Advancement of Monitoring Scheme in FTTH-PON Using Access Control System (ACS)

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Abstract

This paper proposes a new developed system named Access Control System (ACS) which is designed to enhance the monitoring, scalability and survivability of Passive Optical Network (PON) toward the implementation of full & Complete edition of Fiber-to-the Network (FTTH) network. The system automatically identifies faults and controls each optical fiber line to provide the restoration against failure in the drop region of PON downwardly from optical line terminal at the central office to the optical network unit of the subscriber. ACS manages the Optical Time Domain Reflectometer (OTDR) troubleshooting wavelength to enable the status of each line which can be displayed onto one single screen in the central office. Our proposed mechanism in this paper is the first reported thus far.

Keywords: ACS, monitoring, path routing, experimental, FTTH-PON

1. **Introduction**

In the PON era, it is expected that broadband network provision will require thousands of optical fibers to be accommodated in a central office (CO) for the optical access network. Optical fiber is capable of delivering bandwidth-intensive integrated, voice, data and video services at a distance beyond 20 km of the subscriber access network. All transmissions in a PON are performed between the optical line terminal (OLT) and optical network unit (ONU). The OLT resides in the central office, connecting the optical access network to the metro back-bone, and the ONU is located at the end-user location. Optical fiber maintenance is a very important issue to be considered in developing high quality and reliable PON. The long feeder line in a PON is a vulnerable part of the network; when unprotected, if breaks; will put the whole PON out of service. A type of network protection which was described in Telecommunication Standardization Sector (ITU-T) Recommendation G.983.1, is-shown in Figure 1. The figure illustrates the protection scheme of the feeder fiber using only a spare fiber over which the traffic can be rerouted by means of optical switches.

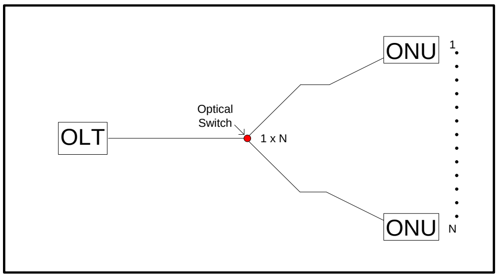


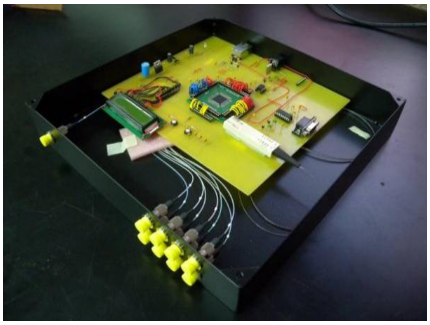
Figure1. Protection Scheme: feeder fiber as referred to ITU-T Recommendation G.983.1

Monitoring equipment for detecting break in optical fiber networks is traditionally set up on dark fiber as this provides good balance between the cost of material, system provisioning effort and fault detection success rate. Most monitoring systems used for physical fault detection and positioning employ OTDR [1]. In PON topology, fiber fault detection by OTDR is not suitable because the Rayleigh back-scattered light from different branches could not be distinguished at the OTDR. To overcome this drawback, several methods have been proposed [2, 3].

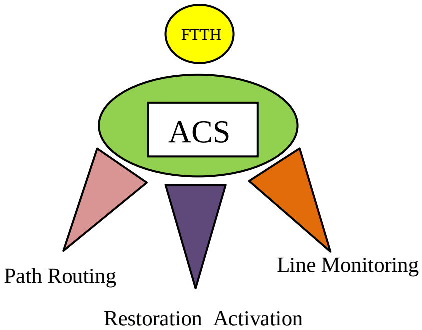
2. **Access Control System Architecture**

In this study, we design the ACS scheme for PON protection with the objective to reduce the cost and misspend time. This scheme controls the status of any optical switch device connected to it and transmits its status to the PIC18F97J60 microcontroller. It then arranges the information in the form of a packet and transmits it over the LAN using the embedded Ethernet system. The ACS developed prototype is shown in Figure 2 (a). The ACS function support is depicted in Figure 2 (b), which three function can be addressed by ACS to enhancement the efficiency, flexibility, survivability of optical passive FTTH network. Refer to Figure 2 (a), the directional coupler is not included as the survivability is not discussed and this paper will focus specifically on the path routing. Meanwhile, the wavelength selective coupler was installed externally during the network testing.

An optical switch can be used for monitoring and measurement. A switch is included 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 [4]. If breakdown occurs in the feeder section, ACS will send a signal to activate the dedicated protection scheme. However, if the breakdown is the detected in the 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 activate the dedicated protection scheme. Yet, if the 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 signal is sent by the activation section in ACS [5].



(a)

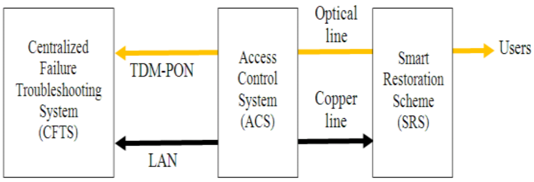


(b)

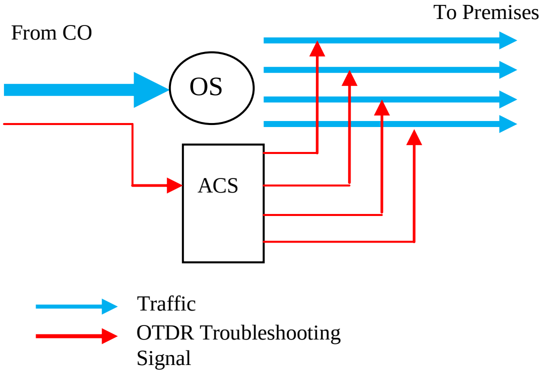
Figure 2. Diagram of Access Control System (ACS) (a) Prototype (b) Functional

3. Path Monitoring Control

In the proposed system design, the optical network system (FTTH-PON) is integrated with conventional asymmetric digital subscriber line (ADSL) network as illustrated in Figure 3 (a). The FTTH-PON uses fiber to carry information signal, meanwhile the ADSL uses metallic wire to carry control signal. The ADSL is used as the access control network to activate the installed devices/elements in the network system. Besides, if the optical network goes down, ADSL will be used for high priority signal communications. The mechanism of path routing is depicted in Figure 3 (b) which show the ACS is used to diverted the OTDR test signal across the optical splitter to enable every signal line connected to premises can be monitored.



(a)



(b)

Figure3. (a) The integration of FTTH-PON and ADSL network (b) The mechanism of path routing implemented in FTTH-PON by using ACS and OTDR

4. Experimental: Control and Optical Switching

We have proposed survivability scheme through optical switch based on microcontroller on a FTTH-PON network testbed at the Networking System Laboratory in Universiti Kebangsaan Malaysia (UKM), Malaysia. This experimental lock diagram is similar to Figure 3(a). Each ONU is connected to optical splitter output terminal by two fibers; working line and protection line through optical switch that is controlled by ACS. In this experiment, ACS is used to monitor the status of both working line and protection line. ACS recognized the types of failure and sent the activation signal to the related optical switch according to the activated protection mechanisms. To locate a failure without affecting the transmission services to other customers, it is essential to use a wavelength different from the triple-play services operating wavelengths (optical signals; 1310 nm, 1490 nm, and 1550 nm) for failure detection. ACS integrated Ethernet is using the 1625 nm testing signal for failure detection control and in-service troubleshooting. The triple-play signals are multiplexed with 1625 nm testing signal from OTDR. The OTDR is located at the CO and connected to a remote personal computer (PC) to display the troubleshooting result. 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 optical splitter. The WSC coupler only allows the 1625 nm testing signal enters into the taper circuit and rejects all unwanted signals (1310 nm, 1490 nm, and 1550 nm) that contaminate the OTDR measurement. The downstream signal will go through the WSC coupler which in turn connected to a splitter before it reaches the ONUs. On the other hand, the 1625 nm testing signal which is demultiplexed by WSC coupler will then be configured by using optical switch in which each output is connected to a single line of ONU. The operational of optical switch is controlled by ACS system that is activated by LAN. This section presents the results obtained from switching mechanism in the ACS. Two power meters are used to measure the signal. The wavelength used in the experiment is 1550 nm instead of; in actual operation the 1625 nm is used (if use OTDR). Figure 4a shows the experimental set up on ACS switching and Figure 4b show the ACS web controller in which the operation of ACS is controlled. The diagram of the experimental set up is shown in Figure 5. The result of power meters reading of each 1x8 optical splitter line is seen in Figure 6.

(a)

(b)

Figure 4. remotely switching performed by ACS a) Diagram of experimental set up b)Web based control system

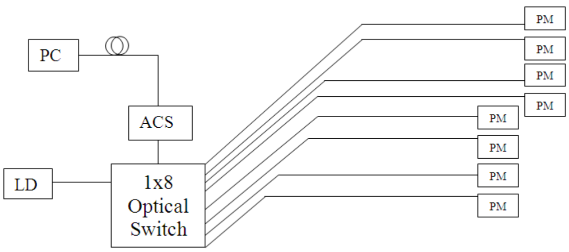


Figure 5. Block diagram of ACS remotcontrol switching experimental set up

Figure 6. The optical power measured which pass through the optical splitter. The optical switch is controlled remotely by ACS

5. Smart Access Network Testing, Analyzing and Database (SANTAD)

SANTAD is a centralized access control and surveillance system that enhances the network service providers by means of viewing traffic flow and detecting any breakdown as well as other circumstances which may require taking some appropriate actions via the graphical user interface (GUI) of Visual Basic programming.

The working principles of SANTAD are structured into three main parts to support its operations: (i) Optical monitoring with OTDR, (ii) Interfacing OTDR test module with PC, and (iii) Advanced data analyzing with SANTAD. A commercial available OTDR is equipped with Ethernet PC card to be connected to Ethernet LAN to allow direct communication between OTDR and PC. The remote control function is used to operate the OTDR measurement system running on a remote PC at CO or point of link control (remote site) for distant monitoring. Communication is achieved via standard commands for programmable instruments (SCPI), which are used for setup and results readout functions. By using SANTAD together with a PC or laptop equipped with modem or LAN connection, the field engineers and technicians can communicate easily with the OTDR test module from anywhere in the world without on-site personnel, e.g. the field engineers and technicians at the field (fiber plant) can receive assistance from CO.

The functionalities of SANTAD can be generally classified into pre-configured protection and post-fault restoration, which can help network operators and field engineers in FTTH-PON network system to perform the following activities:

- Monitors and controls the network performance
- Detects degradations before a fiber fault occurs for preventive maintenance
- Detects any fiber fault that occurs in the network system and troubleshoots it for post-fault maintenance

SANTAD accumulated all OTDR measurement into a single computer screen for advanced data analyzing. SANTAD is focusing on providing survivability through event identification against losses and failures. A failure message "*Line x FAILURE at z km from CO!*" will be displayed to notice the failure to the network operators and field engineers if SANTAD detects any fiber fault in the network system. The failure location was identified by a drastic drop of optical signal level. To obtain further details on the performance of specific line in the network system, every measurement results obtained from the network testing are analyzed in the *Line's Detail* form. SANTAD is able to identify and present the parameters of each optical fiber 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.

6. 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. In normal operation (good condition), it allows the network operators and field engineers to determine the path used by the services through the network, whereas under failure (breakdown) conditions, it allows the fields engineers to identify the faulty fiber and failure location without making a site visit. SANTAD enables network operators and field engineers to analyze the optical fiber line's status, display the line's detail, track the optical signal level, and losses as well as monitor the network performance. SANTAD ensures that when the detection of a fiber fault occurs on the primary entity in optical access network, it will automatically reports the failure status to the field engineers, and the field engineers can determine sharply the break point before taking some appropriate actions. In the meantime, it activates the restoration scheme to switch the traffic from failure line to protection line to ensure the traffic flow continuously. This functionality alerts the service providers and field engineers on any fiber fault before being reported by the customer of premises or subscribers.

The simulation results are illustrated in Figure 7. Figure 7 shows the capability of SANTAD to configure the optical signal level and attenuation/losses through event identification method. To obtain further details on the performance of specific testing line in the network system, every measurement results obtained from the network testing are analyzed in the *Line's Detail* window as depicted in Figure 8. SANTAD is able to identify and present the parameters of each optical fiber 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.

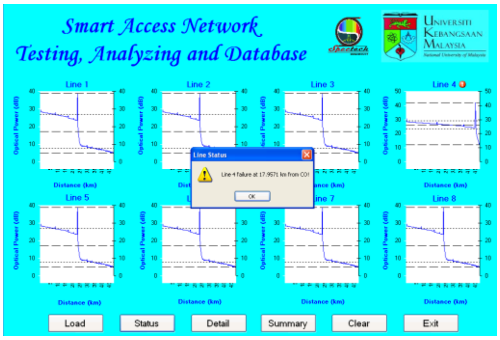


Figure 7. A failure message displayed for every eight graph

7. Conclusions

The survivability of a PON monitoring and restoration with microcontroller has been proposed. With a unique combination of the hardware and software, 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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