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OPTICAL FIBER CABLE FAULT LOCALIZATION IN FTTH NETWORK USING OTDR

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ABSTRACT: - In this paper, the mechanism of optical fiber break in Passive Optical Network (PON) is discussed and the monitoring issues with conventional fiber fault localization technique by using Optical Time Domain Reflectometer (OTDR). A cost-efficient fully reliable and accurate monitoring solution supporting fault detection, identification, and localization in different fiber access topologies also discussed. We also studied the previous fault localization technology that had been recommended. Here, we proposed a centralized inline monitoring and network testing system named as Centralized Failure Detection System (CFDS). CFDS will be installed with Optical Line Terminal (OLT) at the Central Office (CO) or network operation center to centrally monitoring each optical fiber line's status and detecting the failure location that occurs in the multi-line drop region of Fiber-To-The-Home (FTTH) access network downwardly from CO towards the customer premises to improve the service reliability and reduce the restoration time and maintenance cost.

KEYWORDS: fiber fault localization, OTDR, online monitoring, FTTH, CFDS.

I. INTRODUCTION

FTTH is a technology that deploys optical fiber cable directly to the home or business to deliver data, voice and video services with a high speed through the Optical Distribution Network (ODN). FTTH has been utilized effectively for providing various communications and multimedia services, including carrier-class telephony, high-speed Internet access, digital cable television and interactive two way video-based services to the end users [1]. Owing to the very high capacity of optical fibers, FTTH can deliver greater capacity than competing copper-based technologies [2]. For broadband access Passive Optical Network (PON) based on some multiplexing technologies, including Time Division Multiplexing (TDM), Wavelength Division multiplexing (WDM), Hybrid WDM/TDM, and Optical Code Division Multiplexing (OCDM) are considered as good solutions [3].The TDM-PONs have been thoroughly explored and standardized and they are the first Point-to-Multipoint (P2MP) solutions moving into the field. Therefore, products in agreement with the Broadband PON (BPON), Gigabit PON (GPON), and Ethernet PON (EPON) standards already exist. While considering other PONs GPON is the efficient one. In general, the architectures of PON have three basic topologies, which are bus, tree and ring structure [4]. The P2MP connectivity between the OLT and multiple Optical Network Units (ONUs) or Optical Network Terminals (ONTs) at different residential customer locations are obtained employing a passive branching device (passive optical splitter) at the Remote Node (RN).

II. FIBER FAULT IN FTTH ACCESS NETWORK

This architecture can accommodate a large number of subscribers, when a fiber break occurs at one point in an optical fiber the signal will be unreachable after the break point [4]. Any service outage due to a fiber break can be translated into tremendous financial loss in business for the service providers [5]. A FTTH-PON network failure due to fiber break in current optical communication system could make the service providers very difficult to restore the system back to normal [6].If one of the ONUs goes down then the customers in that branch will lose service. In order to troubleshoot and restart the service the technician must measure the optical power level to determine if it is sufficient to allow the ONU to synchronize with the OLT [7].

According to the cases reported more than one-third of service disruptions are due to fiber cable problems. This kind of problem usually take longer time to resolve compared to the transmission equipment failure [6].The semiconductor-based lasers are most widely used light sources which highly monochromatic and the light beam is very directional [2]. Even though low power laser with just few miliwatts (m W), it can cause the retina eye burning and permanent damage in seconds or even less time when it explored at the transmission end (This will be happen when the optical fiber cable is break).

III. OPTICAL MAINTENANCE FUNCTIONS

The installation and powering up of an optical fiber communication system requires measurement techniques for verifying the link has been configured properly and that its constituent components are functioning correctly [2]. Optical maintenance is a very important issue to be considered in developing a high quality and reliable PON network. Covers, all the means to guarantee the performances of the OON. Maintenance functions for an optical network are classified by International Telecommunication Union Telecommunication Standardization Sector (ITU-T) in two main categories: Preventive maintenance and Post-fault maintenance. For each of them, three activities are considered:-.

A. PREVENTIVE MAINTENANCE (BEFORE A FAULT OCCURS)

• Surveillance - to detect degradation in optical fiber components, or any other anomalous condition not preventing the signal transmission,
e.g.: water penetration in splice closures.
• Testing - to measure and locate any detected degradation or anomalous condition.
• Control - fiber identification and fiber transfer to allow the testing of the link.

B. POST-FAULT MAINTENANCE (AFTER THE OCCURRENCE OF A FAULT)

• Surveillance - to detect alarms or trouble reports and activate a procedure for restoration.
• Testing - to locate the fault / verify the carrier performances after the restoration.
• Remedy - fiber identification, fiber repair or fiber transfer to restore the link [8].

IV. FAULT LOCALIZATION WITH OTDR

Fiber fault within any type of the FTTH-PON network becomes more significant due to the increasing demand for reliable service delivery [3].Several developed test gears are invented to locate(detect) a fiber fault in an optical fiber, such as fault locator and OTDR based on a single wavelength source [5], [6]. Optical fiber line testing system with OTDR is the best method available for determining the exact location of broken fiber in an installed optical

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fiber cable when the cable jacket is not visibly damaged and also for determining loss due to individual splice, connector. Also provides the best representation of overall fiber integrity [8]. If only one ONU is inactive, meanwhile the other ONUs served by the same splitter synchronize with the OLT at the CO, then the problem relates to the distribution fiber located between the inactive ONU and splitter. Whenever a fault occurs, OTDR is plugged manually to the faulty cable by the technician to detect where the failure is located. A technician launches an OTDR test from the out-of-service ONU. In Figure 1, the red line denotes the OTDR test on the faulty branch of the splitter (malfunction caused by a macro bend), while the other branches of the same splitter (green lines) are still in service. In this situation, there is no fiber break; therefore, the OTDR signal can go up to the OLT, past the macro bend and possibly interfere with the lasers of the transmitters operating at 1490 nm and 1550 nm wavelengths. In addition these incoming signals may blind the avalanche photodiode of the standard OTDR, which will stop the OTDR analysis [7].

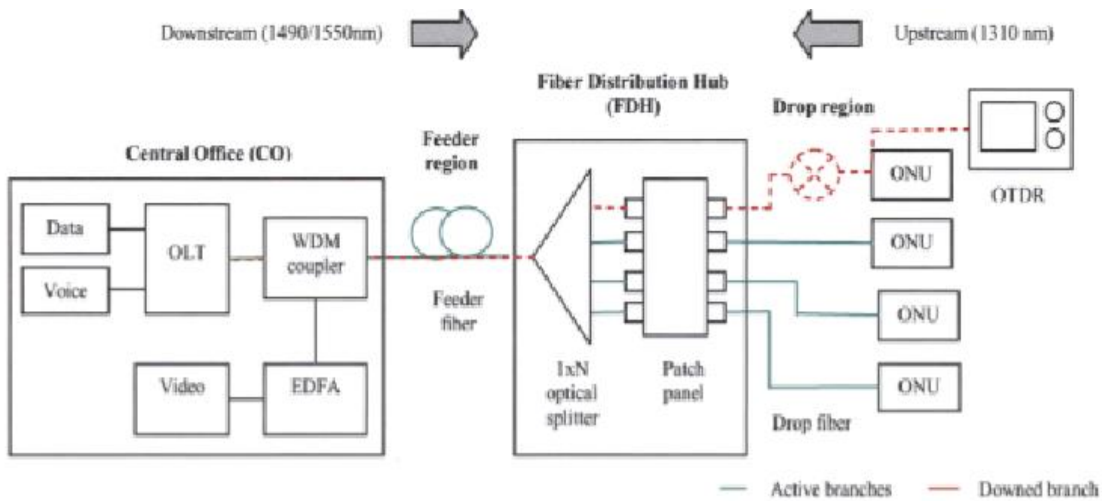

Figure 1. A fiber fault in tree-structured FTTH access network is located by using OTDR upwardly from multiple ONUs at different residential locations toward OLT at CO

However, the technician can determine if it is only one subscriber not receiving service. The technician cannot use a standard 1310/1550 nm OTDR. An OTDR using standard 1310/1550 nm signals from one particular ONU location will interfere with the live video signals sent by the transmitters at 1550 nm, and with the live 1490 nm data and telephony signals going through the feeder fiber between the splitter located at the Fiber Distribution Hub (FDH) and OLT. In addition, the transmitter lasers emitting these signals from the CO may be destabilized, creating unwanted bit error rate when the dynamic range of the OTDR will reach the CO. This extra Bit Error Rate (BER) will affect the quality of the transmission to the other ONUs served by the same splitter. Moreover, the OTDR trace will get corrupted by the presence of traffic on the line because the traffic power is much stronger than the weak backscattering signal used by the OTDR for its measurement [7]. In fact, most OTDR designed specifically for in-service PON troubleshooting features a dedicated port for testing at 1625/1650 nm and incorporates a filter that rejects all unwanted signals (1310 nm, 1490 nm and 1550 nm) that could contaminate the OTDR measurement. Only the OTDR signal at 1625/1650 nm is allowed to pass through the filter, generating a precise OTDR measurement. In-service OTDR troubleshooting of optical fiber should be done in a way that does not interfere with the normal operation and expected performance of the information channels [7].
The OTDR signal does not interfere with the CO's Transmitter lasers, because the 1625/1650 nm wavelength complies with the ITU-T L.41 (Maintenance wavelength on fibers carrying signals) Recommendation. This ITU-T recommendation suggests a 100 nm difference between the OTDR wavelength used for in-service maintenance and the closest transmission wavelength (in this case is 1550nm). The addition of a broadband filter, acting as a 1625/1650 nm testing port at the CO's WOM coupler, may also be beneficial. As a result, the quality of Service

provided to other subscribers serviced by the same splitter is not affected. Armed with this technology, the technician can connect the OTDR's 1650 nm port to the ONU and send the signal towards the CO. If a 1625/1650 nm testing port is added to the CO, it is also possible to perform tests from the CO down to the ONUs, but 1625/1650 nm filter may be needed at each ONU. As seen above, the main advantage of is its two-port versatility. The first port features a broadband filter and is dedicated to in service PON troubleshooting at 1625/1650 nm, while the second port operates at the more common wavelengths (1310/1550 nm). This allows users to perform in-service PON troubleshooting, as well as standard 1310/1550 nm OTDR testing, which saves valuable time [7].

V. MONITORING ISSUES WITH OTDR

A FTTH-PON tree structured has many drop fibers (branches) in the drop region. Thus, it may be necessary to send a technician to the ONUs side at different residential locations to inject an OTDR pulse into the drop fiber from customer premises to the CO. This conventional technique delays the restoration (repair or maintenance) time of the FTTH-PON network system because this approach would require much time and effort [9]. Moreover, OTDR can only display a single measurement result in a time. To reduce the time delay, one of the solutions is to install an OTDR or a fault locator to the system permanently. However, it is not cost effective since an OTDR is very expensive. Adding them to the system will increase the cost of the system extremely.

On top of that, adding these test gears into the system is impractical; especially when considering that the event of fiber breaks does not occur frequently [6].It is important to be able to locate any fiber break after the installation of FTTH-PON network. Furthermore, a simple and effective monitoring configuration is highly desirable for timely failure detection along the fiber link [6]. The faster the fault is detected, the faster the restoration can be done, thus reducing the probability of service disruption [6]. A particular problem in this regard is that a failure occurred at the drop region must be located without affecting the service to other customers [10].

A good fault surveillance system is essential to identify the fiber fault without interrupting the services, while other channels are still in service to maximize the link utilization [4]. Therefore, an optical line monitoring and testing system is essential for failure detection to improve the service reliability and reduce the restoration time and maintenance cost of FTTH access network. is difficult to detect a failure in optical line equipped with optical splitter by using a conventional OTDR in the CO downwardly from CO to the customer premises, because the Rayleigh backscattered (RBS) light from different branches overlap with each other (accumulate) in the OTDR trace and cannot be distinguished [5].

VI. FAULT LOCALIZATION TECHNIQUES

In order to verify the detectable event magnitude, a test bed based on 1:8 splitter and several fiber spans was assembled, Fig. 2a. To emulate faults in the ODN different attenuators were used (event losses in the drop links) and/or some sections were disconnected (fiber breaks in the drop links). The same type of single-mode fiber was applied in each section, the OTDR operated in the 1650 nm band, and all fiber connectors were angled (FC/APC), including the drop link floating ends.

One of the key results is the minimum detectable event magnitude in a 1:8 splitter configuration. In test 2 a 1 dB loss in a single drop link gives a 0.1 dB step on the OTDR trace, which is the minimum event value detectable by a regular OTDR. This, on the other hand, complies with the standard requirements for triggering an OTDR minor-fault alarm according to ITU-T L.40. Also according to ITU-T L.40, the major-fault alarm concerning a 3-dB loss (test 3) is triggered when an event of 0.22 dB is detected in the setup. Test 4 concerns a situation of two events positioned in different drop links the same distance from the splitter. The resulting step on the OTDR is a superposition of the two component steps. To distinguish the two events, additional information on the received optical power at ONTs is needed.

It is provided by the OTM, as explained earlier. Mapping the two sources of information, OTDR and OTM, gives complete information on fiber fault definition and localization. Tests 5, 6, and 7–10 show how open splitter ports influence the measured step difference. For example, in test 5 a single disconnected drop port results in 0.29 dB

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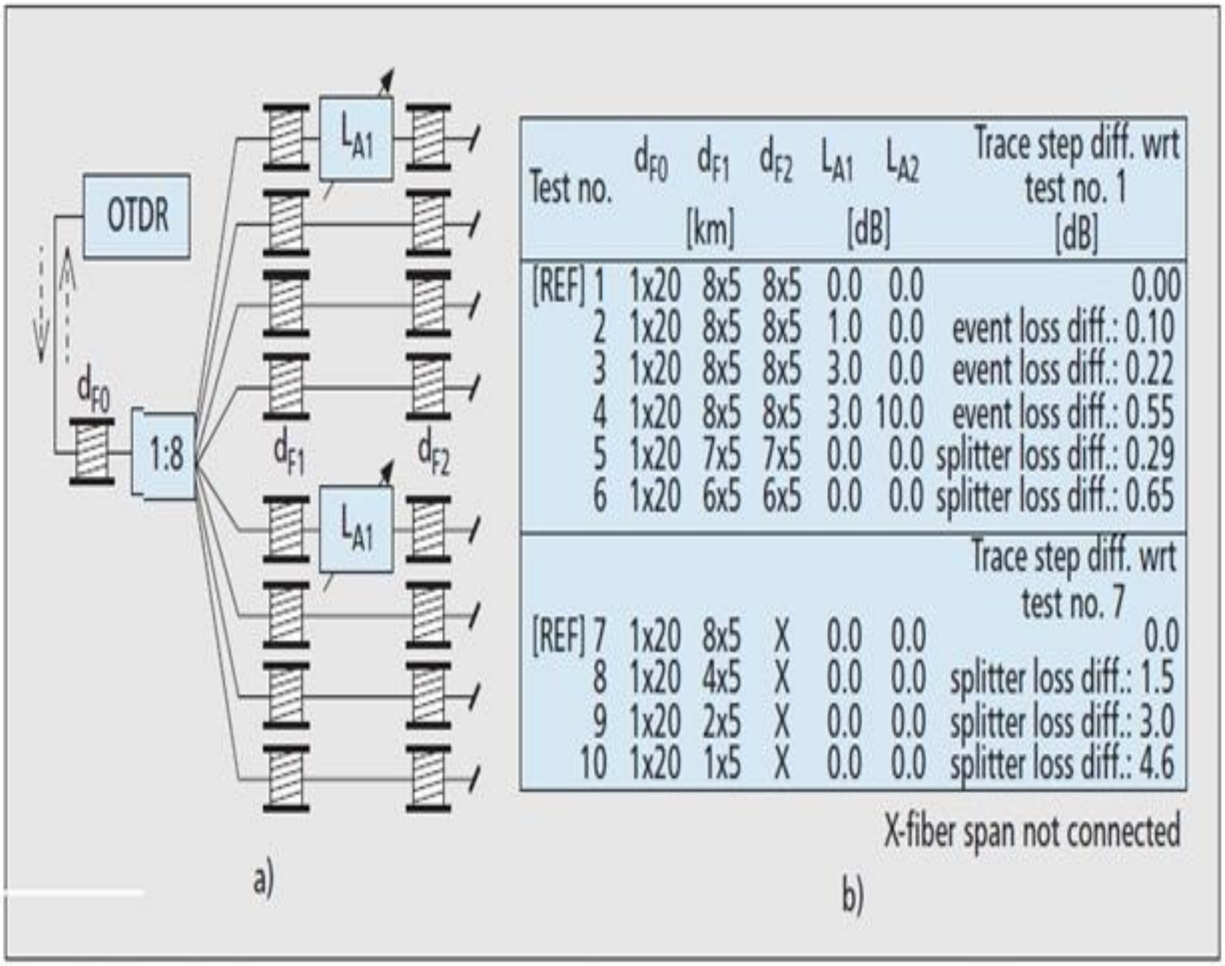
difference in the step magnitude corresponding to the splitter loss. The difference grows while disconnecting more drop links (tests 7–10). This behavior can be overcome once the number of (dis) connected drop links is known beforehand and the measurement results can be corrected. Advanced system measurements on a live WDM-PON system have also been performed and are a subject of [11].



Test no.	d_{F0}	d_{F1} [km]	d_{F2}	L_{A1}	L_{A2} [dB]	Trace step diff. wrt test no. 1 [dB]
[REF] 1	1x20	8x5	8x5	0.0	0.0	0.00
2	1x20	8x5	8x5	1.0	0.0	event loss diff.: 0.10
3	1x20	8x5	8x5	3.0	0.0	event loss diff.: 0.22
4	1x20	8x5	8x5	3.0	10.0	event loss diff.: 0.55
5	1x20	7x5	7x5	0.0	0.0	splitter loss diff.: 0.29
6	1x20	6x5	6x5	0.0	0.0	splitter loss diff.: 0.65
						Trace step diff. wrt test no. 7
[REF] 7	1x20	8x5	X	0.0	0.0	0.0
8	1x20	4x5	X	0.0	0.0	splitter loss diff.: 1.5
9	1x20	2x5	X	0.0	0.0	splitter loss diff.: 3.0
10	1x20	1x5	X	0.0	0.0	splitter loss diff.: 4.6

Figure 2: a. Test bed structure, **b** .Measurement results

VII. OTDR EMULATION SOFTWARE

OTDR emulation software is application software that performs analysis of trace data measured by OTDR on a Personal Computer (PC). The measurement results can be transferred from OTDR to PC using a floppy disk or USB memory (manually transfer), or used the data transfer function to transfer the measurement results recorded by the OTDR directly to PC via serial port (RS-232) extension cable. The OTDR trace normally is saved (recorded) in trace (TRC) file. The users can record the OTDR trace in text or American Standard Code for Information Interchange (ASCII) format for subsequent use by spreadsheet software such as Microsoft Excel or Lotus 1-2-3. Unfortunately the emulation software is same as the OTDR which can only display a single testing result in a time and also time consuming and cost misspend. This makes the troubleshooting work become very complex and leads to increase the maintenance and operation cost.

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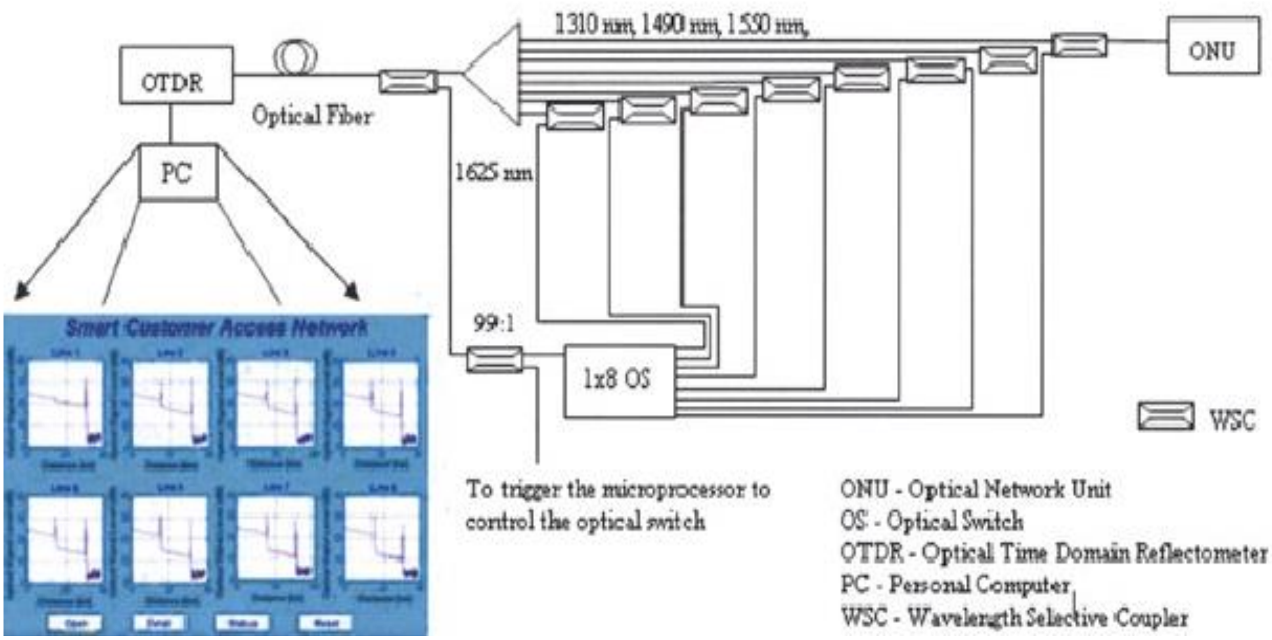

Figure 3. The interconnection of optical switch to splitter and microprocessor system

VIII. CENTRALIZED FAILURE DETECTION SYSTEM (CFDS)

To reduce the cost and enhance the benefit, we are developing a Smart Customer Access Network (SCAN), which involves in the failure detection, automatic recovery and increases the survivability and maintainability of FTTH access network. SCAN consists of four main subsystems that support the, they include Failure Detection System (FDS), Access Control System (ACS), Optical Cross Add and Drop Multiplexer (OXADM), and Optical In-line Taper (OIT). CFDS is one of the subsystems of SCAN, which able to monitor the status for each line and detect the failure in multi-line drop region of tree structured FTTH access network downwardly. CFDS is a centralized monitoring and access control program that provides the service providers with a means of viewing optical signals flow and detecting breakdowns and other circumstances which may require some action with the graphical user interface processing of MATLAB software. CFDS has the same features of the OTDR and computer-based emulation software for performing more OTDR trace processing and analyzing functions but with more flexibility and reliability to be used in optical communication system.

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 for failure detection [12]. SCAN 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 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) or WDM coupler 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. CFDS is interfaced with the OTDR to accumulate every network testing result to be displayed on a single computer screen for further analysis. The analysis result will be sent to field engineers or service providers through the mobile phone or Wi-Fi / Internet computer using wireless technology for promptly action. Anywhere, the traffic from the failure line will be diverted to stand-by (protection) line to ensure the traffic flow continuously.

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IX. RESULTS AND DISCUSSION

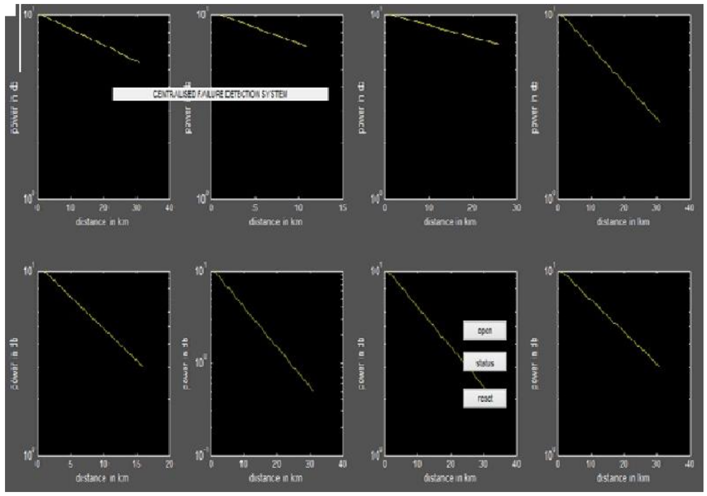

Figure 4.a Results of FTTH monitoring using OTDR

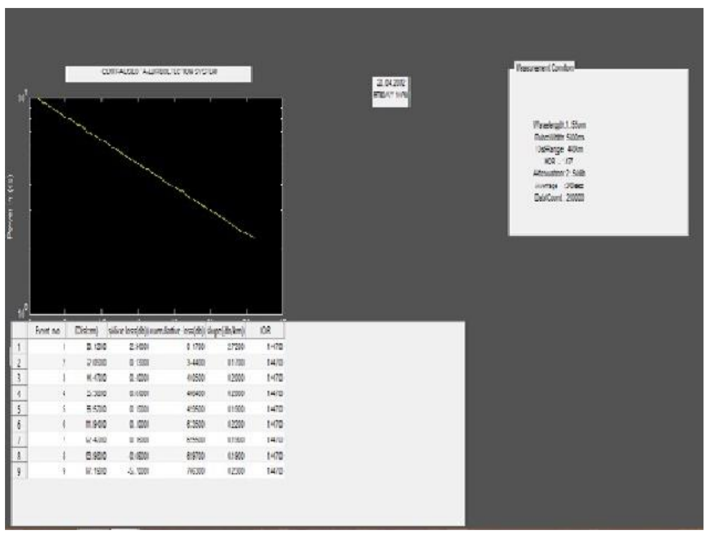

Figure 4.b Results of individual reading

From the figure 4a, we can say that using OTDR technique the in the n no of channels can be detected easily. The above shows the results for eight channels. From figure 4b, it is said that we can measure the amount of loss in the cable in a particular place. It is done at different places and the readings are tabulated.

X. CONCLUSIONS

To provide a reliable service, fault detection in a FTTH-PON network becomes more significant. The CFDS technology using OTDR is the efficient method for monitoring and fault detection. CFDS helps the service providers and engineers to find the fault in the multi-line drop region of FTTH downwardly from CO. CFDS able to improve the service reliability and reduce the restoration time and maintenance cost. With CFDS no more cost and time misspending due to the troubleshooting mechanism is done downwardly.

XI. FUTURE WORK

In the present work, we gave entire control to the central office. In the future, the control can be given to every administrator with an IP address where they can log in with a password given to them anywhere and detect the faults in the fiber.

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