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A Simple Centrally Controlled Survivable WDM-PON Architecture using Optical Carrier Suppression

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***Abstract*-- A simple centrally controlled survivable WDM-PON architecture using optical carrier suppression with no optical switches is proposed and demonstrated. The architecture can simultaneously protect distribution and feeder fibers, while keeping ONUs colorless.**

I. Introduction

The wavelength-division-multiplexed passive optical network (WDM-PON) architecture needs high survivability in case of fiber cuts so as to avoid enormous loss in data and business. Several interesting schemes [1-6] have been proposed to provide protection and restoration functions in WDM-PONs. In [1-3], survivability and restoration were realized either through the periodic properties of array waveguide gratings (AWG) [1], or the intra-protection between the grouped optical network units (ONUs) [2-3]. However, optical switches were required for protection switching at the ONUs. Although some centrally controlled protection architectures have been proposed in [4-5] based on ONU-grouping method, dedicated light sources for downstream and upstream transmission were needed, increasing the system cost and complexity. A recently proposed centrally controlled protection architecture [6] utilized optical carrier suppression (OCS) [7] to generate subcarriers for the upstream transmission.

In this paper, we proposed and demonstrated a simple, centrally-controlled, WDM-PON architecture with colorless ONUs. The protection subcarriers are generated from a single continuous wave (CW) light source residing in each transmitter at the OLT, via OCS, thus requiring no additional light sources. The survivable protection architecture can simultaneously protect the distribution and feeder fiber failures, and the protection switching is realized by sub-wavelengths switching through OCS [7] with fast switching time. We have experimentally demonstrated 10-Gbit/s WDM-PON in both normal and protection modes.

II. Proposed Survivable WDM-PON Architecture

Fig. 1 depicts the proposed centrally-controlled survivable WDM-PON architecture with N ONUs. At the OLT, the CW light from each transmitter is first fed into a Mach-Zehnder intensity modulator (IM) biased at null point driven by a control clock which will be turned on under the protection mode to generate two optical sub-carriers through OCS. Each downstream wavelength then

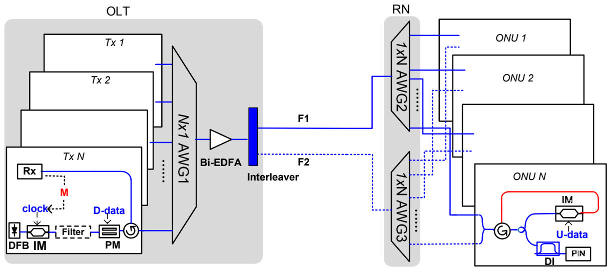

Fig. 1: Proposed survivable WDM-PON architecture.

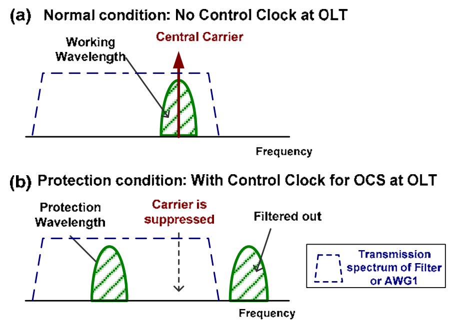

Fig. 2: Spectra of downstream carrier to illustrate the principle.

passes through a filter to suppress one optical sub-carrier in the protection mode, so as to avoid the possible coherent beating noise between the two optical sub-carriers at the ONU. This optical filter can be eliminated by making use of the filtering effect of the N×1 arrayed waveguide grating (AWG1). The downstream wavelength is then fed into an opticalphas emodulator (PM) for downstream data (D-data) modulation, before being combined with other downstream wavelengths from all transmitters at the OLT, via AWG1. The combined downstream carriers are amplified and then separated by an optical interleaver (IL), where central carriers during normal mode, are delivered over the fiber feeder (F1) and demultiplexed at the remote node (RN), via 1×N AWG2, while the optical sub-carriers of protection mode are delivered over the fiber feeder (F2) and demultiplexed, via 1×N AWG3. The demultiplexed carriers from AWG2 and AWG3 are then combined at their respective destined ONUs through two distribution fibers. At the ONU, half of the downstream power is tapped off for detection and the other half is used for upstream ASK data (U-data) remodulation. The upstream signal is then transmitted back to the respective receiver unit at the OLT, where part of the received upstream power is fed into the monitoring unit (M) for fault detection. Any reported fault alarm will trigger the clock signal for optical sub-carrier generation at the OLT under the protection mode.

Fig. 2 shows the spectra of the downstream carrier to illustrate the principle of the protection mechanism. Under the normal working mode, the monitoring unit (M) at the OLT turns off the clock signal and thus only the central carrier exists for the downstream transmission, which will be delivered on the working path (including the feeder and distribution fibers). On the contrary, if any fiber cut occurs along working path, loss of signal in the respective upstream path will enable the clock signal of its transmitter, so as to generate optical sub-carriers through OCS. Due to the wavelength shift introduced by OCS, the newly generated optical sub-carrier is delivered on the protection path (including the protection feeder and distribution fibers).

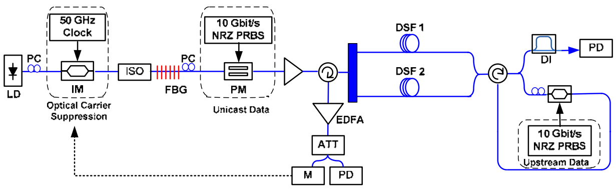

Fig. 3: Experimental setup.

III. EXPERIMENTAL DEMONSTRATION AND RESULTS

Fig. 3 shows the experimental setup for the proposed scheme. A CW light at 1547.37 nm was first fed into a 40-Gb/s optical IM, driven by a 50-GHz clock controlled by the monitoring unit. In the protection mode, the clock was turned on to create two subcarriers, λ_{sub1} at 1546.97 nm, and λ_{sub2} at 1547.77 nm, while in the normal mode, the clock was turned off and only λ_0 at 1546.97 nm existed. The downstream wavelengths were then fed into an ISO before an FBG with a reflection FWHM passband of 0.2 nm and a reflectivity of 99%, so as to select either λ_0 in the working (normal) mode or λ_{sub1} in the protection mode. The selected carriers were then reflected into an PM, where they were phase modulated by the 10-Gbit/s 2^{31}-1 PRBS NRZ data before being amplified to about 5 dBm and forwarded to a 50/100 GHz optical interleaver, which delivered λ_0 onto a piece of 20-km fibre (DSF1) and λ_{sub1} onto another 20-km DSF2. Dispersion-shifted fibre (DSF) was employed to emulate dispersion compensated transmission path (both for feeder and distribution fibres). The two DSFs were then combined at the ONU, where half of the received power was used for detection after an optical delay interferometer (DI) and the other half was re-used for upstream data transmission, via another IM, driven by the 10-Gbit/s 2^{31}-1 PRBS upstream NRZ data. The upstream ASK signal was then sent back to the OLT, before it was separated from the downstream signal and detected. At the OLT, part of the received upstream data was fed into the monitoring unit for status monitoring.

Fig. 4 shows the measured BER performances in the normal working mode. About 1.7 and 1.8 dB penalty were observed for the downstream and the upstream data after 20-km transmission respectively, which is mainly due to Rayleigh backscattering in the bi-directional

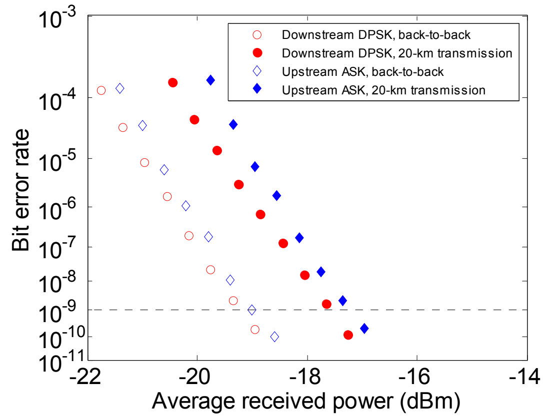

Fig.4: BER measurements in the working (normal) mode.

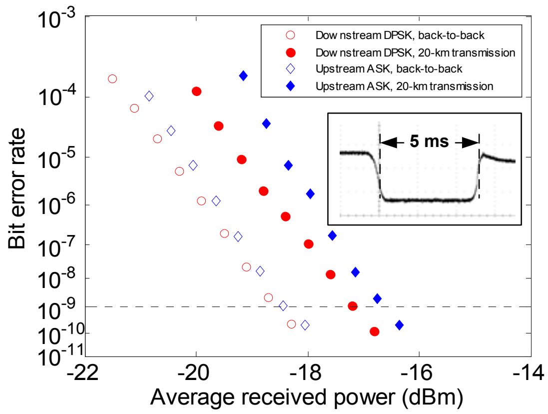

Fig.5: BER measurements in the protection mode.

transmission. Fig. 5 shows the BER performances in the protection mode, which shows similar performances in both the downstream and the upstream transmissions except for about 0.4 dB degradation, which may be due to the limited optical carrier suppression ratio and non-ideal filtering effect. Similar performances in normal working and protection modes implying a good restoration function. The switching time was also investigated at the monitoring unit, as shown in the inset of Fig. 5. About 5-ms switching time was experimentally observed, implying our scheme could achieve fast restoration and enhanced survivability.

IV. CONCLUSIONS

We have proposed and experimentally investigated a simple, centrally-controlled, WDM-PON architecture with colorless ONUs and protection against distribution and feeder fiber failures. By using OCS, protection optical subcarriers are generated, and thus a protection lightpath is setup. The control of protection performed at the OLT only.

REFERENCES

[1] S-B Park et al, OFC, paper JWA57 (2005)
[2] T.J. Chan et al, OFC, Paper FQ6 (2003)
[3] C.M. Lee et al, ECOC, Paper Th2.4.2 (2003)
[4] X.F. Sun, et al, PTL, 18, 631–633 (2006).
[5] Z.X. Wang et al, PTL, 17, 717–719 (2005).
[6] A. Chowdhury, et al, OFC, Paper JThA95 (2008).
[7] O. Akanbi et al, PTL, 18, 340–342 (2006)