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Installation and Field Testing of Video Delivery System

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ABSTRACT

This research studies the optical signal level (transmission loss) and video quality of 1550 video signal delivery system in Passive Optical Network (PON)-based intelligent fiber-to-the-home (*i*-FTTH) for performance monitoring purposes. A simple Optical Power Meter (OPM) loss measurement method is used to fast trace any degradation or failure that occurs in a PON-based *i*-FTTH network testbed during installation testing and field testing. The link loss for each branch is compared with the reference loss for determining the current condition based on the measurement analysis without using Optical Time Domain Reflectometer (OTDR). The video signals received from customers' locations are observed to verify the current condition of each fiber link. The disrupted signal in failure line is diverted to protection line, but the noise is higher due to extra loss. The level of modulator and gain of Erbium-Doped Fiber Amplifier (EDFA) are adjusted in order to obtain better quality of video signals.

Key words: Transmission loss, video quality, performance monitoring, PON-based *i*-FTTH, OPM

INTRODUCTION

With the expansion of Internet services, backbone networks have experienced significant growth in bandwidth capacity to satisfy the ever-increasing bandwidth demand of network users when using high-speed services. Compared with the current access network technologies, PON technologies are a promising solution for the full service access network, since optical fiber can satisfy the increasing bandwidth demand. The PON architecture consists of a centralized Optical Line Terminal (OLT), splitter and connects a group of associated Optical Network Units (ONUs) over point-to-multipoint (P2MP) topologies to deliver broadband packet and reduce the cost relative to maintenance and power (Hwang *et al*., 2009).

The main challenge of developing a high speed broadband network is the fast failure detection since the fiber cuts or equipment failures cause tremendously financial loss to Network Service Providers (NSPs) as well as the customers. Intelligent Fiber-To-The-Home (*i*-FTTH) is associated with centralized monitoring, failure troubleshooting, protection switching and automatic recovery features for conventional PON-based FTTH. The design of PON-based *i*-FTTH consists of 3 main systems: (1) Centralized Failure Detection System (CFDS), (2) Access Control System (ACS) and (3) Customer Access Protection Unit (CAPU).

CFDS is a centralized troubleshooting system for centralized monitoring and degradation/failure detection from Central Office (CO) towards customer residential locations in downstream direction. ACS is deployed at middle of the network system for bypassing the 1625 nm OTDR testing signal from optical splitter and responsible to route it to each individual fiber link in drop section as well as control the mechanisms of troubleshooting mechanism carried out by CFDS and restoration mechanism carried out by CAPUs. Special customized made Wavelength Selective Coupler (WSC) coupler is designed to separate or combine triple play signal and 1625 nm OTDR signal in a single optical fiber according to frequencies. A functional programming PIC microcontroller controls the optical path routing process of 1×8 optical fiber switch in PON-based i-FTTH for every 33 sec.

CAPU is implemented at the end-users side just before ONU to perform self-restoration against fiber failures. Each CAPU consists of 1 unit 2×1 optical switch and 1 unit 2×2 optical switch. It has 3 input ports to receive signals form main line, its own protection line or neighbor protection line as well as 2 output ports to send signals to ONU or neighbor protection line. Any failure/breakdown occurs in the network system will be restored by switching the distributed signals to protection line by CAPU that coupled with Asymmetric Digital Subscriber Line (ADSL) copper wire from CO through ACS. In case of both working line and protection line is failure, the disrupted traffics can be recovered by using neighbor protection line.

Figure 1 shows PON-based *i*-FTTH system architecture with the application of these 3 main systems. These 3 main systems previously had been introduced by Ng *et al*. (2010a). Besides using in-service OTDR measurement method as presented by Ng *et al*. (2010d), we study and analyze the optical signal level (transmission loss) in each branch of PON-based *i*-FTTH to detect and locate the degradations/failures for performance monitoring purposes based on the communication signals (1310, 1490 and 1550 nm).

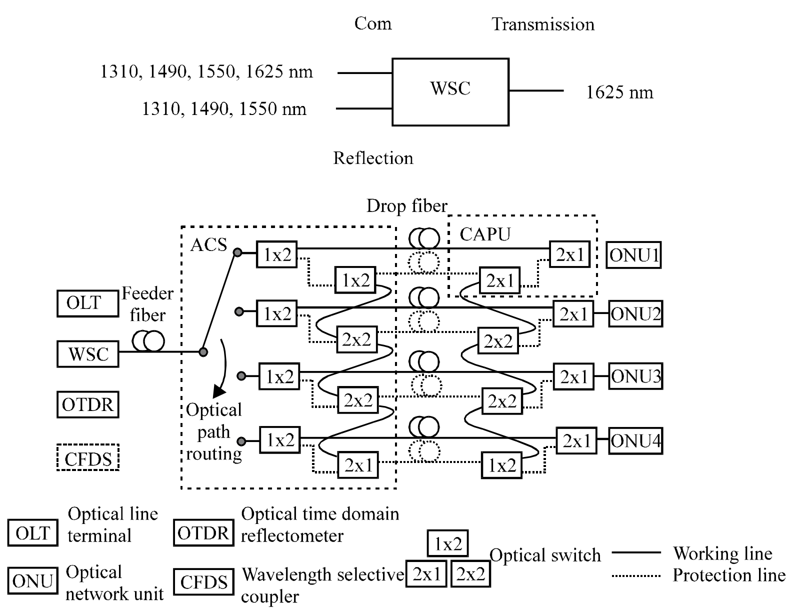

Fig. 1: PON-based intelligent fiber-to-the-home (*i*-FTTH) system architecture. (a) Design structure of WSC coupler and (b) Schematic diagram for CFDS, ACS, and CAPU

Generally, optical power, Optical Signal to Noise Ratio (OSNR) and channel center wavelength are considered as the most important performance parameters which can be accurately measured. Among these optical performance parameters, optical power is the most convenient and direct performance parameter to reflect network status. Therefore, failure detection and localization based on real-time optical power analysis is regarded as an ideal solution (Huang *et al*., 2010).

Failures is defined as the faults and attacks that may lead to the unexpected power variations and can interrupt the ideal functioning of the network. An "attack" defined as an intentional action against the ideal and secure functioning of the network. Attacks can broadly be classified as eavesdropping or service disruption and could differ in nature ranging from malicious users (i.e., users inserting higher signal power) to eavesdroppers. While traversing an optical fiber or optically transparent network elements in optical network, an optical signal can be affected by some significant miscellaneous failures such as fiber cuts, power jamming attacks (within optical amplifiers), crosstalk attacks (within routing and switching nodes) and correlated jamming attacks (tapping attacks). As a result, these impairments aggregate and their impacts on the signal quality become larger as the signal progresses towards its destination. These failures can be classified into 4 categories based on the effects they inflict on the signal: power drop in-band jamming, out-band jamming and wavelength misalignment (Mas *et al*., 2005).

These 4 failures cover most of the failures that may occur in optical network. In this study, we just consider 2 kinds of failures: link failure caused by fiber cut and device failure. These 2 failures can spread rapidly through the network. The term link refers to a unidirectional fiber link between two nodes. Link failure is common in network and usually caused by fiber cut. A fiber cut usually occurs due to a duct cut during construction or destructive natural events, such as earthquakes, etc. All the light paths that traverse the failed fiber will be disrupted so a fiber cut can lead to tremendous traffic loss (Li and Ramaswami, 1997). For device failure, we mainly consider the failures of ASC, as ASC is the most important and complicated element in PON-based *i*-FTTH.

INSTALLATION TESTING ON PON-BASED *I*-FTTH NETWORK TESTBED

OPM is a test instrument used for absolute optical fiber power measurement as well as fiber optic loss related measurement. Typically, OPM and light source are used together to measure the transmission loss (optical signal level) in a fiber or optical device. The light source launches the light into one end of the fiber, while the OPM (display and measurement unit) is connected to the other end to measure the received optical power and the wavelength being measured is displayed. A series of experiment were carried out to determine the loss contributes by optical components and devices before the installation of PON-based *i*-FTTH.

Figure 2 shows the configuration of 1550 nm video signal delivery system in PON-based *i*-FTTH network testbed. The developed network testbed is firstly characterized in normal situation with OPM to obtain the optical level by replace the 1550 light source as video signal. The point 1 in the network testbed, which place before CAPU, is for triple-play service monitoring purpose, while the point 2, which place before CAPU, is released for protection and restoration purpose.

The obtain value is used as the reference values to determine the status of each optical line in the following tests. As show in Fig. 3, if the loss measurement result is same or less than the reference value, it will consider as normal situation, else the exceed value is the degradation loss of measured fiber link in degradation situation. However, if the loss results that obtain during measurement are big different from the reference value, it will consider as fault situation. The loss results at measurement point are summarized Fig. 4 and 5.

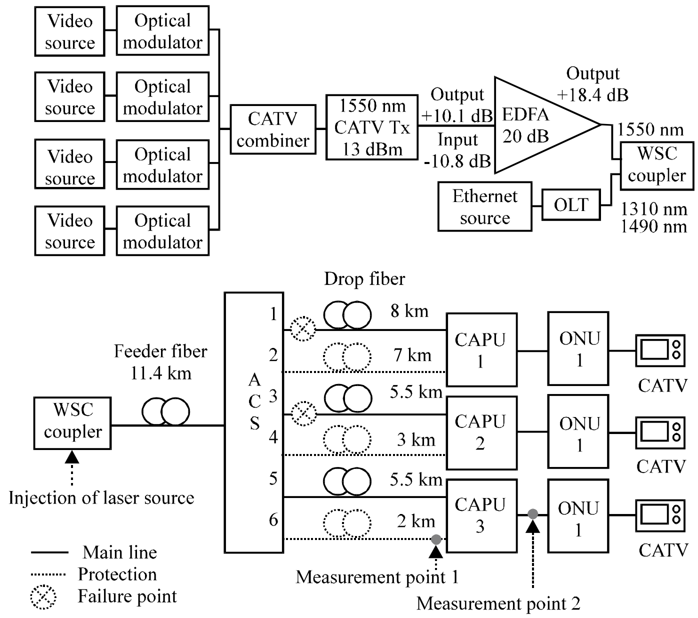

Fig. 2: Configuration of 1550 nm video signal delivery system in PON-based *i*-FTTH

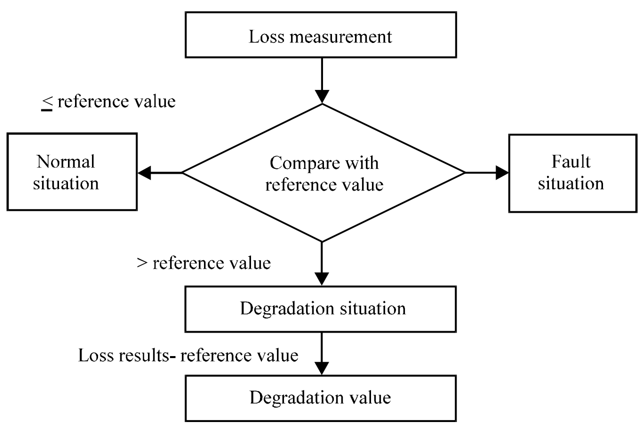

Fig. 3: Flowchart status identification via optical loss measurement

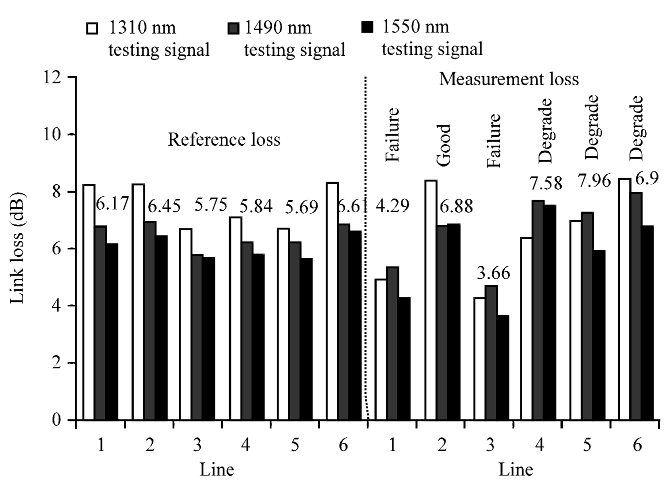

Fig. 4: OPM loss measurement results at point 1 in PON-based *i*-FTTH (for monitoring purpose)

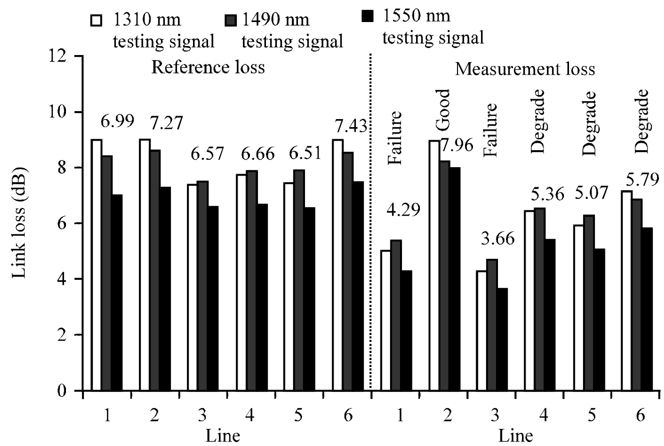

Fig. 5: OPM loss measurement results at point 2 in PON-based *i*-FTTH (for protection and restoration purpose)

As compared to the optical power budget in Ng *et al.* (2010e), the loss measurements for communication signals are lower than the calculation losses. In calculation, the transmission loss for each line is calculated based on the maximum insertion loss contributed by optical fiber lines, components and devices such as optical splitter, optical switches, couplers, adapters, etc. However, the exact insertion losses of these devices in the real measurement test are much lower. Therefore, the accumulation insertion losses of these devices contribute lower transmission loss in this study.

FIELD TESTING ON 1550 VIDEO SIGNAL DELIVERY SYSTEM

The Radio Frequency (RF) signal is distributed from a standard RF head end modulator system to an externally Electrical-to-Optical (E/O) modulated optical transmitter. An EDFA amplifies the video signal and distributes it to Customer Premise Equipment (CPE). A special customized made WSC coupler combines the RF signal with data traffic from OLT, which uses a different wavelength, putting both wavelengths on the same fiber in PON and distributing them downstream through the splitters to ONUs or Optical Network Terminals (ONTs). Or it also can be replaced by using Wavelength Division Multiplexing (WDM) coupler. The optical performance of 1550 nm video signal delivery system in listed in Table 1.

In order to obtain better quality of video signal with lower loss:

- Adjust the level, video, and audio of RF output at the modulator head end system
- Adjust the gain of EDFA (from minimum 0 dB to maximum 20 dB)

Figure 6 depicts the capture of video signals send to both working and protection lines. The quality of video signal received from working line is better than received from protection line because the noise and loss are lower. In normal situation, the video signal is transmit to ONU via working line, however if the working line is failure, the CAPU will restore by switching the distributed signals to its own protection line (Fig. 7, 8). In case of both working line and protection line is failure, no signal is received as shown in Fig. 9, the disrupted traffics can be recovered by using neighbor protection line.

Fig. 6: Signals send to both working and protection lines. (a) Received from transmitter, (b) Received from working line and (c) Received from protection line

Fig. 7: Normal condition where signals send to working line. (a) Received from transmitter, (b) Received from working line and (c) Received from protection line

Fig. 8: One failure case where signals send to protection line. (a) Received from transmitter, (b) Received from working line and (c) Received from protection line

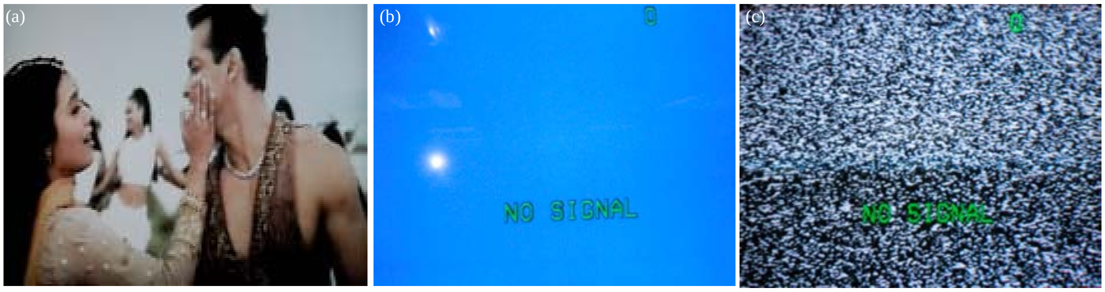

Fig. 9: Two failure cases where both working and protection are failure. (a) Received from transmitter, (b) Received from working line and (c) Received from protection line

Table 1: Optical performance of 1550 nm video signal delivery system

Test	Testing condition	Measurement at point A (dB m)	Measurement at point B (dB m)	Measurement at neighbour site (dB m)	Crosstalk (dB m)
1	Normal	17.79	15.28	13.81	44.03
2	1 failure case	18.11	15.71	16.20	48.34
3	2 failure cases	19.32	16.50	16.27	48.41

CONCLUSIONS

This study presents a simple transmission loss measurement method to fast trace any degradation or failure that occurs in PON-based *i*-FTTH network testbed based on OPM analysis without using Optical Time Domain Reflectometer (OTDR). However, the exact failure point still needs to be localized by using OTDR. The video signals received from customers' locations are observed in both working condition and failure condition to verify the current condition of each fiber link during installation testing and field testing. The disrupted signal in failure line is diverted to protection line, the modulator level of and EDFA gain are adjusted to obtain better quality of video signals.

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