

# MATLAB-based System for Centralized Monitoring and Self Restoration against Fiber Fault in FTTH

Mohammad Syuhaimi Ab-Rahman, Boonchuan Ng, and Kasmiran Jumari

**Abstract**—This paper presented a MATLAB-based system named Smart Access Network Testing, Analyzing and Database (SANTAD), purposely for in-service transmission surveillance and self restoration against fiber fault in fiber-to-the-home (FTTH) access network. The developed program will be installed with optical line terminal (OLT) at central office (CO) to monitor the status and detect any fiber fault that occurs in FTTH downwardly from CO towards residential customer locations. SANTAD is interfaced with optical time domain reflectometer (OTDR) to accumulate every network testing result to be displayed on a single computer screen for further analysis. This program will identify and present the parameters of each optical fiber line such as the line's status either in working or non-working condition, magnitude of decreasing at each point, failure location, and other details as shown in the OTDR's screen. The failure status will be delivered to field engineers for promptly actions, meanwhile the failure line will be diverted to protection line to ensure the traffic flow continuously. This approach has a bright prospect to improve the survivability and reliability as well as increase the efficiency and monitoring capabilities in FTTH.

**Keywords**—MATLAB, SANTAD, in-service transmission surveillance, self restoration, fiber fault, FTTH.

## I. INTRODUCTION

FTTH has played the major role in alleviating the last mile bottleneck for next generation broadband optical access network [1]. A number of factors are increasing the interest among network service providers in offering the triple play services of voice, video, and high-speed data access. Most importantly, subscribers are finding a

This work was supported in part by the Malaysian Ministry of Science, Technology and Innovation (MOSTI) under National Science Fund (NSF) 01-01-02-SF0493.

Mohammad Syuhaimi Ab-Rahman, Boonchuan Ng, and Kasmiran Jumari are with the 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 (phone: +603-89216448; fax: +603-89216146; e-mail: syuhaimi@vlsi.eng.ukm.my, ngbc@vlsi.eng.ukm.my, kbj@vlsi.eng.ukm.my).

growing number of applications that drive their desire for higher bandwidth, including Internet access, interactive games, and video delivery. The first serious interest in FTTH began in the late 1980s as the telephone companies gained experience with Integrated Services Digital Network (ISDN) wideband services to subscribers [2]. 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 (CATV), and interactive two-way video-based services to the end users [3].

FTTH technology using passive optical network (PON) is the most promising way to provide high quality broadband access. PON are nowadays extensively studied and some commercial deployments are already reported [4]. The PON is commonly deployed as it can offer a cost-efficient and scalable solution to provide huge-capacity optical access [5]. Since the PON can accommodate a large number of subscribers, when any fault occurs in FTTH, the 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 network service providers [6].

Fiber fault within FTTH becomes more significant due to the increasing demand for reliable service delivery [6]. Conventionally, OTDR is used to identify a fiber fault in FTTH upwardly from multiple optical network units (ONUs) at different residential customer locations toward OLT at CO (in upstream direction). 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 [7]

Since a FTTH has many branches in the drop region. Whenever a fault occurs, OTDR is plugged manually to the faulty fiber by the technician to detect where the

failure is located. However, this approach would require much time and effort. Moreover, OTDR can only display a measurement result of a line in a time. Therefore, it becomes a hindrance to detect a faulty fiber with a large number of subscribers and large coverage area in the fiber plant by using an OTDR. Besides, it is difficult to detect a failure in optical line equipped with passive optical splitter by using a conventional OTDR downwardly from CO (in downstream direction), because the Rayleigh back-scattered (RBS) light from different branches overlap (accumulate) with each other in the OTDR trace and cannot be distinguished [6].

## II. CONCEPTUAL DESIGN OF SANTAD

SANTAD is a centralized access control and surveillance system that enhances the network service providers with a means of viewing traffic flow and detecting any breakdown as well as other circumstance which may require taking some appropriate action. It involved in the failure detection, automatic recovery, and increases the survivability and maintainability of FTTH. The principle operation of SANTAD can be divided into three main parts, consists of measuring optical fiber lines with OTDR, interfacing OTDR with personal computer (PC), and system testing and analyzing with SANTAD.

SANTAD is potentially used to increase survivability, efficiency, and flexibility of FTTH with point-to-multipoint (P2MP) connectivity or tree-based structured between the OLT at CO and multiple ONUs at different residential customer locations, particularly for downwardly in-service transmission surveillance and self restoration against fiber fault. Overall, it can reduce the time needed to restore the fault to maintain and operate the FTTH more efficiently.

### A. Principle Enhancement of SANTAD

SANTAD not only enables the field engineers to monitor the status and determine any failure or circumstance which may require promptly action in FTTH, but also to determine deployment, connection, and losses (connection losses, splice losses, optical device/component losses, fiber losses or attenuation) in the network system. Besides, it also able to track the optical signals level (input/output power) and losses at each point as well as monitoring the network performance. The developed program also provides the network service providers with a control function to intercom all subscribers with CO. The mechanism of SANTAD detection is illustrates in Fig. 1.

Whenever a failure occurs on the primary entity, the traffic (service delivery) is switched from the working (primary) line to the protection (backup) line to ensure the

traffic flow continuously and the failure status will be automatically sent to the field engineers through the mobile phone or Wi-Fi/Internet computer using wireless technology for repairing and maintenance operation. After the restoration/maintenance process, the traffic will be switched back to the normal operation. The whole operation process can be simplified in the flow chart as depicts in Fig. 2.

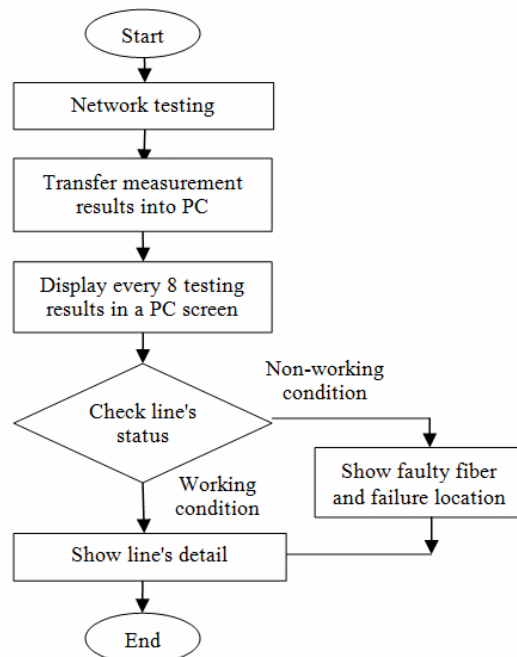


Fig. 1 Flow chart for mechanism of SANTAD detection.

### B. Measurement System Configuration

Our system architecture design is presented in Fig. 3. A commercially available OTDR with a 1625 nm laser source is used in failure detection control and in-service troubleshooting without affecting the triple-play services transmission. The OTDR is connected to a PC or laptop to display the troubleshooting results. The triple-play signals (1310 nm, 1490 nm, and 1550 nm) are multiplexed with 1625 nm testing signal. When four kinds of signals are distributed, the testing signal will be split up by wavelength selective coupler (WSC), which is installed before the optical splitter. The WSC only allow the 1625 nm signal to enter into the taper circuit and reject all unwanted signals (1310 nm, 1490 nm, and 1550 nm) that contaminate the OTDR measurement.

The downstream signal will go through the WSC, which in turn connected, to optical splitter before it reaches the optical network units (ONUs) at different residential customer locations. On the other hand, the testing signal

which is demultiplexed by WSC will be split up again in power ratio 99:1 by using directional coupler (DC) to activate the microprocessor system. The 99% 1625 nm signal will then be configured by using optical splitter, which each output is connected to single line of ONU. The operational of optical switch is controlled by microprocessor system that is activated by 1% of 1625 nm signal. With the method described in this paper, no any expensive additional equipments or devices are required.

III. EXPERIMENTAL SETUP AND NETWORK TESTING

In order to gauge the effectiveness and benefits of SANTAD, we tested our technique on a P2MP network. The instruments and measurement equipments used in the experiment are summarized in Fig. 3 with the help of the schematic diagram. After that, the measurement results for

each line are saved in the OTDR and then transferred into PC. After completing the transferring process, all the results are be recorded in database and then loaded into the developed program for further analysis as shown in Fig. 4. As a first step, no default was introduced in the network and OTDR measurements were performed. One can indeed observe that the OTDR testing signals in for each connection in a working (good/ideal) condition in Fig. 5. Then, we introduced a fiber break in one of the branches at distance of 15 km and 30 km. The optical fiber is not connected to any device at another end (unplugging) to represent the break point in a testing line. It visualized the actual break point of an optical line at that distance in a real condition. The analysis results for non-working (failure/breakdown) condition are presented in Fig. 6 and 7.

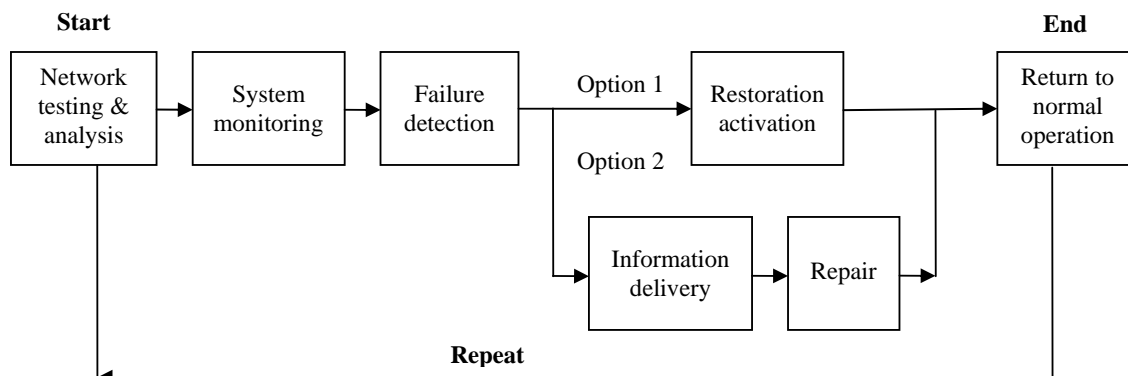


Fig. 2 The process flow for failure detection and restoration in SANTAD.

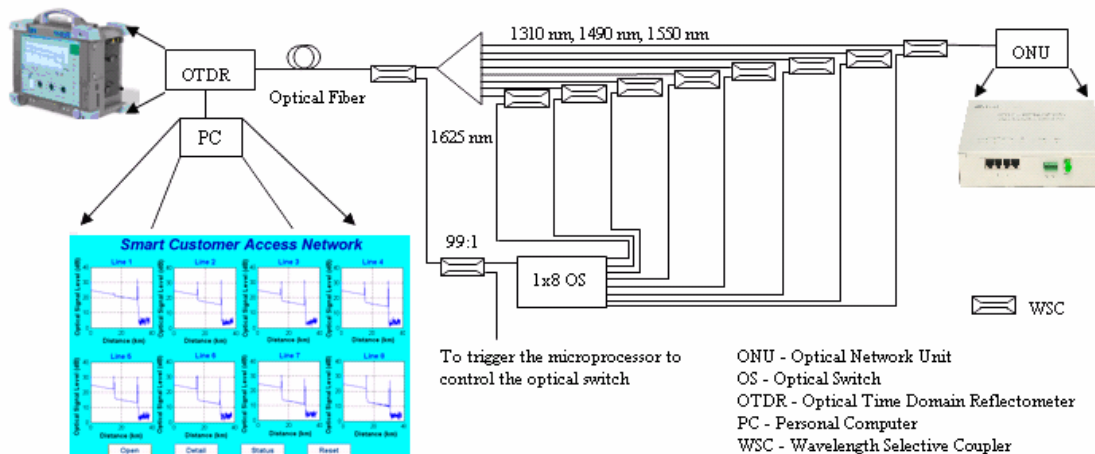


Fig. 3 SANTAD is installed at CO for centralized monitoring and fiber fault identification downwardly from CO towards residential customer location (in downstream direction).

IV. SIMULATION RESULTS AND DISCUSSIONS

SANTAD is focusing on providing survivability through event identification against losses and failures. SANTAD involves the fiber fault detection, notification,

verification, and restoration functions. Under working condition, it allows the network services providers to determine the path used by the services through the network, whereas under non-working conditions, it allows

the fields engineers to identify the faulty fiber and failure location without making a site visit. SANTAD enable the network service providers and field engineers to analyze the optical line's status, display the line's detail, track the optical signal level, and losses as well as monitor the network performance. In combination of the distinctive features, SANTAD provides a convenient way to solve the particular upwardly or downwardly measuring issues with OTDR and produce capability of fiber fault localization in

line to ensure the traffic flow continuously. This functionality alerts the network service providers and field engineers of a fiber fault before it is reported by the customer premises or subscribers.

Fig. 4 shows the ability of SANTAD to specify a faulty fiber and failure location among a number of optical fiber lines in FTTH by measuring the optical signal level and losses. Every eight network testing results will be

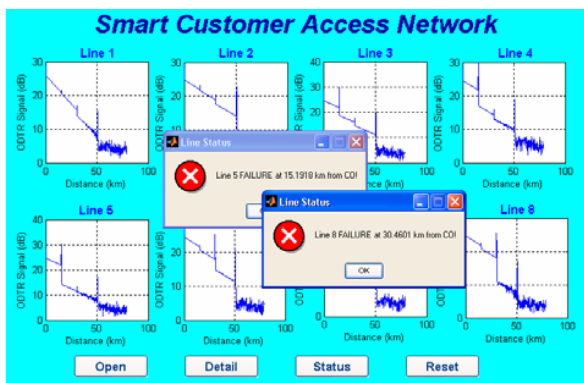


Fig. 4 Eight graphs are displayed on the *Line's Status* window. Two failure message display to show the faulty fibers and failure locations in the network system.

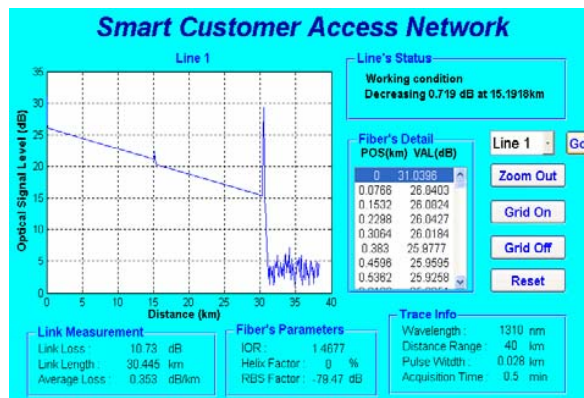


Fig. 5 An example of working line in the *Line's Detail* window. The optical power level in line 1 is decreasing 0.719 dB at 15.1918 km.

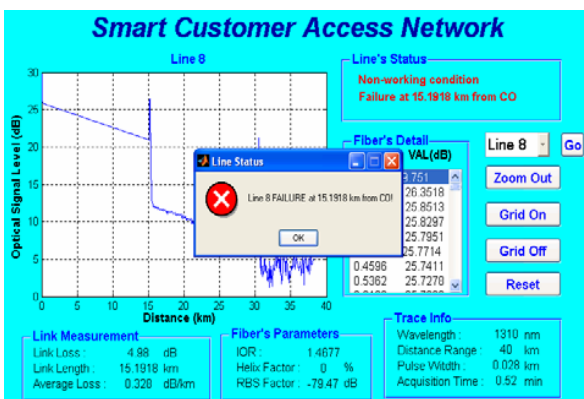


Fig. 6 An example of failure line in the *Line's Detail* window. The line 8 is failure at 15.1918 km when the fiber is unplugged at 15 km to represent the break point occurs at that distance in FTTH network system in a real condition.

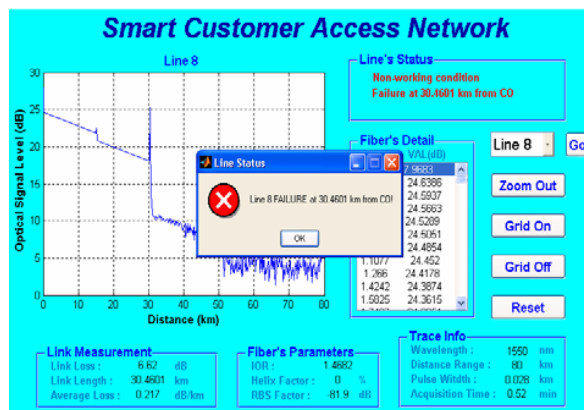


Fig. 7 Another example of failure line for two events. The line 8 is failure at 30.4601 km when the fiber is unplugged at 30 km.

SANTAD will be designed to operate by itself with a minimum need for operator action. SANTAD ensures that when detect a fiber fault occurs on the primary entity in FTTH network system, it is automatically reported the failure status to the field engineers, and the field engineers can determine sharply the break point before taking some appropriate actions. Meanwhile, activate the restoration scheme to switch the traffic from failure line to protection

displayed in *Line's Status* window for centralized monitoring, where the distance (km) represented on the x-axis and optical signal level (dB) represented on the y-axis. A failure message "Line x FAILURE at z km from CO!" will be displayed to inform the field engineers if SANTAD detect any fiber fault in the network system.

To obtain further details on the performance of specific line in the network, every measurement results obtained from the network testing are analyzed in the *Line's Detail* window. SANTAD is able to identify and present the

parameters of each optical line such as the line's status, magnitude of decreasing at each point, failure location and other details as shown in the OTDR's screen.

SANTAD displayed every status for the testing line in the *Line's Detail* form. A "Good condition" or "Decreasing  $y$  dB at  $z$  km" message displays at the line's status panel in a working condition (see Fig. 5). However in the non-working condition, a failure message "*Line x FAILURE at z km from CO!*" displays to show the faulty fiber and failure location in the network as illustrated in Fig. 6 and 7. It is flexible and easily to use for those who are inexperienced in the optical fiber testing by just reading the information gain from the messages. As a final remark, we highlight that our strategy may also be modified to be applicable in the long haul optical communication link or other FTTH schemes.

## V. CONCLUSION

Each status of optical line within a FTTH access network has been investigated using a commercially available OTDR. The proposed MATLAB-based system accumulated all the measurement results from OTDR into a PC screen and accurately determined the faulty fiber as well as identified the failure location in the network system using event identification method. It is a cost-effective way to detect any failure occurs within FTTH to improve the service reliability and reduce the restoration time and maintenance cost.

## ACKNOWLEDGMENT

The authors are 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.

## REFERENCES

- [1] C.H. Yeh, and S. Chi, "Optical fiber-fault surveillance for passive optical networks in S-band operation window," *Opt. Express*, vol. 13, no. 14, pp. 5494-5498, 2005.
- [2] S.S. Gorshe. 2006. FTTH technologies and standards industrial highlights, [Online]. Available: [www.ezcom.cn/English/digital%20library/200612/13.pdf](http://www.ezcom.cn/English/digital%20library/200612/13.pdf).
- [3] L. Lee, S.B. Kang, D.S. Lim, H.K. Lee, and W.V. Sorin, "Fiber link loss monitoring scheme in bidirectional WDM transmission using ASE-injected FP-LD," *IEEE Photon. Technol. Lett.*, vol. 18, no. 3, pp. 523-525, 2006.
- [4] M. Wuilpart, A. Grillet, K. Yuksel, D. Gianone, G. Ravet, and P. Megret, "Dynamics enhancement of OTDR-based monitoring systems for passive optical networks," *Proceedings Symposium IEEE/LEOS Benelux Chapter*, Brussels, pp. 167-170, 2007.
- [5] J. Prat. 2008. Optical networks: towards bandwidth manageability and cost efficiency, [Online]. Available: [http://www.e-photon-one.org/ephotonplus/servlet/Utils.MostrarFitxerPublic?fitxer=D\\_V](http://www.e-photon-one.org/ephotonplus/servlet/Utils.MostrarFitxerPublic?fitxer=D_V)

DA\_3.pdf&pathRelatiu=E-

Photon+One+%2B%2FPublic%2FPublic+Deliverables%2F

- [6] C.K. Chan, F. Tong, L.K. Chen, K.P. Ho, and D. Lim, "Fiber-fault identification for branched access networks using a wavelength-sweeping monitoring source," *IEEE Photon. Technol. Lett.*, vol. 11, no. 5, pp. 614-616, 1999.
- [7] B. Chomycz, *Fiber Optic Installation: a Practical Guide*, McGraw-Hill, New York, USA, 1996.



**Mohammad Syuhaimi Ab-Rahman** received the B.Eng., M.Sc. and PhD degrees in Electrical, Electronics and Systems Engineering from Universiti Kebangsaan Malaysia (UKM), Malaysia, in 2000, 2003, 2007 respectively.

He joined the Institute of Micro Engineering and Nanoelectronics (IMEN) in 2003. He is currently a senior lecturer in UKM, Malaysia. He is also an associated research fellow of IMEN since 2006. His current research interests are in the area of photonic networks and optical communication technologies such as optical security nodes, device fabrication, photonic crystal, laser technology, active night vision, plastic optical fiber, fiber to the home, fiber in automotive and optical code-division multiplexing (OCDM). The current and interest project is development of survivability and smart network system for customer access network then can be called as an intelligent FTTH (*i*-FTTH), collaborated with Ministry of Science, Technology and Innovation (MOSTI) of the Government of Malaysia.



**Boonchuan Ng** graduated from UKM with a B.Eng. in Computer and Communication Engineering in 2008. In July 2008, he joined as a researcher in the Computer and Network Security Research Group, UKM. Currently, he is doing a M.Sc. degree in Electrical, Electronics and Systems Engineering at the Faculty of Engineering and Built Environment, UKM. His current research interests are in the area of optical communication and optical

access network.



**Kasmiran Jumari** is a professor in the Department of Electrical, Electronics and Systems Engineering, UKM. He received the B.Sc. and M.Sc. in Physics and Instrument Design from UKM and University of Aberdeen in 1976 and 1978, respectively. In 1985, he holds a PhD degree in Electronics from University of Kent.

His research is in the area of security system, intrusion detection system, signal processing, image processing and computer communications networks. Currently, he is also hold a position as an associate research fellow of Institute of Space Science (ANGKASA).