FTTH-EPON. A next feature is the high speed restoration achieved by automatic re-routing using fiber status monitoring. Each OXADM has a node controller which receives reports on the status periodically from access control system (ACS). When a failure is detected, The ACS will send a command to the related OXADM to be activated. The proposed restoration system is the first in its kind which covers the survivability in the drop section of FTTH access network. The proposed architecture is simulating under two conditions; ideal and product theoretical to prove the system feasibility. Both results show the agreement and supporting each other.

Key words: survivability, ACS, OXADM, FTTH-EPON, tree-based architecture.

INTRODUCTION

Ethernet based Passive Optical network (PON) technology is emerging as a viable choice for the next-generation broadband access network. EPON is a PON that carries Ethernet traffic. A PON is a point-to-multipoint fiber optical network with no active elements in the signal's path. All transmission in a PON are between on Optical Line Terminal (OLT) of central office (CO) and Optical Network Unit) (ONUs). Three wavelengths are used typically 1310 nm for data/voice upstream transmission and 1490 nm for the downstream data/voice transmission. Meanwhile 1550 nm is used to transmit downstream video signal. In the downstream direction (OLT to User), packets are broadcast by the OLT and extracted by their destination ONUs based on their media access control (MAC) address. In the upstream direction (user to OLT), each ONU will use a time shared channel (TDM) arbitrated by the OLT. OLT is function to aggregates Ethernet traffic from remote ONU devices through passive optical splitters (Hossain, A.S.M.D., 2005). EPON works over point-to-multipoint topologies such as three, ring and bus. Our extensive research attention was focused on EPON tree architecture. Survivability in EPON is necessary and becomes important to provide seamless services and ensure network reliability. Protection and restoration mechanisms have been applied in backbone networks, but access networks are not considered significantly in the scope of survivability. Full benefit of backbone protection is not realized if the traffic doesn't reach the end user due to the lack of protection in access. Therefore survivability of EPON is necessary and become important to provide seamless services and ensure network reliability (Hossain, A.S.M.D., 2005).

Architecture and technologies for fiber to the home (FTTH) deployments have taken precedent in the last few years with several field trials and deployments implemented in various parts of the world (Nadarajah, N., 2005). Next generation customer access networks must be able to deliver services based on customer demand

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and with guaranteed service requirements as agreed with the service provider. Therefore the protection and restoration of access networks have become very significant for reliable service delivery and business continuance (Ab-Rahman, M.S., 2006). Protection at the optical layer against fiber cuts and equipment failure is most cost effective for high bandwidth services (Ab-Rahman, M.S., 2006). Automatic protection switching (APS) in which transmission is switched to a predetermined optical path upon detection of a fiber cable break may be used for restoration for the affected channels (Hossain, A.S.M.D., 2005). In this letter, we proposed an ACS scheme to monitor the status of signals flow and provide the restoration against failure by using Optical Cross Add and Drop Multiplexer (OXADM). OXADM is expected to be a key component which provides survivability through optical restoration (& protection) by switching to alternative routes in the optical layer and access network. The switching performed within the access node will be able to achieved high speed restoration against the failure/degradation of cables, fibers & also optical amplifiers. Each OXADM has a node controller which receives reports on the status periodically from access control system (ACS). When a failure is detected, The ACS will send a command to the related OXADM to be activated (Ab-Rahman, M.S., 2006).

Two restoration mechanism schemes have been proposed which are suitable for survivability in FTTH-EPON. These restoration schemes are dedicated protection and shared protection. Dedicated protection is activated when failure occurs in working fiber while the shared protection is activated when failure occurs for both working and protection fiber.

No degradation in the BER was observed, as confirmed by a comparison of the simulation results with those obtained from system without restoration function in ideal condition to prove the system feasibility. The product theoretical condition is also included in the analysis to define the exact level of the three conditions as in real practice. The proposed scheme is the first in approached which covers the restoration in FTTH access network specified in dropping section. Among benefits of this future-proof FTTH technology to the end user is its bandwidth capacity, reliability, security and scalability delivered over a single fiber optic cable to all Internet Protocol (IP) based services simultaneously.

Optical Cross Add and Drop Multiplexer (OXADM) Switch:

The introduction of new modeling device that is designed to overcome drawbacks that occur in WDM application in expected. The device is called Optical Cross Add and Drop Multiplexing (OXADM) which use combination concept of Optical Cross Connect (OXC) and Optical Add and Drop Multiplexer (OADM) as depicted in Figure 1. OXADM is the first switch-based prototype from Institute of MicroEngineering and Nanoelectronic (IMEN) laboratory. Its enable the operating wavelength on two different optical trunks to be switched to each other while implementing add and drop function simultaneously (Ab-Rahman, M.S., 2006). Here, the operating wavelengths can be reused again as a carrier of new data stream. The wavelength transfer between two different cores of fiber will increase the flexibility and also efficiency of the network structure. To make device operational more efficient, MEMS mirror mechanism is used to control the mechanism of operation. Optical switches play an increasingly important role as today's optical networks become more complex and carry more capacity. The switches can be deployed in applications such as network protection and restoration and dynamically re-configurable add/drop modules. The MEMs switch here is employed in the design to control the add/drop wavelength and wavelength transfer operation. The introduction of new function that 'accumulates all signals on one path' expands the application of OXADM.

It can be a restoration switch in WDM-FTTH network via sharing the signals on the breakdown line to the second working line. This feature differentiates the OXADM from other existing switching device such as OXC, TRN and OADM (Tzanakaki, A., 2003; Tsushima, H., 1998). The restoration function is essential for ensuring the survivability of the optical layer network. On the other hand, the OXADM provides the cross connection for the granularity of the individual optical channel of OC-N x N. The routing of individual wavelengths makes it possible to groom individual wavelength paths. Besides that, the 'accumulation all signal in one path' also becomes the value added of the system and will be the main feature. As a result, the OXADM is capable of performing wavelength based restoration, as well as bandwidth management (based on wavelength), which will be requisite in the optical layer for large numbers of incorporated wavelengths.

Survivability in FTTH-EPON:

In dedicated protection FTTH-EPON scheme, each ONU is connected to splitter output terminal by two fibers; working line and protection line through two OXADM switches that is controlled by ACS. The function of OXADM is to switch the signal to the protection line when failure occurs in the working line. The route depends on the restoration mechanism that is activated according to the types of failure.

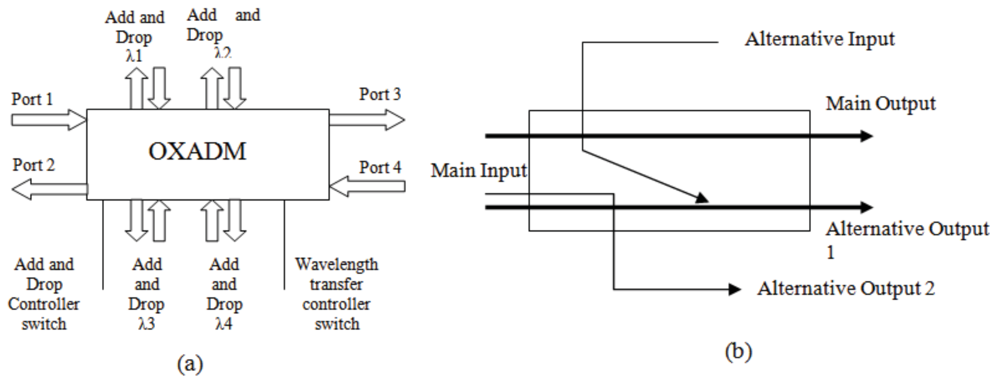


Fig. 1: Optical Cross Add Drop Multiplexer (OXADM) a) block diagram b) path routing mechanism used for FTTH EPON restoration scheme

Figure 2(a) depicted the signal flows through the working line in normal condition for both line A and line B. The OXADM switches are in bypass state that allows signals to pass through the device and be received at ONUs. The two OXADMs are allocated in the transmission line in which both ONU and splitter are located. First OXADM is used to switch the signal to protection line at local transmission or switch to protection line at transmission line nearby. The second OXADM will switch the signal in protection line back to the original path before sending it to the local ONU. When the failure occurs in the working line, the first OXADM will switch the signal to the local protection line and the second OXADM will be activated simultaneously to switch the signal back to the transmission line. The restoration scheme is referred to dedicated protection similar to that deployed in ring configuration (Hossain, A.S.M.D., 2005). Figure 2(b) shows the mechanism of dedicated protection in FTTH access network.

Figure 2(c) shows the shared protection scheme which diverts the signal to the adjacent protection line. The interruption in both working and protection lines need the shared protection scheme to be activated. The first OXADM is activated directly but the second OXADM is activated by sending the activation signal utilizing the adjacent protection line by ACS. The protection line is connected to the drop-port of OXADM 1 and add-port of OXADM 2 and it will become the third route of transmission in case of both local lines breakdown.

The proposed restoration functions above are essential for ensuring signals flow continuously and survivability of drop region in optical access network. The architecture of restoration scheme embedded in the FTTH-EPON is illustrated in Figure 3.

Access Control System (ACS):

Due to lack of active devices in FTTH network, the function of ONUs are passively and don't provide any sensor related to fault or breakdown. To overcome the incomplete in FTTH technology, access control system (ACS) is introduced to control the survivability in FTTH access network. ACS is used to monitor the status of the working and restoration fibers. The unique monitoring system architecture requires a single switch element and coupler connection between the ACS and both transmission paths. Before activating a suitable protection scheme, ACS will recognize the types of failure and send the activation signal to the related OXADM switches according to the activated protection mechanisms (Ab-Rahman, M.S., 2006).

The architecture of ACS is shown in Figure 4. It consists of two major parts, monitoring signal section and activation section. The function of ACS is the same as the optical performance monitor (OPM) which is applied in both ring and mesh metropolitan network. Normally, ACS is integrated in a single system, which also includes splitter and first OXADM of each access line. Tapping 3% of the downstream and upstream signal by using coupler can recognize the status of feeder section and drop section. If breakdown occurs in feeder section, ACS will send a signal to activate the dedicated protection scheme. But if the breakdown is the detected in drop section, ACS will recognize the related access line by the 3% tapped signal that is connected to every access line. The activation signal is then sent to active the dedicated protection scheme. But if fault is still not restored, the shared protection scheme will be activated. The monitoring signal section is responsible for sensing fault and its location whereas generation of activation of signal is sent by activation section in ACS.

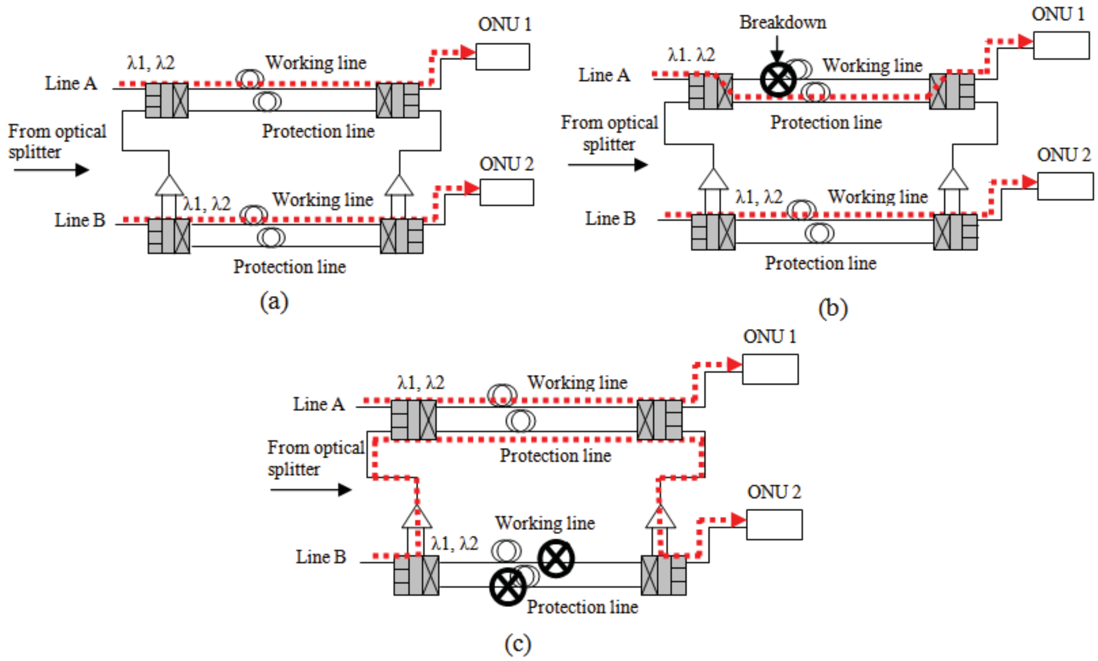


Fig. 2: Mechanisms of protection in FTTH-PON access network in normal condition and two different breakdown locations. (a) Normal condition (b) Breakdown at working line in Line A (c) Breakdown at both working line and protection in Line B.

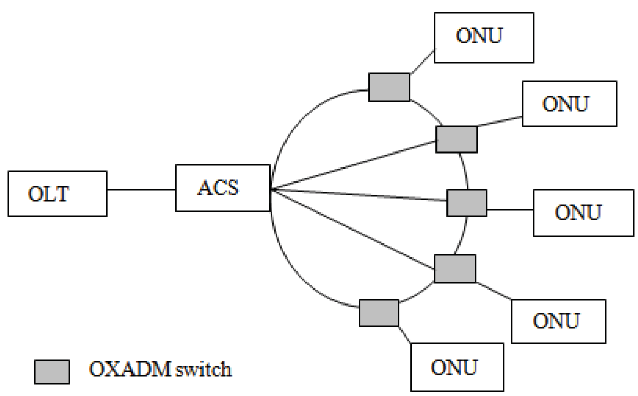


Fig. 3: The architecture of restoration scheme implementing in drop region for FTTH-EPON.

Table 1 describes the possible condition in the monitoring system captured from tapped signal and diagnosis of the fault. The couplers will tap 3% of the downstream and upstream signal in turn, and sending it to ACS for interpretation. The condition of the tapped signal will represent the status of feeder section and drop section.

Table 1: Possible status of tapping signal A and B and related fault diagnoses

A	B	Diagnose
O	O	Both feeder and drop region are in good condition
X	O	Fault occurs in feeder region, No fault in drop region
O	X	No fault in feeder region, Fault occurs in drop region
X	X	Both feeder and drop region are in breakdown.

X = no signal detected
O = signal detected

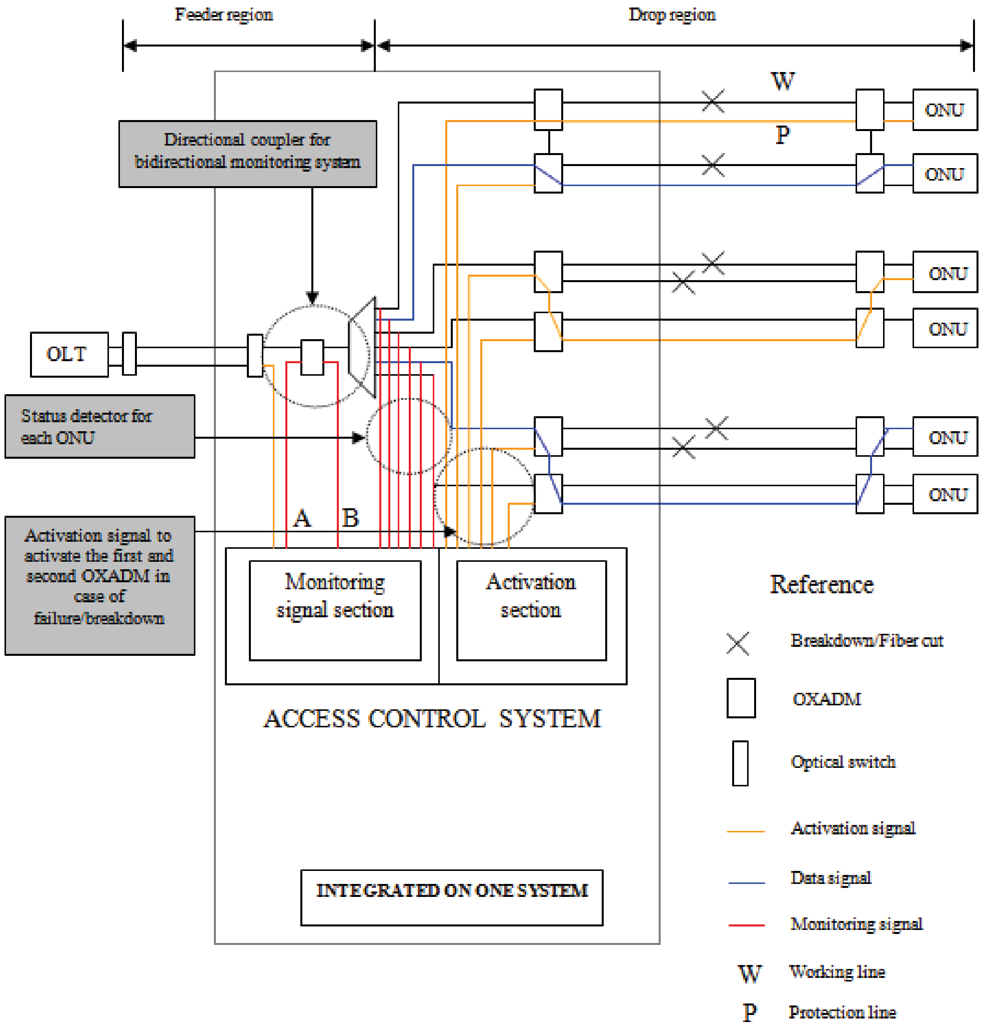


Fig. 4: Architecture of restoration in FTTH access network centralizing at ACS which control the monitoring subsystem and restoration activation subsystem.

Figure 5 shows the flow chart of restoration process that is controlled by ACS. ACS will determine the mechanism of protection by detecting & analyzing the monitored signal to the end of restoration process. All is described in the flowchart.

RESULT AND DISCUSSION

Ideal Condition:

Figure 6 shows the simulation result for the output received power collected at each ONU in condition of without and with restoration through the activation of dedicated and shared protection condition. The graph will identify the losses that are generated during the protection schemes are enabled. The result shows no loss can be found between the lines with and without restoration except the insertion loss of the device itself. The simulations are done under ideal condition (IL = 0 dB), in order to make the analysis clear and system feasibility. The maximum distance that can be achieved at sensitivity of -21.8 dB is 14 km dB, but the value will be bigger than 21 km if the sensitivity is decreased to -25 dB. In fact, the distance between optical splitter and ONU in an actual application is about 10 km only. BER performance versus distance at sensitivity -21.8 dB is shown in Figure 7. No degradation of BER is observed as comparing the systems with and without redundancy in both signals. Practically, there are 4 dB different between shared protection and normal condition and no different between normal condition and dedicated protection. 4 dB losses are referred to the loss that

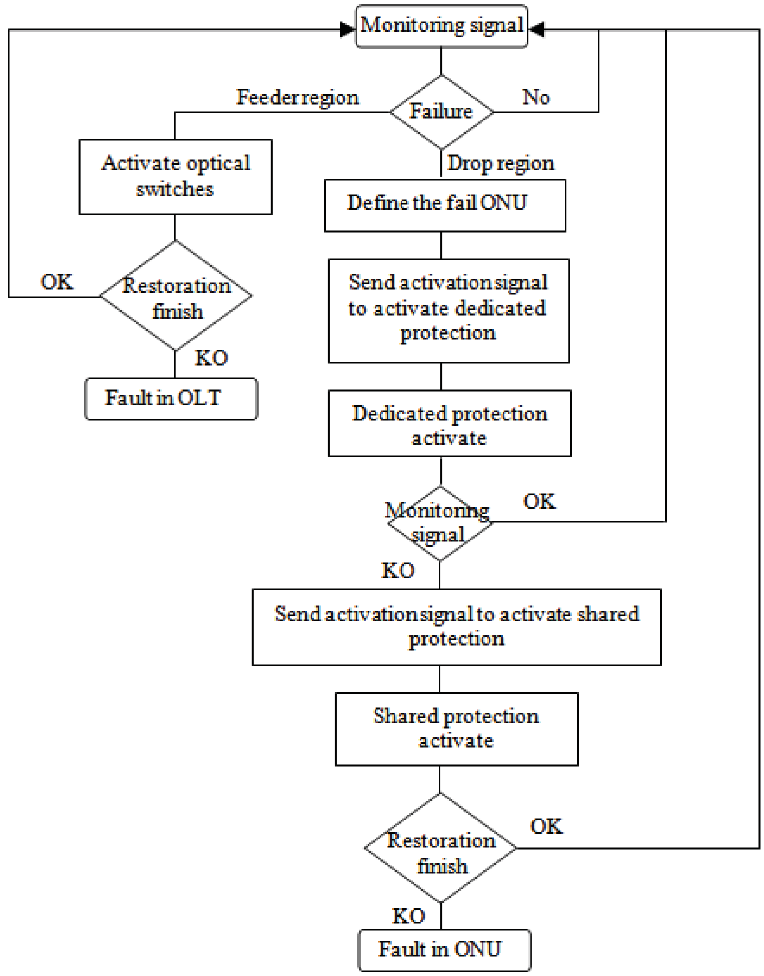


Fig. 5: Flowchart of restoration mechanism in FTTH access network

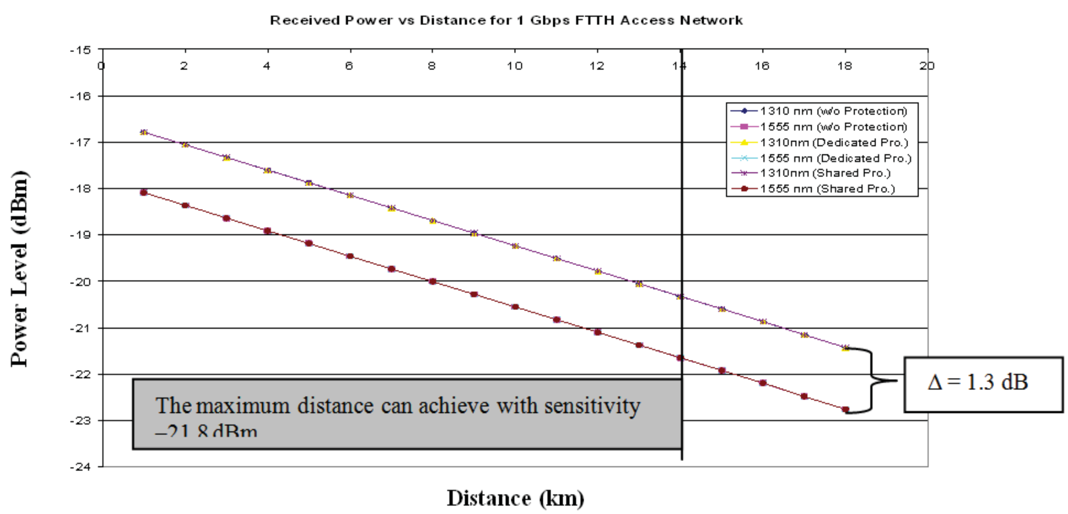
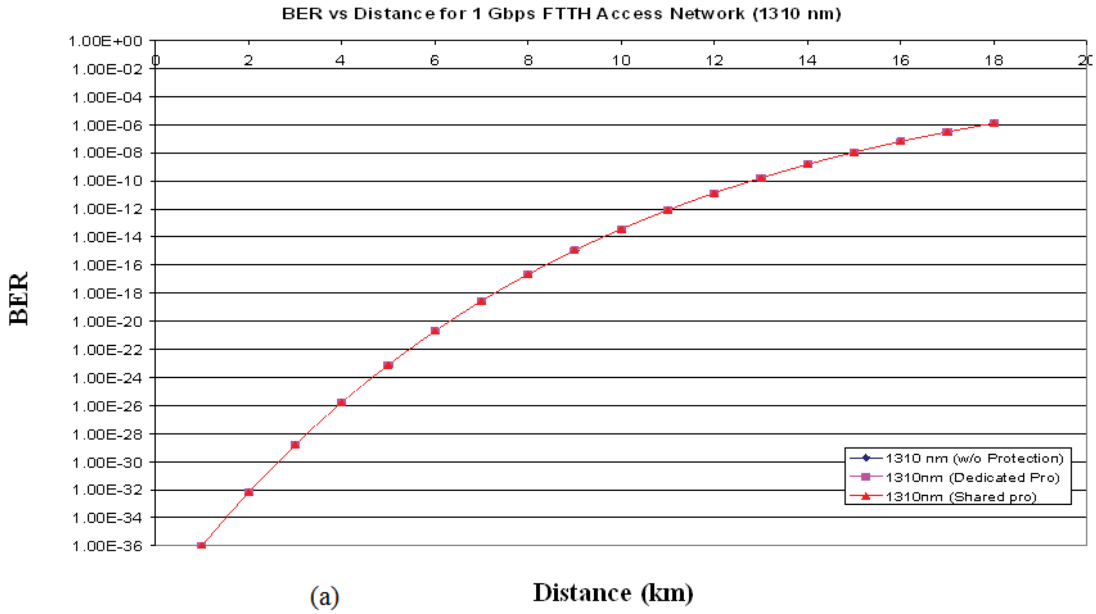
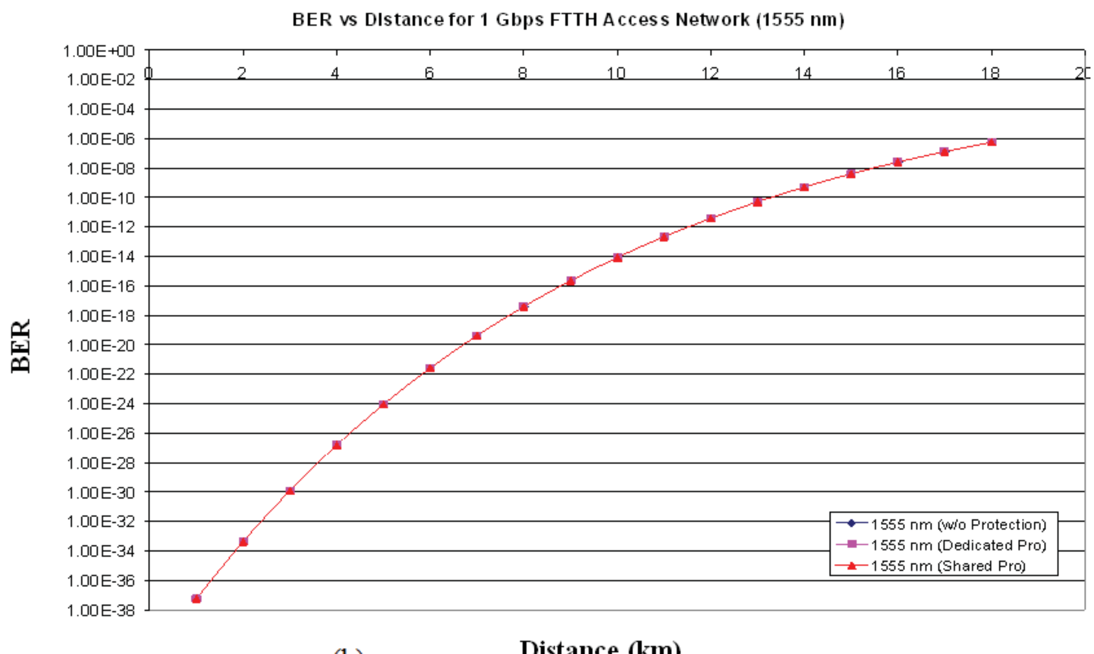


Fig. 6: The ONU receive power in three conditions as a function of a distance.



(a)



(b)

Fig. 7: The effect of transmission distance to BER performance for three condition under ideal condition (a) 1310 nm (b) 1555 nm

are generated by drop and re-add the signal to the adjacent line in shared protection mechanism. This will be discussed in next section under the sub-topic of Device Theoretical Condition.

Product Theoretical Condition:

The simulation on Product Theory Condition is used to study the actual characteristics in term of ONU received power for the three conditions by referring the actual values of the commercialized device to build the system. The testing is running at 1 Gbps. Figure 8 and 9 respectively shows the simulation result for the

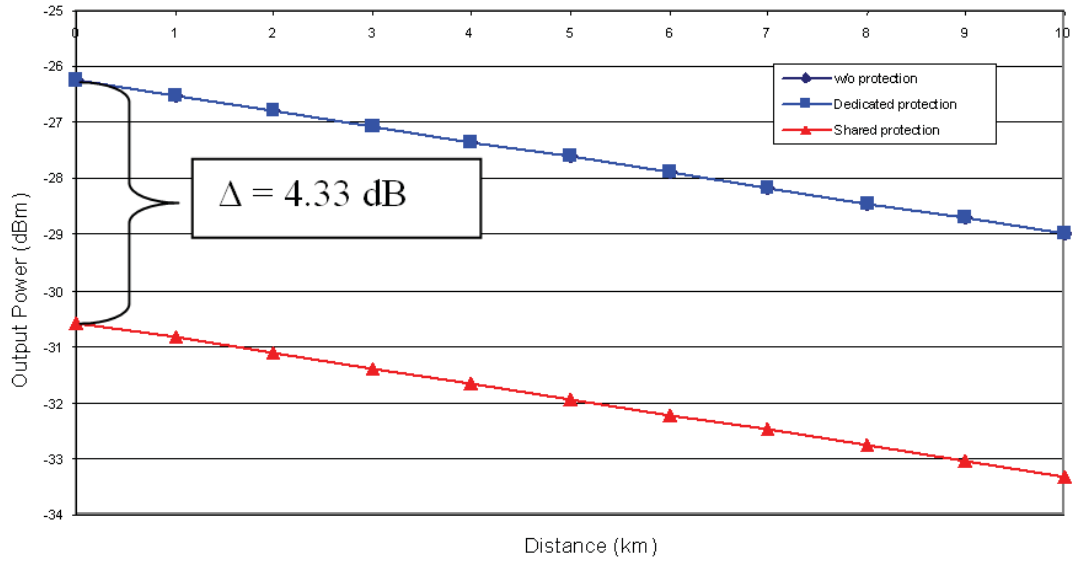


Fig. 8: The comparison between the ONU received power at difference distance for three conditions for wavelength 1310 nm under product theoretical condition.

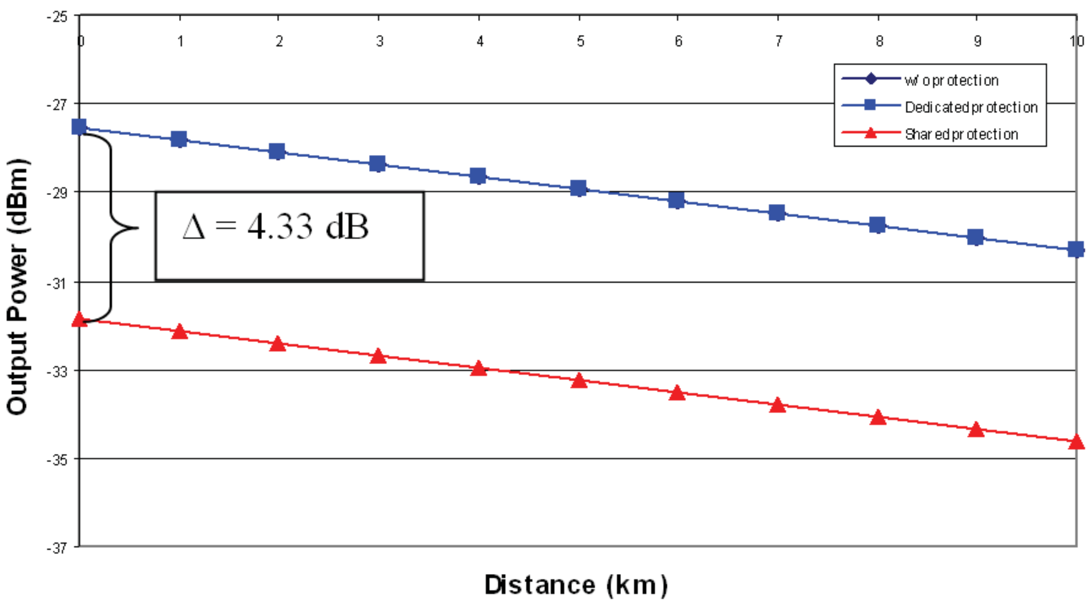


Fig. 9: The comparison between the ONU received power at difference distance for three condition for wavelength 1550 nm under product theoretical condition.

output received power collected at each ONU in condition of without and with restoration through the activation of dedicated and shared protection condition for the wavelength 1310 nm and 1555 nm. No change could be found in term of ONU received power when the dedicated protection is activated due the insertion loss at these conditions is same. In contrast whereas the decrement is about 4.33 dB occurs at the magnitude of power between normal condition and restoration condition can be seen when shared protection activated. This is happened because the shared protection implementing add and drop function to switch over the traffic to the neighbor's line will add up a few losses when the restoration scheme is activated.

Conclusion:

This paper described the development of an access control system (ACS). The ACS focuses on providing survivability through the OXADM restoration scheme against failure by means of dedicated and shared protection that can be applied in EPON-FTTH. The survivability of EPON is necessary to provide seamless services and ensure network reliability. Single failure in the line connected will activate dedicated protection while shared protection is activated when both fiber (working and standby fiber) are breakdown. The BER characteristics were measured at 1 Gbps and no degradation was observed, as confirmed by a comparison of these simulation results with those obtained from systems without restoration element. The proposal of FTTH restoration system (ACS with OXADM) particularly in drop section will make a debut because no work has been reported on this area. The proposed protection scheme was simple but capable of failure detection within 2 ms and guaranteeing zero packet loss.

Although successful proposal have been obtained, it is apparent that there are still many issue which have to be solved in order to establish complete optical layer routing and supervision are also expected to be integrated in the optical layer. For the global interworking of the optical layer through to customer access network, the requirements of international standardization such as IEEE 802.3ah-2004 must be satisfied.

ACKNOWLEDGMENT

This project is supported by Ministry of Science, Technology and Environment, Malaysia Government, through the National E-Science Project fund 01-01-02-SF0493 and Research University Grant fund UKM-GUP-TMK-07-02-108. The author would also like to thank the Institute of MicroEngineering and Nanoelectronic (IMEN) for supporting this research.

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