Vázquez, D.S Montero, J. Montalvo, A. Tapetado (2015). "Monitoring Techniques in Broadband Access Networks". *Proceedings of the 17th International Conference on Transparent Optical Networks, ICTON2015, Budapest, (Hungary), 5-9 July, 2015,* pp.1-3

Monitoring Techniques in Broadband Access Networks

C. Vázquez[1], Senior *Member, IEEE*, D.S Montero[1*], J. Montalvo[2], A. Tapetado[1]
[1] Universidad Carlos III de Madrid. Avda. de la Universidad 30, 28911, Leganés (Madrid), Spain
Tel: (+34) 916248865, Fax: (+34) 916249431, e-mail: dsmontero@ing.uc3m.es
[2] Telefónica Investigación y Desarrollo, S.A.U, Ronda de la Comunicación s/n, 28050, Madrid, Spain

ABSTRACT
Broadband access networks needs specific monitoring techniques at the physical layer to provide the quality of service required by the users. Similarities between sensor and access networks will be analysed to get best practices in both scenarios to provide novel monitoring and self-reference techniques.

Keywords: broadband access network, monitoring technique, self-referencing, drop fiber

1. EXTENDED ABSTRACT

Broadband penetration is related to Gross Domestic Product (GDP) and labour productivity in countries and business efficiency is also related to the use of internet, whose use is highly dependent on broadband speed and penetration. During the last years, strategic plans stimulating broadband access are taking place all over the world. Access networks with sections of optical fiber increasingly closer to the customer premises have been massively deployed around the world offering higher access speeds up to 1 Gb/s per customer. As an example, Fiber to the Home (FTTH) Council Europe reported 63 million homes passed and 16.2 million subscribers in Fiber to the Home/Building (FTTH/B) networks in Europe at the end of 2012, with respective Compound Annual Growth Rates (CAGR) of 40% and 50% between years 2009 and 2012 [1].

Among the different fiber access networks, FTTH networks are access networks fully built of optical fiber from the operator to the customer premises. Among them, Passive Optical Networks (PONs) use point to multi-point logical topologies using optical power splitters in the Optical Distribution Network (ODN) to communicate the network operator equipment, namely Optical Line Termination (OLT), located in the Central Office (CO), with several end user devices, namely Optical Network Terminal (ONT), located in the customer premises. More recently, new PON systems are emerging that employ Wavelength Division Multiplexing (WDM) techniques in an exhaustive way as a more efficient way to deliver traffic to Customer Premises Equipment (CPE) devices, where the end-users are connected to the services, in an individual way with a dedicated capacity of up to 10 Gb/s full-duplex for each single customer. These systems, commonly referred to as WDM-PON, are still under standardization process and field trials, having the most relevant commercial deployments only taken place in a few countries like Japan and Korea [2].

In this scenario, telecom operators have come across the challenge of supervising a new outside plant with PON architectures in point-to-multipoint topologies, in order to achieve a low operational cost of the network, a reduced risk of service disruption and a rapid recovery time in case of failure at the optical physical layer. The cost efficiency of fiber access networks is a key issue, being the reduction of operational expenditures (OPEX) for the maintenance of the fiber infrastructure a relevant aspect to be considered.

Typical fiber problems that may take place in the distribution and drop stages of a PON outside fiber plant are dirty contacts between connectors, damaged connectors, macrobending and fiber breaks. While these problems can be easily detected in point-to-point optical fiber links using conventional Optical Time Domain Reflectometer (OTDR) techniques, the monitoring of FTTH/B systems with point-to-multipoint physical configurations is a new challenge to take into account**.** OTDR is a well- established and well-known technology for the physical layer supervision of optical fibers. OTDRs periodically transmit optical supervision signals modulated with electrical pulses into the fiber to test, and receive the backscattered signal from the fiber, thus characterizing the fiber through distance. This is a very challenging scenario for troubleshooting using OTDRs, because the reflected signals from different fiber branches behind power splitter overlap and the optical attenuation is very high.

OTDRs can be used for Operation and Maintenance (O+M) of ODNs in two approaches:

- De-centralized approach, which involves a technician dispatch to the Outside Plant (OSP) with portable OTDR when the network operation center (NOC) detects an alarm which may be caused by a fiber fault.

- Centralized approach, which involves using OTDR functions from the operator CO where OLTs are installed, combining the information obtained from the OTDR measurements with remote active elements supervision. Thus achieving the diagnostic of the ODN in case of active alarms related to one or more

ONTs. A variation of this approach consists in using optical demarcations based on optical reflectors in the ONT side [3], thus discriminating between a communication problem due to a problem inside the customer premises and a physical layer failure in the ODN before the optical demarcation point. It is also possible to reserve a few dark fibers (which are not being used for any optical communication) in a fibre cable only for monitoring purposes. Typically, fiber cables deployed from COs may have 128-256 fibers. A dark fibre can be used to perform OTDR measurements all along the optical path of the fiber cable in a point to point fashion, thus being able to detect and locate major fiber cable faults involving a large number of PONs. Nevertheless, this approach is not scalable in a cost-efficient way for supervision of all the PON fibers, especially for those which are more close to the end-customer, and it is more adequate for supervision of feeder fiber sections which are close to the CO.

Centralized monitoring is the most cost effective approach because it allows the cost sharing of the test equipment among all the PONs located in the same CO, as well as a centralized management and control from the O+M systems. A qualitative performance and cost analysis of centralized OTDR techniques can be found in [4].

Novel alternatives have been recently proposed for increasing system performance by partially avoiding OTDR traces overlapping behind power splitters, based on the use of Multi-wavelength OTDRs with selectable wavelength of the test signal, in combination with special splitters in the ODN [5]. Potential cost savings using a multi-wavelength OTDR centralized PON ODN supervision with regards to de-centralized supervision have also been analysed in [6]. Other reported approaches in order to ensure that each individual branch contributes to the OTDR trace in a distinguishable way were based on the use of Raman amplification [7], Optical Code Division Multiplexing (OCDM) [8], embedded low-cost OTDR inside ONTs [9] or drop-fibers with individually-assigned Brillouin frequency shifts [10]. Even though these approaches can be very useful in certain situations, still they may require expensive equipment (Tuneable OTDR, Brillouin OTDR, OSA), non-scalable and inefficient fiber deployment (Brillouin frequency-shifted drop fibers) or do not avoid the need for end-user collaboration (OTDR at ONTs).

Other authors have proposed a centralized permanent fiber supervision approach capable of locating faults up to the customer location in FTTH PONs behind power splitters, with no need to modify or replace the remote nodes of the ODN, by the use of monitoring blocks both at the Central Office (CO) and at the CPE in-line with the PON data signals. As the distance between the OLT and each ONT is known, the delay between the reception times of the failure event at the corresponding blocks can be used to calculate the location of the fiber fault [11].

An alternative approach consists of employing RF-modulation self-referencing techniques and delay line filters in a centralized monitoring unit that allows the individual measurement of power attenuation taking place within drop fibers in WDM-PON systems. This approach included an optical switch/filter to launch the monitoring signals into the network [12].

Finally, it is worth mentioning that the communications PON architectures can fit the physical topology of sensor networks. The above WDM-PON topology can form the main core concerning passive optical networks in which there is no need for optical amplification. However, the usefulness of the WDM approach in sensor applications has not received as much practical attention. So hybrid networks can be considered as an interesting opportunity, sharing one optical fiber among multiple buildings/homes/subscribers/sensors. In addition to this, the communications mass-market has been promoting optical band-splitting devices and optical sources which offer a great potential for remote optical sensing.

ACKNOWLEDGEMENTS

This work has received funding from the Spanish Ministry of Economía y Competitividad under projects TEC2012-37983-C03-02 (CFOOT-TIC) and TEC2009-14718-C03-03, and support from the Comunidad de Madrid project under grant S2013/MIT-2790 (SINFOTON-CM).

REFERENCES

[1] FTTH Council Europe, http://www.ftthcouncil.eu.

[2] Zhaowen, X., et al., ”10 Gb/s WDM-PON based on FP-LDs injection locked by downlink optical carrier”, Optics Communications, 2008, 281, (20), pp. 5213-5217.

[3] ITU-T L.66: Optical fiber cable maintenance criteria for in-service fiber testing in access networks (Appendix II), 2007.
[4] J. Chen et al., "Cost-Efficient Fault supervision Schemes for Next Generation Optical Access" (invited), Asia Comm. And Photonics Conf. 2014, paper Ath1H.4, Shanghai (China), 11-14 Nov. 2014.
[5] P. Urban et al., "Fiber Plant Manager: an OTDR and OTM-based PON Monitoring System", IEEE Comm. Mag., Vol. 51(2), pp. S9-S15, Feb. 2013.
[6] P. Urban et al., "Detection of fiber faults in passive optical networks", J. Opt. Commun. Netw., vol. 5(11), pp. 1111-1121, Nov. 2013.
[7] Yuksel, K., et al: "Centralised optical monitoring of tree structures PON using a Raman-assisted OTDR", Proc. Int. Conf. Transp. Opt. Netw., Rome, Italy, July 2007, pp. 175-178.
[8] Fathallah, H., and Rusch L.A., "Code-division multiplexing for in-service out-of-band monitoring of live FTTH-PONs", Journal Optical Networking, 2007, 6, (7), pp. 819-829.
[9] Chen, W., et al: "Embedded OTDR Monitoring of the Fiber Plant behind the PON Power Splitter", Proc. Symp. IEEE/LEOS Benelux Chap., Eindhoven, Netherlands, Nov-Dec. 2006, pp. 13-16.
[10] Honda, N., et al: "Bending and connection loss measurement of PON branching fibers with individually assigned Brillouin frequency shifts", Proc. Opt. Fiber Comm. Conf., Anaheim, California, March 2006, OThP6.
[11] A. Tapetado, D.S. Montero, J. Montalvo, P.J. Pinzón, C. Vázquez, "Sistema permanente de supervisión de detección y localización de fallos de fibra óptica en PONs", 9ª Reunión Española de Optoelectrónica OPTOEL´15, Salamanca (Spain), Jul. 2015.
[12] J. Montalvo, D.S. Montero, C. Vázquez, J.M. Baptista, J.L. Santos, "Radio-frequency self-referencing system for monitoring drop fibers in wavelength division multiplexing passive optical networks", IET Optoelectronics, 4(6), 226-234, 2010.