

Transmission Surveillance and Fiber Fault Identification in FTTH Access Network with Passive In-line Monitoring (PIM) Device

Mohammad Syuhaimi Ab-Rahman, Boonchuan Ng, Rosmawati Ismail

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

Abstract: This paper proposed a fully passive device prototype, named Passive In-line Monitoring (PIM) device, which used to tap out a small ratio of triple-play signals for monitoring purpose without affecting the transmission in tree-structured fiber-to-the-home (FTTH) access network. This device will be installed with the main lines in FTTH permanently to allow the field engineers or technicians to simply connect it to a portable tester unit for transmission surveillance and failure detection. The PIM device is used to sharply determine location of break point before repairing. A passive taper circuit is required to obtain the optical signals to provide a visual way of monitoring the receiving signal performance. The entire optical components that had been used in the circuit design including connectors, splices, optical isolators, and optical couplers. This device is potentially to improve the service reliability and reduce the repairing cost and time.

Key Words: PIM device, FTTH, transmission surveillance, failure detection.

INTRODUCTION

FTTH is a network technology that deploys optical fiber cable directly to the home or business to deliver triple-play (data, voice, and video) services with a high speed up to the customer premises via the optical distribution network (ODN). FTTH has played the major role in alleviating the last mile bottleneck for next generation broadband optical access network (Yeh, 2005). Today, FTTH has been recognized as the ultimate solution for providing various communications and multimedia services, including carrier-class telephony, high-speed Internet access, digital cable television, and interactive two-way video-based services to the end users (Lee *et al.*, 2006). Owing to the very high capacity of optical fibers, FTTH can deliver greater capacity as compared to copper-based technologies (Keiser, 2000).

Since the passive optical network (PON) or point-to-multipoint (P2MP) connectivity in a FTTH access network can accommodate a large number of subscribers, when any fault occurs at one point in an optical fiber line, the FTTH-PON access network will without any function behind the break point. Any service outage due to a fiber break can be translated into tremendous financial loss in business for the service providers (Chan *et al.*, 1999). According to the cases reported to the Federal Communication Commission (FCC), more than one-third of service disruptions are due to fiber cable problems. This kind of problem usually take longer time to resolve compared to the transmission equipment failure (Bakar *et al.*, 2007).

Conventionally, optical time domain reflectometer (OTDR) is used to identify a fault of an optical fiber in FTTH access network. OTDR testing is the best method for determining the exact location of broken optical fiber in an installed optical fiber cable when the cable jacket is not visibly damaged. It determines the loss due to individual splice, connector or other single point anomalies installed in a system. It also provides the best representation of overall fiber integrity (Chomycz, 1996). Whenever a fault occurs, OTDR is plugged manually to the faulty fiber by the technician to detect where the failure is located. By means of

Corresponding Author: Mohammad Syuhaimi Ab-Rahman, Spectrum Technology Division, Computer and Network Security Research Group, Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
Tel.: +603-89216448; Fax: +603-89216146
E-mail: syuhaimi@vlsi.eng.ukm.my, ngbc@vlsi.eng.ukm.my

OTDR, one can get the distance from the fault site to the measurement site along the optical fiber housed in the optical cable. However, one of the issues with testing using OTDR is this approach would produce inaccurate results if two trouble spots are very close together or if the pulse has a long travel length (David White, 2008).

Besides, serious problems may occur when the field engineers or technicians measuring the optical signal strength at each node in the network for monitoring the signal quality and troubleshooting the connection problems. Typically to measure the, the technicians have to break the connection to shut down the node for measuring the relative optical strength at a node. If there are multiple wavelengths going through the same node, then the technicians need to use an optical spectrum analyzer (OSA) or wavemeter to examining the spectral composition of optical waveform. This creates a risk of contaminating the fiber ends when disconnecting or reconnecting the node to the FTTH access network. It leads to create some serious problems later on and possible costly repairs, therefore these measurements can be quite costly (OZ Optics, 2006).

The OZ Optics had developed Smart Patchcords that can be used to monitor a FTTH access network (OZ Optics, 2006). The Smart Patchcords can be built onto the fiber of each node and installed at a convenient location in the network, such as a patch panel. It allows the technicians to simply connect this device to a laptop or personnel digital assistant (PDA) to record and log the measurements effortlessly. The Smart Patchcords only tap about 1% of the signal out at a specific wavelength without interrupting transmission. Thus three units could be used to three separate wavelengths (for the triple-play signals) at each node (OZ Optics, 2006). However, this approach needs relatively additional devices that impose high operation and maintenance cost. The service providers need to keep capital and operational expenditures (CAPEX and OPEX) low in order to be able to offer economical solutions for the customers. Therefore, improving network reliability performance by adding redundant components and systems have shortcomings in terms of implementation cost and flexibility (Prat, 2007).

Fiber fault within a FTTH access network becomes more significant due to the increasing demand for reliable service delivery. It is important to be able to locate any fiber break after the installation of FTTH access network. Furthermore, a simple and effective monitoring configuration is highly desirable for timely failure detection along the fiber link (Chan *et al.*, 1999). A particular problem in this regard is any fiber fault occurred in the network must be located without affecting the service to other subscribers (Sankawa *et al.*, 1990). A good fault surveillance system is essential to identify the fiber fault without interrupting the services, while other channels are still in service to maximize the link utilization (Chan *et al.*, 1999). Therefore, an optical line monitoring and testing system is essential for failure detection to improve the service reliability and reduce the maintenance costs of FTTH access networks.

The Overview of PIM Device

To reduce the cost and enhance the benefits, we are developed a PIM device prototype in this paper. The PIM device is a fully passive device, where all the optical components in the device do not require electronic control for their operation. It is purposely developed for monitoring the three main operating wavelengths (optical signals; 1310 nm, 1480 nm, and 1550 nm) which associated with FTTH-PON network. The 1480 nm (or 1490 nm) downstream signal and 1310 nm upstream signal are used to transmit data and voice. The 1550 nm downstream signal is used for analog video overlay. Broadcast video is transmitted at 1550 nm being a low loss window and a wavelength can be amplified by erbium doped fiber amplifier (EDFA). The device is consists of four ports for tapping function, as shown in Figure 1, which are controlled by optical couplers to perform the optical power combining and splitting in the device.

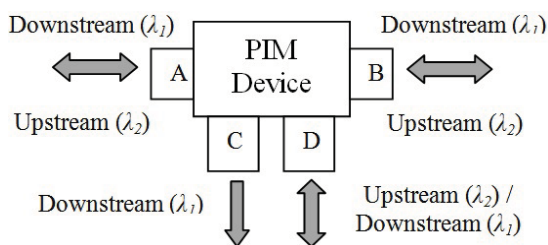


Fig. 1: Block diagram of PIM device prototype.

The upstream or downstream signals from the FTTH trunk line will be entering the taper circuit. This device provides a visual way of monitoring the receiving signal performance, when connected to a small TV screen which the user can view the broadcast channel of the FTTH mini cable television (CATV) video or and PDA for data communication. It taps out a small ratio of these signals in order to monitor the status along the main line without affecting both upstream and downstream transmission.

The device will be installed on every node with the main lines permanently in tree-structured FTTH access network depending on the options selected. The field engineers or technicians only need to bring a portable tester unit to test the transmission. It may connect the output signals from port C and D to a CATV and PDA at the central office (CO), as illustrates in Figure 2. It allows the field engineers or technicians to identify the faulty fiber and failure location without making a site visit. One there is any fiber fault or unable to receive the signals reported by the subscribers, allows the field engineers can verify the problem occurs in which region (in feeder region, distribution region, or drop region). The PIM device is used to sharply determine where the break point located before taking some appropriate action. After that, the exact failure location will be identified by using OTDR.

A passive taper circuit is required to obtain the triple-play signals to provide a visual way of monitoring the receiving signal performance. The entire optical components that had been used in the design of passive taper circuit including connectors for connecting two optical fibers, splices for attaching one bare fiber to another, optical isolators that prevent unwanted light from flowing in a backward direction, and optical couplers used to tap off a certain percentage of light for performance monitoring purposes (Keiser, 2000).

Among the optical components, optical coupler is the main components in the PIM device. Since it is one of the passive optical components, it do not require external source of energy to perform an operation or transformation on an optical signal. The concept of a coupler encompasses a variety of functions, including splitting light signal into two streams, combining two light streams, tapping off a small portion of optical power for monitoring purposes, or transferring a selective range of optical power from one fiber to another. Another important component in the device is optical isolator that allow light to pass through them in only one direction. This is important in a number of instances to prevent scattered or reflected light from travelling in the reverse direction (Keiser, 2000).

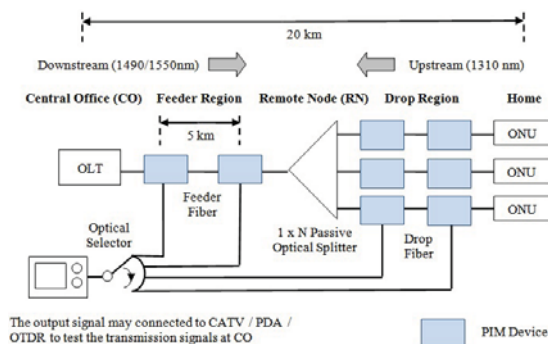


Fig. 2: The implementation of the PIM device in tree-structured FTTH access network.

Characteristics of PIM Device:

A prototype is developed to prove the feasibility of the PIM device. Two methods are being used to study the specifications of the PIM device: device testing and network testing. The parameters of each port in the PIM device such as insertion loss, reflection loss, and crosstalk are measured through a device testing, which used a tunable light source (TLS), circulator, and OSA, as depicts in Figure 3 and 4. TLS is used for light emitting with different emission wavelengths and OSA is used for examining the spectral composition of optical waveform. Meanwhile the network testing utilizes the OTDR to study the specifications of PIM device.

In specifying the performance of PIM device, we indicate the percentage division of optical power between the output ports of the couplers by means of the splitting ratio or coupling ratio by adjusting the parameters. However, in any practical coupler there is always some light that is lost when a signal goes through it. The two basic losses are excess loss and insertion loss. The excess loss is defined as the ratio of the input power to the total output power, while the insertion loss refers to the loss for a particular port-to-port path. Another performance parameter is crosstalk, which measures the degree of isolation between the input at one port and the optical power scattered or reflected back into the other input port (Keiser, 2000).. The specifications and performances of PIM device are listed in Table 1 and 2.

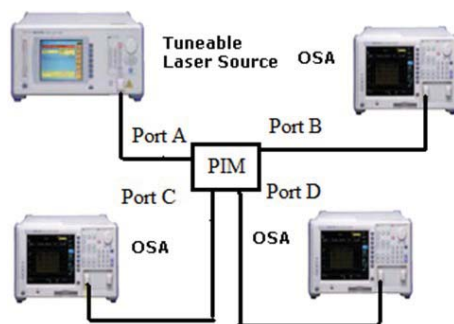


Fig. 3: The experimental setup for measuring the insertion loss of each port in the PIM device.

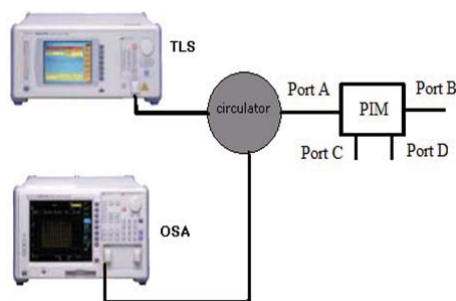


Fig. 4: The experimental setup for measuring the crosstalk of each port in the PIM device.

Power Budget:

PON is the most common form of FTTH in several parts of the world where it using a shared optical fiber cables from CO to deep in the network and usually terminates at a splitter cabinet. The connectivity in PON is based on P2MP structure, where the optical line terminal (OLT) located in the CO of the local Internet service provider (ISP) or access network provider providing connectivity to multiple optical network units (ONUs) at different residential customer locations via 1xN passive optical splitter (branching device) at remote node (RN), where $N = 8, 16, 32, 64,$ and 128 . Since the attenuation (reduction) of the signal strength arises from various loss mechanisms in a transmission medium is important when considering the factors such as the effects of tapping off a small part of an optical signal for monitoring purposes, for examining the power loss through some optical element, or when calculating the signal attenuation in a specific length of optical fiber. We are doing a power budget to calculate the maximum number of PIM device that can be installed in the network.

The power budget for network configuration is based on the power drop for each type of splitter, which has different value of insertion loss. All the losses for basic components including OLT and ONUs in FTTH are estimated in the power budget. This is purposely to calculate the maximum number of PIM devices can be installed in the FTTH access network without affecting the upstream and downstream transmission. The more number of devices installed with the main line, the more easily to specify the failure part before verifying the exact location with an OTDR.

Figure 5 shows the number of PIM devices allow to be installed in the network without any disruptions. With the sensitivity level -30 dBm and safe margin 5 dB, the maximum losses in the network are allow are less than -25 dB. As shown in the Figure 5, only maximum up to 4 unit of PIM devices are achieve the acceptability signal level, to consider it as safe (no interruption). With the maximum distance between the OLT and ONU can up to 20 km, this indicates that each PIM device can be installed at every 5 km within the FTTH access network. However, if the maximum number of PIM devices is more than 4 units, the subscribers still can receive the triple-play signal with several noise and disruption.

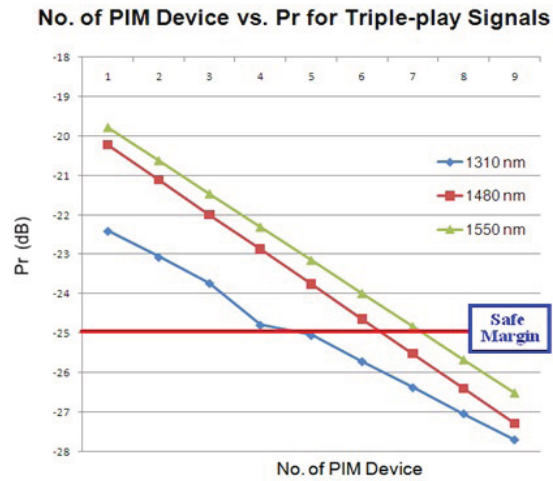


Fig. 5: Unit number of PIM device vs. receiving power, P_r , plot for the triple-play signals in FTTH access network.

Conclusions:

In this paper, we bring up an approach to improve the service reliability and reduce the repairing cost and time in FTTH access network through the PIM device. The PIM device focuses on determining the failure location before taking some appropriate action against fiber fault. In future research activity, we aim to reduce the size of the PIM device by packaging the passive taper circuit into two layers, so that it will require a small spacing.



Fig. 6: Photographic view of PIM device prototype before chasing.

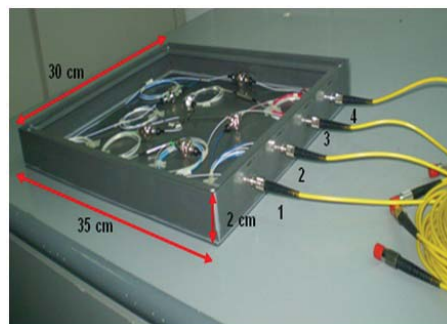


Fig. 7: Photographic view of PIM device prototype before packaging.



Fig. 8: Photographic view of the developed PIM device prototype.

ACKNOWLEDGMENT

This research work was supported by the Ministry of Science, Technology and Innovation (MOSTI), Government of Malaysia, through the National Science Fund (e-Science) 01-01-01-SF0493. The authors are also grateful to the Photonic Technology Laboratory, Institute of Micro Engineering and Nanoelectronic (IMEN), Universiti Kebangsaan Malaysia (UKM), Malaysia for providing the facilities to carry out the experiments. The PIM device had firstly been exhibited in 19th International Invention, Innovation and Technology Exhibition (ITEX 2008), Malaysia and was awarded with Bronze medal in telecommunication category.

REFERENCES

- Bakar, A.A.A., M.Z. Jamaludin, F. Abdullah, M.H. Yaacob, M.A. Mahdi and M.K. Abdullah, 2007. A New Technique of Real-time Monitoring of Fiber Optic Cable Networks Transmission. *Optics and Lasers in Engineering*, 45: 126-130.
- Chan, C.K., F. Tong, L.K. Chen, K.P. Ho and D. Lim, 1999. Fiber-fault Identification for Branched Access Networks using a Wavelength-sweeping Monitoring Source. *IEEE Photon. Technol. Lett.*, 11(5): 614-616.
- Chomycz, B., 1996. *Fiber Optic Installation: A Practical Guide*. McGraw-Hill, New York, USA.
- David, White, 2008, What is an OTDR?. <http://www.wisegeek.com/what-is-an-otdr.htm>
- Keiser, G., 2000. *Optical Fiber Communication* (3rd ed.). McGraw-Hill, New York, USA.
- Lee, K.L., S.B. Kang, D.S. Lim, H.K. Lee and W.V. Sorin, 2006. Fiber Link Loss Monitoring Scheme in Bidirectional WDM Transmission using ASE-injected FP-LD. *IEEE Photon. Technol. Lett.*, 18(3): 523-525.
- Yeh, C.H. and S. Chi, 2005. Optical Fiber-fault Surveillance for Passive Optical Networks in S-band Operation Window. *Optics Express*, 13(14): 5494-5498.
- Prat, J., 2007. *Optical Networks: Towards Bandwidth Manageability and Cost Efficiency*. http://www.e-photon-one.org/ephotonplus/servlet/Utils.MostrarFitxerPublic?fitxer=D_VDA_3.pdf&pathRelatiu=E-Photon+One+%2B%2FPublic%2FPublic+D+eliverables%2F.
- Sankawa, S.I. Furukawa, Y. Koyamada and H. Izumita, 1990. Fault Location Technique for In-service Branched Optical Fiber Networks. *IEEE Photon. Technol. Lett.*, 2(10): 766-768.
- OZ Optics, 2006. *Optical Taps and Monitors*. http://www.ozoptics.com/ALLNEW_PDF/DTS0042.pdf.