Abstract

The access network is the final part of the telecommunication network delivering data to the end user. From 20 years, this network has been based on the PON architecture, a point-to-multipoint fiber-optic structure allowing the access directly into end-users' houses.

In this Thesis, we first analyze the current state of PONs, then explore their future, and finally study the telecommunication network in the growing application area of optical sensing.

About PONs evolution, in September 2021 the ITU-T standardization entity released the 50G-PON standard setting a downstream capacity of 50Gbps for the access segment. To achieve this high rate, various strategies have been introduced, such as APD receivers and equalization procedures, but also the quality of the transmitter needs to be sufficiently high expressed by TDEC. The TDEC is the parameter that assesses the optical quality of a 50Gbps transmitter through an algorithm applied to

the measured eye-diagram transmitted. To highlight the key parameter dependencies and simplify the procedure in some cases, we study the TDEC algorithm in detail, by means of simulations and experimental validations.

For the future PONs, we underline that the 50G-PON rate is achievable with IM/DD modulation, the simpler and more cost-effective format used in PONs since their inception. However, due to chromatic dispersion, IM/DD is nearing its limits. Even though the next 100G-PON may remain based on IM/DD (maybe changing modulation format from PAM2 to PAM4 and adding amplifier stages in the central offices), we are approaching the end of IM/DD's capabilities. The debate on the future is ongoing, but the scientific community has started to explore the possibility of introducing coherent modulation in the access network.

The associated challenges are significant, including increased cost and complexity, and a redefinition of the access network will require, potentially merging the access with the metro network. In this scenario, we analyze this merger possibility inserting ROADMs at their boundary. We first try to address the challenges and, then, we provide simulation and experimental results demonstrating the real possibility of convergence in terms of both performance and architectural details. We performed analysis on fully coherent modulation signals at 200G PM-QPSK and 400G PM-16QAM. For 400G, we demonstrate the ability to meet current PON constraints at eight times the transmission rate of today, while for 200G we show excellent results increasing the covered distance of the access network and number of end-users growth.

Finally, we consider the telecommunication network in a different and expanding application field, the sensing, utilizing the Distributed Acoustic Sensing (DAS). DAS systems can detect natural phenomena such as earthquakes or vibrations along the length of the optical fibers acting as sensors. To perform acquisitions, DAS typically uses fibers not implemented for data transmission, known as dark fibers. However, considering the extensive reach of the telecommunication network, it can be very useful to integrate the sensing analysis with data transmission. In the last part of the Thesis, we analyze the coexistence of a 40WDM fully coherent transmission with DAS, showing that coexistence seems possible.