Advanced Monitoring Systems for Next Generation Passive Optical Networks

Passive optical networks (PONs) have been currently widely deployed in the field. They provide fixed broadband data connections to business and residential subscribers with various services, such as high-quality IP telephony, video on demand and high-speed data communications. With the rapid growth of bandwidth needs and number of connected devices requested by the paradigm shift to support future mobile networks (5G) and Internet of Things (IoT), standardized legacy PONs (e.g., Gigabit-PON, GPON, ITU-T recommendation series G.984.1-G.984.6 and Ethernet-PON, EPON, IEEE 802.3ah) are not sufficient to satisfy the customers’ requirements. They have gradually evolved into next generation PON (NG-PON) systems that are expected to offer higher data rate (40Gbit/s in downstream and 40Gbit/s in upstream), larger coverage (>60km), while keeping low maintenance cost, supporting multiple applications and allowing higher link budget (29-35dB).

On the other hand, a failure on the physical layer causes a reduced optical power at the reception, introduces accordingly a service degradation which affects the users’ quality of experience and eventually results in a revenue reduction for the operator. Particularly, in NG-PONs with high capacity and large coverage, any connection interruption may introduce a huge amount of data loss. In order to minimize the service interruption and to improve the network reliability, pro-active fault monitoring becomes of key importance for the NG-PONs. In general, a monitoring system is required to provide real-time information on fiber/device fault detection and localization.

Different physical layer monitoring techniques for characterization of optical components and fibers have been developed to enable effective fault management in PONs, most of which in the field are nowadays based on optical time domain reflectometry (OTDR). Besides providing fault detection and localization information in a point-to-point fiber link, OTDR is also capable of measuring parameters such as fiber attenuation, length, insertion losses and return losses of the optical components deployed in the link. Nevertheless, for efficient NG-PON monitoring, improvements and breakthroughs are still required to address some certain limitations of the OTDR method.

In the frame of this thesis, we focus on the development of simple and effective NG-PON monitoring schemes. We proposed two transmission reflection analysis (TRA) based PON monitoring techniques, which is based on the measurement of transmitted and Rayleigh-backscatter powers. Accordingly, two fast and simple monitoring schemes are developed for different monitoring applications of NG-PONs. Both theoretical analyses and experimental validations show that the proposed two solutions are able to monitor the network with a good spatial accuracy, a high detection speed and a low impact on data traffic.