A Mobile Fronthaul System Architecture for Dynamic Provisioning and Protection

Qianmei Yang[1], Ning Deng[2], Xu Zhou[2] and Chun-Kit Chan[1]
[1]*The Chinese University of Hong Kong, Shatin, NT, Hong Kong*
[2]*Fixed Networks Research, Huawei Technologies Co., Ltd., Shenzhen, China*
yq013@ie.cuhk.edu.hk

Abstract: *We propose a mobile fronthaul architecture to handle the tidal effect for dynamic provisioning, and also protect the main baseband units, using injection locking of Fabry-Perot laser diodes. Downstream transmissions at 2.5 Gbit/s to 4 Gbit/s over 20-km have been experimentally demonstrated over the proposed architecture.*
Keywords: *fronthaul, injection locking, dynamic provisioning.*

I. Introduction

In next generation 5G mobile systems, cloud radio access network (C-RAN) is widely recognized as a practical approach to support mobile fronthaul. It centralizes the processing units, leaving only the radio access units at the remote cell sites [1]. It has been reported that there is a peak traffic load transition, recognized as tidal effect, between the office area and the residential area over different time periods in a day. With the centralization of the baseband units (BBUs), the C-RAN can achieve more efficient dynamic provisioning of the processing resources, based on the tidal effect, at both the office and the residential areas [1]. Therefore, the cost and power consumption can be reduced or optimized. Two approaches have been considered. One is to combine the channels of different remote radio heads (RRHs) into one at off-peak time for saving the processing resources [2] and the other one is to shut down some of the RRHs at off-peak time periods. The latter one is shown to be more effective in energy saving.

In this paper, we propose a mobile fronthaul architecture to simultaneously achieve dynamic provisioning, via shutting down the RRHs at off-peak time periods, as well as protect the BBUs in a cost-effective way, based on injection locking of Fabry-Perot laser diodes (FPLD). We have experimentally demonstrated 20-km downstream transmissions of six wavelength channels at 2.5-Gbit/s, 3-Gbit/s and 4-Gbit/s over the proposed architecture.

II. Proposed Architecture

Fig. 1 shows our proposed mobile fronthaul architecture. The central office (CO) serves both the office and the residential areas, via two dedicated sets of static BBUs, sharing the same set of wavelengths, as the two areas do not overlap each other. One additional set of dynamic BBUs are designated to serve these areas according to the need of extra traffic demand. The wavelength multiplexers are the cyclic arrayed waveguide gratings (AWGs) such that each port supports two passband channels, one in blue band (1527.5-1542.5nm) and the other in red band (1547.5-1561nm). Wavelength channels in the blue band are allocated to the static BBUs and red-band wavelength channels are for the dynamic BBUs. At each dynamic BBU, a Fabry-Perot laser diode is employed as the optical source and it is injection-locked by an optical frequency comb source, or spectrally-sliced broadband light source. Its output port is connected to an optical red/blue (R/B) multiplexer for channel separation, via a 1×2 optical switch, in order to select a particular channel in either red band or blue band. All downstream channels are then optically combined and sent over the feeder fibers to reach different areas.

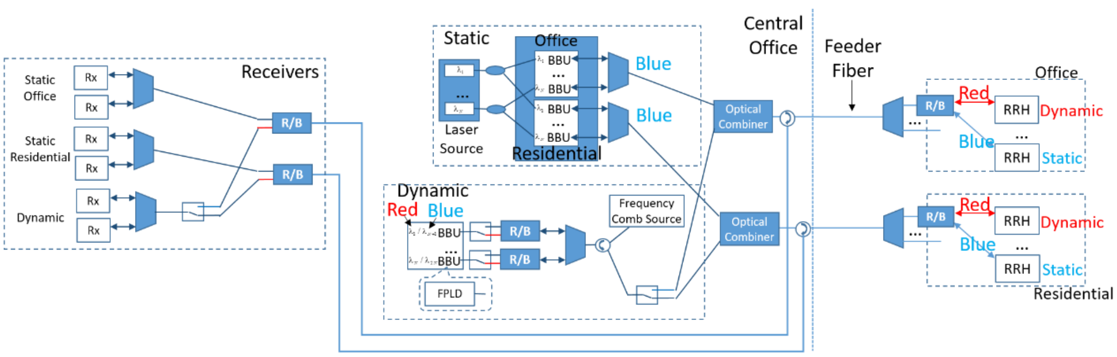


Fig. 1. The proposed mobile fronthaul architecture.

As illustrated in Fig. 2(a), for the downstream transmission, when the dynamic BBUs serve the RRHs for dynamic provisioning, they are connected to the red-band channels, so that the static BBUs and the dynamic BBUs occupy different sub-bands and wavelengths are multiplexed by an optical combiner.

Once a static BBU fails in the downstream transmission, the corresponding dynamic BBU is switched to the blue band to replace the failed static BBU and its red-band wavelength will be given up, as shown in Fig. 2(b). The failed static BBU is shut down and the alternative channel is multiplexed to the blue band, via the optical combiner. Thus, the RRHs in the static sub-network can still work normally, while the corresponding dynamic RRHs are disabled. The static BBUs are protected because the sub-network that the static BBUs are assumed to carry more important traffic than that the dynamic BBUs carry. This assumption is reasonable as the static BBUs serve a complete network supporting the whole area at off-peak time and the dynamic BBUs are supplementary to the static networks at peak time.

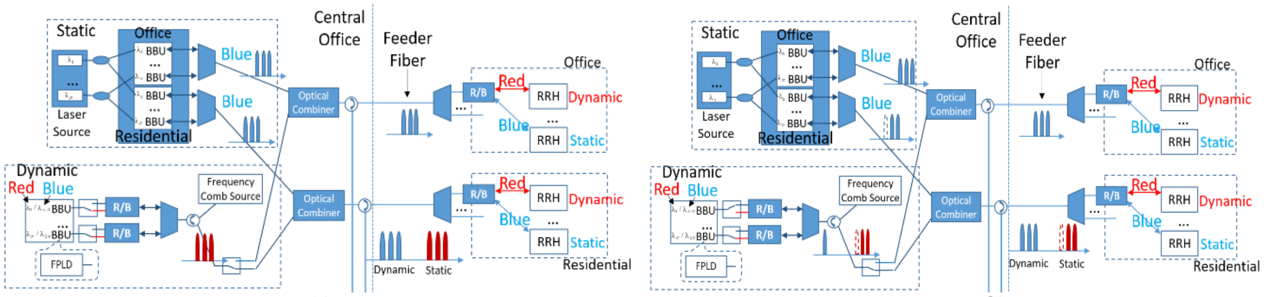


Fig. 2. The illustration of (a) the dynamic provisioning mode and (b) the protection mode.

III. Experiment and Results

At each dynamic BBU, a Fabry-Perot laser diode (FPLD) is employed as the optical source and it is injection-locked by an optical frequency comb source, or spectrally-sliced broadband light source. Here, we have analysed the performance of different channels of the FPLD in both red and blue bands, as a slave laser in optical injection locking. Fig. 3 shows the experimental setup. We employed two external cavity lasers (ECLs) as the master lasers to emulate two wavelengths in the optical comb source, as they were wavelength tunable. They provided different wavelengths in the red band and the blue band, separately, which could pass the same port of the cyclic AWG, simultaneously. The cyclic AWG had a channel spacing of 100 GHz, thus the free spectral range (FSR) at each port was 1.6 THz, as the dashed blue curve shown in Fig. 4(a). The red/blue multiplexer had the spectral range of 1547.6-1559nm and 1532-1542nm for the red band and the blue band, respectively, as dash-dot pink curve and the dot green curve, as shown in Fig. 4(a). We used a 2.5-Gbit/s FPLD as our slave laser and the FSR of the FPLD was around 146 GHz, shown as the solid red curve in Fig. 4(a). The FPLD was directly modulated by a pulse pattern generator (PPG) in non-return-to-zero (NRZ) format with a 2^{15}-1 pseudorandom binary sequence (PRBS). The modulated signal passed through the optical switch, the red/blue multiplexer and the cyclic AWG and was then transmitted over 20-km single-mode fiber, before being detected by a PIN photodiode. The received electrical signal was amplified and filtered out by proper low-pass filter (LPF) and was analysed by a bit error rate tester (BERT).

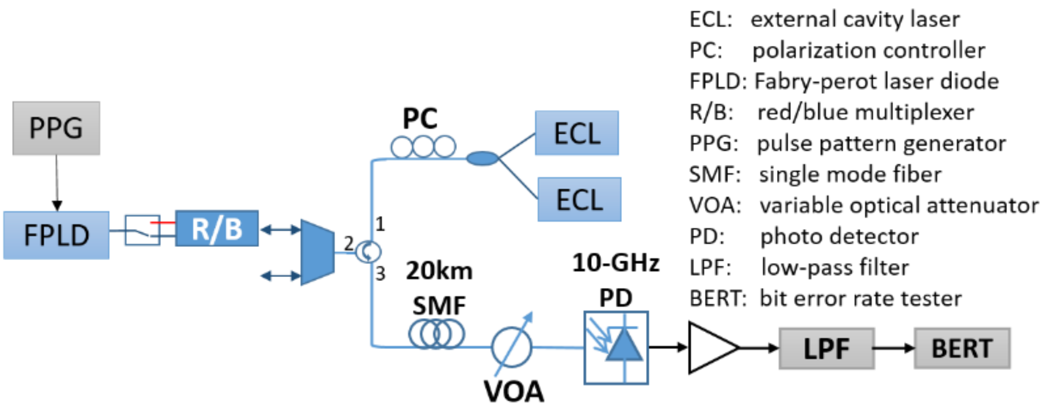
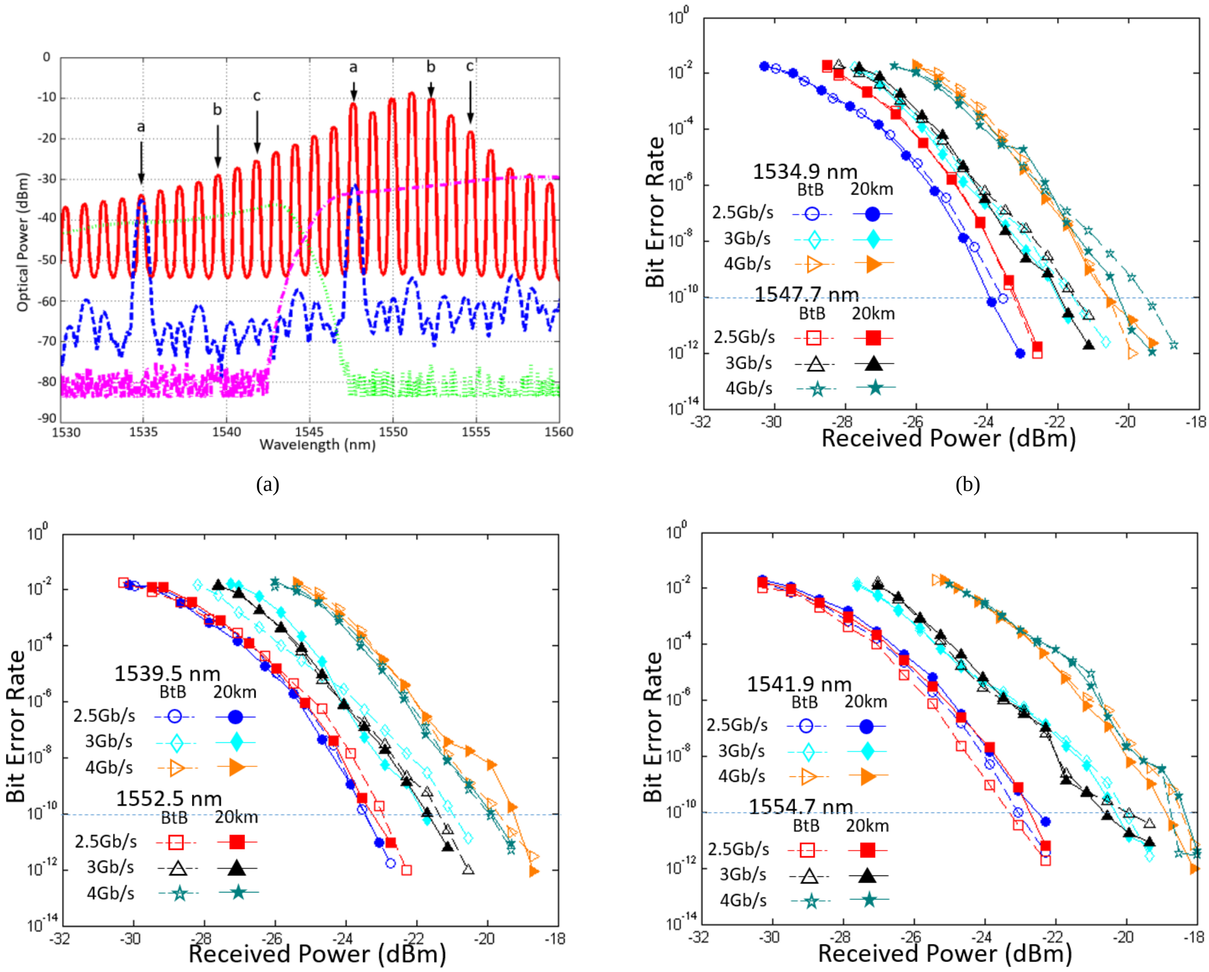


Fig. 3. Experimental setup.

We have tested the performance of six different channels with wavelengths of 1534.9 nm, 1539.5 nm, 1541.9 nm, 1547.7 nm, 1552.5 nm and 1554.7 nm. They formed three pairs where each pair could pass through the same port of the cyclic AWG, while one was in the red band and the other was in the blue band. The pairs were chosen on purpose that the wavelength of 1541.9/1554.7 nm and 1534.9/1547.7 nm were at the edge of the red/blue multiplexer, while the last pair was randomly chosen within the range of the red and the blue bands. Three different transmission rates were studied which were 2.5 Gbit/s, 3 Gbit/s and 4 Gbit/s. The LPFs used at the receiver were with bandwidths of 2.4 GHz, 2.4 GHz and 3.4 GHz, respectively.



(a) (b)

(c) (d)

Fig. 1. (a) Spectra of free-run FPLD (solid red), red/blue multiplexer (dash-dot pink/dot green) and a port of cyclic AWG (dash blue); BER curves for (b) 1534.9nm, 1547.7nm (label a in (a)), (c) 1539.5nm, 1552.5nm (label b in (a)), (d) 1541.9nm and 1554.7nm (label c in (a)) channels.

Figs. 4(b)-(d) show the measured BER curves of the six channels. The six channels had very similar performance, in terms of the BER, even though the free-running FPLD had different output powers at these wavelengths. This might be attributed to the high-quality injection locking, as the side-mode suppression ratio of the FPLD was over 40 dB after injection locking. The 20-km transmission exhibited penalty free performance as compared to the back-to-back case, for the relatively low transmission rates. For the same channel, the power penalties between 2.5-Gbit/s and 3-Gbit/s transmission as well as between 3-Gbit/s and 4-Gbit/s, were both around 2 dB. Error free transmissions were achieved at all the three transmission rates, but could hardly be achieved at 5-Gbit/s, which was far beyond the FPLD modulation bandwidth. However, the transmission rate could be further improved by employing pre-emphasis or OFDM format.

IV. Summary

We have proposed a mobile fronthaul architecture for dynamic provisioning in mobile networks and protecting the main BBUs against possible BBU failure. Injected locked FPLDs are employed as optical sources at the BBUs. With these optical sources, we have demonstrated 20-km transmission at the data rates of 2.5 Gbit/s, 3 Gbit/s and 4 Gbit/s, among six different channels, in both the red band and the blue band. The similar performances among the channels in the red and the blue bands have confirmed that our proposed architecture can provide high-quality and cost-effective downstream transmissions in both dynamic provisioning and protection modes in future mobile fronthaul systems.

References

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