All-optical packet routing by an out-of-band optical label and wavelength conversion in a full-mesh network based on a cyclic-frequency AWG

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Abstract: We demonstrate all-optical packet routing using an out-of-band optical label and wavelength conversion in a cyclic-frequency-AWG-based full-mesh network with shared multiple light sources. Gigabit Ethernet packets were successfully routed using our technique.

1. Introduction

The rapid growth of the Internet and data and wireless communications has created a great demand for large-capacity networks. WDM technology, which utilizes the wide bandwidth of optical fiber, has enabled large-capacity point-to-point connection. With the increase in link capacity, the network nodes have to process a large amount of incoming data, which is becoming difficult by electrical processing alone. In order to manage large-capacity data processing at each node, it is desired that the optical signals be routed without being converted to electrical signals for processing; that is, they should be routed in the optical layer.

An arrayed-waveguide grating (AWG) is an optical device that can route optical signals in the optical layer according to their wavelengths. Recently, we have demonstrated a 32 x 32 full-mesh WDM metro-scale network (AWG-STAR) [1] using a uniform-loss cyclic-frequency AWG (ULCF-AWG) [2]. In this network, each node is equipped with multiple light sources with the same set of wavelengths and the ULCF-AWG works as a wavelength router, connecting each node according to the transmission wavelength. As all nodes use multiple light sources with the same set of wavelengths, instead of each node having multiple light sources individually, it is possible to introduce a set of multiple light sources that every node in the network can share without losing full-mesh connections.

In this paper, we report all-optical packet routing using an out-of-band optical label technique in a full-mesh network based on a cyclic-frequency AWG with shared multiple light sources. We achieved packet-by-packet routing using commercially available Gigabit Ethernet (GbE) signal.

2. Network and system configurations overview

Fig. 1(a) shows the basic system configuration of the AWG-STAR with the shared multiple light sources. Each node is connected to the optical packet router (OPR), which routes the incoming packets from each node to destination nodes according to the routing information obtained from the optical labels transmitted along with the optical packet signals. The OPR structure is schematically illustrated in Fig. 1(b). The OPR is equipped with shared multiple light sources, an optical label analyzer (OLA), wavelength converters, wavelength multiplexers (MUX-AWGs), and an ULCF-AWG. Each node has two transmitters that are used to communicate with the other nodes comprising the network, one for optical signal transmission and the other for optical label transmission.

Optical packet signals from the nodes are transmitted with optical labels containing routing information of the corresponding optical packet signals (Fig. 1). Different wavelengths are used for the optical signals (λ_d) and labels (λ_L), which simplifies their separation. At the OPR, optical signals are wavelength-converted to a wavelength that allows them to be routed to the destination node by the ULCF-AWG based on the routing information contained in the optical label.

Optical packet signals and optical labels are demultiplexed by a WDM coupler. The optical labels are then received by a photodiode (PD) in the OLA. On the other hand, the optical signal, after passing through the WDM coupler, is distributed using an optical splitter to SOA-based wavelength converters (SOA-WCs), each of which are supplied with a CW light from the shared multiple light sources. Since SOA-WCs also work as optical gates, the conversion wavelength of the optical signals is selected according to the optical label information. The wavelength converted optical signals are then multiplexed using an AWG and fed to the input port of the ULCF-AWG where optical signals are routed according to their wavelength to the output port to which the destination node is connected. At each node, the incoming optical signals are demultiplexed by an AWG and received by PDs connected to its output ports. Since the optical signal from the node can be converted to multiple wavelengths, our OPR supports multicasting and broadcasting.

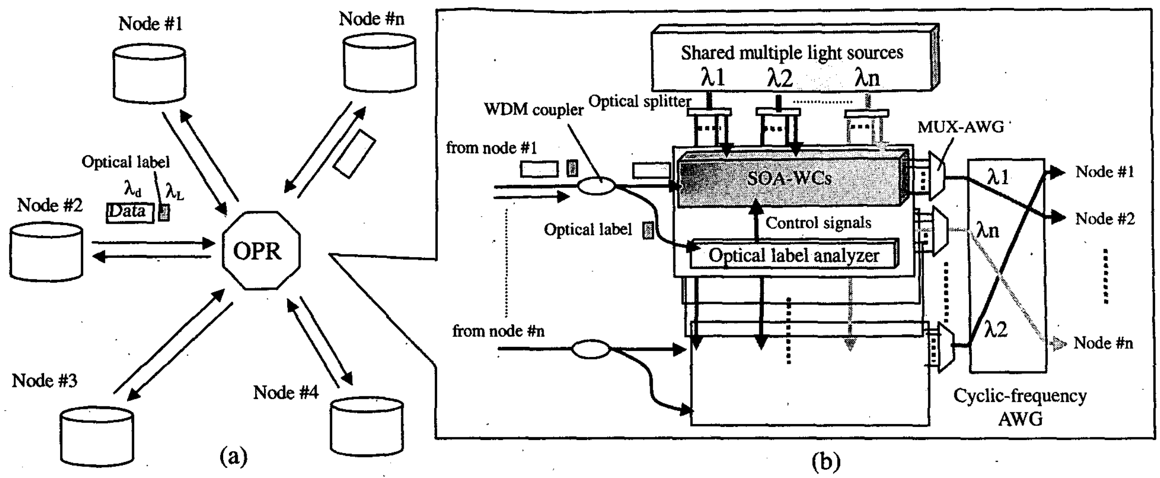

Fig. 1 Basic system configuration of AWG-STAR (a) and the structure of the optical packet router (b). OPR: optical packet router. λ_d and λ_L denote the wavelength of a data packet and an optical label, respectively.

3. Experiments and results

For our preliminary experiments, we developed node equipment and an OPR as shown in Fig. 2. We used commercially available GbE as data signal to verify our technique. The node equipment comprises transmitter modules, receiver modules, and an AWG module. One of the two transmitter modules receives GbE signals from the local network and extracts electrically an IP address or a MAC address from the incoming GbE signal packet. The GbE signal packet is buffered during the extraction. The extracted IP/MAC address is then transmitted at 1.25 Gbps from one of the light sources in the transmitter module as an optical label with a wavelength of 1.31 μm. After a predetermined delay time α, the buffered data packet is sent from the transmitter module at 1.25 Gbps using another light source in the transmitter module. The data-packet wavelength is OE-EO converted to a wavelength in the 1.55-μm region using the other transmitter module. The delayed transmission time α is determined considering the optical label processing time at the OPR and the wavelength dispersion of the optical fiber, so that the optical data packets are properly gated at the OPR. The optical label and the data packet are multiplexed using a WDM combiner. We used commercially available GbE media access controller chips for frame processing. Though the shortest frame for the standardized GbE is 64 bytes, we used a frame of around 30 bytes, including the preamble and frame check sequence. In the present experiments, we directly sent an IP or MAC address as an optical label, but we believe that our optical label signal format is suitable for sending labels for MPLS as well.

The detailed structure of the OPR is illustrated in Fig. 3. The processes for data packets and optical labels at the OPR are described in Section 2. For the preliminary demonstration, we designed an OPR that can accommodate eight nodes in the network. The ITU-grid wavelengths of the 8-ch shared multiple light sources ranged from 1548.52 nm (193.6 THz) to 1554.13 nm (192.9 THz) with 100-GHz spacing. We used a spot-size converted SOA (SS-SOA) array module integrated on a planar lightwave circuit [3] for SOA-WCs that operates based on cross-gain modulation. The SS-SOA array module is shown in Fig. 2(c) along with the driver circuits.

The demonstration of optical packet routing is shown in Fig. 3. Prior to the experiment, we tabulated the routing table in the OLA, relating the IP/MAC addresses to the wavelengths to which the data-packet wavelength was converted. We confirmed that the optical packets were converted to the wavelength according to the accompanied label information and the gating was operated during the interframe gap time. In our system, the wavelength of the optical signal is selected so that the original optical signal can be filtered by the MUX-AWG in the OPR.

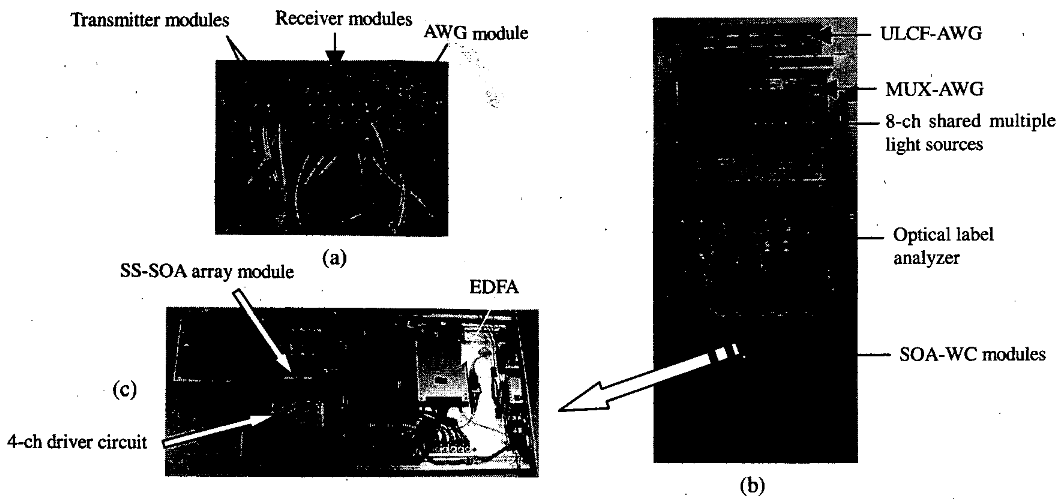

Fig. 2 Photographs of the developed node equipment (a), optical packet router (OPR) (b) and the SS-SOA array module with driver circuits.

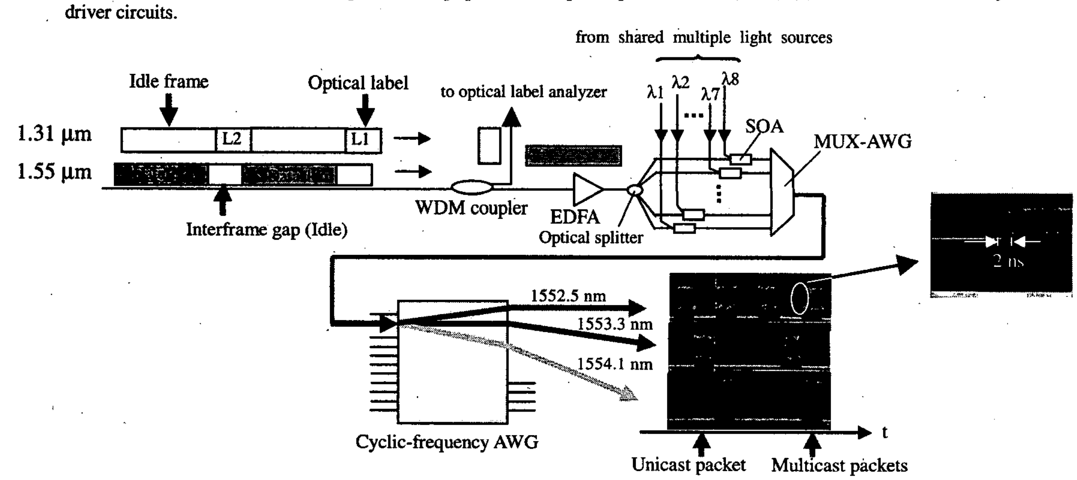

Fig. 3 Detailed structure of OPR and the demonstration of optical packet routing using GbE as an optical signal. L1 and L2 are the optical labels of Data 1 and Data 2, respectively.

4. Summary

We have demonstrated optical packet routing in a full-mesh network based on a cyclic-frequency AWG with shared multiple light sources. The GbE data packets were all-optically routed packet-by-packet to the destination node by means of our out-of-band optical label technique and wavelength conversion. Our optical label technique can be used with higher bit-rate data signals.

5. References

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