An advanced Dark Fiber Monitoring System for Next Generation Optical Access Networks

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We propose a simple and effective monitoring system based on multi-wavelength bi-directional transmission reflection analysis approach for Next Generation long-reach passive optical networks. Both experimental and simulation results have demonstrated that the proposed system can reach high accuracy for fault localization.

Introduction

Long-Reach Passive Optical Networks (LR-PONs) spans the extends from the traditional range of 20 km to 100 km, which in turn reduces the number of central offices (COs) in the field, realizing a potential cost saving. Among different topologies, "ring-and-spur" approach where a ring is employed for feeder section followed by several sub-trees for distribution segments, is considered as promising for LR-PONs thanks to its low infrastructure cost and high reliability performance [1]. However, due to high capacity provisioning and large coverage, a single failure occurring in the LR-PON (especially in the feeder section) can result into a huge loss of data. In order to minimize the interruption time and to improve the network reliability, pro-active fault monitoring of the LR-PON becomes extremely important. In this paper, we report a monitoring system using a "dark fiber" and multi-wavelength bi-directional Transmission Reflection Analysis (nλ-BD-TRA) system (as shown in Fig.1), which is capable of detecting, identifying and localizing major faults (breaks, bendings/seepage) in the feeder ring. A "dark fiber" refers to a fiber that is deployed in the same cable as the data-carrying fibers but do not carry any data. Dark fiber monitoring can cover the major faults of all the fibers in the cable, such as cable cuts and bending/seepage [2]. Also, by using a dark fiber, one can choose any set of monitoring wavelengths without affecting the data signals. The dark fiber based monitoring scheme therefore enables an effective and flexible LR-PON monitoring.

Operation principle

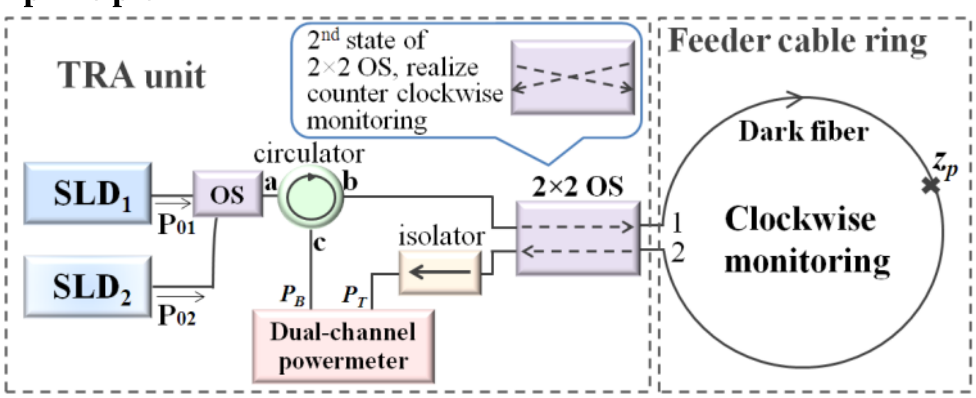

Fig. 1. Schematic diagram of the proposed "dark fiber"and nλ-BD-TRA based monitoring scheme

Instead of using the conventional OTDR technique for dark fiber monitoring, we have implemented a multiple-wavelength TRA approach that has already been mentioned in [3]. TRA only requires measuring the power levels of transmitted (P_T) and backscattered (P_B) signals when an un-modulated continuous wave (CW) light source is sent into the fiber under test. It could outperform OTDR thanks to its superior detection speed and simple system configuration [4,5]. However, for the case of long reach (e.g. fiber length >20 km), the TRA technique presents a quite low fault localization accuracy when the events occur close to the remote end. In order to improve its accuracy, we propose a bi-directional configuration, specifically tailored for any ring-based LR-PONs.

Let us note that the events occurring in a fiber can be divided into non-reflective and reflective events. Bending and seepage are included in the first type while fiber break belongs to the second type. For achieving high accuracy of localization, 1λ- and 2λ-TRA should be applied in the first and second case, respectively. The overall monitoring procedure is described hereafter. If a fault occurring in the feeder cable ring is detected by the logical/network layer, one of the two light sources in the monitoring system will be first triggered. The next step consists in measuring the transmitted monitoring power (P_T) detected by the powermeter (see Fig. 1). If the powermeter shows a null output of P_T, it indicates the occurrence of a fiber break. In such a case, the other light source will also be triggered to realize a 2λ-BD-TRA solution and localize the break. If the powermeter only shows a decrease of P_T, it indicates that the fiber is still connected but a lossy event is introduced, which implies a fiber bending or seepage. The 1λ-BD-TRA measurement will then be activated to localize the bending or seepage.

Experimental validation and discussion

The experimental set up is shown in Fig. 1. In this experiment, a fiber break is introduced at four different locations along a 56.03 km-long standard single-mode fiber. For comparison purposes, the events localization has also been measured by a commercial OTDR, which has a localization accuracy of 30 m (a pulse duration of 300 ns has been selected in order to get a necessary dynamic range). The experimental results are presented in Tab. 1.

Tab. 1: Comparison of the event localization (z_p) measured by OTDR and the proposed TRA based approach

Break locations	z_{p1} [km]	z_{p2} [km]	z_{p3} [km]	z_{p4} [km]	**Bending locations**	z_{p1} [km]	z_{p2} [km]	z_{p3} [km]	z_{p4} [km]
TRA	-0.001	1.726	26.44	51.12	**TRA**	0.015	1.724	26.43	51.12
OTDR	0	1.727	26.42	51.13	**OTDR**	0	1.727	26.42	51.13
Difference	1m	1m	20m	10m	**Difference**	15m	3m	10m	10m

As depicted in Tab.1, the proposed monitoring scheme provides very similar localization results as OTDR, demonstrating its capability of localizing different types of events in a fiber ring with good accuracy.

Conclusion

A dark fiber based monitoring system for Ring–and-Spur LR-PON has been proposed. The capability of localizing different kinds of faults along the feeder ring has been theoretically analyzed and experimentally verified. Compared to OTDR, the proposed nλ-BD-TRA system provides better localization functionality for LR-PON monitoring.

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