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TDM 100 Gb/s Packet Switching in an Optical Shuffle Network

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The growth of demands for bandwidth in the last few years indicates the need of developing the next generation computer networks using photonic switching. While WDM has attracted most of the research attention, some recent network demonstrations have proved that optical time-division multiplexing networks are potentially superior in many network performance aspects including throughput, latency, reliability and scalability. With advances in the development of fiber lasers and device integration, crucial technologies for OTDM are becoming mature. This paper discusses the feasibility of achieving large throughput in a single wavelength channel using TDM based on the results from a network demonstration operating at 100 Gbit/sec developed at Princeton University. The current technology in optical processing can only perform very simple logic. We implement our system with electronic routing control, such networks are often referred as transparent optical networks (TONs). The processing time required by the electronic routing controllers depends on the complexity of the routing algorithm employed, therefore it is critical to develop simple and efficient routing schemes. One of the most studied regular network structures is the shuffle topology. The multihop nature of shuffle networks makes it suitable for the application of packet-switched local area networks. Taking advantage of its regular structure, the routing control follows a scheme developed to allows bit-level self-routing and deflection routing for contention resolution in the network. This significantly reduces the time required for routing processing (almost 50%) and simplifies the network node, and leads to cost effective design and high scalability.

The optical source used in the experiment is a 1.313 um Nd:YLF 100 MHz mode-locked laser. The laser is synchronized with a pattern generator which serves as the electronic data source. The outputs of the pattern generator are modulated with the laser outputs to produce optical packets with 16-bit routing tags at 100 Mbps. These packets are optically compressed to 100 Gbps using a compressor with a feed-forward delay line structure. One drawback of using the packet compressor is the latency due to the packet buildup time required. Because this delay, new packets must be generated before a vacant time slot becomes available. No input buffer is implemented in our system. A pre-generated new packet is injected into the network if the arriving time slot is empty or discarded otherwise. The main switch consists of four 2x2

$LiNbO_3$ crossbar switches connected in two stages to form a 4x4 configuration, connecting 2 network input links and two output links, node transmitter and receiver and a single-packet buffer. Even though the switch is blocking, it has the lowest optical power loss. When a packet arrives at an input link, part of its power is tapped off for header recognition. According to our routing scheme, only 3 bits are necessary for routing at every node. We use precise pointer control to select the appropriate 3 bits to demultiplex from the 100 Gb/s data stream by an array of terahertz optical asymmetric devices (TOADs) at every node. The switching window of each TOAD is adjusted to be approximately 10ps. An electronic routing controller is designed to process the headers in 20ns and apply gating signals to the main routing switch. Fiber delay is necessary before the main routing switch to count for the time required for routing processing so that the packet enters the switch after the main routing switch is set to appropriate state. The number of TOADs required at each receiver is determined by the recovery time of the TOAD and the bandwidth of photodetectors. Both parallel and serial configurations have been developed. The system demonstrates packet switching in an 8-node shuffle network using a single physical node by connecting the two output links back to one of the input links using 500 meters of fiber. The routing controller traces the path of a test packet by reconfiguring the node identity after performing switching on the test packet. Our experimental results illustrated reliable routing at the bit rate of 100 Gb/s. Further studies on the performance of the system have been done using analytical models and simulations, and the results indicate that the system is suitable for the applications of packet-switched local area networks. Network throughput over 60% can be achieved, and the optical signal degradations is tolerable for internodal spacing of 1 km.