

SIGNAL PROCESSING IN HIGH SPEED OTDM NETWORKS

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With the amount of Internet traffic doubling every 100 days [1], it is clear that the use of lightwave technologies will be absolutely necessary to meet the bandwidth requirements of future local and wide-area communication systems. Electronic packet-switching is an efficient technique for achieving maximum utilization of a given channel, as proven by the current Internet. In addition, given sufficient channel bandwidth, packet switching can provide adequate low latency communication for the majority of applications. The evolution of packet-switching to the optical domain is a natural extension, provided that the capabilities as well as the limitations of lightwave technologies are taken into consideration during the design process. The inherent low loss properties, small size, low cost, and multi-terahertz bandwidth of optical fiber make it a nearly ideal transmission channel. However, when compared with electronics, the number of photonic devices currently available to implement a practical system is limited. Therefore, it is necessary to minimize the complexity of the system and take advantage of the limited available technologies.

A major issue in designing high-speed optical networks is how to utilize the bandwidth of the fiber efficiently. Currently, there are two primary techniques for multiplexing data onto a single fiber: time-division multiplexing (TDM), and wavelength-division multiplexing (WDM). A great deal of recent research in optical networks has been focused in the area of WDM technology [2] and some groups are currently working on WDM packet switching [3-6]. Although TDM technologies have not advanced as quickly as WDM due to the difficulties in developing ultrafast demultiplexing and processing devices as well as the lack of optical TDM technology transition to the commercial market, the use of ultrafast TDM can simplify some areas of a system implementation since only a single wavelength is used in the network. For example, systems performance issues such as four wave mixing (FWM) and component spectral nonuniformities will impose limitations on the capabilities of a WDM system. Although ultrafast TDM systems are not limited by these effects, they have their own set of technical challenges such as network synchronization and nonlinearities in the system due to the high peak power of ultrashort pulses. A table summarizing the major performance limitations found in both systems is given in Table 1.

Table 1.

Comparison of system performance limitations in TDM and WDM optical networks

System performance limitations	
TDM Systems	WDM Systems
Power budget-short pulse amplification	Power budget-wide bandwidth amplification
ASE noise accum.	ASE noise accum.
Dispersion-pulse broadening	Dispersion-adj. channel walkoff
Nonlinearities-SPM	Nonlinearities-XPM, FWM
Adjacent time channel crosstalk	Adjacent wavelength channel crosstalk
Synchronization & jitter	Component spectral nonuniformities

A number of large groups are currently doing research on ultrafast TDM technology including BT Labs [7, 8], NTT [9], Heinrich-Hertz-Institut [10], MIT Lincoln Laboratory [11], University of Michigan [12] as well as many others. Some applications that can benefit from TDM technologies include localized networks such as those found in processor interconnects and computer LANs as well as larger area networks such as the Next Generation Internet (NGI).

OTDM networks based on our recently-developed Terahertz Optical Asymmetric Demultiplexer (TOAD) will enable construction of crossbar interconnect systems with aggregate capacities approaching 1 Tb/s. The synchronicity inherent in an OTDM system can be exploited to implement efficient arbitration and control methods that scale linearly with the number of attached nodes. OTDM based interconnect systems challenge the current generation of switching fabrics that use electronic routers by offering low latencies, high bandwidth, and globally visible event ordering. Furthermore, nodes are connected to a central switching hub in a star-like fashion where each node requires two optical fiber connections, independent of the system size.

This paper presents the design and experimental results of an optical packet-switching testbed capable of performing message routing with single wavelength TDM packet bit rates as high as 100 Gb/s. The physical topology of the Packet-switched Optical Networking Demonstration (POND) node is based on an 8-node ShuffleNet architecture. The key enabling technologies required to implement the node such as ultrafast packet generation, high-speed packet demultiplexing, and efficient packet routing schemes are described in detail. The routing approach taken is a hybrid implementation in which the packet data is maintained purely in the optical domain from source to destination whereas control information is read from the packet header at each node and converted to the electrical domain for an efficient means of implementing routing control. The technologies developed for the interconnection network presented in this paper can be applied to larger metropolitan and wide area networks as well. In this talk recent experimental demonstrations of both ultrafast demultiplexing and high-speed time slot tuning that show that a 100 node network with an aggregate capacity of 100Gb/s is practically achievable. Additionally, will be presented the technologies that enable this broadcast star network fabric also can be applied to high speed all-optical packet-switching networks. Our recent 100 Gb/s packet-switched multihop testbed using ultrafast demultiplexing and efficient packet compression demonstrate the feasibility of this approach to provide a reliable means of improving the capacity of all-optical networks.

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