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Session 7.6 – Performance improvement and monitoring in PONs

Chair: Nikolaus Gieschen (T-Systems Enterprise Services GmbH, Germany)

Simple Approach to Enhance Bidirectional Transmission Performance of WDM-PONs with RSOAs

Shu-Chuan Lin (National Taiwan University of Science and Technology, Taiwan);
San-Liang Lee (National Taiwan University of Science & Technology, Taiwan)

Centralized Frequency Stabilization by Dithering Transmission Spectra of PLC-Type MZI-AWG for DWDM-PON

Masamichi Fujiwara (NTT Access Network Service Systems Laboratories, Japan);
Hiro Suzuki (NTT Access Network Service Systems Laboratories, Japan);
Takuya Tanaka (NTT Corporation, Japan); Naoki Ooba (NTT Corporation, Japan);
Naoto Yoshimoto (NTT Access Network Service Systems Laboratories, Japan);
Makoto Tsubokawa (NTT Access Network Service Systems Laboratories, Japan)

Reduction of Signal-Induced Rayleigh Noise in a 10Gb/s WDM-PON using a Gain-Saturated SOA

Eimear MacHale (University College Cork and Photonic Systems Group, Ireland);
Giuseppe Talli (University College Cork, Ireland);
Chi Wai Chow (Photonic Systems Group, Tyndall National Institute, Ireland)

Low-Cost Non-intrusive Fiber Monitoring in a PON Last Drop

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Xing-Zhi Qiu (Ghent Univ., Belgium); Wei Chen (Ghent University, Belgium);
Bert De Mulder (Ghent University, Belgium);
Johan Bauwelinck (Ghent University, Belgium);
Bart Baekelandt (Ghent University, Belgium)

Remotely Powered Optical Switch for Remote Subscriber Aggregation and OTDR Measurement in PON

Roger Helkey (Calient Networks, USA);
Michael Inbar (Calient Networks, USA);
Olivier Jerphagnon (Calient Networks, USA);
Volkan Kaman (Calient Networks, USA);
Shifu Yuan (Calient Networks, USA);
Jim Klingshirn (Calient Networks, USA);
Nicholas Madamopoulos (Calient Networks, USA);
John Bowers (Calient Networks, USA)

Effect of PON Geographical Distribution on Monitoring by Optical Coding

Habib Fathallah (Université Laval, Canada)

Low-Cost Non-intrusive Fiber Monitoring in a PON Last Drop

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Abstract Low-cost embedded negative step response OTDR performs PON last drop fiber plant monitoring from an ONU without need for additional optical components, without penalty on network link performance and without service interrupt.

Introduction

With growing deployment and splitting factors of passive optical network (PON), preventive monitoring of PON fiber plants becomes a hot topic. A commercial optical time domain reflectometer (OTDR) cannot be deployed for continuously monitoring active PONs because of cost and labor penalties, and the intrusive nature of the measurements. OTDR performed from the optical line terminator (OLT) cannot distinguish the different drop sections towards the optical network units (ONUs) as shown in Fig.1, nor overcome high losses of power splitting up to 1x64. The newly developed non-intrusive OTDR technique (called FiberMon, patented) however can be embedded at low incremental cost. In this paper, results are presented for different methods of OTDR signal acquisition, and the method for PON last drop fiber monitoring is discussed.

Fig. 1 Embedded OTDR can monitor the last fiber drops of PON from ONU without ambiguities comparing with the conventional OTDR from OLT.

FiberMon concept

FiberMon is a passive, non-intrusive OTDR technique [1] [2] acquiring reflections and backscattering from the data bursts emitted by the ONU laser for upstream data communication without OTDR excitation pulses. The hardware cost is minimized by re-using the ONU laser diode (LD) and/or its associated monitor photo diode (MPD) for acquiring the OTDR echoes, and no additional OTDR optical or electro-optical components are needed. All front-end components required for FiberMon OTDR are purely electronic (Fig. 2), and can be integrated economically in the laser driver chip.

Experimental results

Reusing the ONU laser as photo-detector requires

that no optical isolator is present that blocks the reflected light. This is common practice, as the ONU is very cost sensitive. Suitable commercial PON laser types can be FP, DFB or VCSEL. Different optical components were evaluated as an OTDR photo-detector, against a separate PIN photodiode and a 10/90 optical coupler used as a reference in our experiments.

Fig. 2 OTDR RX embedded into ONU transceiver

Table1 Different OTDR echo acquisition approaches

LD / MPD as OTDR Rx	Responsivity (A/W)	Sensitivity (dBm)
INPHENIX DFB-MPD	0.040	-43.8
FP-LD (Sumitomo SLT4716)	0.12	-48.0
FP-MPD (Sumitomo SLT4716)	0.033	-43.6
VERTILAS VCSEL	0.18	-49.7
10/90 Coupler + PIN PD (Siemens SFH2223)	0.079	-49.4

Table 1 lists the responsivity and sensitivity measured on a FiberMon OTDR RX with 5 MHz bandwidth. The FP-LD and VCSEL show better RX sensitivity than DFB-MPD and FP-MPD due to their higher responsivity. The measurements show that the responsivity of the zero-biased VCSEL is polarization independent, but the zero-biased FP-LD and the FP-MPD are somewhat polarization dependent. By simultaneously measuring on both the LD and the MPD of an FP module, the polarization dependency can be largely compensated. The dependency of the detector responsivity on wavelength and temperature

was investigated, and both theoretical analysis and experimental results do not show a significant limit on the OTDR echo acquisition.

A FiberMon lab prototype is based on negative step response (NSR) which conforms a prior publication [2]. Fig. 3 OTDR curves (log scale) were measured on the FP-MPD prototype, showing two cascaded sections of ITU-T G.652 compliant single-mode fiber with a similar backscatter constant and attenuation: a first section of 5.1 km, and a second of 2.5 km with a PON power splitter emulating the last drop termination as an Fresnel reflector at the end. A 10/90 tap was inserted between two sections of fiber. Pulses with 100 μ s length and 3 dBm peak optical power were injected repeatedly into the test fiber. To improve the signal-to-noise ratio, an averaging function and low-pass filtering were activated in FPGA following an A/D converter.

In the measured NSR curve, a discrete Fresnel reflection does not show up as a reflected pulse but as a step in the level of the reflected light (artifact A in Fig.3), which can increase the spatial resolution substantially. The emulated pulse (2 μ s) response of artifact A (in the left-bottom of Fig. 3) illustrates the fiber event in a more familiar way [1]. Experimental results confirm the artifact A with 1.4 dB loss and -45 dB Fresnel reflection at 5.1 km, and the artifact B at 7.6 km with a -50 dB Fresnel reflection as termination.

Fig. 3 Measured NSR OTDR curve in linear scale on FP-MPD from the lab prototype.

PON last drop monitoring

1) Valid NSR conditions

Maximum information can be extracted from non-intrusive OTDR based on the NSR when two network parameters, the length of the fiber to be monitored (L_{Fiber}) and the length of the data burst (W_{Burst}), are known beforehand [1]. Assuming the length of the fiber to be investigated is known to the network operator (ITU-T Recommendation L.53 (2003)). Since the FiberMon OTDR functionality is embedded within the ONU transceiver, the length of each data burst transmitted by the ONU is known, and can be acquired by the OTDR circuitry located in the same module.

To clarify the measurement concept without losing generality, a PON topology with a single-stage splitter

has been analyzed and assuming that the speed of light inside the fiber is 5 μ s/km.

- When $W_{\text{Burst}} > L_{\text{Fiber}} * 10(\mu\text{s})$, the NSR can be obtained without any interference from other ONU excitations. If the idle window after the OTDR excitation (reusing data burst) is longer than $L_{\text{Fiber}} * 10(\mu\text{s})$, there is no interference from its following excitation.
- When $W_{\text{Burst}} < L_{\text{Fiber}} * 10(\mu\text{s})$, only pulse response can be obtained. If the idle window before the OTDR excitation is longer than $L_{\text{Fiber}} * 10(\mu\text{s})$, there is no interference on the whole OTDR trace from other ONU excitations.
- If both above conditions a) and b) can not be satisfied, it means that the first part of the OTDR trace is interfered by other ONU excitations reflected by the power splitter. Although the power level of the interferences is rather low (smaller than -50 dBm), it can still make the OTDR trace very distorted in an uncontrollable way. Under this situation, an extended ranging window can be allocated to this ONU by the OLT. This may require some minor adaptations of the TC layer protocol.

OTDR traces from all three conditions can be merged by data processing [2] into a standard NSR format.

2) Transient issue and fiber break

The transient and ripple (Fig. 3) at short distance from the source are due to speed limitations and parasitics of the board-level electronics performing the switch-over from transmit mode to OTDR mode. These imperfections can be reduced substantially by integrating the high-speed electronics inside the burst-mode laser driver chip. In case the fiber is broken completely, FiberMon still can locate the break when it falls outside the transient region (technically it is feasible to limit this transient effect within 100 meter away from the location ONU). Though there is no upstream path left to communicate this location of the fiber break to the OLT, this faulty location can be displayed on the ONU box signaling a failure condition readable by the customer or service staff, or be communicated via other means (internet, cell phone, wireless readout).

Conclusions

Experiments show that embedded NSR OTDR can yield as good a precision for locating an abrupt change in attenuation as the classic impulse-response backscattering. The low cost and non-intrusive nature make it very suitable for PON last drop monitoring from the ONU.

References

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