

Identifying Fiber Fault in Fiber to the Home Using Access Control System

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ABSTRACT

This paper proposed a design of identifying fiber fault in fiber-to-the-home passive optical network (FTTH-PON). Our design works on a standard local area network (LAN) using a specially designed hardware interfaced with a microcontroller integrated Ethernet to monitor the status of optical signals flow and provide the restoration against fiber fault in FTTH. This design will be implemented with optical line terminal (OLT) at central office (CO) to monitor and control each optical fiber line's status as well as detect any failure that occurs in the network system downwardly from CO towards multiple optical network units (ONUs).

Keywords

Fiber Fault, FTTH-PON, ACS

1.0 INTRODUCTION

Live monitoring technologies have been used to reduce the time and manpower to detection failure in optical access network. Currently FTTH has become one of the hottest technologies implemented in PON application. The PON is a promising architecture in optical access networks. The access network, which links the central office to the customer's premises, is of key importance in supporting the emerging triple-play service era. To guarantee quality of service through the PON, monitoring techniques should be provided under the in-service state through both fault diagnosis and maintenance.

Monitoring tool for detecting failure in optical access networks is traditionally set up on dark fiber as this provides good balance between material cost, system provisioning effort and fault detection success rate. Most identification systems used for physical fault detection and positioning employ optical time domain reflectometer (OTDR) (Chen, 2007). In a PON topology, fiber fault detection by OTDR is not suitable because the Rayleigh back-scattered light from different branches

cannot be distinguished at the OTDR (Integrated Publishing, 2008). To overcome this drawback, several methods have been proposed (Bakar et al, 2007; Yeh et al, 2006).

2.0 ACCESS CONTROL SYSTEM

ACS 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 with the graphical user interface (GUI) processing capabilities. ACS integrated Ethernet is using the operating wavelength 1625 nm for failure detection control and in-service troubleshooting. The triple-play services operating wavelengths (1310 nm, 1490 nm and 1550 nm) are multiplexed with a testing signal (1625 nm) from OTDR. The OTDR is installed in the OLT and will be connected to a PC to display the troubleshooting result. The detailed diagram for ACS scheme is shown in figure 1.

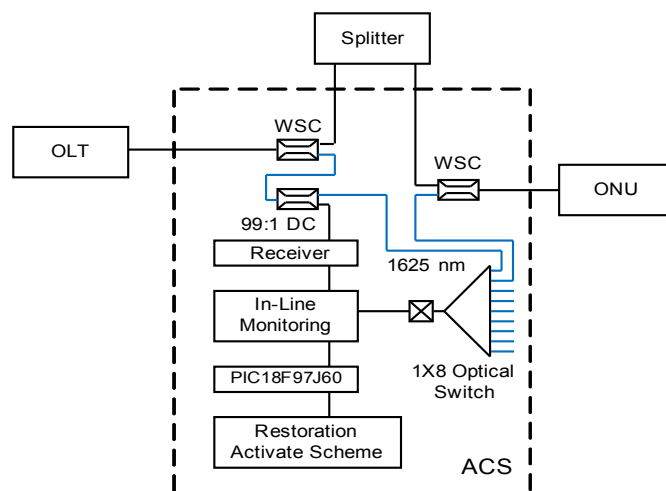


Figure 1: ACS scheme

When four kinds of signals are distributed, the testing signal will be split up by the Wavelength Selective Coupler (WSC) which is installed before the splitter. The WSC only allow the testing signal at 1625 nm 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 splitter before it reaches the ONUs. The distance between the OLT and ONU is about 20 km. 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 to activate the ACS. 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 ACS system that is activated by 1% of 1625 nm signal.

The principal limitation to live fiber monitoring at 1625 nm, will come from the spontaneous Raman scattering noise that reaches the OTDR port. In case of bidirectional transmission, OTDR power and transmission power levels may require adjustments so that effect remains negligible.

Access Control System (ACS) is control the status of any optical switch device connected to it and transmits its status to the PIC18F97J60. Its then arranges the information in the form of a packet and transmits it over the LAN using the embedded Ethernet system. It consists of four major parts, PIC18F97J60 microcontroller integrated Ethernet, 1x8 optical switches, wavelength selective coupler (WSC), directional coupler (DC), receiver, In-Line Monitoring (ILM) and Restoration Scheme Activate (RSA). Generally, ACS is integrated in a single system, which also includes splitter, OTDR and personal computer (PC). 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 (Rahman, 2008)

2.1 Optical Switch

In fiber optic networks, light signals are transmitted along optical fibers to transfer information from one location to another. Optical switches are used to selectively couple light from an input fiber to an output fiber. Fiber optic switching is an important component in any telecommunication system. These systems use switches to establish communication

channels among two or more of their interfaces. Fiber optic switches have been developed for selectively switching optical signals from one fiber to another fiber. An optical fiber switch is capable of optically connecting, or aligning, any one of a first group of optical fibers with any one of a second group of optical fibers, or vice versa, enabling an optical signal to propagate through the optical interface junction from one fiber to the other. Switching for these fibers has previously been achieved with optoelectronic devices. Optical fibers are coupled with circuitry that permits the switching to be done electrically, and then the electrical signals are converted back to optical signals for further transmission. Optical switching technology's main advantage is to route optical data signals without conversion to electrical signals, resulting in the independence of data rate and data protocol. In general a pure optical switch routes beams of light with encoded data from one or more input optical fibers to a choice of two or more output optical fibers.

An optical switch can uses to monitoring and measurement. The device has optimized mechanical latching system combined with a prism, and used in specialized systems such as optical network. A switch that enables signals in optical fibers or integrated optical circuits to be selectively switched from one circuit to another, or may be used for alternate routing of an optical transmission path, e.g., routing around a fault (The Omron Electronic Component Website, 2008).

2.2 Ethernet Module

The Ethernet Module System is designed to transmit the status of optical switch device connected to our system over the LAN or internet connectivity applications through Ethernet connection.

The PIC18F97J60 microcontroller with integrated Ethernet is a complete connectivity solution, including full implementations of both Media Access Control (MAC) and Physical Layer transceiver (PHY) modules. Two pulse transformers and a few passive components are all that are required to connect the microcontroller directly to an Ethernet network (The Microchip Website, 2008).

The Ethernet module consists of the five major functional blocks:

- The PHY transceiver module that encodes and decodes the analog data that is present on the twisted-pair interface and sends or receives it over the network
- The MAC module that implements IEEE 802.3 compliant MAC logic and provides Media Independent Interface Management (MIIM) to control the PHY.

- An independent, 8-Kbyte RAM buffer for storing packets that have been received and packets that are to be transmitted.
- An arbiter to control access to the RAM buffer when requests are made from the microcontroller core, DMA, transmit and receive blocks.
- The register interface that functions as an interpreter of commands and internal status signals between the module and the microcontroller's SFRs.

To complete the Ethernet interface, the Ethernet module requires several standard components to be installed externally. These components should be connected as shown in figure 2. The internal analog circuitry in the PHY module requires that an external resistor (2.26 k Ω) be attached from RBIAS to ground. The resistor influences the TPOUT+/- signal amplitude. It should be placed as close as possible to the chip with no immediately adjacent signal traces to prevent noise capacitively coupling into the pin and affecting the transmit behavior. It is recommended that the resistor be a surface mount type.

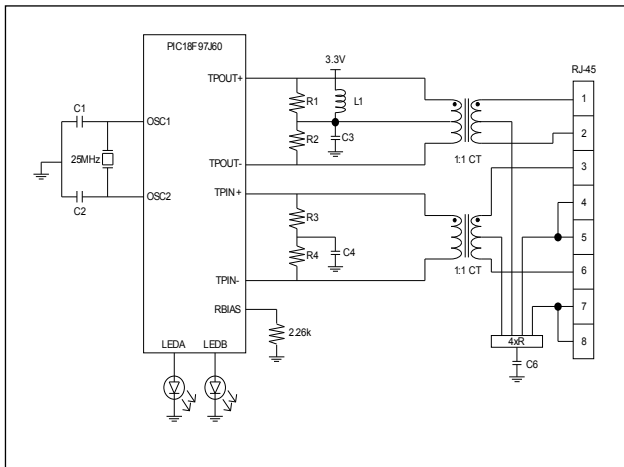


Figure 2: External components for Ethernet module

The Ethernet module is designed to operate at 25MHz. This is provided by the primary microcontroller clock either with a 25MHz crystal connected to the OSC1 and OSC2 pins or an external clock source connected to the OSC1 pin. It uses three independent memory spaces for its operations:

- An Ethernet RAM buffer which stores packet data as it is received and being prepared for transmission.
- A set of 8-bit Special Function Registers (SFRs), used to control the module and pass data back and forth between the module and microcontroller core.
- A separate set of 16-bit PHY registers used specifically for PHY control and status reporting.

Now at this point it must be mentioned that the connection to Ethernet through the RJ-45 connector requires the standard twisted pair for transmission or the TX+/TX- and also the twisted pair for RX+ and RX- (PIC18F97J60 Family Data Sheet, 2008)

3.0 EXPERIMENTAL SETUP

Figure 3 shows the experimental setup to demonstrate the proposed fault monitoring in FTTH-PON. For ACS, coupler, and WSC were used at the CO. We used the 10km single mode fiber to connect the OLT with the optical splitter. To implement a single fiber FTTH-PON, we as signed operating wavelength 1625 nm for the downstream and monitoring signals. In this experiment, the upstream traffic was not considered. The ONU were signed for the upstream traffic and the fault monitoring signals, respectively, and transmitted to the OLT. The OTDR was used as the broadband light source. The wavelength selective couplers (WSCs) in both the OLT and the ONU separate the wavelength 1625 nm monitoring signals. At the OLT, the upstream data signal and the reflected monitoring signal assigned to each ONU separated by the WSC were received by the ACS. In case of an upstream transmitter failure, the pin receiver not receive the data signal, but the monitoring ACS can detect the power of the monitoring signal without intermission. If a distribution fiber cut occurs, the pin receiver and the monitoring ACS can not receive the data signal and detect the optical power, respectively.

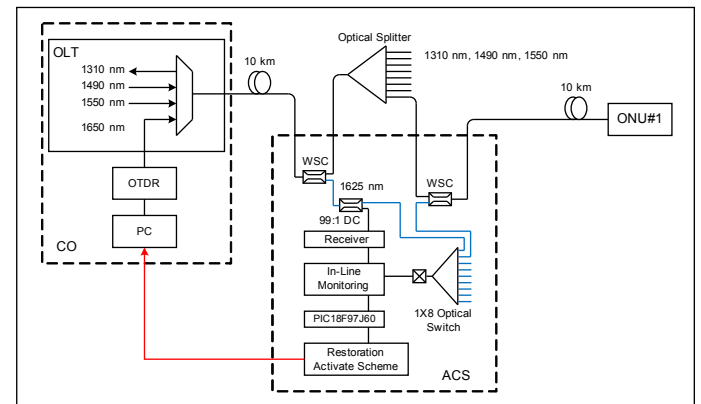


Figure 3: Experimental setup

4.0 RESULT AND DISCUSSION

ACS send 3 bits signal to optical switch and send or received 1 bits signal ready to control and scans route line of each ONU connected to optical switch, respectively. When a failure occurs, which result in low input from optical switch, ACS will send signal to CO through internet. The EXPO FTB-400 optical time domain Reflectometer (OTDR) was used as the CO and a

wavelength of 1625 nm was used to monitor one of ONU in end users to verify fault localization.

To show the performance of the proposed optical switch, table 1 shows the working condition of optical switch of the proposed real-time fiber monitoring. Therefore, by monitoring of the optical switch route of the proposed ACS scheme can be detected the line faults.

Table 1: *Input/output optical switch.*

Route Optical Switch	Input Terminal			3 bit Command	Output Ready (RDY)
	D0	D1	D2		
Line 1	L	L	L	000	1
Line 2	L	L	H	001	1
Line 3	L	H	L	010	1
Line 4	L	H	H	011	1
Line 5	H	L	L	100	1
Line 6	H	L	H	101	1
Line 7	H	H	L	110	1
Line 8	H	H	H	111	1

To demonstrate the fault monitoring function, we simulated a fiber cut on the path and transmitter failure using a 1x8 optical switch. Table 2 shows the fault monitoring characteristics for failure at the line fiber network.

Table 2: *Fault characteristic.*

Route Optical Switch	Input Terminal			3 bit Command	Output Ready (RDY)
	D0	D1	D2		
Line 1	L	L	L	000	1
Line 2	L	L	H	001	1
Line 3	L	H	L	010	1
Line 4	L	H	H	011	0
Line 5	H	L	L	100	1
Line 6	H	L	H	101	0
Line 7	H	H	L	110	0
Line 8	H	H	H	111	1

And to simulate the fault identification process, figure 4 shows the curve of optical power output of the proposed fiber line monitoring when the fiber line 4, 6 and 7 are broken by the external force application. The solid line indicates the normally operation from fiber line 1-3, 5 and 8, and the dotted line shows the fiber fault behavior when the fiber line 4, 6 and 7 are disconnected. The experimental results show that our proposed scheme is very feasible.

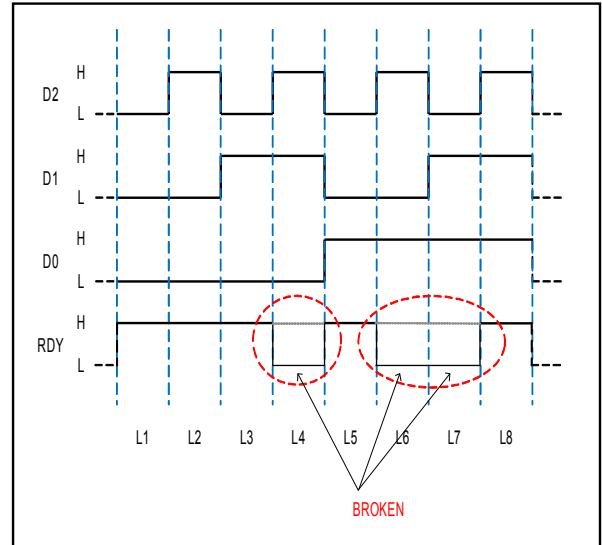


Figure 4: The curve of optical power output of the proposed fiber line monitoring when the fiber line 4, 6 and 7 are broken by the external force application

The status of each line is automatically updated to a web server which can access by remote monitor via internet or LAN. At the CO, the network operator can read the status of each fiber line timely through some web browsers such as Internet Explorer, as shown a figure 5.

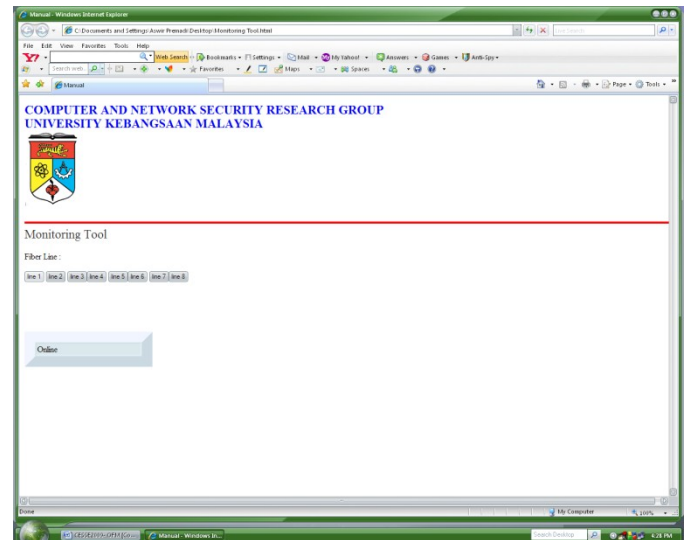


Figure 5: Web-page monitoring

Measurement for each fiber line saved in the OTDR in trace (TRC) file and then transferred into the computer through a serial port extension cable. This process involved the data exploitation and data receiving. After completing the process, the results need to be converted into American Standard Code for Information Interchange (ASCII) form. And then all the results are saved in database. Every 8 testing results displayed

on a computer screen for further analysis as depicted in figure 6. Every 8 graphs that represented the characteristics of optical lines displayed in Linestatus window, where the distance (km) represented on the x-axis and optical signal level (dB) represented on the y-axis.

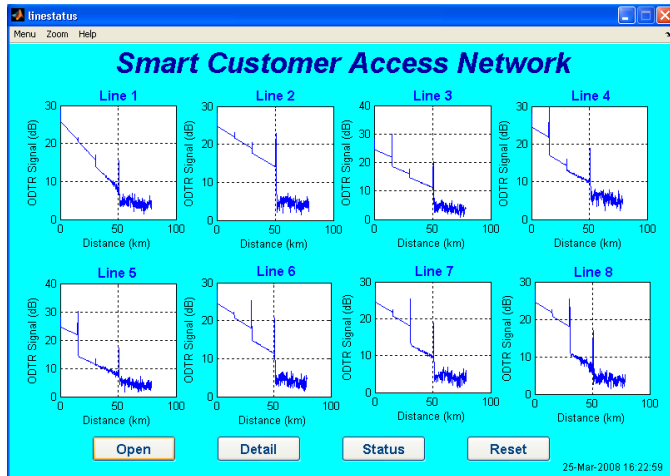


Figure 6: Every 8 graphs display in Linestatus window

The monitoring scheme of a FTTH-PON using ACS has been proposed, we have designed an efficient and cost-effective system for PON appliances. It was successfully identified without affecting communication signal transmission, with the specification available a complete system can be made with 24 man-hours. It will to improve the service reliability and reduce the restoration time and maintenance cost.

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