Abstract

Title: Towards Higher Speed Next Generation Passive Optical Networks.

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Regarding fixed access, all international trends show that Fiber-to-the-Home (FTTH) using Passive Optical Networks (PON) architecture will become so widespread to be considered as a commodity in most urban areas. PON structure based on an optical point-to-multipoint (P2MP) architecture, is illustrated in Fig 1. A PON consists of an Optical Line Terminal (OLT) located at the CO of the operators, a set of Optical Network Units (ONU) close to end customers, and an Optical Distribution Network (ODN) connecting the CO and end customers. The P2MP connection is accomplished by exploiting the passive splitters. Moreover, there are only passive devices, for example, optical fiber, connectors, and optical splitters, in the PON outside plant.

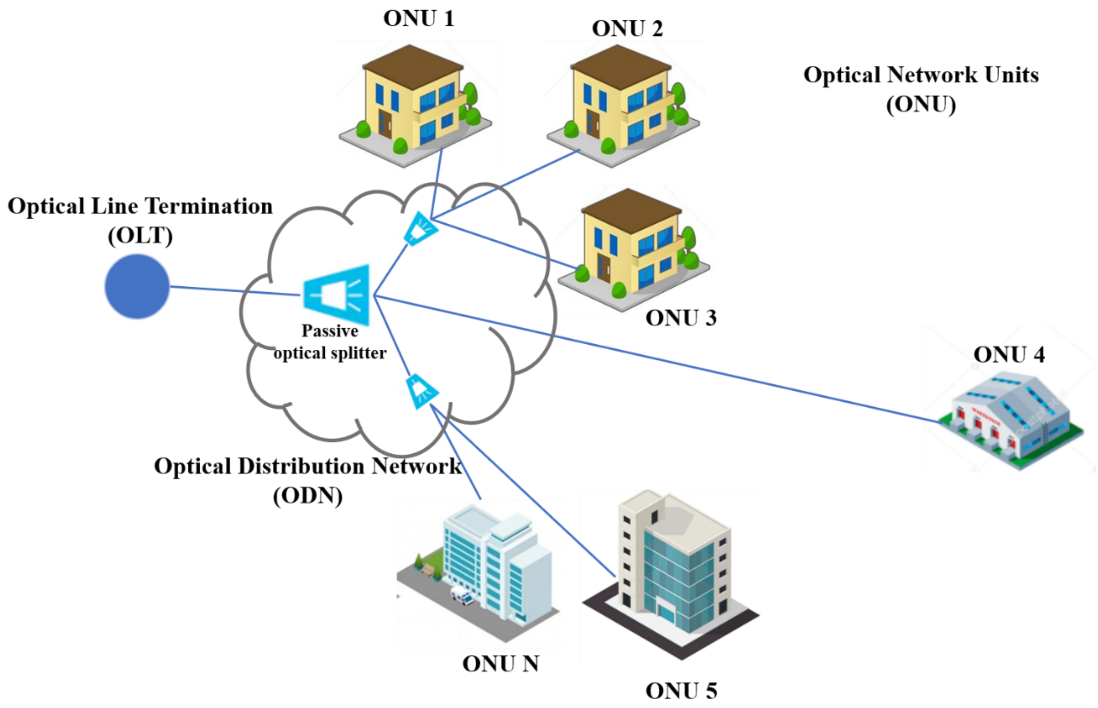

Fig.1 The most common Passive Optical Networks structure, based on point-to-multipoint architecture.

The ever-increasing bandwidth demand at all network levels, including at the edges towards the end-customers, is motivating the continuous increase of PON towards higher bit rates. Currently, the deployment is mostly Gigabit PON (G-PON, 2.5 Gbps) and 10 Gb/s PON (XG-PON, 10 Gbps). PON solutions, able to operate at 50 Gbps per wavelength (λ), have been recently developed and standardized, based on Non-return-to-zero on-off keying (NRZ-OOK) and intensity-modulation (IM) and direct detection (DD) systems. The next step in PON evolution will be driven by 5G/6G fronthauling capacity demands and will require the development of 100 Gbps/λ (and beyond) systems, which poses big challenges if retaining the conventional DD scheme. PON upgrades to higher speed must minimize the cost, including coexistence with legacy PONs. They should work on the already deployed optical distribution network and reuse existing high-volume mature optoelectronic technologies (especially in optical network units (ONU)). To reach all above requirements at such high bit rate, two main challenges must be addressed, i.e., bandwidth limitations in optoelectronics and a severe impact of chromatic dispersion.

In this Thesis, we review the PON evolution roadmap, and propose technologies and solutions for higher speed PON. Through both simulations and experiments, we analyze and study several different PON solutions from 25 Gbps/λ to 100 Gbps/λ all based on the use of advanced digital signal processing (DSP). By means of both a set of laboratory experiments and a metropolitan field trial, we discuss practical PON solutions at 25 Gbps/λ for both downstream and upstream. We study 50 Gbps/λ and 100 Gbps/λ PON downstream alternatives over standard single-mode fiber in the O-band and C-bands, analyzing different modulation formats, different types of direct-detection receivers, and different digital reception strategies. We evaluate by means of simulations the performance of these alternatives under different optoelectronics bandwidth and dispersion scenarios, identifying O-band feasible solutions able to reach 20 km of fiber and an optical path loss of at least 29 dB over a wide wavelength range of operation based on IM-DD architecture. We simulatively and experimentally demonstrate that the digitally pre-compensated modulation schemes that are highly tolerant of chromatic dispersion, showing a possible extension to C-band operation, preserving the conventional DD with linear impairment equalization and simple nonlinear compensation at the ONU side. The additional complexity is added to the optical line terminal (OLT) transmitter, but still keeping the same ONU receiver complexity as the IM-DD approaches. The preliminary simulation analysis at 200 Gbps/λ based on the conventional DD scheme is also performed.