Develop a FTTH Network Management System using Visual Basic

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ABSTRACT

This paper proposed an efficient network management software tool named Smart Access Network _ Testing, Analyzing and Database (SANTAD) for remote control, in-service transmission surveillance, centralized monitoring, and fault detection for fiber-to-the-home (FTTH) using Visual Basic programming. A virtual network is setup to operate the software tool from central office (CO) or remote point. This program is able to prevent and detect the occurrence of fault in network system through event identification against optical signal level, attenuation, and losses. SANTAD enable each status of transmission link to be displayed a single screen with capability to configure the attenuation and detect the failure simultaneously.

Keywords

SANTAD, Transmission Surveillance, Centralized Monitoring, Fault Detection, Event Identification.

1.0 INTRODUCTION

FTTH is a broadband network technology that delivering triple-play (voice, video, and high-speed data access) services with a high speed to the home or business via optical fiber cable. 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 (Gorshe, 2006). 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 (Lee, 2006).

Etisalat, Saudi Telecom Co. and Algerie Telecom in the MEA region, France Telecom, Deutsche Telekom and Telefonica in Europe, Korean Telecom in South Korea, NTT in Japan, and AT&T in the United States, are some of the leading operators heading up the promotion of fiber networks in the residential and enterprise markets. Korea, Japan, and Hong Kong are ranking as the top three economies in FTTH penetration on the planet (Zhang, 2008).

FTTH technology using passive optical network (PON) or point-to-multipoint (P2MP) network is the most promising way to provide high quality broadband access. PON has been early described for FTTH as early as 1986. This architecture is called passive because all intermediate equipment between CO (also named as local exchange, remote terminal or head end) and the optical network units (ONUs) are passive, it has no active electronics and therefore does not need separate power (Occam Networks, 2005). OLT is active equipment that corresponds to the demarcation point between the access network and the metro backhaul network; while ONU is active interface between the broadband access network and the customer's phone, computer, television (TV), etc. These equipments perform among others functionalities optical-to-electrical conversion (and vice versa) (Heard, 2008).

The transmission in a FTTH-PON is performed between an OLT installed in CO and customer premises equipment (CPE) placed at the customer residence or in a building. In most FTTH-PON designs, a single optical fiber (feeder fiber) supports up to 32 or 64 end users from CO. The fiber will reach a fiber distribution point (FDP) or passive coupling node close to a neighborhood containing a passive optical splitter (power splitting element/branching device), or in some cases is an Ethernet switch. From the optical splitter or switch will be a single fiber (drop fiber) dedicated to each subscriber (George & Stallworth, 2007). FTTH-PON minimizes the amount of network interfaces, terminations, and fiber deployment.

2.0 FIBER FAULT IN FTTH ACCESS NETWORK

Optical fiber communication systems often use semiconductor optical sources such as light-emitting diodes (LEDs) and semiconductor lasers because of several inherent advantages offered by them. Some of these advantages are compact size, high efficiency, good reliability, right wavelength range, small emissive area compatible with fiber core dimensions, and possibility of direct modulation at relatively high frequencies (Agrawal, 2002). The concept of the semiconductor laser diode was proposed by Basov and Javan. The first laser diode was demonstrated by Robert N. Hall in 1962. Hall's device was made of Gallium Arsenide (GaAs) and emitted at 850 nm in the near infrared region of the spectrum. The first semiconductor laser with visible emission was demonstrated later the same year by Nick Holonyak, Jr. As with the first gas lasers, these early semiconductor lasers could be used only in pulsed operation, and indeed only when cooled to liquid nitrogen temperatures (77 K). The semiconductor laser is similar to other lasers, such as conventional solid state and gas laser, but the output radiation is highly monochromatic and the light beam is very directional (Keiser, 2000).

The wavelength range used in modern optical systems is around 1550 nm (near infrared). In this wavelength region, powers greater than 21.3 dBm emanating from a fiber end are considered to be intrinsically hazardous to the eye. High power levels in optical communications systems are typically associated with the output of optical amplifiers such as erbium doped fiber amplifiers (EDFAs) or Raman fiber amplifiers (Hinton, 2006). The unprotected human eye is extremely sensitive to laser radiation and can be permanently damaged from direct or reflected beams. The site of ocular damage for any given laser depends upon its output wavelength. According to Bader and Lui (1996), laser light in the visible and near infrared spectrum (400 nm - 1400 nm) can cause damage to the retina resulting in scotoma (blind spot in the fovea). This wave band is also known as the retinal hazard region. Meanwhile, laser light in the ultraviolet (290 nm - 400 nm) or far infrared (1400 nm - 10600 nm) spectrum can cause damage to the cornea and/or to the lens. The extent of ocular damage is determined by the laser irradiance, exposure duration, and beam size.

According to the cases reported to the Federal Communication Commission (FCC) in US, more than one-third of service disruptions are due to fiber cable problems. These kinds of problems usually take longer time to resolve compared to the transmission equipment failure (Bakar et al., 2007). Therefore, fiber fault within optical access network becomes more significant due to the increasing demand for reliable service delivery (Prat, 2007).

3.0 OTDR CONCEPT OF DETECTION

Several developed test gears are invented to locate a fiber fault in an optical fiber, such as fault locator and optical time domain reflectometer (OTDR) (Bakar et al., 2007). OTDR was first reported in 1976 (Barnoki & Jensen, 1976) as a telecommunications application and became an established technique for attenuation monitoring and fault localization in FTTH within the telecommunications industry (King et al., 2004). OTDR is a well-known means of testing an optical fiber cable assembly in optical networks. The OTDR launches a very narrow pulse into the fiber and then records the response of the cable/connector assembly to this pulse. Both reflections and absorption can be observed in the cable, providing the troubleshooter with the information needed to diagnose cable problems (Harres, 2006).

The OTDR measurements can easily be transmitted into computer for advanced OTDR analyzing via RS-232 (serial port) connection, high-speed universal serial bus (USB) interface, ActiveX, General Purpose Interface Bus (GPIB), Ethernet Transmission Control Protocol/Internet Protocol (TCP/IP) connection, and extended memory option (manually transfer through floppy disk or USB memory) in a proprietary encoding format such as .TRC (trace). The users can convert the OTDR traces into text file or American Standard Code for Information Interchange (ASCII) format for subsequent use by spreadsheet software such as Microsoft Excel or Lotus 1-2-3.

Conventionally, OTDR is used to identify a fiber fault in FTTH upwardly from ONUs at different customer residential locations toward optical line terminal (OLT) at CO (in upstream direction). Whenever a fault occurs, OTDR is plugged manually to the faulty fiber by the technician to detect where the failure is located. A technician launches an OTDR test from the out-of-service ONU. By means of OTDR, one can get the distance from the fault site to the measurement site along the optical fiber housed in the optical cable (Lu et al., 2006).

According to Chomycz (1996), 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. 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.

However, the optical splitters in FTTH will make the identification of a fiber fault beyond the splitter very difficult. The OTDR testing signal from all the splitter ports is added into one trace in downstream direction as summarized in Figure 1. Therefore it can become very complicated to localize the failure in the correct split branch of FTTH-PON with tree topology (NIC, 2007).

4.0 FTTH NETWORK MANAGEMENT - SANTAD

As FTTH become increasingly popular, an operation system which employs optical fiber lines will also become increasingly important. Naturally, this would involve factors, such as automatic testing for identifying and locating a fiber fault in the optical lines when it occurs, as well as a measure that could be taken that would reduce the time needed to restore the failure. In addition, FTTH is expected to be provided at a low cost to the subscribers, thus it is very important to maintain and operate more efficiently (Okada, 2008).

In an effort to meet this demand, we developed a FTTH network management software tool named SANTAD in this study. SANTAD is a centralized access control and surveillance system that enhances the network service providers and field engineers with a means of viewing traffic flow and detecting any breakdown as well as other circumstance which may require taking some appropriate action with the graphical user interface (GUI) processing capabilities of Visual Basic programming. The working principles of SANTAD are structured into three main parts to support its operations: (i) Measuring optical fiber line with OTDR, (ii) Interfacing OTDR test module with remote personnel computer (PC)/laptop, and (iii) Advanced data analyzing to support its operations.

4.1 Measurement System Configuration

The schematic illustration of the proposed system is shown in Figure 2. A commercially available OTDR with a 1625 nm light source is used in failure detection control and in-service troubleshooting without affecting the triple-play (1310 nm, 1490 nm, and 1550 nm) services transmission. The OTDR will be located at CO for downwardly monitoring from CO towards customer residential locations (in downstream direction). The OTDR testing signal will enter to a tapper circuit to bypass the optical splitter to overcome the monitoring issue.

The OTDR connected to a remote PC/laptop to display the troubleshooting results in a proprietary encoding format with remotely operated and controlled via Ethernet TCP/IP with Standard Commands for Programmable Instruments (SCPI) commands (see Figure 3). The OTDR must be equipped with an Ethernet PC card (either built-in or external) to be connected to a local area network (LAN) to allow direct communication between OTDR with PC (EXFO, 2006). The remote control is used to operate the measurement system running on a remote PC/laptop at CO or point of link control (remote site) for distant monitoring.

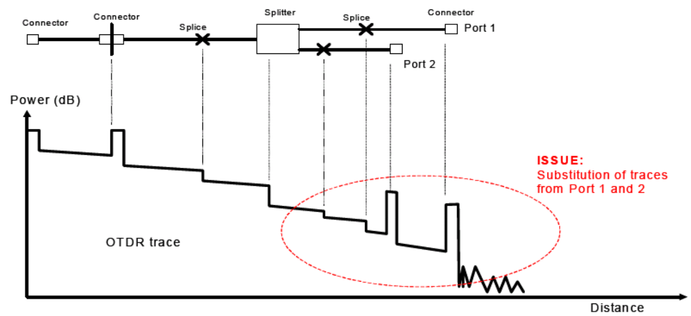

Figure 1: Monitoring issue with using OTDR in the downstream direction (NIC, 2007).

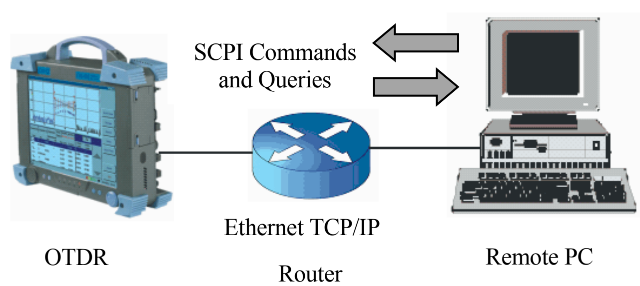

Figure 3: Ethernet remote interface.

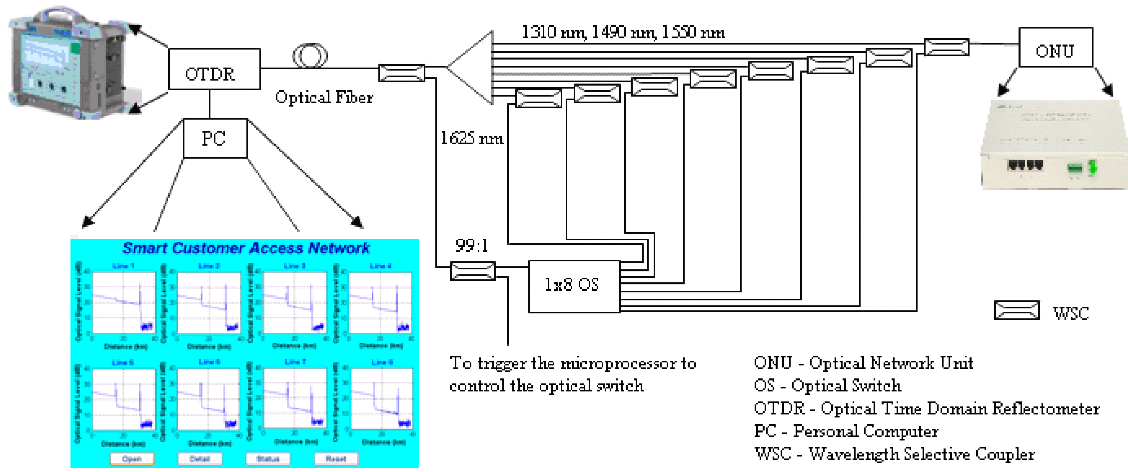

Figure 2: SANTAD is installed at CO for centralized monitoring and fiber fault identification downwardly from CO (in downstream direction)

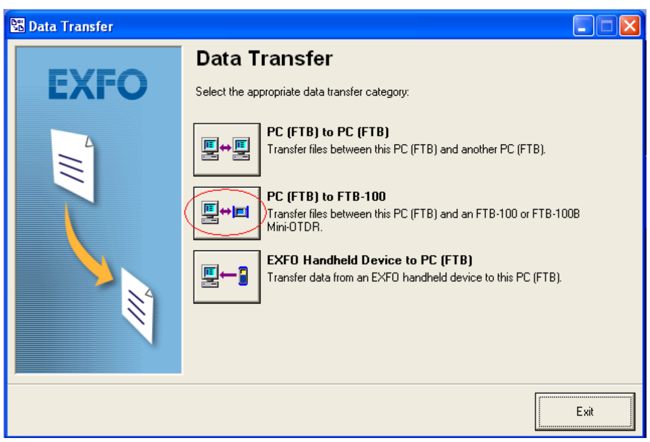

Figure 4: Activate the data transfer application in emulation software.

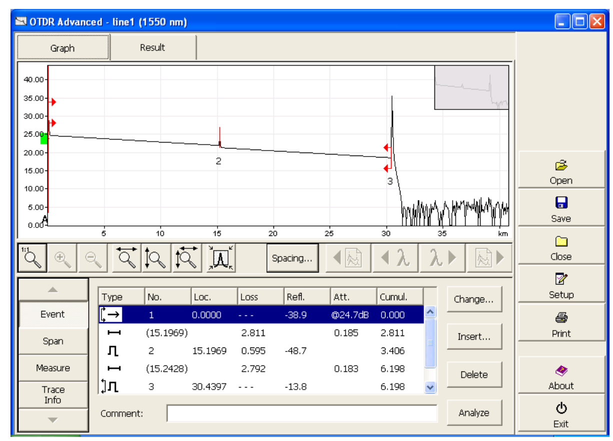

Figure 6: Execution display for line 1 in working condition (in emulation software).

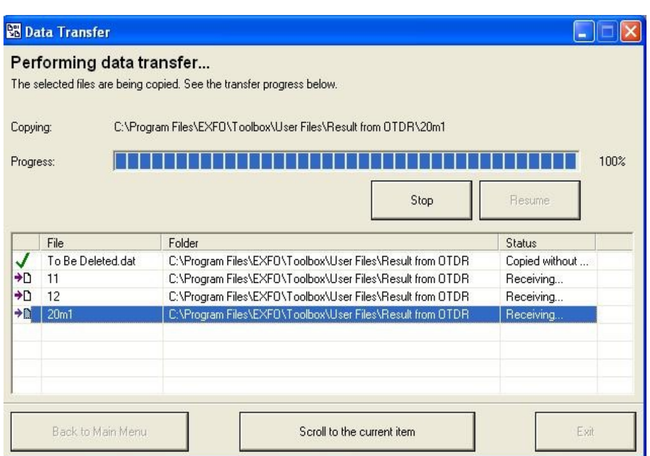

Figure 5: Transferring trace files from OTDR into computer.

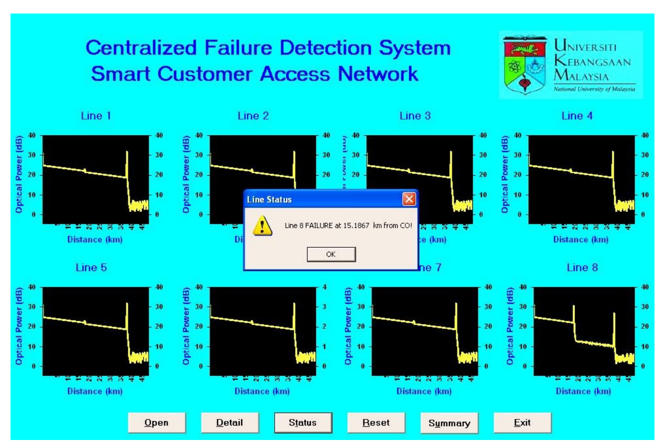

Figure 7: Every eight measurement results are displayed on the *Line's Status* form. A failure message displays to show the faulty line and failure location in the FTTH network system.

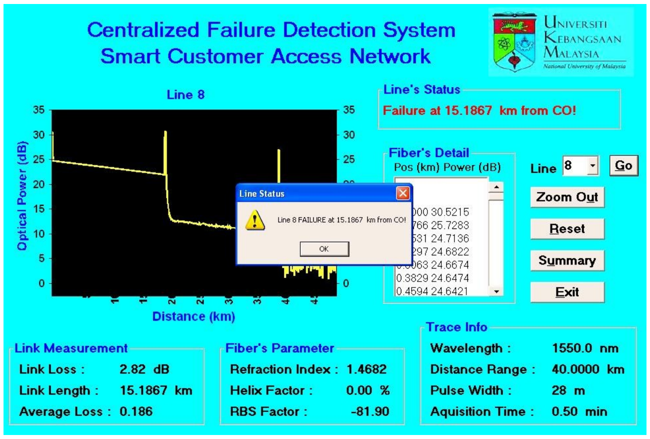

Figure 8: An example of non-working line in the *Line's Detail* form.

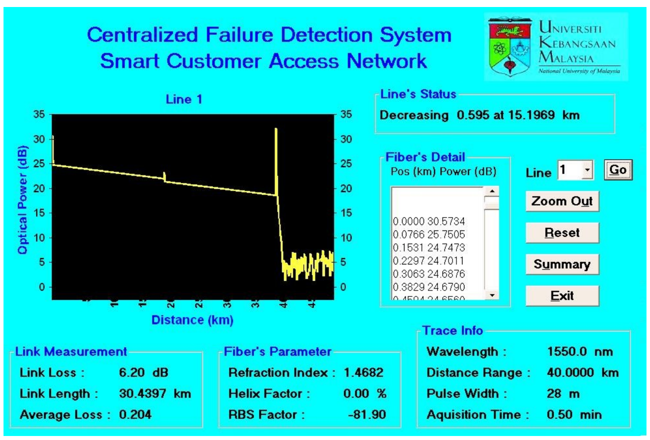

Figure 9: An example of working line in the *Line's Detail* form.

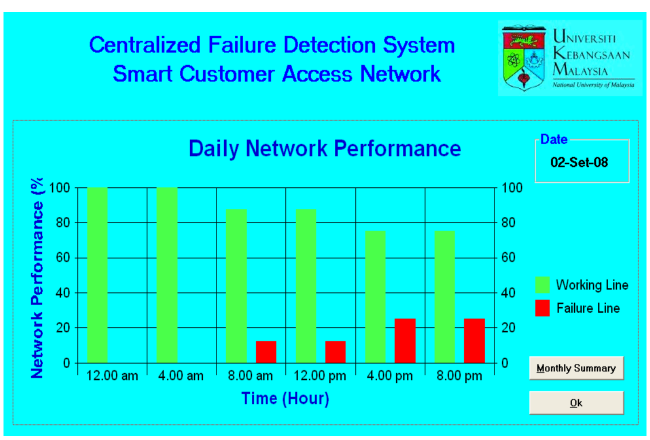

Figure 10: Analysis of the relationship between network failure rate and network performance.

4.2 Alternative Data Achieving with RS-232 Connection

The OTDR measurement for each line is saved in the OTDR and then transferred into PC for advanced data analyzing. The data achieving also can be conducted via RS-232 (serial port) serial ports on both units in case the Ethernet connection is down and RS-232 serial cable (null modem cable) is required to establish the connection. The data synchronization will begin automatically and we have to activate the data transfer application in the OTDR and emulation software (see Figure 4). After completing the data transfer process (Figure 5), we can analyze the results and make any changes as illustrated in Figure 6 and 7. All the results will be saved in database and then loaded into the developed program from database. However, some of the more recent PCs are not equipped with such ports (Serial port and parallel port) (EXFO, 2006).

The network operators and field engineers can communicate easily with the measurement system from anywhere in the world without on-site personnel, e.g. the field engineers and technicians in the field (fiber plant) can receive assistance from CO.

4.3 Advanced Data Analyzing with SANTAD

SANTAD will accumulate every measurement result to be displayed on a single computer screen for advanced data analyzing. The functionalities of SANTAD can be generally be classified into pre-configured protection and post-fault restoration, which can help the network operators and field engineers to perform the following activities in FTTH network system:

1) Events/data recording
2) Further processing of controlling/monitoring information for preventive maintenance
3) Presentation of surveillance image (visual feedback)
4) Provides a control function to intercom all subscribers with CO
5) Monitors and controls the network performance
6) Detect degradations before a fiber fault occurs for preventive maintenance
7) Detects any fiber fault that occurs in the network system and troubleshoots it for post-fault maintenance

SANTAD loaded every 8 measurement from database to be displayed in single PC screen for centralized monitoring as depicted in Figure 8. SANTAD will identify and present the parameters of each optical fiber in the network system such as the fiber's status either in working (good/ideal) condition or non-working (breakdown/failure) condition, magnitude of decreasing as well as the location, failure location, and other details as shown in the OTDR's screen with the GUI processing capabilities of Visual Basic programming (see Figure 8 and 9).

The functionalities of SANTAD involve the fault detection, notification, verification, restoration, and documentation (recording fault). Fault prevention is aims to prevent any failure from happening. Even with the fault prevention mechanisms, failures will still occur, so fault detection techniques need to test each optical line in order to detect potential faults and precisely address the exact failure location. SANTAD can tracks small changes based on the optical signal level (input/output power) and losses (connection losses, splice losses, optical device/component losses, fiber losses or attenuation) at each point for the preventive maintenance purposes. By in-service monitoring with SANTAD, the field engineers can view the service delivery and detecting any circumstances which may require some promptly action before it turns into big trouble and causes a tremendous financial loss.

With detected alarms, fault identification processes will diagnose and determine the real causes. Appropriate recovery actions are taken to treats the link and fiber fault. SANTAD stores the analysis results in database for further processing and queries. All kinds of additional information can be easily accessed and queried later. The database system enables the history of happens frequently in one fiber/device/component at the same location (same point), it should be replaced network scanning process be analyzed and studied by the field engineers. The network service providers and field engineers can first establish the relationship between network failure rate and network performance based on measurements and statistics (Figure 10). The relationship between network failure rate and network performance can be monitored by SANTAD 24 hours a day and 7 days a week.

5.0 CONCLUSION

We had successfully developed SANTAD for FTTH with Operation, Administration, and Maintenance (OAM) features in order to improve the service reliability and reduce the restoration time and maintenance cost. SANTAD is installed at CO for downwardly monitoring from CO towards customer residential locations. SANTAD accumulated all the OTDR measurements to be displayed on a PC screen and addressed the failure location in the network system using event identification method. SANTAD is able to prevent and detect the occurrence of fiber fault in network system and as well as self-protect and auto recovery the fiber fault and failure link.

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