Low Cost Method for Testing and Troubleshooting of FTTH-PON Using Single Optical Power Meter & OTDR : A Case Study

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Abstract

There are several methods for testing and troubleshooting a fiber-to-the-home passive optical network (FTTH-PON). The simplest method would be using a power meter which is able to detect the total loss on the network. However, to identify faulty sections of a network, segmentation need to be done together with the Optical Power Meter (OPM). Another testing and troubleshooting method would be using the optical time-domain reflectometer (OTDR). The OTDR within the network is able to detect the component that causes losses in the network. However, elements acting as a power splitter are not being able to be detected by the OTDR. Therefore, the ACS is developed to bypass those elements and allows the use of OTDR entirely. This method is proven to be a faster method than the first.

1. Introduction

New broadband deployments are frequently justified primarily by today's applications rather than anticipated demands. For example, streaming video content is considered by many as the ultimate bandwidth-hungry application. When one adds the bandwidth requirements of one high definition television (HDTV) stream, a few standard-definition streams, and Internet browsing, it may seem that 20-25 Mbit/s of bandwidth is sufficient in the long term. But historical data and projections indicate exponential long-term growth in bandwidth demand. Indeed, some service providers are already offering 1 Gbit/s access to residential customers today, and there are substantial deployments of 100 Mbit/s networks in some European countries. These bit rates can only be provided via FTTH. FTTH allows the network service providers to branch out being a single service delivery company to participating in various consumer activities with potentially attractive revenue streams, ranging from communications, to entertainment, to information. It has long been thought that fiber's very significant bandwidth would open the way to new applications by the consumer, but it is only recently with the advent of the Internet and the expansion of copper based broadband that this vision may become reality.

PON is a point-to-multipoint (P2MP) fiber optical network with no active elements in the signal's path. The signal transmission in a PON is performed between an optical line terminal (OLT) installed in a central office (CO) or remote terminal and an optical network unit (ONU) placed at the customer residence or in a building. OLT is active equipment that corresponds to the demarcation point between the access network and the metro backhaul network. The architecture of FTTH-PON is shown in Figure 1. The optical splitter is the passive component which is used to distribute the application to all premises. The number of ONU in the network is associated with the size of optical passive splitter available (number of output port).Traffic from an OLT to multiple ONUs is called 'downstream' (P2MP) and traffic from an ONU to OLT is called 'upstream' (multipoint-to-point, MP2P). Two wavelengths are used: typically 1310 nm for the upstream transmission and 1490 nm for the downstream transmission. In the downstream direction (OLT to ONUs), the signals are broadcasted by the OLT and extracted by their destination ONUs based on their media access control (MAC) address.

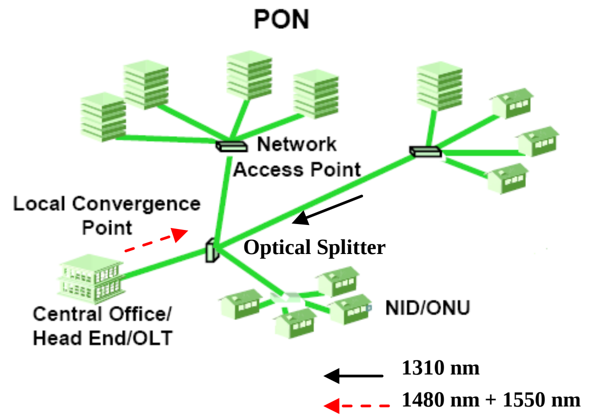


Figure 1. PON architecture

In the upstream direction (ONUs to OLT), each ONU will use a time shared channel (TDM) arbitrated by the OLT. Since the PON connectivity in a FTTH-PON can accommodate a large number of subscribers, when any fault occurs at one point in an optical fiber line, the access network will without any function behind the break point.

It leads to affect the whole services transmission. The upstream signal from multiple ONUs at different residential locations to OLT and CO or the downstream signal from OLT to multiple ONUs after the break point will become unreachable if the fault occurs in the drop region. However, if the fault occurs in an individual subscriber's infrastructure such drop fiber or ONU, since the signals from OLT are successfully shared among other subscriber's ONUs via a passive optical splitter, thus only one subscriber's service is affected.

We have proposed the restoration architecture that can be applied in FTTH-PON, especially in the drop region (from optical splitter to ONUs). Any failure occurs in this region will be sensed by ACS 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. ACS is focusing on providing survivability through the RSA against failure by means of dedicated and shared protection that is applied in PON. ACS is used to monitor the status of the working and restoration fibers. ACS recognized the types of failure and sent the activation signal to the related optical switch according to the activated protection mechanisms.

In this paper, we shared an experience in installing, testing and troubleshooting the network by using low cost equipment which are standard type power meter, OTDR and our own developed centralized monitoring program to monitor the status of each line connected to ONU onto one display screen (computer). The testing process is towards to the installation of Centralized Fiber Troubleshooting System (CFTS). Our proposed centralized monitoring technique is the first reported up to this time.

2. Testing With Power Meter

The FTTH-PON Network is divided into two main layers; Section I: Electronic Application Injection and Section II: Optical Layer. Each section will be characterized respectively by using optical power meters.

Section 1 is starting from signal generation until the OLT and optical splitter. Only one power meters is used to measure the power. Initially, the EDFA gain is set to 0 dB to find the actual received power out from the optical splitter (Feeder section). The power measured at the optical transmitter (after optical modulation) is -7.12 dB. Therefore the power measured at the optical splitter is -18.12 dB. To set the signal at 0 dBm, therefore the EDFA is set as 8 dB and the power. As a result the power at the optical splitter is -10.12 dB. By segmentation the network we can monitor the magnitude of signal power in the line.

The proposed system architecture is presented in Figure 2. The proposed system is associated with optical monitoring, data analyzing, remotely controlling, failure detection, protection switching, and automatic recovery apparatus. The CFDS installed in the network to divert the OTDR testing signal 1625 nm to bypass the filter therefore the line status can be monitored by using OTDR. ACS is the microcontroller based system that has been designed to handle the centralized line detection.

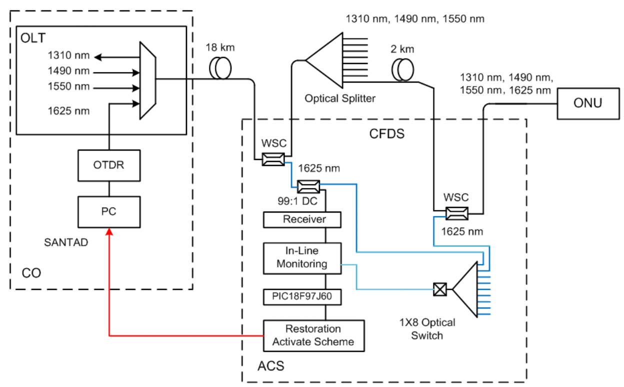


Figure 2. Schematic diagram of the monitoring system for FTTH-PON

The FTTH-PON network test bed at the Networking System Laboratory in Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM), Malaysia, was chosen to conduct our investigation as depicted in Figure 3. Both fiber link between the OLT and optical splitter, and optical splitter and each ONU were about 10 km. In normal operation, both upstream and downstream signals travelled through a transmission distance of 20 km from OLT towards each ONU. The optical signal level is measured by using two units of FOT-600 Optical Loss Test Set manufactured by EXFO Electro-Optical Engineering Inc, one is designated as 1310/1550 nm light source, while the other one reserved as power meter for studying the parameters of loss as shown in Figure 4. The laser source is emitting and passing the conventional network (do not pass through the taper circuit). The values of the optical signal level at the respective points are listed in Table 1 and 2. The optical power for 1550 nm wavelength much lower as compared to 1310 nm because it is more sensitive to the bending of optical fiber lines in the network system.

Using point-to-point measurement, we observed maximum loss occurs in line 2 and further inspection had identified that terrible leakage happened in the WSC device. To combat the problem, the device has to be replaced.

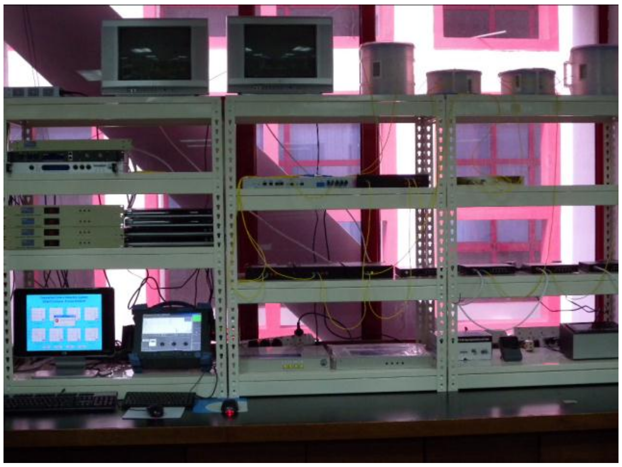


Figure 3. FTTH-PON test in UKM

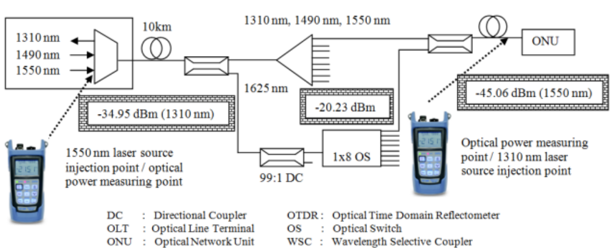


Figure 4. Experimental setup for measuring the optical signal level using one unit of FOT-600

Table 1. Measurement results of optical signal level from CO using 1550 nm light source

Downwardly Testing		Optical Power Level
OLT - ONU1	Loss is found bigger at line	- 45.47 dBm
OLT - ONU2		- 54.20 dBm
OLT - ONU3		- 45.06 dBm
OLT - ONU4		- 46.94 dBm

Table 2. Measurement results of optical signal level from customer sides using 1310 nm light source

Downwardly Testing		Optical Power Level
ONU1 - OLT	Loss is found bigger at line 2	- 36.50 dBm
ONU2 - OLT		- 44.53 dBm
ONU3 - OLT	→	- 34.95 dBm
ONU4 - OLT		- 38.21 dBm

2. Testing With OTDR

After the connectivity of lines is already performed, the next step is the line troubleshooting utilizing OTDR. Our new network configuration (embedded with ACS) has enable the process could be perform downwardly and stationed/centralized at OLT. FTB-400 Universal Test System manufactured by EXFO Electro-Optical Engineering Inc used as an OTDR to investigate the network system. 1625 nm light source is selected to test the network system in downstream direction, from CO towards ONUs using the injection point same as 1550 nm laser source as shown in Figure 4. The laser source is entered into the taper circuit and bypassing the optical splitter in the conventional network. The waveform and event table for the network testing four lines connected to ONU are presented in Figure 5 until Figure 8. Here, the loss of every component, fiber joins and the span can be defined. The high loss at point 2 at line 1 (Figure 5) and line 2 (Figure 6) is caused by the leakage that is introduced by the WSC. The OTDR test result obtained has support the point-to-point test by suing the optical power meter but with OTDR the specific attenuation occurs in the line can be define specifically.

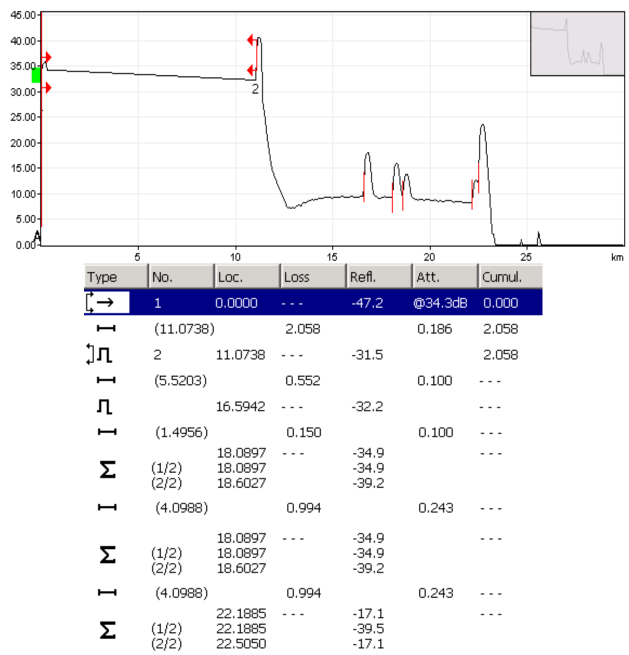
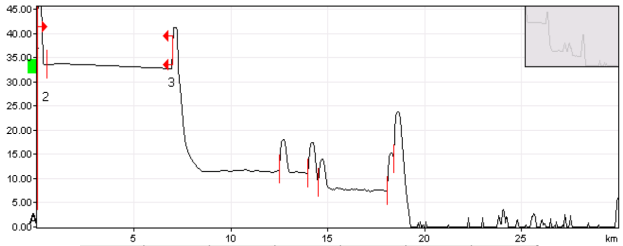
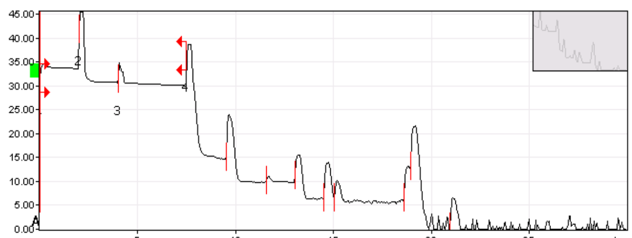


Figure 5. The network testing results for line 1 for the OTDR trace of downwardly testing in the proposed system architecture and the event table for OTDR trace



Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
	1	0.0000	- - -	>-23.9	@33.6dB	0.000
	(0.5104)		0.118		0.232	0.118
	2	0.5104	-0.437			-0.319
	(6.4774)		1.147		0.177	0.828
	3	6.9878	- - -	-30.9		0.828
	(5.5178)		0.552		0.100	- - -
		12.5056	- - -	-35.4		- - -
	(1.4879)		0.311		0.209	- - -
		13.9935	- - -	-35.3		- - -
	(0.5257)		0.053		0.100	- - -
		14.5193	- - -	-37.8		- - -
	(3.5679)		0.529		0.148	- - -
Σ		18.0872	- - -	-15.1		- - -
	(1/2)	18.0872		-32.3		
	(2/2)	18.4215		-15.1		

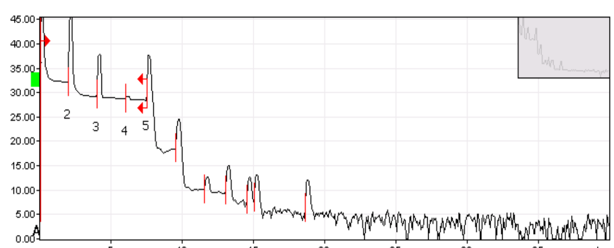
Figure 6. The network testing results for line 2 for the OTDR trace of downwardly testing in the proposed system architecture and the event table for OTDR trace



Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
	1	0.0000	- - -	-50.8	@34.0dB	0.000
	(2.0034)		0.370		0.185	0.370
	2	2.0034	2.605	>-24.0		2.975
	(2.0264)		0.335		0.165	3.310
	3	4.0299	0.006	-39.7		3.316
	(3.4786)		0.629		0.181	3.945
	4	7.5085	- - -	-30.8		3.945
	(2.0315)		1.813		0.892	- - -
		9.5400	- - -	-28.8		- - -
	(2.0315)		0.330		0.163	- - -
		11.5715	- - -	-48.8		- - -

Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
	(1.4573)		0.404		0.277	- - -
		13.0288	- - -	-36.4		- - -
	(1.4930)		0.149		0.100	- - -
		14.5218	- - -	-33.1		- - -
	(0.5385)		0.808		1.500	- - -
		15.0603	- - -	-41.7		- - -
	(3.5526)		0.355		0.100	- - -
Σ		18.6129	- - -	-16.1		- - -
	(1/2)	18.6129		-33.2		
	(2/2)	18.9396		-16.1		
	(2.3480)		0.235		0.100	- - -
		20.9609	- - -	-38.1		- - -

Figure 7. The network testing results for line 3 for the OTDR trace of downwardly testing in the proposed system architecture and the event table for OTDR trace



Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
	1	0.0000	- - -	>-23.1	@32.6dB	0.000
	(2.0054)		0.451		0.225	0.451
	2	2.0054	2.432	>-22.1		2.883
	(2.0131)		0.621		0.309	3.504
	3	4.0185	0.008	-31.1		3.512
	(2.0105)		0.401		0.200	3.913
	4	6.0291	-0.007	-53.5		3.906
	(1.4900)		0.307		0.206	4.213
	5	7.5191	- - -	-30.3		4.213
	(2.0182)		0.202		0.100	- - -
		9.5373	- - -	-36.1		- - -

Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
	(2.0233)		0.592		0.293	- - -
		11.5606	- - -	-44.9		- - -
	(1.4722)		0.390		0.265	- - -
		13.0328	- - -	-37.3		- - -
	(1.5028)		1.062		0.707	- - -
		14.5356	- - -	-37.7		- - -
	(0.5026)		0.955		1.900	- - -
		15.0383	- - -	-37.5		- - -
	(3.5797)		0.845		0.236	- - -
		18.6180	- - -	-34.4		- - -

Figure 8. The network testing results for line 4 for the OTDR trace of downwardly testing in the proposed system architecture and the event table for OTDR trace

Conclusion

Testing and troubleshooting an FTTH-PON network can be done either by using an Optical Power Meter (OPM) or by OTDR. While using the OPM can be proved simplest, this device only allows measurement on the loss of the entire network only, unless segmentation is done. By using OTDR, on the other hand, proves to be a faster and better method than the OPM. Even though elements acting as a power splitter cannot be detected by the OTDR, but through the use of ACS, it allows the use of OTDR in troubleshooting a FTTH network.

References

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