TuG2 (Invited)
11:00 am – 11:30 am

Optical Packet Switching and Associated Optical Signal Processing

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Abstract

In this talk we will review functions for optical packet switching and ultra-fast network functions that can be handled using all-optical signal processing technologies. We will review research results utilizing ultra-fast all-optical nonlinear fiber wavelength converters and InP integrated optical wavelength converters. Application to all-optical label swapping and WDM/OTDM networks will be discussed.

Introduction

Within today's Internet, data is transported using optical fiber transmission and wavelength division multiplexing (WDM) systems that today carry a typical 32-80 wavelengths modulated at 2.5 Gbps to 10 Gbps per wavelength. Today's routers and electronic switching systems need to handle almost 0.5 Terabit per second in order to redirect incoming data from fully loaded WDM links. The capacity of optical fibers continues to double every 8-12 months with today's fiber capacity exceeding 10 Tbps. Compared to the increase in electronic processor speeds which doubles every 18 months (Moore's Law) there exists a bandwidth mismatch. Future routers and switches will potentially terminate hundreds or thousands of optical wavelengths and the increase in bit-rate per wavelength will head out to 40 Gbps and beyond to 160 Gbps. Additionally, electronic memory access speeds only increase at the rate of approximately 5% per year, an important data point since memory plays a key role in how packets are buffered. The process of moving a massive number of packets per second (greater than 100 million packets/second) through the multiple layers of electronics can therefore lead to congestion and exceed electronic performance.

Optical Packet Switching and Label Swapping

All-Optical Label Swapping (AOLS) is one technique intended to solve this potential mismatch between fiber capacity and router capacity. AOLS imparts the functionality to direct packets through an optical network without the need to pass these packets through electronics whenever a routing decision is necessary [1-6]. Inherent to this approach is the ability to route packets independently of bit-rate, packet or coding format and packet length. An example AOLS network is illustrated in Figure 1. IP packets enter the network through an "ingress" node and are encapsulated with an optical label and then re-transmitted on a new wavelength. Once inside the network, only the optical label is used to make routing decisions and the wavelength is used to dynamically redirect (forward) packets. At the internal nodes, labels are read and optically erased, then a new label is attached to the packet and the optically labeled packet is converted to a new wavelength using all-optical wavelength conversion. Throughout this process, the contents (e.g., the IP packet header and payload) are not passed through electronics and are kept intact until the packet exits the optical network through the "egress" node where the optical label is removed and the original packet is handed back to the electronic routing hardware. Optical label swapping requires optical data regeneration, optical label removal, optical label rewriting, and packet rate wavelength conversion. These functions can be handled using the module architecture illustrated in Figure 2 and implemented using InP based and nonlinear fiber based wavelength converter technologies.

Ultra-Fast WDM/OTDM Networks

Another important architecture is the OTDM/WDM network shown in Figure 3 which employs optical signal processing elements based on the same nonlinear fiber wavelength converters [7] used in AOLS. The basic elements are the WDM/OTDM and OTDM/WDM transmultiplexers and OTDM add/drop multiplexers [8-11]. Ultrafast traveling wave EAMs are also a critical component used in the high speed OTDM transmitters and receivers. These technologies have been demonstrated at 40 Gbps and 80 Gbps with multicasting capabilities and have the potential to scale to higher bit -rates.

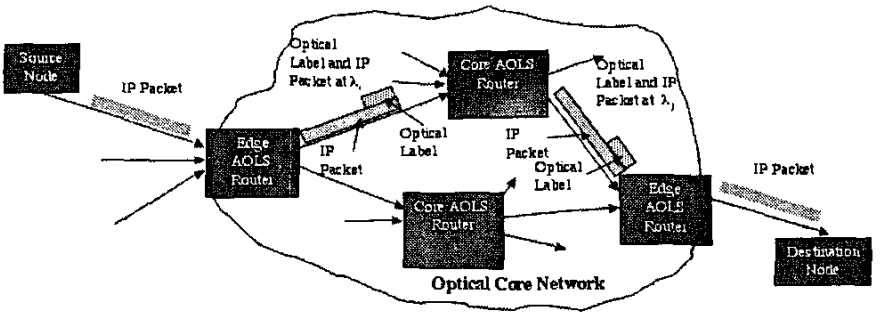

Figure 1. An optical label-swapping network.

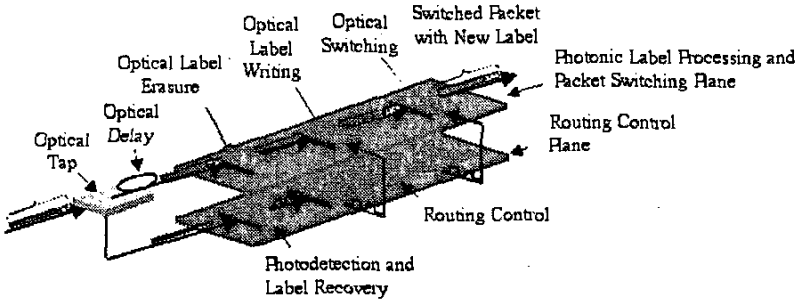

Figure 2. Optical label swapping module function.

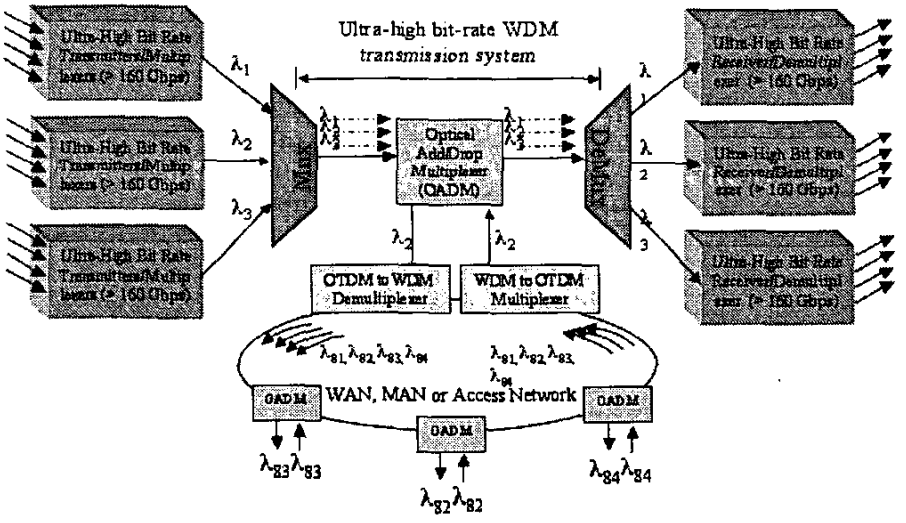

Figure 4. WDM/OTDM network based on ultra-fast all-optical wavelength converters.

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[6] "OPERA: An Optical Packet Experimental Routing Architecture with Label Swapping Capability," *IEEE JLT*,, pp. 2135-45, Dec. 1998.
[7] "All-Optical Demultiplexing using Fiber Cross-Phase Modulation and Optical Filtering," *IEEE PTL*, **13** (8), pp. 875-877, August 2001.
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[10] "Wavelength Multicasting Using an Ultra High-Speed All-Optical Wavelength Converter," *OFC '01*, March 17-23, 2001.
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