Towards 50G/100G Passive Optical Networks with Digital Equalisation and Coherent Detection

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Increasing bandwidth demand in residential, business, and Wi-Fi/cellular backhaul applications means that passive optical networks (PONs) with dense wavelength division multiplexing and bit rates per wavelength channel of 50 or 100 Gb/s will soon be required [1]. However, PON technologies need to be low cost, particularly the optical network units (ONUs). Additionally, the high optical losses arising from the optical splitters used at remote nodes to distribute the signals to and from multiple ONUs, lead to the requirement for high receiver sensitivity. Coherent receivers, since they surpass the sensitivity limitations of the intensity-modulated direct-detection (IMDD) systems currently used, are an attractive solution [2 – 4]. Besides its sensitivity, coherent detection provides other advantages. The local oscillator achieves good wavelength selectivity, avoiding the need for narrow optical bandpass filters. The use of digital signal processing (DSP) enables spectrally efficient signalling and digital equalization of optical transmission impairments

To implement coherent transceivers for PON applications, their cost must be reduced to the required level. Firstly, the number of components in the ONU should be kept to a minimum. Conventional coherent systems employ polarisation multiplexing, with each polarisation requiring separate balanced-photodetectors (BPD), and optical components are needed to separate the two orthogonal polarisations. For PON applications, low complexity polarisation insensitive ONU receivers have been proposed, using a variety of approaches: polarisation scrambling [5], polarisation-time block coding (Alamouti coding) [6] and differential group delay predistortion [7]. The cost and optical loss arising from the 90° hybrid used to separate in-phase and quadrature components can be avoided through its replacement with a 3-dB coupler. A single-ended photodetector (rather than balanced-photodetectors) can be employed, with the penalties from signal-signal beating interference being reduced using DSP [8].

Secondly, the cost of the individual devices in the ONU can be reduced. For example, low-cost, low-power and widely tunable distributed Bragg reflector (DSB) lasers, integrated with the data modulator, could be used [9].

The high linewidth (> 1 MHz) of low-cost lasers in the ONU can be handled using advanced phase recovery DSP, e.g., with pilot symbol-based carrier phase estimation (CPE) [10], and signal constellation shaping can improve tolerance to residual phase noise [11].

Finally, low complexity digital equalisation methods are being developed to deal with fibre dispersion and nonlinearities in the link, including machine learning (ML) based approaches [12]. End-to-end deep-learning auto-encoders, which have been shown to be effective in experiments with IMDD systems [13], could be developed for coherent PONs, and work is ongoing to develop real-time ML-based equalization.

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