Seamlessly Converged Optical-Wireless Access Networks Using Free-Running Laser-enabled mmWave Signal Generation and RF Envelope Detection

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Seamlessly Converged Optical-Wireless Access Networks Using Free-Running Laser-enabled mmWave Signal Generation and RF Envelope Detection

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Abstract: Low-cost component-based converged optical-wireless networks without DSP at intermediate RRHs are proposed and experimentally demonstrated, supporting 1.67 Gbit/s/ch dynamic and continuous BBU-UE data flows over 50 km SSMF and 3 m 38 GHz wireless links.

1. Introduction

Mobile communications are currently being advanced towards beyond fifth-Generation (B5G) for providing high peak data rates of ⩾1 Tbit/s, low end-to-end latency of 10–100 μs, while being still capable of simultaneously offering a massive connection density of 10 million devices/km^2 [1]. To meet these requirements, the deployment of millimeter wave (mmWave) communications become indispensable due to their relatively wide bandwidths, small element sizes and narrow beams [2]. On the other hand, from the practical implementation point of view, it is also vital to seamlessly integrate the mmWave wireless networks and optical networks to enable signals of any characteristics to continuously flow between baseband units (BBU) and all user ends (UE) without utilizing extensive digital signal processing (DSP) at any intermediate radio remote head (RRH) nodes.

To address the above challenges, the explorations of cost-effective and tunable mmWave signal generation approaches are highly desirable to reduce overall network expenditures, as existing photonic mmWave signal generation techniques based on the effects such as phase locking, multimode sources, external modulation and nonlinearities are relatively complex and expensive for applications in cost-sensitive access scenarios [3]. Free-running laser-based mmWave photonic generation is more attractive due to its simplicity, low cost, and excellent frequency tunability. To automatically reduce the unwanted phase noise and frequency offsets arising from optical signal beating between two independent lasers, RF envelope detectors may be utilized for undertaking mmWave signal down-conversions [4].

To deliver the abovementioned design objective, this paper proposes and experimentally demonstrates, by incorporating low-cost free-running laser-based mmWave photonic generation and RF envelope detection, a cost-effective seamlessly integrated optical-wireless network without DSP at intermediate RRHs. The proposed techniques have the following unique advantages including low latency, high cost-effectiveness, excellent performance stability and mmWave frequency tunability. This work may pave a path to practically realizing seamlessly converged optical and wireless access networks.

3. Experimental Setup

The experimental setup of the proposed converged optical-wireless networks is shown in Fig. 1(a). In the CO-BBU,

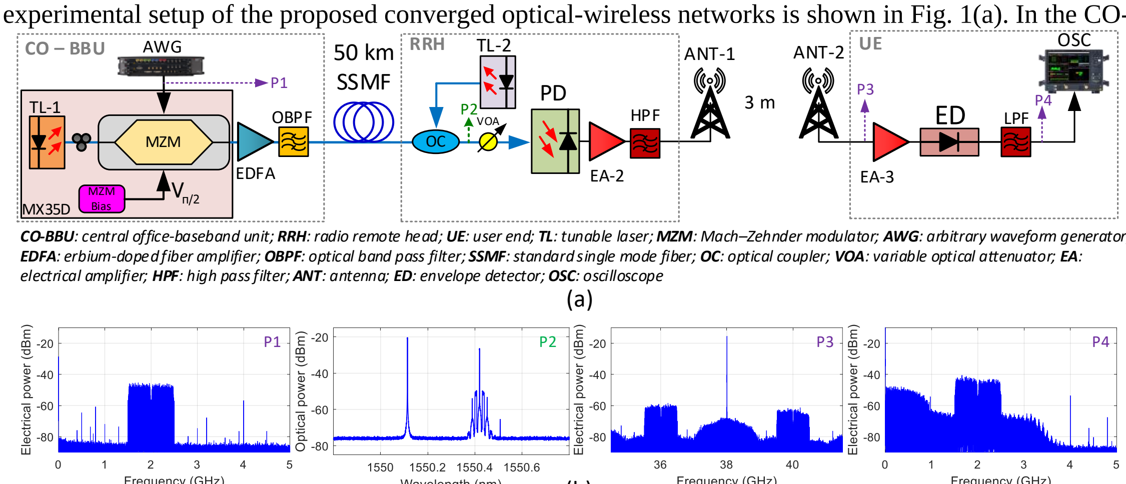

Fig. 1. (a) Experimental setup and (b) optical and electrical spectra at different points depicted in the experimental setup.

an AWG generates a single 1.67 Gbit/s OFDM band located at a 2 GHz IF, as shown in P1 in Fig. 1(b). The band contains 15 16-QAM-encoded subcarriers. A quadrature-biased-MZM modulates the produced OFDM signal onto a 0 dBm optical carrier at 1550.415 nm. An EDFA amplifies the optical signal to 12 dBm, followed by an 0.8 nm OBPF. After 50 km SSMF transmissions, at a RRH, a standalone free-running laser generates an optical carrier with a 38 GHz frequency gap with respect to the BBU-side laser, as shown in P2 in Fig. 1(b). After a 40 GHz PD and a 27 dB EA, a 26~50 GHz HPF is employed to filter the generated 38 GHz mmWave signal before being transmitted over a 3 m wireless link. The UE-received mmWave signal, as displayed in P3 in Fig. 1(b), is first amplified by a 30 dB EA-3, and then down-converted to the baseband region by a RF envelope detector. After passing through a 2.5 GHz LPF, the baseband signal, whose spectrum is illustrated in P4 in Fig. 1, is digitized and offline processed for signal demodulation using conventional OFDM demodulation procedures without phase noise and frequency offset estimation and compensation.

3. Results and Discussions

The measured bit error rate (BER) versus received optical power (RoP) performances are shown in Fig. 2(a). The fiber and wireless link transmission-induced power penalties, which are defined as the degradations of the minimum required RoPs corresponding to BERs at an adopted 20% overhead SD-FEC limit of 2.2×10^{-2} [5], are <0.3 dB and <0.7dB respectively (see inset (i) in Fig. 2(a)). Nevertheless, the minimal required RoPs, over which the BERs are below the FEC limit for the fiber and wireless links are >-7.5 and >-6.8 dBm, respectively. The insets (ii) and (iii) in Fig. 2(a) show the constellations at a -4 dBm RoP, which corresponds to BERs of 4.48E-4 and 4.25E-4 for the fiber, and converged fiber and wireless transmissions, respectively.

Based on the parameters used in obtaining Fig. 2(a), the impact of RRH-embedded laser output power (P_{laser}) on the transmission performance for different wireless link distances are illustrated in Fig. 2(b). The results indicate that increasing the RRH-embedded laser output power can boost the produced wireless signal power, thus not only relaxing the need of requiring any extra post-detection RF amplifiers to compensate signal power losses, but also further improving transmission performances and extending mobile network coverages. For example, for a P_{laser} of 0 dBm (4.6 dBm), the employment of such an amplifier is not necessary for wireless links of <1 m (<3 m).

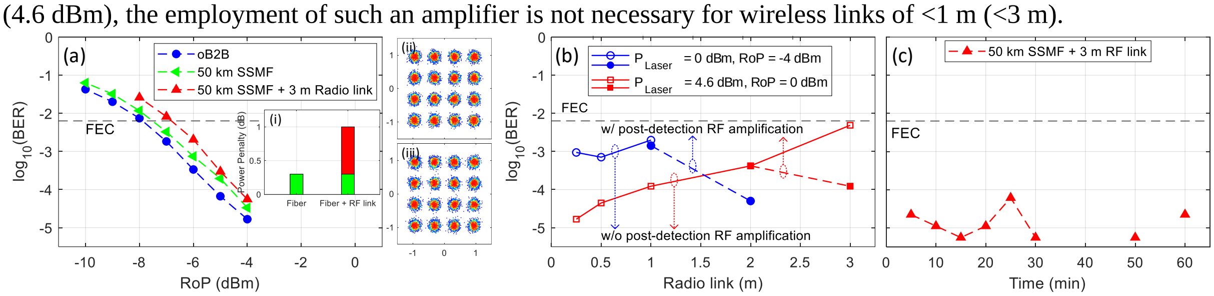

Fig. 2. (a) BER performances versus RoP, (b) BER performances for different RF link distances after fiber transmission, and (c) system stability over time. Insets: (i) power penalty respect to oB2B at FEC limit; (ii) and (iii) measured constellations after 50 km SSMF, and 50 km SSMF and 3 m RF transmissions, respectively, with a fixed RoP of -4 dBm.

Based on the parameters/setup used in Fig. 2(a), the performance stability of the proposed technique is evaluated and presented in Fig. 2(c). In obtaining the figure, over a 60-minute time period, the BER performances after the 50 km fiber and 3 m RF transmissions are measured every 5 minutes subject to a fixed 0 dBm RoP. The results imply the proposed techniques have excellent performance stability, i.e., BERs are <1E-4. This is valuable for practical applications.

3. Conclusions

This paper has proposed and experimentally demonstrated a low-cost seamlessly converged optical-wireless access network without implementing DSPs at intermediate RRHs, by using free-running laser-based mmWave generation and RF envelope detection. Dynamic low-latency BBU-UE connections with stable performances and a bitrate of 1.67 Gbit/s have been successfully established over 50 km fiber and 3 m 38 GHz mmWave wireless transmission links.

5. References

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