WDM PON for Next-Generation Optical Broadband Access Networks

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Abstract
Recent research activities on WDM-PON access network architectures and related systems technologies are reviewed. Some key issues of current interest in WDM PON are discussed, and potential roles of WDM-PON in the next-generation optical broadband access networks will also be addressed.

1 Introduction

TDM-PON systems such as BPON and GPON are being deployed in current generation FTTH/FTTP access networks for providing broadband access offering triple play services including video, data and voice. In the near future, it is in general agreed that WDM based access networks will be enabling the next-generation optical broadband access [1-4]. WDM-PON is promising to enhance the penetration of WDM technology in the optical access networks and enable the delivery of higher capacity services to the subscribers. Each optical network unit (ONU) will be served by a dedicated wavelength channel to communicate with the central office or the optical line-terminal (OLT). The ranging problem in conventional time-shared optical access networks can also be eliminated since all upstream wavelengths will be multiplexed at the remote node (RN) without any signal collision. Each ONU can enjoy a dedicated bandwidth, which can be readily scalable according to the need of the individual ONU. These further enhance the system capacity and access network upgrade flexibility.

2 Key Issues in WDM PON Networks

Among the many research topics of WDM-PON, there are several key issues of current research interest [5-18]: (1) developing the WDM-PON protection architectures for traffic restoration schemes; (2) studies of WDM-PON architectures with a "*colorless*" (non-wavelength-specific) and "*sourceless*" ONU design, probably with centralized light source for downstream distribution at ONU for re-modulation and upstream transmission; and (3) WDM-PONs with dedicated and broadcast bandwidth and with a smooth migration path and upgrade flexibility from the current generation TDM-PON. These issues aim to enhance the networking functionalities of WDM-PONs and to enable lower cost installation, operation and maintenance.

3. WDM PON Protection Architectures for Traffic Restoration

Conventional passive optical networks adopted fiber duplication and protection switching scenarios for network protection. All in-service wavelength channels may be momentarily interrupted due to any protection switching against even only one distribution fiber failure. To address this issue, a group protection scheme [5,6] and several survivable network architectures [5-8] have been proposed that are suitable for protection and traffic restoration in WDM-PONs. The main idea is to inter-connect two adjacent ONUs [5,6] or RNs [8] by a piece or a pair of fiber such that the affected bi-directional traffic could be re-routed via the adjacent ONU or RN. Novel wavelength assignment schemes were proposed to facilitate the intelligent wavelength re-routing for traffic restoration. In [7], an alternate path switching scheme was proposed and all protection switching was performed at the OLT to protect both the feeder fibers and the distribution fibers. Such WDM-PON protection architectures and schemes could become essential in next-generation optical access network design using WDM, as both the high-bandwidth needs and reliability demand increase. This necessarily increases the complexity of the WDM broadband access networks but it could become an essential per performance goal for high-end broadband services.

4. Colorless ONUs

To lower the cost of the WDM-PONs, it is highly desirable to develop a low-cost and colorless ONU. The ONUs should be *colorless* (in other words, no ONU is wavelength-specific) to decrease the costs of operation, administration, and maintenance (OA&M) functions, as well as the production cost since mass production becomes possible with just one ONU specification. Recently, several schemes for colorless ONU in WDM-PONs have been proposed. Centralized broadband light source at the OLT, such as SLD [9,10], Fabry-Perot (FP) laser [11], or supercontinuum-based broadband light source [12], are spectrally-sliced at the RN and distributed to each ONU as upstream carriers for data modulation. In [11-19], Fabry-Perot (FP) laser diodes [13,14], reflective semiconductor optical amplifiers (R-SOA) [15-18] or vertical-cavity surface-emitting laser (VCSEL) [19], are employed at each ONU, and injected by amplified spontaneous emission (ASE) light to provide the light source for the upstream traffic. However, the upstream bit-rate was limited to about 1.25 Gb/s

Another approach to achieve upstream data transmission is to re-use or re-modulate the downstream carrier at the ONUs such that no light source is required at the ONUs. In WDM-PONs using centralized light sources at the OLT, the downstream signal is delivered to the ONU, where it is partially split and fed into an optical receiver for downstream data reception. The rest of the signal is fed into an upstream data transmitter where the downstream signal power is re-modulated, via an optical modulator, with the upstream data [20-23]. The re-modulated upstream carrier is finally routed back to the central office via the RN. With this architecture, the downstream carrier received at the ONU is re-used as the upstream data carrier. Therefore, no wavelength registered dedicated light source is required at the ONU, and this relaxes the wavelength management. Several schemes have been proposed to perform data erasure via injection-locking of Fabry-Perot laser diode as well as adopting various constant-intensity modulation schemes, including DPSK [21], FSK [22], inverse-RZ [23], for the downstream signal so that the upstream ASK signal can be readily modulated onto it, via an optical intensity modulator.

5. Future Migration

We have outlined the key issues of current research interest in WDM PON access networks and discussed briefly the implications. It is also important to consider the issue of flexible migration and upgrade path from the currently deployed PONs such as BPON and GPON to the next-generation WDM-PON architectures. This needs to be achieved with minimum change to the installed passive outside fiber plant while ensuring the capability of providing the cost-effective dedicated ultra-broadband services with high-bandwidth optical access, performance and network reliability.

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