4:00pm - 4:30pm (Invited)
ONS4.2

TDM Optical Networks

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Most research efforts to date on optical networks have concentrated on wavelength-division multiplexing (WDM) techniques where the information from different channels is routed via separate optical wavelengths. The data corresponding to a praticular channel is selected at the destination node by a frequency filter. Optical time-division multiplexing (OTDM) has been considered as an alternative to WDM for future networks operating in excess of 10 Gb/s. Systems based on TDM techniques rely upon a synchronized clock frequency and timing to separate the multiplexed channels. Recent advances in device technologies have opened new opportunities for implementing OTDM in very high-speed long-haul transmission as well as networking. The multi-terahertz bandwidth made available with the advent of optical fibers has spurred investigation and development of transparent all-optical networks that may overcome the bandwidth bottlenecks caused by electro-optic conversion.

The electronic bottleneck may be overcome in so-called *transparent optical networks* (TONs)[1,2]. TONs allow signals to remain in an optical format until they arrive at their destination, and therefore provide several important advantages for terabit communications and ultra-fast data networks as follows:

The bandwidth capacity of the network is increased by avoiding O/E or E/O conversion bottlenecks at each node;

The throughput-delay performance is improved by eliminating conventional bandwidth-distance limited multiple access protocols;

Routing control is simplified by processing only a small fraction of the information flowing through at each node (e.g., packet header);

Complicated resource-sharing and flow-control algorithms are eliminated by using integration of transparent, concurrent optical channels.

Most of the TONs considered so far are based on wavelength division multiplexing [3]. Various network architectures have been considered including single-hop broadcasting networks (e.g., passive optical star coupler, bus or ring) as well as multihop transport networks[4,5]. The most important consideration for WDM networks seeking to utilize the fiber bandwidth involves achieving a large number of closely-spaced channels. This requires wavelength-agile transmitters at each node, such as a bank of transmitting lasers or a single tunable laser. Current challenges include the development of broadband laser sources with rapid tunability, fiber nonlinearities, and the spectral dependence of amplifier gain. All of these considerations ultimately determine the maximum number of wavelength channels and the transmission distances.

Time-division multiplexing (TDM) is a technique used to increase the bandwidth of a single wavelength channel[6]. It can be used in conjunction with WDM to further increase the network capacity. In TDM, channels are assigned based on time slots in a frame. A mode-locked laser is used as the source generating very narrow short pulses of 1 to 10 picosecond (ps) in duration. Incoming electronic data is imprinted upon the pulse stream via an electro-optic (EO) modulator. Thus, the time-multiplexed data can be encoded inside a sub-nanosecond (ns) time slot. Many such time-slots are time-interleaved into a frame format, sent through the optical fiber, and demultiplexed at the receiver. Optical TDM (OTDM) networks have the potential to carry Tb/s aggregate throughputs on a single wavelength channel by sharing and processing vast amounts of data simultaneously (see [7] for micro- and local-area interconnect applications of OTDM.).

In this paper, an overview of the OTDM networks is presented. We survey various design approaches from several research groups and their supporting technologies. Some fundamental issues of OTDM networks including noise sources, synchronization, and nonlinear transmission effects are discussed. We also introduce our design approach for an OTDM network and describe the related enabling technologies. We focus on the multihop transparent packet-switching network architecture which offers both ultra-high speed and maximum parallelism.

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2. P.R. Prucnal, D.J. Blumenthal, and M.A. Santoro, "A 12.5 Gbps fiber optical network using all-optical processing," *Elec. Lett.*, 23, pp. 629-630, 1987.
3. A.S. Acampora and M.J. Karol, "An overview of lightwave packet networks," *IEEE Network Magazine*, pp. 29-40, Jan. 1989.
4. B. Mukherjee, "WDM-based local lightwave networks, Part I: Single-hop systems," *IEEE Network Magazine*, pp. 12-27, May 1992.
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