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Implementing Optical Access Network with Online Monitoring Solution to Increase the Efficiency

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***Abstract*— This paper presents the design and implementation of Gigabit Passive Optical Network (GPON) access network with online monitoring technique. The main objective of the paper is to obtain optimum BER and to increase the efficiency of the network performance. Optical fiber cable is the efficient media for data transmission with unlimited bandwidth. FTTH is the system of connecting service provider to various customers directly. To reduce the fiber complexity and the cost of implementing a Fiber To The Home (FTTH) technique, a Point To Multipoint GPON architecture is designed, with Time Division Multiplexing (TDM) and Time Division Multiple Access (TDMA) techniques. The network performance is increased by using OTDR for the fault localization, detection of losses and optimization. With the help of Centralized Fault Detecting Systems (CFDS), online monitoring of the access network can be done. CFDS improves the service reliability and maintenance cost due to availability of troubleshooting mechanisms.**

***Index Terms*— Centralized Fault Detecting Systems, Gigabit Passive Optical Network, Optical Time Domain Reflectometer, Optical Access Network**.

I. INTRODUCTION

Recently, growing demand for high speed internet services from users has led to a deployment of passive optical network (PON) architectures. To improve the network performance and to support the customer requirements, the network design should be done properly by the Internet Service Providers (ISPs). The customer requirement is primarily based on applications such as Internet, Voice Oriented Internet Protocol (VOIP), Internet Protocol TV (IPTV) and many other services. The video-based services will require higher data speeds. Hence, telecommunication providers are switch over from copper based network to fiber optical networks.

To allow high speed connections, the fiber cable gets closer and closer to the customer. The Fiber To The Home (FTTH) technique is the most suitable choice. FTTH delivers the transmitted signal from the service provider directly to the customer's home. It appears to be the most utilized technique to provide triple play services.

There present two main topologies in FTTH as Point-to-Point and Point-to-Multipoint. In Point-to-Point topology, each customer is provided with a dedicated fiber. Hence, the fiber usage is increased thereby installation cost also increases. The Point-to-Multipoint is the architecture where a single fiber is shared among many customers. So, the fiber complexity is reduced.

The broadband accessing can be provided by using PON which splits the data and voice at the subscriber end. A PON is a fiber network that uses only uses fiber and passive components like splitters and combiners rather than active components like amplifiers, repeaters or shaping circuits. This network costs significantly less than the active components.

Over the years, various PON standards have been developed. The Broadband PON (BPON) has downstream data rate as 622 Mbps and upstream data rate as 155 Mbps. BPON is stable standard that re-uses ATM infrastructure and its standard is ITU-T G.983. The Ethernet PON (EPON) is focusing on direct support of Ethernet services. EPON uses CWDM and TDM to provide bi-directional and point-to-point communications over a fiber and maintains frame structure for both upstream and downstream. EPON has the downstream and upstream capacity of 1.25 Gbps and its standard is IEEE 802.3ah. The GPON provides high data rate than the BPON. The standard of GPON is ITU-T G.984 with downstream data rate 2.5 Gbps and upstream data rate 1.25 Gbps. GPON uses Generic Framing Procedure (GFP) protocol

to provide support for both voice and data oriented services.

In India, the GPON is used upto 32 number of splits whereas in other countries 128 number of splits used. The number of customers will be decreased if the splitting ratio is increased. In finding faults in the fiber, the main testing instrument used is Optical Time Domain Reflectometer (OTDR). By using this, losses can be measured. But it is difficult to find failure in a Point-to-Multipoint connectivity by using OTDR because the Rayleigh back-scattered light from various branches may overlap with each other in the OTDR trace. Thus, the Centralized Fault Detecting System (CFDS) is used to reduce the cost and operational expenditures of the network.

II. COMPONENTS OF PON ARCHITECURE

A PON generally contains an Optical Line Terminal (OLT), a number of Optical Network Terminals (ONTs) or Optical Network Units (ONUs) and passive Optical Splitters (OS).

A. Optical Line Terminal

The Optical Line Terminal (OLT) is usually placed in the Local Exchange. It is the engine which drives the FTTH system. It has two float directions: one is upstream getting distributing different type of data and voice traffic from customers, the other is downstream getting data, voice and video traffic from metro network or from a long haul network and sending it to all ONT modules on the optical distribution network (ODN).

Fig.1 Optical Line Terminal (OLT)

B. Optical Network Terminal or Optical Network Unit

Optical Network Terminals or Units are deployed at customer's premises. ONTs are connected to the OLT by means of optical fiber and no active elements are present in the link. A single ONT can serve as point of access for one or multiple customers and be deployed either at customer's premises or on the street in a cabinet. The ONU usually communicates with an ONT, which may be a separate box that connects the PON to TV sets, telephones, computers, or a wireless router. The ONU or ONT can be the same device. The picture on the right shows an ONT.

Fig.2 Optical Network Unit or Optical Network Terminal (ONU/ONT)

C. PON Splitter

Fig.3 PON Splitter

Passive Optical Splitters divide a single optical signal into multiple equal but lower-power signals, and distribute the signals to users. The final splitting ratio can be achieved using a single splitter device. Some characteristics of passive optical splitter are high reliability, it supports network survivability and protection policy, it requires minimal dimensions, has low insertion loss and broad operating wavelength range.

III. ARCHITECTURE OF THE NETWORK

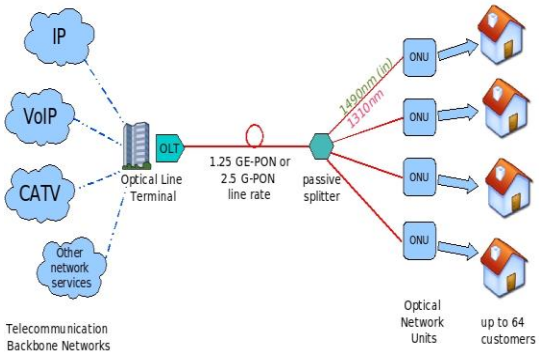

Fig.4 General GPON Architecture

The architecture of Passive Optical Network is Point to Multipoint which is cost effective optical fiber based access system. It provides triple play services (voice, video & data). In this network, optical fiber and optical power splitters are used to connect the OLT at the local exchange (Central Office) to the customer's ONU.

The splitting ratio of the passive splitters is 1:32 over a maximum distance of 20Km. The OLT provides switching and aggregation functionality between the core network and PON interfaces and supports management functions. ONU provides access to the users i.e. an External Plant / Customer Premises equipment providing user interface for many/single customer. Different wavelengths are used for downstream and upstream traffic. This greatly simplifies network operation & maintenance and reduces the cost.

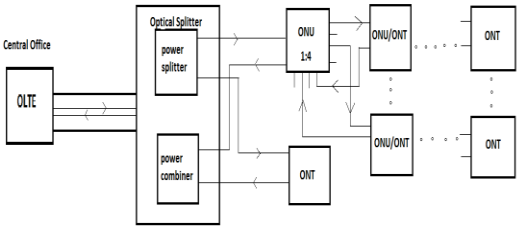

Fig.5 Block Diagram of GPON access network

The OLTE has a unit of pulse generator, optical source, modulator and multiplexer for downstream transmission and a reception unit of optical detector, filter and regenerator for upstream. In downstream transmission, different wavelengths such as 1490nm (audio/data), 1550nm (video) and 1625nm (monitoring) are generated and transmitted through single-mode bidirectional fiber to the ONTs. The modulation technique used for downlink transmission is Time Division Multiplexing (TDM). TDM is a method of putting multiple data streams in a single signal by separating the signal into many segments, each having a very short duration. Each individual data stream is reassembled at the receiving end based on the timing.

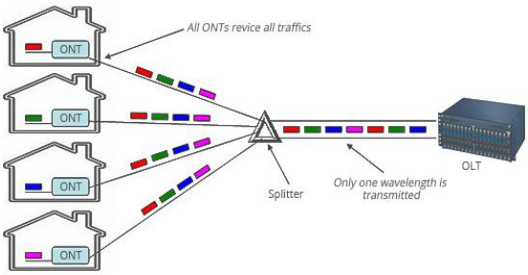

Fig.6 Configuration of TDM-PON

In OLT, a unit of optical detector, filter and regenerator is present for receiving the transmitted signals from OLTE. It uses an optical transmitter for transmission of 1310nm wavelength as upstream which is received by reception unit of OLTE.

For uplink transmission, the Time Division Multiple Access (TDMA) technique is used. TDMA is the popular method being considered for building PON architecture to provide FTTH services. By using this technique, dedicated time slots to each of the multiple customers. Each subscriber can use the full upstream bandwidth for the duration of its allotted time slot. The important characteristic of the TDMA approach is Dynamic Bandwidth Allocation (DBW) which means, when some ONTs do not have much data to transmit then the unused channel capacity will be allotted to the other ONTs if they have more data to transmit. This makes the efficient usage of bandwidth. To avoid collision of the upstream data, the OLT assigns different time slots to each user.

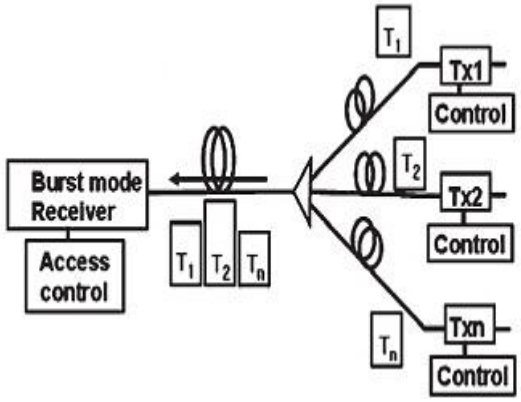

Fig.7 Configuration of Time Division Multiple Access

IV. FAULT LOCALIZATION

The purpose of fault localization is to increase the reliability of the network. The localization of fiber faults can be done easily by the Optical Time Domain Reflectometer, upto the maximum range of 250km to 400km. OTDR is an optoelectronic instrument used to characterize an optical fiber. By injecting a series of optical pulses into the fiber under test and extracts, from the same end of the fiber, light that is scattered or reflected back from points along the fiber. The scattered/ reflected light that is gathered back is used to characterize the optical fiber.

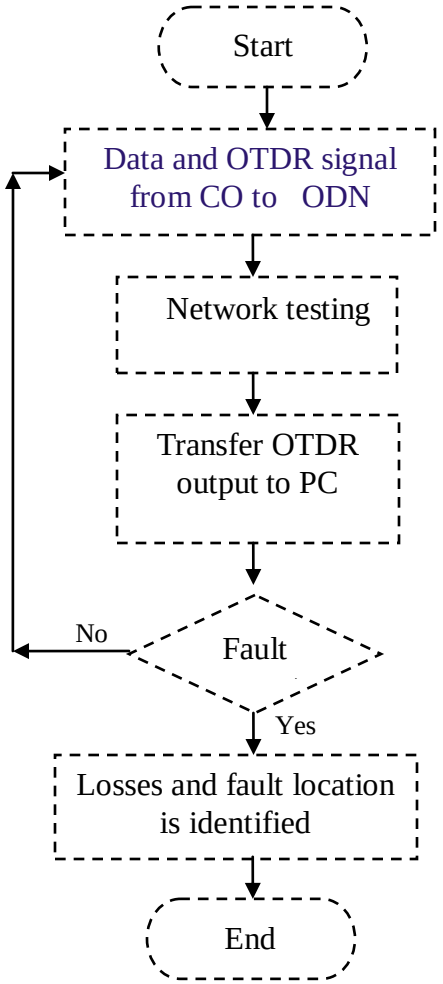

Fig. 8 OTDR Flowchart

By using the OTDR, the losses can be measured. The connector loss and break loss are known as Reflective losses and this can be measured by using the Fresnel equation. The splice loss and cable loss are called as Non-Reflective losses and can be calculated by using the Rayleigh event. These parameters are contributing to the optical power loss in GPON FTTH optical access networks.

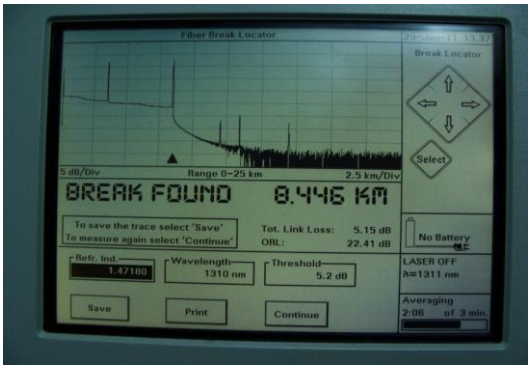

Fig.8 OTDR traces analysis

To identify the exact cable fault location, the OFFSET diagrams are needed. OFFSET Diagram is a written document to find faults based on the detail entered in this document. It should contain mainly four basic detail about the fiber namely length, side, offset and depth.

In Point to Point architecture, OTDR is used and is called as the OFFLINE measurement. Since, OTDR tracing is not sufficient for Point-to-Multipoint network. In order to detect failure location in the multi-line drop region of FTTH access network in downward direction from Central Office (CO) to customer ends, the Centralized Fault Detection System is used with OLT at the CO.

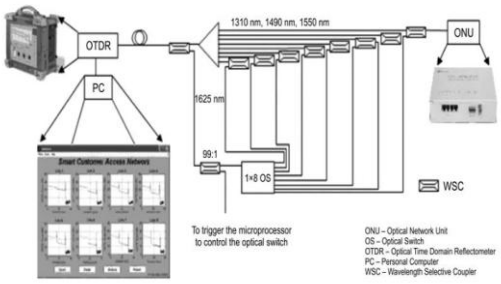

Fig.9 System Architecture of CFDS

CFDS which is the centralized monitoring and access control program is connected with OTDR to collect every fiber testing result which is to be displayed on a computer screen. It has capability to configure optical signals flow and breakdown detection using the computer based emulation software. It monitors centrally each optical fiber line's status. It reduces the restoration time and maintenance cost and improves the service reliability.

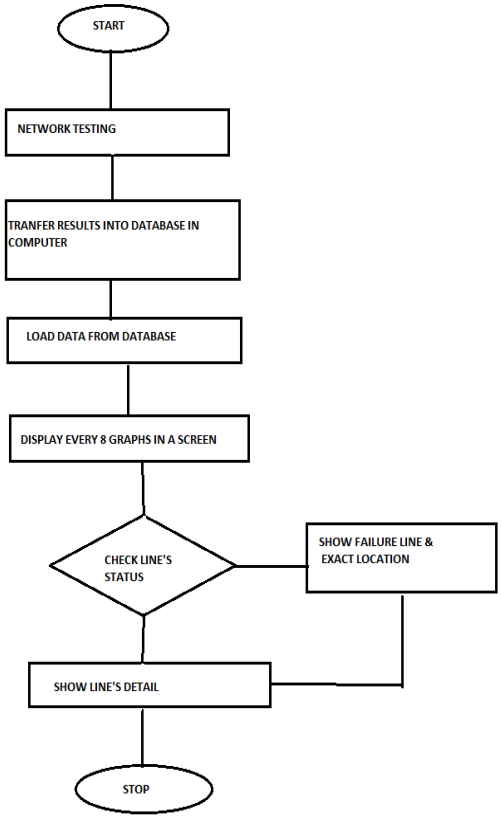

Fig. 10 Flowchart of CFDS

CFDS processes more OTDR trace and analyze functions, to locate a failure without affecting the services transmitted to customers. It uses a different wavelength (1625nm) rather than the wavelength of triple play services, for failure detection. The OLT multiplexes the wavelength of testing signal from OTDR with wavelengths of triple-play services. The result analyzed by CFDS will be sent to Field Engineers for further action. Hence, using CFDS along with OTDR makes the network efficient.

V. RESULT

The GPON optical access network design is implemented in the OPTISIM simulation tool. OptiSystem is an innovative optical communication system simulation package that designs, tests, and optimizes virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broadcasting systems to intercontinental backbones. In simulation, the output of Bit Error Rate (BER) analyzer is shown in Fig.10 with minimum error as 10^-9 present in ONT. In Fig.11 BER analyzer output in OLTE with minimum error as 10^-6 is shown.

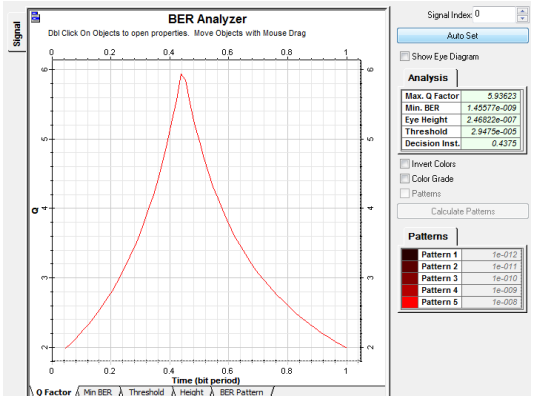

Fig. 10 BER Analyzer output at ONT

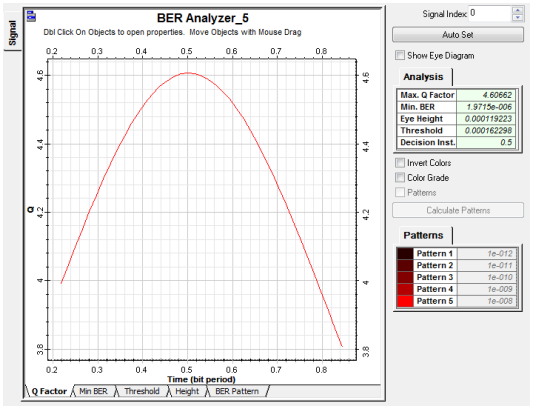

Fig. 11 BER Analyzer output at OLTE

The received power at subscriber side ONT is shown in Fig.12.

Fig. 12 Optical Power Meter output

The OTDR simulation output is shown in Fig.13.

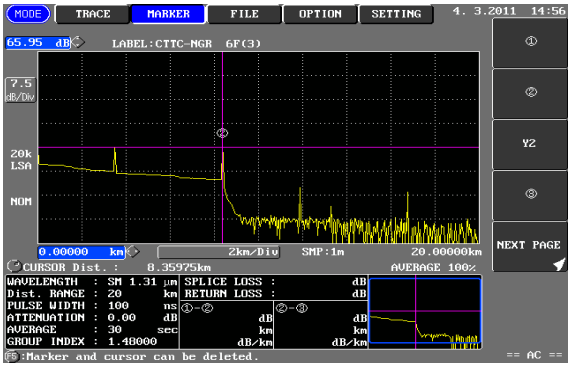

Fig.13 OTDR Simulation Output

VI. CONCLUSION

This paper presented the design and implementation of FTTH-GPON access network over 20 km with online monitoring to increase the efficiency of the network. Fiber fault localization in the FTTH-PON network is used to improve the network performance using OTDR. In addition to OTDR for online monitoring, the Centralized Fault Detecting System (CFDS) is used to detect the failures in multi-line drop region of the FTTH-PON network. It notifies the service provider about every status with option for analysis of the trace, event table etc. from the execution results of OTDR or emulation software. It is used to reduce the capital and operational expenditures of the network. The optimum Bit Error Rate (BER) is achieved in this design.

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