A Single-Fiber Self-Healing CWDM Metro Access Ring Network for Broadcast and Dedicated Broadband Services

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Abstract
A simple and effective self-healing CWDM metro access network architecture using unidirectional OADM in a hub/access-node single-fiber ring is proposed and experimentally demonstrated where both broadcast and dedicated broadband services can be distributed.

1 Introduction

Recently, hub/access-node ring architecture has emerged as a promising approach for WDM metro access ring network where the traffic for each access node (AN) is transmitted/received to/from a hub, and the hub is responsible for controlling and exchanging traffic between the ANs and the higher layer networks. Hence, this effectively forms a physical-ring/logical-star architecture. Conventionally, dual ring has been used for protection against fiber failure [1]. Recently, single-fiber bi-directional self-healing ring [2, 3] has been proposed to reduce the required amount of fiber and the corresponding deployment cost by half. In these schemes, the specially designed bi-directional add/drop multiplexer (BADM) were employed in the network. In [4], we have proposed a single-fiber self-healing ring architecture utilizing the commercially available low cost thin-film unidirectional optical add/drop multiplexer (OADM) to further simplify the design and reduce the cost. However, all these schemes [2-4] are only concerned with the dedicated service for each AN, while the issue of adding broadcast service into this kind of single-fiber ring network has not been studied yet, which is also important in practice. In this paper, we propose and experimentally demonstrate a simple and effective CWDM hub/access-node single-fiber self-healing ring network, which can provide additional broadcast service with negligible influence on the dedicated service channels.

2 Operation Principle

Fig. 1 shows the proposed CWDM metro access network architecture. It consists of one hub and N ANs (here, N=3 for simplicity) distributed around a single-fiber ring. At the hub, it includes one CWDM MUX/DMUX, one 1×2 3-dB coupler, N pairs of CWDM transmitters (Tx) and receivers (Rx) for dedicated bidirectional service and one extra Tx for broadcast service. Each pair of Tx and Rx corresponds to one specific AN, responsible for the downstream and upstream traffic respectively. For each Tx and Rx, a distinct wavelength is assigned. For instance, Tx2d at the hub with the wavelength λ_{2d} is designated for transmitting the downstream communication with AN2, while Rx2u with the wavelength λ_{2u} is for receiving the upstream traffic from AN2. The broadcast Tx will also employ a specific wavelength. The CWDM standard wavelengths are used for the dedicated services for each specific AN, except that 1550 nm is reserved for the broadcast service. The hub is connected to the ring via the 1×2 3-dB coupler.

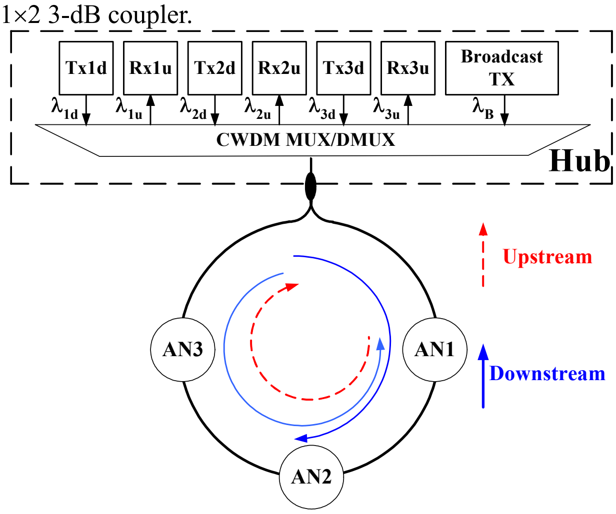

Fig. 1 Proposed network architecture

Fig. 2 (a) illustrates the structure of AN2, for example. There are two band filters to divide the traffic into two categories (dedicated and broadcast) and then combine them together again. The CWDM 3-port thin-film filter (TFF) (in this kind of filter, a specific wavelength will pass between port1 and port 3 while other wavelengths will pass between port1 and port 2) with 1550nm center wavelength can be used as the band filter. In the dedicated path, there are one unidirectional CWDM OADM and a pair of Rx and Tx, which are named as Rx2d and Tx2u, and are matched to the Tx2d and Rx2u at the hub, respectively. This OADM is responsible for adding channel λ_{2u} and dropping channel λ_{2d} at AN2. The channel add-drop is also performed via CWDM 3-port TFFs. In the broadcast path, a coupler is used to drop the broadband signals. The drop direction should be the same as the OADM in this node (shown with the solid arrows). In such a single-fiber ring network, the downstream (including broadcast) traffic will arrive at each node from both directions; hence the Rayleigh backscattering induced crosstalk might degrade the system performance. In dedicated path, the OADM will block the downstream traffic from one of the directions to prevent the bidirectional transmission. In the broadcast path, an isolator is used to prevent this situation.

Under normal operation, the 2×2 optical switch is set in bar state. Thus, AN2 can receive/send data from/to the hub through the counter-clockwise/clockwise (CCW/CW) direction. For other wavelength channels, they can just pass through AN2 from either direction. Fig. 2 (b) illustrates the protection mechanism in case a fiber failure occurs between AN2 and AN3, for example. In this case, the control circuit at AN2 as well as all subsequent ANs in the CCW direction (e.g. AN1) detect the downstream signal loss from CCW direction, which triggers its optical switch to change from the bar state to the cross state. Hence, AN2 as well as all affected ANs can still communicate with the hub via the CW direction of the ring without interrupting other in-service data streams.

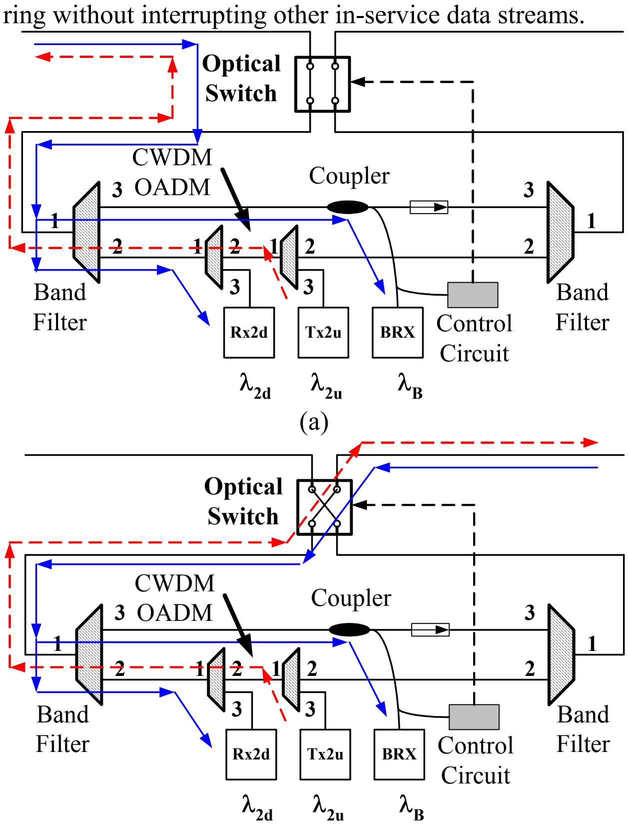

Fig. 2 Structure of AN2 in (a) normal state; (b) protection state. Arrows show the add-drop directions

3 Experiment

The experimental setup was the same as Fig. 1. The length of SMF spans between the hub and AN1, AN1 and AN2, AN2 and AN3, AN3 and hub are 8.8km, 6.6km, 1.0km and 8.8km respectively. Seven commercial CWDM GbE SFP transceivers were used for demonstration. The wavelength assignment is: 1550nm (broadcast); AN1: 1590nm (downstream) and 1510nm (upstream); AN2: 1610nm (downstream) and 1530nm (upstream); AN3: 1570nm (downstream) and 1490nm (upstream). The dropping fiber couplers used here have the dropping ratios of 20%. The optical switches used at the ANs were commercially available opto-mechanical switches and their switching times were measured to be 5ms (at AN1), 3ms (at AN2) and 8ms (at AN3), respectively. To simulate the fiber cut scenario, the fiber link between AN2 and AN3 was disconnected.

We measured the BER performance using 1.25-Gb/s (to simulate the data rate of GbE signal) 2^{23}-1 PRBS data for all of the traffic of AN2 in normal and protection mode, as shown in Fig. 3. The receiver sensitivities were smaller than -27.0dBm in all cases and the induced power penalties were smaller than 0.5dB. We have also measured the restoration time, as shown in the inset of Fig. 3 (b). The measured restoration time was about 5.2ms, and the transient on the restoration time curve is due to the impact of AN1, as explained in [4]. A wait period is added to the control circuit to eliminate its impact.

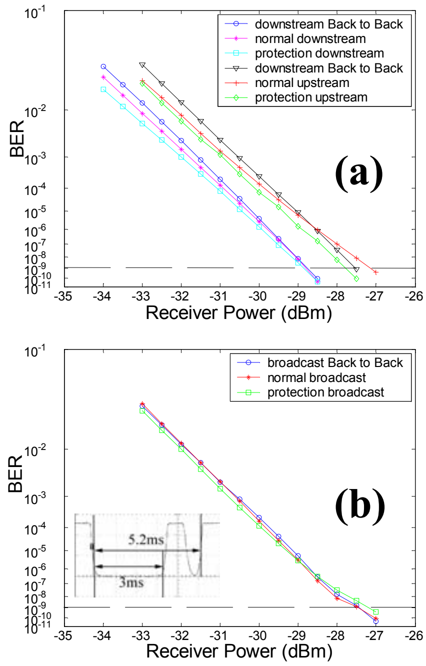

Fig. 3 BER measurements of AN2: (a) dedicated bi-directional service; (b) broadcast service. Inset shows the restoration time curve of AN2

4 Experiment

We have proposed and demonstrated a simple and effective single-fiber CWDM metro-access ring network with hub/access-node architecture. It can provide automatic optical protection against fiber cut using unidirectional OADMs and support both broadcast and dedicated services. The transmission performance using 1.25-Gb/s CWDM transceivers and fast automatic protection have been experimentally characterized. This network architecture is data-rate transparent and can be readily extended for application in multi-wavelength 10GbE single-fiber ring network.

5 References

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