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Abstract: We have proposed a new colorless smart edge based on microring modulators to overlay 5G services in a wavelength division multiplexing optical access network. Experiments have verified the proposed scheme.

1. Introduction

The emerging fifth-generation (5G) mobile communication has raised new challenges on optical access networks (OAN), such as high throughput, low latency, and more. To address these new demands, optical access network sees the necessity to reform in many ways [1]. For example, as an efficient way to improve the total system throughput, wavelength division multiplexing passive optical network (WDM-PON) has been standardized, and has led the upgrade of OAN [2]. Meanwhile, among many innovations, silicon photonics (SiP) based solution stands out due to its low cost, high integration, low power consumption, and complementary metal-oxide-semiconductor (CMOS) compatibility [3]. In [4], we proposed a new smart edge for access networks. It intercepts the PON traffic, and overlays 5G services to optical network users (ONU), which serve as the access point of 5G. Here, we propose a new smart edge with SiP-based microring modulators (MRM), to integrate 5G services into a WDM optical network.

Fig. 1(a) depicts the schematic view of the proposed scheme. The optical line terminal (OLT) distributes the broadband services to the optical network users. At the remote node, the 5G services are overlaid to the broadband signal, by employing its optical carrier. To do this, a SiP chip is inserted, which consists of several cascade MRM. As is shown in Fig. 1(b), the first MRM generates the side carriers for 5G services overlay, while the following MRM modulate the 5G services. In this figure, two 5G services are overlaid, one of which is a radio-over-fiber (RoF) signal, and the other is a baseband signal to be up-converted to radio frequency at the antenna.

As a colorless device, MRM works in different WDM band with different thermal tuning [5]. It is then possible to integrate more MRM, and overlay 5G services to more than one WDM bands, without interfering each other. Fig. 1(c) shows the proposed WDM smart edge. We define 3 MRM in Fig. 1(b) as a group of MRM to overlay 5G services onto one WDM channel, in Fig. 1(c), two groups of 5G services are overlaid to two WDM channel, which correspond to two ONU in a WDM network. The interference or attenuation from other MRM is very low thus could be ignorable.

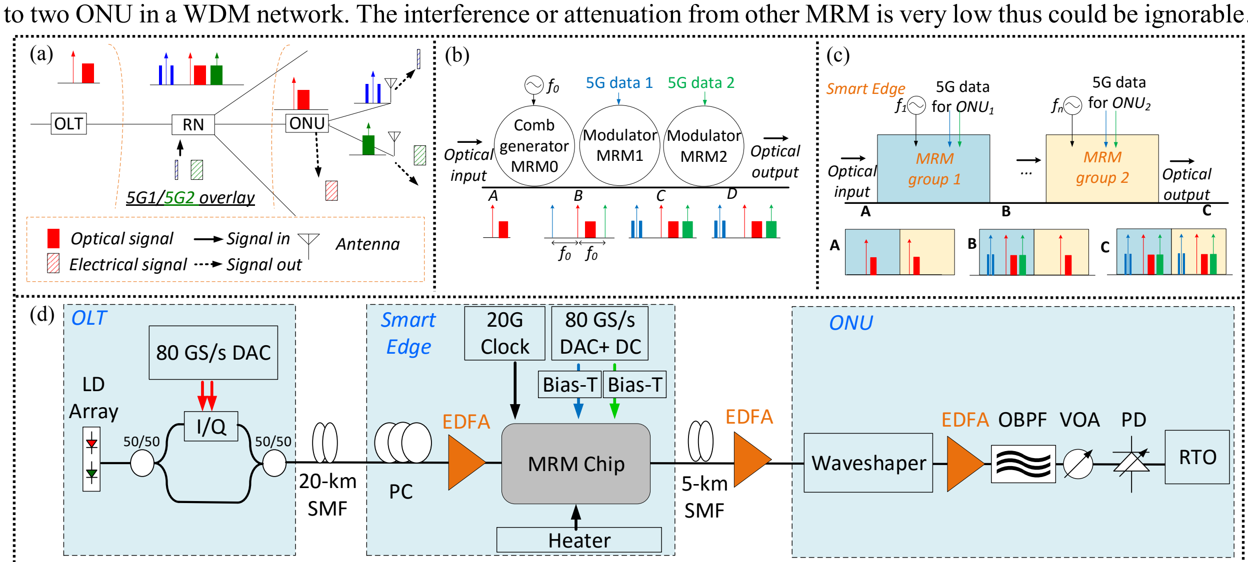

Fig. 1 (a) schematic view; (b) 5G overlay for one WDM channel; (c) 5G overlay for two WDM channels; (d) Experimental setup

2. Experiments

Fig. 1(d) shows the experimental setup. Two C-band lasers at 1537.792 nm and 1538.581 nm are splitted into two portions, one of which is modulated with a SSB-OFDM signal with 10 Gbps net bit rate, and the other portion combined back to serve as the carrier for 5G services. An I/Q modulator generates the SSB-OFDM, with two channels of a 64 GSa/s digital to analog converter (DAC). After transmission over a 20-km single mode fiber (SMF), the optical signal is amplified, and fed into the silicon chip. A polarization controller (PC) combats the polarization sensitivity of the silicon chip, which could be removed with a future polarization insensitive design. The chip insertion loss is 14-dB loss, 11.5-dB of which is the extra coupling loss which can be saved with optical packaging. On the silicon chip,

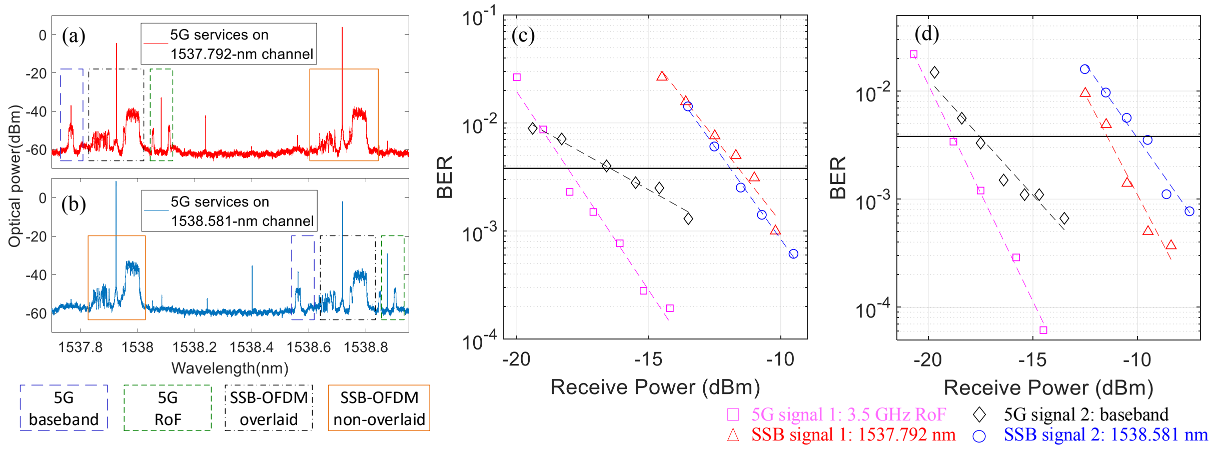

Fig. 2. (a) Spectrum with 5G overlay on 1537.792-nm channel; (b) Spectrum with 5G overlay on 1538.581-nm channel; (c) BER vs. receive power with 5G overlay on 1537.792-nm channel; (c) BER vs. receive power with 5G overlay on 1538.581-nm channel

three MRM are driven by a clock source at 20 GHz, and two 5G services. One of the 5G service is a 1-Gbaud QPSK-OFDM signal, and the other is a 750-Mbaud QPSK-OFDM RoF signal with a carrier frequency at 3.5 GHz. To work in different WDM channels, the MRM are thermally tuned with on-chip heaters. In our experiment, a 0.5-V heater voltage difference makes the MRM to work in the two WDM bands, respectively. After another 5-km SMF, the signal is filtered out with a waveshaper, boosted, and attenuated with a variable optical attenuator (VOA). A real-time oscilloscope (RTO) receives the signal with a photo detector for digital signal processing (DSP).

We first overlay the 5G services onto one of the WDM channel by thermally tuning the MRM to work in the 1537.792-nm band. The spectrum after 5G services overlay is shown in Fig. 2(a). To receive the baseband 5G service, SSB-OFDM signal after 5G overlay, RoF 5G service, and the other SSB-OFDM signal without 5G overlay, the waveshaper's central wavelength and bandwidth is set to be 1537.632 nm/10 GHz, 1537.792 nm/30 GHz, 1537.952 nm/10 GHz and 1538.581 nm/ 30GHz, respectively. The signals and their corresponding filters are shown by the boxes in the figure. In the experimental results in Fig. 2(c), the solid horizontal line is the threshold for hard decision forward error correction (HD-FEC), of $3.8x10^{-3}$. It can be seen that 5G RoF signal is below the threshold at 18-dBm receive power, while the baseband 5G service reaches below the threshold at a receive power of -16.7 dBm. With 5G services overlay, the BER of SSB signal at 1537.792 nm reaches the FEC threshold at -12-dBm receive power, showing ignorable penalty with the other SSB-OFDM at 1538.581 nm without 5G service overlay.

Then, the MRM are thermally tuned to work in the other WDM channel. As observed in Fig. 2(b), now the 5G services are overlaid onto the WDM channel at 1538.581 nm. We filter out and detect the services, and the BER versus receive power curves are shown in Fig. 2(d). As can be seen, the RoF and baseband 5G services BER drop below the FEC threshold at -19-dBm and -17.5-dBm receive power, respectively. The SSB-OFDM with 5G overlay requires a receive power of -10 dBm at the FEC threshold, which is about 1.5-dB higher than that without 5G overlay.

3. Conclusions

We have proposed and experimentally demonstrated a new smart edge to overlay 5G services in a WDM optical access network. The proposed scheme overlays 5G services onto broadband WDM channels, without significantly decreasing the original signal performance. This research was funded by National Science and Engineering Research Council of Canada (NSERC) grant CRDPJ499664, PROMPT Quebec grant 52_Rusch 2016.09, TELUS, and Aeponyx.

4. References

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