Experimental Demonstration of Low-Cost S- / C-Band Broadcast-Overlay in WDM-PON

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Abstract: We present an experimental study on downstream broadcast overlay in WDM-PON systems using a low-cost reflective semiconductor optical amplifier (RSOA) as broadband signal source. Reach and achievable bitrate are compared for S- and C-Band overlay.
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1. Introduction

In the past, several passive optical network (PON) architectures and technologies have been proposed [1]. While currently deployed PON systems are mostly relying on time division multiple access (TDMA), there are several flavors of next generation PON under discussion such as wavelength division multiplex PON (WDM-PON) [2] or time and wavelength division multiplex PON (TWDM-PON) [3]. WDM-PON systems are often realized as so-called "wavelength-routed" networks, making use of a wavelength-selective filter in the remote node (typically an arrayed-waveguide grating, AWG). A characteristic of such AWGs is their cyclic transfer function. Channels not only in one band are multiplexed or demultiplexed, but simultaneously in several neighboring bands, with a channel spacing slightly depending on the grating order [4]. This allows operation of the WDM-PON system e.g. with all downstream channels in the L-band and upstream channels in the C-band. Furthermore, adding additional channels in a separate band is possible (e.g. for broadcast overlay at the OLT) without replacement of the installed AWG [5].

In this paper, we experimentally investigate a (downstream) broadcast overlay in C- and S-bands (C: 1530-1565 nm, S: 1485-1520 nm). For this purpose, a low-cost reflective semiconductor optical amplifier (RSOA) is deployed at the OLT or the remote node (RN). Typically such a device is operated with external seeding [1]. However, in our demonstration the broadband noise from the RSOA is directly modulated, resulting in a broad spectrum (>150 nm) modulated optical signal, which can be filtered to fit e.g. into the C- or S-band. In this way a broadcast channel can be realized, which can transmit information downstream to each attached ONU. We show for the first time to our knowledge a study on the performance of C- and S-band overlay using an unseeded RSOA.

2. Experimental setup S-band overlay

A schematic of a WDM-PON system using S-band broadcast overlay is depicted in Fig. 1 (upper part, (1)). In the experimental setup we used only a subset of 5 downstream channels in the L-band and 5 upstream channels in the C-band. All channels were transmitted and received by standard small form pluggable (SFP) transceivers, modulated with 1.25 Gb/s Ethernet data from an Ethernet protocol tester. For the broadcast overlay we used a commercially available RSOA SFP by MEL Inc. (WR32-OLT). To reduce additional losses, the broadcast signal was added by means of a multiplexer (band-splitter). Due to the availability of components, the modulated noise spectrum of the RSOA was reduced to part of the S-band (1501 nm to 1519 nm) and not the full S-band. The inset in Fig. 1 shows the downstream spectrum before the AWG. Standard single mode fiber (SSMF) of 10.8 km, 20.8 km or 31.6 km with an attenuation of 2.6 dB, 4.6 dB or 7.2 dB, respectively, was used as transmission fiber between OLT and RN. At the RN, a cyclic AWG according to ITU-T recommendation G.698.3 had been deployed, which is specified for up to 40 channels in the C-band on a 100 GHz grid. In the L-band, the frequency spacing is 97.15 GHz. At the ONU, the broadcast signal was separated from the C-and L-band signals by the same filter as used at the OLT. To measure the BER of the broadcast signal, the RSOA SFP had been placed on an SFP evaluation board and connected to a bit error rate tester (BERT), which allows generating arbitrary bit rates up to 3 Gb/s. The broadband overlay was detected using a standard 2.5 Gb/s SFP, which was also connected to the BERT. To determine BER vs. received power, a variable optical attenuator was placed before the receiver. In addition to the length of SSMF, we varied the data rate of the overlay signal from 1.25 Gb/s to 2.5 Gb/s.

3. Experimental setup C-band overlay

The setup using the C-band overlay is shown in Fig. 1 (bottom part, (2)). Any RSOA noise present in S- and L-bands needed to be filtered out, therefore a combination of the S-band multiplexer and a C/L-band splitter was applied. Since the setup had to be transparent for the conventional upstream C-band, the simple use of a multiplexer as for the S-band was not possible and a combination of a 3-dB coupler and an isolator was used instead. At the RX, a circulator was used to split the C-band upstream and the broadband downstream signals. This part of the setup is critical: Since the received power of the broadband signal was very low (around -30 dBm), any reflection of the upstream C-band signal led to severe distortions. Therefore, the power level of the upstream signal was kept as low as possible. In our setup, we inserted additional 14 dB attenuation after the ONU transmitter, i.e. the transmit signal level was set to approximately -10 dBm. Due to this limitation and due to the additional insertion loss in the broadband overlay path (3-dB coupler, isolator, circulator), the reach of the system was reduced in contrast to the S-band overlay setup. Moreover, since the spectrum of the RSOA is not flat, not all overlay channels met the power requirements for error free transmission over 20.8 km SSMF between OLT and RN. The power budget could be improved by reducing the fiber length or coupling the overlay at the RN instead of at the OLT. Results are presented for one channel in the middle of the C-band (1545.32 nm), for coupling at the RN with 20.8 km SSMF and for coupling at the OLT with 10.8 km and 20.8 km SSMF. Again, the data rate was varied. The additional components required for a combination of C- and S-band overlay, are marked by grey boxes in Fig. 1.

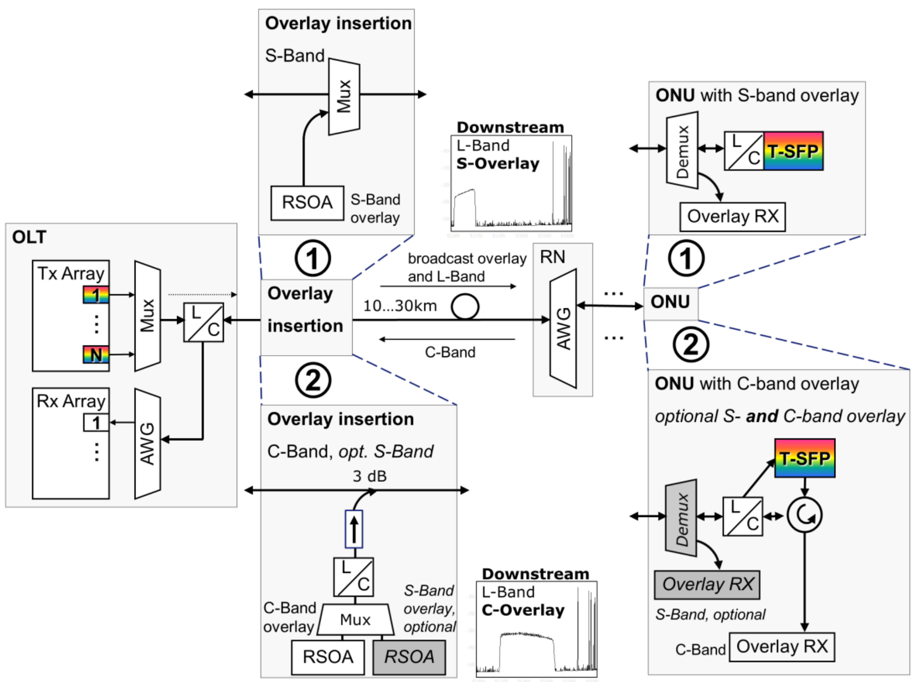

Fig. 1. Schematic of WDM-PON system with broadcast overlay (OLT: optical line terminal, RN: remote node, ONU: optical network unit, RSOA: reflective semiconductor optical amplifier). Upper part alternative (1): overlay in S-band, lower part alternative (2): overlay in C-band with optional additional S-band overlay (grey boxes).

4. Results

Fig. 2 (left) shows the BER vs. received power for the S-band overlay signal. Error free transmission over 20.8 km was verified for 1.25 Gb/s data rate. For increased fiber length, limited received power prevented error free detection. The transmission was not dispersion limited. Operation at higher data rates was only possible, if forward error correction (FEC) were applied to the broadband signal. Vertical lines mark the maximum received power for the overlay at the RX at different fiber lengths.

Besides the measurements of the overlay signal, we verified the operation of the C- and L-band point-to-point channels to be error free and to show no difference in the presence of the broadband overlay. BER vs. received power for one overlay channel in C-band is presented in Fig. 2 (right). Conventional C-band upstream was transmitted on the same wavelength. Error free transmission was only achieved for 10.8 km of SSMF or insertion of the overlay at the RN. As mentioned before, some C-band overlay channels may show slightly worse performance, therefore RN coupling of the overlay is preferable. Again, the limitation in reach resulted from the power budget, not from chromatic dispersion. Higher rates would only be feasible, if FEC were assumed. Again, the error-free operation was verified for all conventional L- and C-band channels, not depending on the use of the overlay.

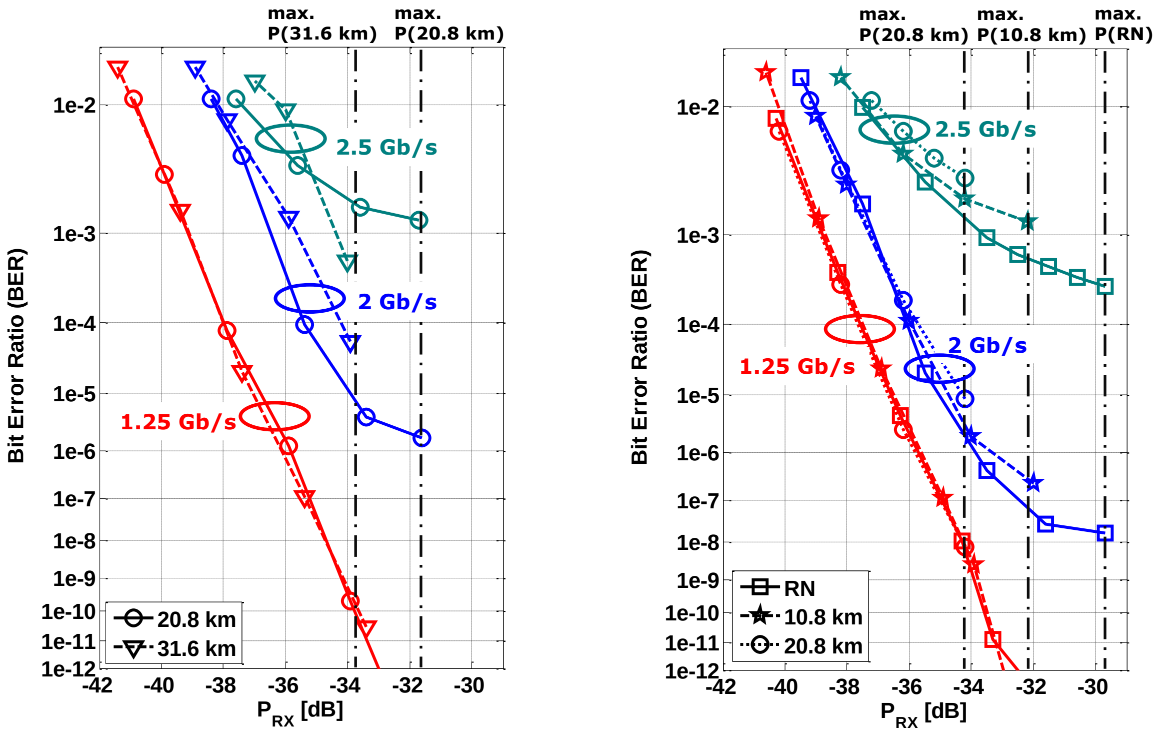

Fig. 2 left: BER vs. received power P_{RX} for S-band overlay for 1.25 Gb/s, 2 Gb/s und 2.5 Gb/s and different transmission lengths. Vertical lines: max. received power dependent on reach.
right: BER vs. received power P_{RX} for C-band overlay channel 20 (1545.32 nm) for 1.25 Gb/s, 2 Gb/s and 2.5 Gb/s and different transmission lengths or insertion of overlay at RN. Vertical lines: max. received power dependent on reach.

4. Discussion and conclusion

We have presented a study on broadcast channel overlay in the C- and S-bands (e.g. for RF-TV distribution) for WDM-PON systems using an unseeded RSOA. While an S-band overlay provides error-free 1.25 Gb/s capacity over 20.8 km, for C-band overlay, the insertion loss of additional components reduces the available power budget, and reflections limit the C-band upstream power. Therefore, the setup might be more challenging for practical application. However, if FEC is used, or if an RSOA component with adapted spectral characteristics or slightly higher output power is available, also a combination of two broadband overlays, in S- and C-band is conceivable, doubling the multi-cast capacity. In neither case, the performance of the WDM-PON channels was degraded by the presence of the additional overlay channel (apart from the slightly reduced link loss budget due to the additional multiplexer components).

Acknowledgements

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