Local Area Network Emulation in Passive Optical Networks by Wavelength Switching the Distributed Feedback Laser

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Abstract: *A novel scheme for upstream transmissions and local area network emulation amongst customers in a passive optical network by fast current-tuning a distributed feedback laser placed at the customer premises is proposed and experimentally demonstrated.*

Introduction: Passive optical network (PON) technology is considered as the most promising candidate for next generation broadband access due to its cost effectiveness, simplicity, and easier upgradeability [1]. Apart from the upstream and downstream transmissions between the central office (CO) and the optical network units (ONUs), customers of a PON may require private communication links between themselves for various services. To facilitate these services, a number of optical layer local area networking (LAN) schemes have been demonstrated [2, 3]. One of the earlier proposals for the optical layer LAN emulation scheme uses a separate optical transceiver at each ONU [2]. The use of a separate optical transceiver at each ONU for the LAN emulation is not effective in a cost-sensitive access networks. RF subcarrier multiplexing has also been used to carry LAN traffic whereby a single laser source is used at each ONU [4, 5]. However, this scheme requires a narrow linewidth laser and high frequency RF electronics at each ONU making the cost and complexity at the ONUs high. In this paper, we propose and experimentally demonstrate a simple and cost efficient solution for optical layer LAN emulation using a single uncooled distributed feedback (DFB) laser placed at each ONU. The lasing wavelength channel of the DFB laser is switched by changing the bias current of the DFB laser and therefore two separate traffic transport can be carried out. Compared to the previous schemes, this scheme does not require high speed RF electronics, stable laser sources, and modulators at each ONU. Moreover, this scheme enables that the time slots allocated to each ONU are efficiently used [6]. We experimentally demonstrate the proposed LAN emulation scheme with 2.5 Gb/s downstream traffic, 1.25 Gb/s upstream traffic, and 1.25 Gb/s LAN traffic.

System Architecture: The proposed scheme for implementing upstream transmission and LAN emulation by fast current-tuning a DFB laser is shown in Fig. 1. A (1xN) star coupler (SC) is used to split/combine the optical signals to/from each ONU, whereby the number of ONUs attached to the SC is N. An uncooled DFB laser is used at each ONU and the operating wavelength channel of this DFB laser is changed by varying the bias current of the laser. For the bias current I_1, the DFB laser is tuned to upstream wavelength channel (λu) and therefore upstream transmissions to the CO can be carried out. When the current is changed to I_2, the DFB laser is tuned to LAN wavelength channel (λ_{LAN}) and therefore LAN transmissions to other ONUs in the PON can be performed. A FBG is placed in feeder fiber close to the star coupler (SC) such that it reflects LAN wavelength channel (λ_{LAN}) back to the ONUs. Moreover, as data for CO and LAN are separated using the FBG, no further filtering is required at CO and ONUs. Unlike previous LAN emulation schemes, this scheme enables higher bandwidth LAN traffic transport. Upstream access follow the time division multiple access (TDMA) protocol, while LAN may follow any media access control protocol.

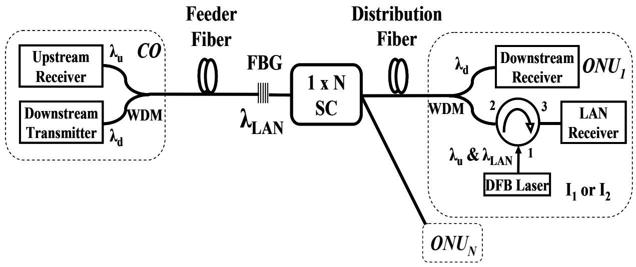

Fig. 1: PON architecture supporting LAN emulation with a single wavelength switchable DFB laser placed at the ONU.

Experimental demonstration: The experimental setup to demonstrate the feasibility of the proposed scheme is shown in Fig. 2. A downstream signal of 2^{31}-1 pseduo random binary sequence non-return to zero (PRBS NRZ) data at 2.5 Gb/s was modulated onto downstream wavelength channel λ_D = 1540.08 nm using a Mach-Zehnder modulator and transmitted to the ONUs through a 10 km feeder fiber, a 4 x 4 SC and a 3 km distribution fiber. At the ONUs, λ_D was separated from wavelength channels λ_U (=1550.56 nm) and λ_{LAN} (=1550.92 nm) using a coarse wavelength division multiplexing (CWDM) coupler. For the upstream transmisison mode, the DFB laser was biased at 30 mA, while the bias current was

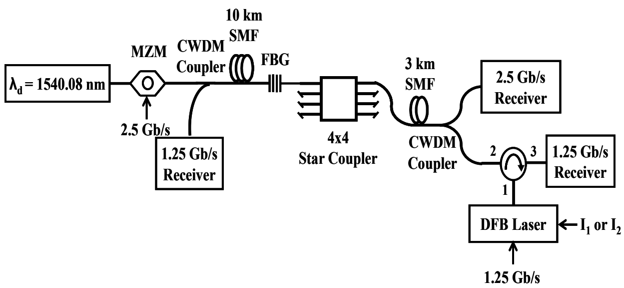

Fig. 2: Experimental setup to demonstrate the proposed scheme.

increased to 45 mA for the LAN transmission mode. Therefore, a wavelength change of 0.36 nm was obtained from the DFB laser for 15 mA difference in the bias current. A FBG with a Bragg wavelength of 1550.92 nm and a 3 dB bandwidth of less than 30 GHz was placed in the feeder fiber next to the SC for the reflection of λ_{LAN} back to the ONUs. In both transmission modes, 2^{31}-1 PRBS NRZ data at 1.25 Gb/s was directly modulated onto the DFB laser and transmitted in the upstream direction. The signals on all three wavelength channels were detected using a 2.5 Gb/s p-i-n receiver. The unused ports of the SC were anti-reflection treated. A series of experiments were conducted and bit error rates (BERs) for all signals were measured.

Results and Discussions: Fig. 3 shows the observed optical spectra at the FBG for upstream and LAN wavelength channels. A suppression of more than 18 dB was observed for λ_{LAN} between the reflected and transmitted portion of the signals. For $\lambda_{U,}$ more than 28 dB suppression was observed between the transmitted and reflected spectra. Fig. 4 shows the measured BER curves for the signals. For the 2.5 Gb/s downstream data, no penalty was observed when the signals were transmitted through the link in the presence of upstream signals compared to the back-to-back (B-B) measurements. Similarly, no penalty was observed for the 1.25 Gb/s

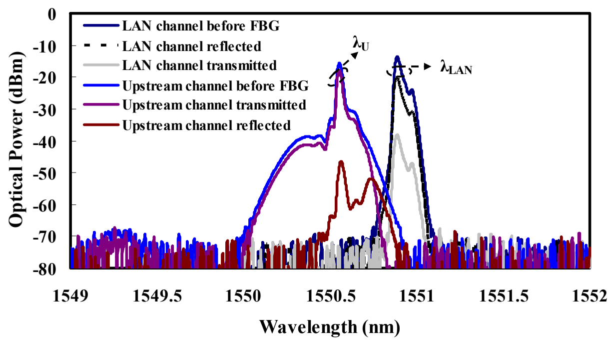

Fig. 3: Observed optical spectra at the FBG for the upstream and LAN wavelength channels.

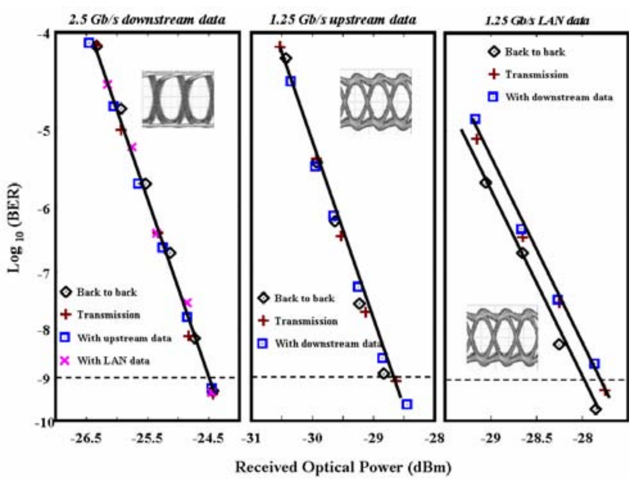

Fig. 4: Measured BER curves for all signals.

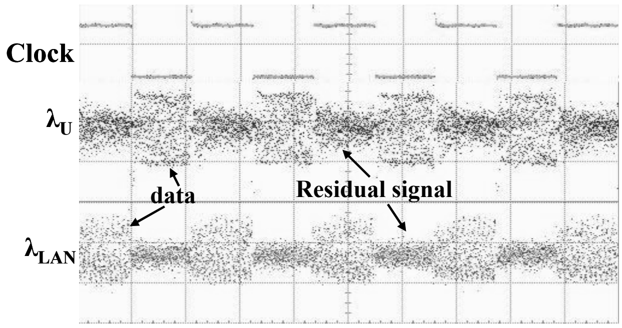

Fig. 5: Observed timing diagrams for the LAN data and upstream data with DFB laser wavelength switching.

upstream data compared to B-B measurements. A penalty of less than 0.2 dB was observed for the 1.25 Gb/s LAN data compared to B-B measurements.

The switching time of the DFB laser is required to be fast to achieve higher transmission efficiency for the signals. An experiment was carried out to measure the swithcing time of the DFB laser used in the experiment. The DFB laser was directly modulated by a square wave signal at two different current levels (representing two different wavelenth channels) and the signals were detected at the LAN data and upstream data receivers. For this purpose, the fibers used in experiment were removed. Fig.5 shows the timing diagrams for the received upstream and LAN data signals when the wavelength difference between λ_U and λ_{LAN} was approximately 0.4 nm. From the experiment, it was observed that 280 µs pulse width signal can be recovered without much distortion. The switching of the desired wavelength channel is performed in smaller steps and an additional 75 µs rise/fall time is required. Therefore, the DFB laser is capable of wavelength switching at a rate of 355 µs for a wavelength difference of 0.4 nm. The residual signals observed in the timeslots in Fig. 5 are due to the imperfect filtering of signals. Using a narrowband FBG for filtering the signals, clean traces can be obtained. It should be noted that LAN data traverses through the SC twice and therefore the bandwidth of the LAN data is limited by the power budget. However, using a (N+1) x (N+1) SC and a secondary distribution fiber between the SC and each ONU, the bandwidth limitations can be overcome.

Conclusions: We have proposed and experimentally demonstrated a scheme for upstream transmissions and LAN emulation capability in PONs using a single DFB laser placed at the ONU. The experimental results show that all signals can be recovered with minimal penalty.

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