

A Comparative Study of Various Fault Location and Protection Mechanisms For LR-PON's (Long Reach Passive Optical Networks)

Shippu Sachdeva¹, Dr. Jagjit Malhotra²

shippu.16822@lpu.co.in, jmalhotra292@gmail.com

¹Assistant Professor, Electronics and Communication Engineering, Lovely Professional University, Phagwara

²Associate Professor, Electronics and Communication Engineering, DAVIET, Jalandhar

Abstract- Long-Reach Passive Optical Networks (LR-PONs) are those optical access networks which are attracting the researchers because of its huge coverage and capacity. In this network the separation between the central office (CO) and the end users has been increased from a earlier range of 20Km to 100 Km and more. Therefore it decreases the number of central offices and other active optical components in the system, which results in reduction in expenses. As it provides enough capacity and coverage, probability of failures is quite high. So, it becomes very important to monitor the network so that performance and reliability of network would increase. In this paper, we are going to compare the different monitoring solutions on an advanced LR-PON which can be used to reduce the expenses for the monitoring of whole network.

Keywords: LR-PON's (Long reach passive optical network) Optical Time domain Reflectometry (OTDR), Optical code domain Reflectometry(OCDR), Transmission reflection analysis(TRA).

1. INTRODUCTION

In LR-PON's(Long reach Passive optical networks), the distance from the central office (CO) to end users has been increased from 20Km to 100Km and beyond which makes it as the best option for the broadband access networks. It also provides enormous bandwidth, high security, and easy upgradability. Because of its large coverage (≥ 60 km) and enormous bandwidth, long reach passive optical network (LRPONs) is seeking more attention of researchers.[1,2]. There could be different structures for LR-PONs, among the various topologies proposed the "ring and spur" topology is being mostly used for research because cost required for infrastructure is quite low along with this it provides high reliability. [3]. It was observed that the maximum of the expenses under operation and maintenance are used on monitoring link faults [2,3]. Therefore, to reduce the cost for both the network providers and customers, researchers are working on effectively location of the faults in the fiber occurring in multiple branches of PONs. The various monitoring techniques used in LRPONs includes conventional Optical time domain reflectometry (OTDR) which can be combined with Optical Code domain reflectometry(OCDR) for improved performance. Next, is Transmission Reflection analysis (TRA) which provides better fiber monitoring functionality.

2. OPTICAL CODING MECHANISM AND OTDR TECHNIQUE

The remote end monitoring of fiber networks in P2P technologies mostly done by the use of standard OTDR technique. In this technique the backward signals are measured coming in the fiber, which is the result of the Fresnel reflections and Rayleigh scattering, when a short light pulse is launched into the fiber from one end. By computing the power versus the distance a trace of these signals is being plotted which characterized the link status. This plot obtained as explained above, can be used to find any kind of fault in the fiber such as bends, cracks, fiber misalignment, mismatch, dirty connections and so on [14]. To improve the performance of standard OTDR technique, OCDR is combined with it. In this technique, by using optical coding technique failed optical fiber link is identified and after that by using OTDR, location of faulty point can be easily determined.

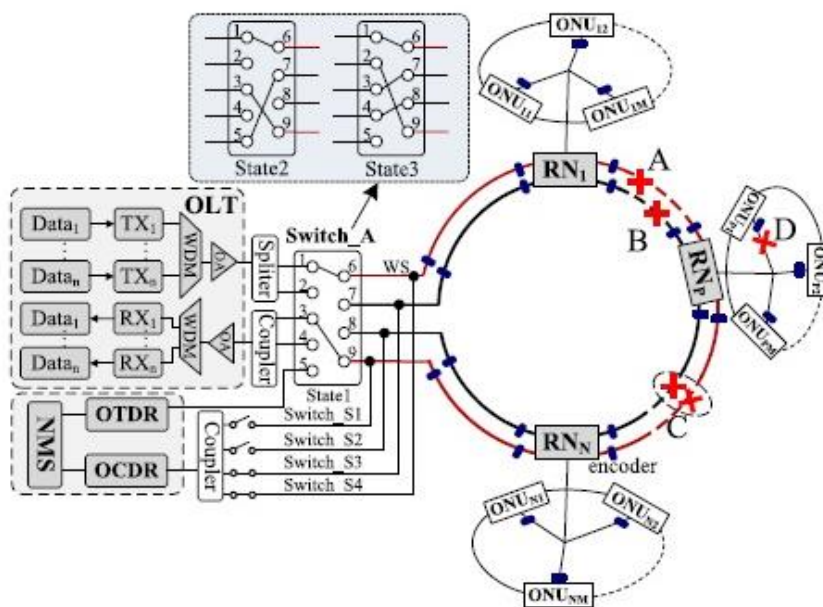


Fig. 1 Design of advanced LR-PON system

The design of advanced LR-PON system is shown in Fig. 1. It is a dual-fiber ring based structure in which the central office (CO) contains the optical line terminal which is connected to various number of Remote nodes (RN's), and every RN is connected to some number of optical network units (ONUs) through the optical distribution network (ODN) [11]. There are N number of RNs on the ring, and each RN supports M number of ONUs. WDM is used in ring network and TDM is used in tree network [2]. The Switch_A ensures data transmission and locating online by OTDR work when there is a fault. When the network works normally, Switch_A is in state 1. Switch_A can also work in state 2 or state 3 in protection modes. Three states are displayed in Fig. 1. For the normal operation, transmission of two monitoring pulses in U-band is done by OCDR device in clockwise direction on both rings by turning on Switch_S3 and Switch_S4. The wavelength used for monitoring is λ_{OCDR} . With the help of wavelength selector (WS), monitoring

signal can ignore RNs and travel on the ring. The monitoring signal on the inner ring can also go down to the tree network. Each encoder can reflect a unique encoded signal back to OLT. The locations of encoders on the ring are shown in Fig. 1. The reflected optical coding pulses are collected by NMS located on OLT, which matches the received signal with its decoder cyclically, to extract the state of a particular segment. Then it compares the auto-correlation peak and threshold to decide whether there is a fault. There is no data signal transmission on the inner ring when the network works normally

Optical coding technology is a fast physical layer monitoring scheme. Periodic optical orthogonal code (OOC) is selected for its simplicity. The auto-correlation peak value of any OOC is the same as code weight ω . And the cross-correlation peak is 1 for all codes. The encoders are designed on the base of encoder structure in Ref. [13]. It is less expensive and can realize more flat optical reflected pulses.

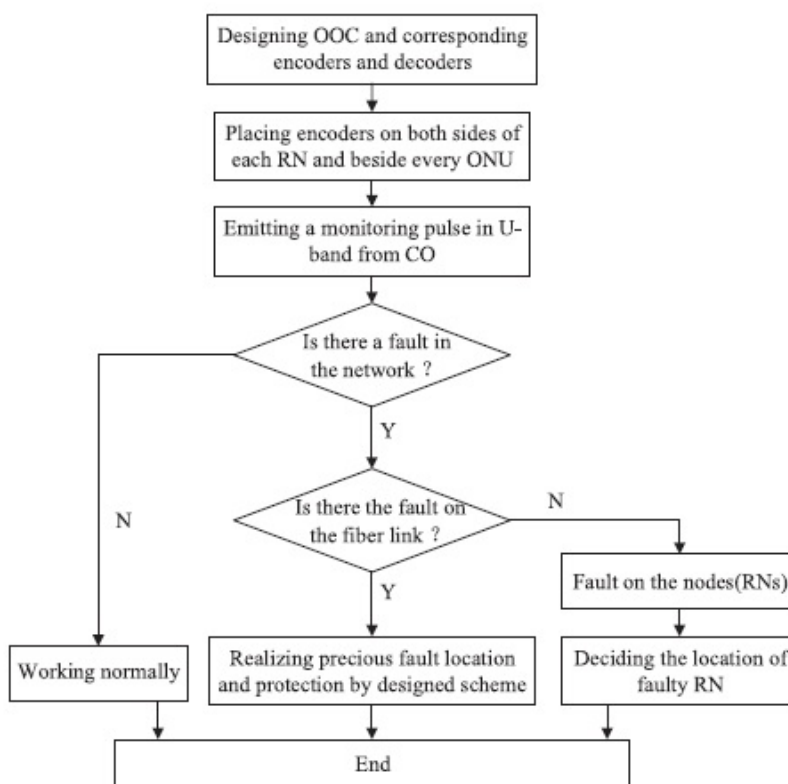


Fig. 2 Complete Working Process

The working process of the system is shown in Fig.2. First, the type of fault can be determined by OCDR technology. If all auto-correlation peaks are higher than thresholds, then all components in the network are healthy. If fault occurs in a RN, technicians are required to repair it. Otherwise, if the fault is on the fiber segment, then the fault can be determined precisely by designed OTDR equipment and the network is protected at the same time.

3. TRA BASED MONITORING TECHNIQUE

Transmission reflection analysis (TRA), is the scheme compared with other various monitoring techniques, which only requires measurement of the monitoring signals in the transmitting

direction along with backscattered power monitoring signals. This technique gives better results in terms of time taken to locate faults, complexity of system and dynamic range as compared to standard OTDR. For the ring and spur topology of LR-PON, shown in fig.3. $n\lambda$ - TRA technique is applied to locate the various lossy events in the single mode fiber. For point-to-point configuration, TRA is considered to be a very simple, efficient and cost effective monitoring technique, using a single-mode fiber [7].

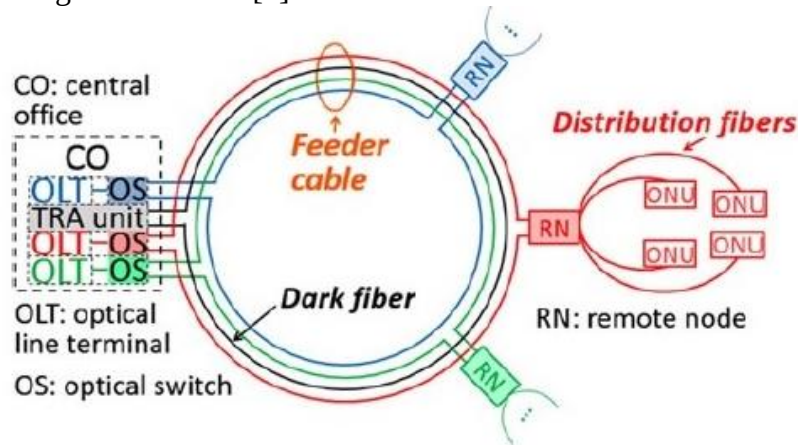


Fig. 3 Ring and Spur LR-PON with $n\lambda$ BD TRA scheme

The operation of this technique is discussed in [7]. As shown in Fig. 4(a), some optical source will generate a continuous light signal having power P_0 which is fed to the one end i.e transmitting side of the optical fiber, and at the other end transmitted power P_T can be measured. A reflected/backscattered power P_B , is also being observed by using some power meter at the transmitting end of the fiber because the Rayleigh backscattering is distributed throughout the fiber, The double wavelength-Transmission Reflection Analysis technique is shown in Fig. 4(b).

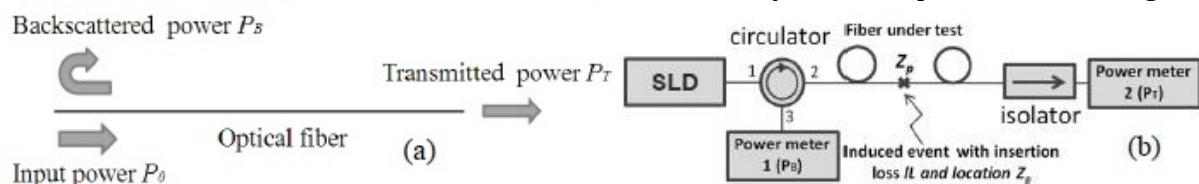


Fig. 4 Transmitted and backscattered power (a), block diagram for 2λ TRA scheme (b)

In the above said technique, a continuous light signal generated by the optical source which is super Luminescent Diode (SLD) is then fed to a single mode fiber with the help of an optical circulator. In this link an optical isolator is used which minimizes the reflection from the fiber end. After isolator a power meter is used to measure the transmitted power P_T at the other end of the fiber and back scattered power, P_B is also measured by the same device used at the other end also. For the single fault in the fiber the P_T and P_B are related to each other depending upon location of the event. By measuring the values P_B as well as P_T , the fault could be located. The technique explained above is only working for the events without reflection (e.g., bending, seepage).

As reflection of signal can also occur in the LR-PON because of breakage of fiber, so to locate such events a multi-wavelength TRA ($n\lambda$ -TRA) technique is used. The representation of this said

technique is shown in Fig. 5, where a two wavelength-TRA is taken as an example. In this approach two wavelengths are being used. Each time, one of the two sources (SLD₁ at λ_1 and SLD₂ at λ_2) emits a continuous light wave and fed into the fiber used for testing.. It works same as that of single-wavelength TRA, here the transmitted power (PT_1 at λ_1 and PT_2 at λ_2) as well as the combined reflected/Rayleigh backscattered power (PB_1 at λ_1 and PB_2 at λ_2) would be collected by the two different power meters. By defining a unique relation between the backscattered (PB_1 and PB_2) and transmitted (PT_1 and PT_2) powers, the fiber break can be located for a give event location (z_p) and return loss(RL). For determining the two unidentified values (i.e. z_p and RL), PB_1 and PB_2 can be expressed in two different equations. By solving these two equations, the localization of an event can be done.

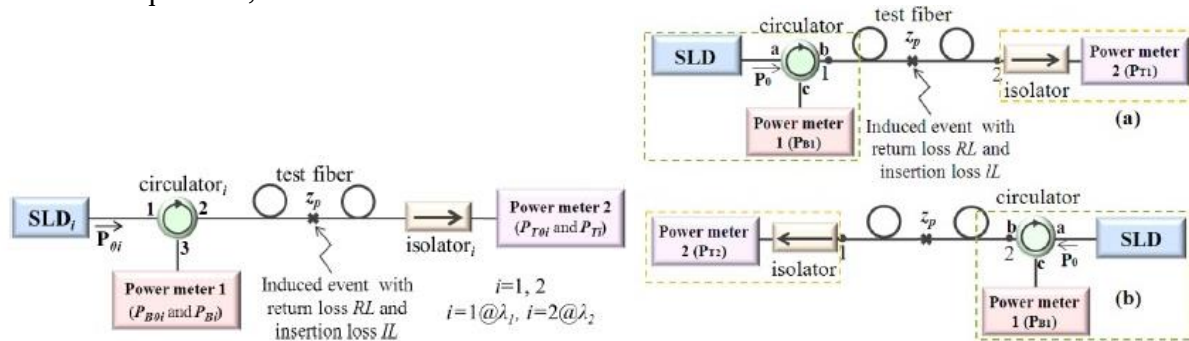


Fig. 5 Block diagram for 2λ-TRA technique

Fig.6 Block diagram of BD TRA technique

At the remote end of fiber a bi-directional scenario is being proposed in [9] for improving the low accuracy and also to measure the event location As shown in Fig. 7, at both fiber ends signal is launched from both ends of the fiber, so that the remote end in Fig. 7(a) becomes the front end in Fig. 7(b).By using this bi-directional scheme accuracy in locating a fault near the far end of fiber could be increased. [9].

4. OPERATION PRINCIPLE OF BD- TRA

The given Long Reach Passive Optical Network ring based system shown in Fig. 7, represents the combination of nλ-TRA and the Bi-Directional-TRA. An OS (optical switch) of 2×2 configuration is used to obtain the measurement from two opposite directions for the ring structure. The clockwise direction measurement is indicated by the parallel lines in OS state whereas the state of crossing lines indicates the counter-clockwise direction. With the help of dual-channel power meter both P_T 's and P_B 's are measured.

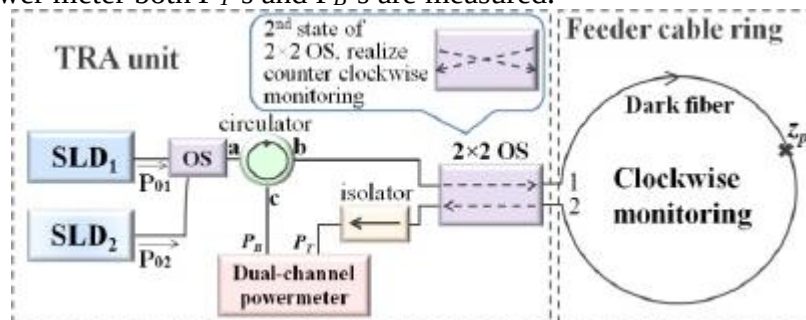


Fig. 7 Block diagram for 2λ-BD-TRA

As lossy events of an fiber optic link could be classified in two categories: non-reflective events and reflective events. In the first category, bending of fiber and leakage are included while in the second fiber break is considered. For locating the event with high accuracy, single wavelength and double wavelength TRA should be used in the mentioned categories, respectively. For checking the bendings of fiber and breaks, the corresponding mechanisms are explained in [10] and [11]

The procedure for monitoring the fault is explained here. If the fault is detected in the feeder cable ring then at the instant triggering of one of the light source will be done. After which the transmitted monitoring power (P_T) is measured by the power meter located within the central office (CO). If the output of the power meter is zero, this is the indication of the breaking of a fiber. For locating the precise break point, triggering of the another light source is to be done for initializing a double wavelength-BD-TRA method. If there is decrease of power P_T , in the power meter, it indicates that there is no break in fiber, but a lossy event has occurred, which may either be a bending of fiber or leakage. Then single wavelength-BD-TRA measurement will be used for the localization of the bending or seepage.

5. CONCLUSIONS

A fast and precise failure location scheme combining OCDR and OTDR technique in dual-ring LR-PON is displayed. The whole network can be observed by an optical coding mechanism. By measuring auto-correlation peak, detection of faulty fiber segment is done if its value is lower than threshold, then specific faulty point position can be located by OTDR device. At the same time, a protection mechanism dealing with failures is provided. It can protect the whole LR-PON against various faults, with low loss, low noise and high reliability. This designed structure can help to achieve monitoring by OCDR, precise locating online by OTDR and data signal protection in a single process.

As the TRA technique requires only the measurement of power levels, and the time required for measurement is also very less approx. 2–3 seconds, while in the OTDR it is in some minutes. Furthermore, this technique ensures potential cost-saving because of the use of light source without modulation and a simple power meter which makes very simple monitoring system. In OTDR, trade-off between spatial resolution and the dynamic range is obtained while in TRA, when the input power level is increased, a large dynamic range (>60 dB) along with a high spatial resolution can be realized. This scheme can also differentiate one as well as multiple event cases.

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