Wireless-PONs with Extended Wavelength Band Overlay

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Abstract: An advanced architectural platform based on wireless-enabled PON topologies is described. Network modelling of WiMAX channel transmission, based on FDM, over a multi-wavelength, splitter-based PON has demonstrated EVMs below -30dB and error-free multipath transmission.

OCIS codes: 060.4250 (Networks), 060.4510 (Optical communications)

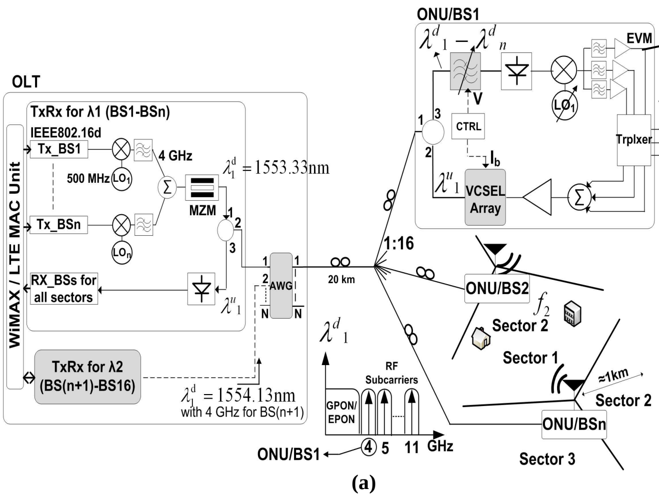
1. Introduction

Convergence of optical and the rapidly growing by means of, deployment and standards wireless networking, represents the current challenge for ubiquitous broadband multimedia communications [1]. To that extent, this paper presents an innovative architecture demonstrating transparent transmission of broadband wireless signals to remote Optical Network Unit/Base Stations (ONU/BS) addressed by frequency division multiplexing (FDM) over different wavelengths of splitter-based PONs.

2. Network architecture

Compared to [2], the key feature of the topology shown in Fig. 1 is enhanced network scalability through the application of multi-wavelength transmission over splitter-based PON [3] allowing for each BS up-converted subcarrier downstream to be dynamically multiplexed on different wavelengths relaxing bandwidth requirements of optical/electrical components. This has been demonstrated in the network by the same BS subcarrier in the FDM window being utilised to transmit wireless channels to multiple ONU/BSs on two different wavelengths. Any wavelength of the selected operating spectrum could be partly or exclusively assigned to different ONU/BSs, providing service level similar to WDM-PONs with slightest modifications in network hardware through a dense array waveguide grating (DAWG) in the optical line terminal (OLT) and tuneable optical filters [3] in ONU/BSs. The centre frequency of the latter can be adjusted by the OLT by means of a controller (CTRL) circuit.

Another significant feature of the proposed topology lays in the use of low-cost long-wavelength VCSEL arrays [4] in upstream to demonstrate colourless terminations with simple coupling optics, not limited by Rayleigh backscattering. VCSEL wavelength selection can be managed by a means similar to tuning the ONU/BS filters. Since multiple-wavelengths are used in upstream the up-conversion is not required.



IEEE802.16d	Parameters
Freq. range DW&UP	3.3-3.7 GHz
Ch. spacing	100MHz
Ch. bandwidth DW/UP	20/10 MHz
Cyclic Prefix	1/4
Modulation DW/UP	64/16 QAM with 256-OFDM
Data rate DW/UP	60/40 Mbit/s

(b)

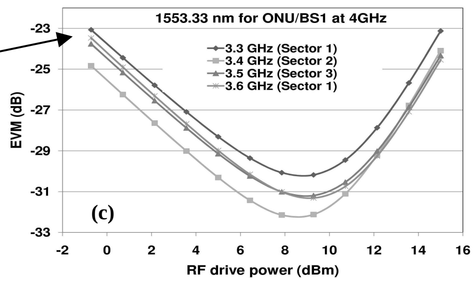


Fig. 1. (a) WiMAX over multi-wavelength, splitter PONs; (b) WiMAX parameters; (c) EVM versus RF drive power in MZM

3. Network modeling and results

A physical layer simulation test-bed was implemented using Virtual Photonics Inc. (VPI) enriched with MATLAB simulation functionalities to model wireless transmission over a multi-wavelength PON in terms of error vector magnitudes (EVMs) and bit error rates (BER) in a typical WiMAX sectorised approach.

According to the deployed scenario shown in Fig. 1, the four WiMAX channels from Tx_BS1 and Tx_BS2 are frequency shifted around 4 GHz subcarrier for ONU/BS1 and BS2 respectively before being modulated on the two different wavelengths. After being routed through the optical circulator for bidirectional transmission and a DAWG output port the two wavelengths are then broadcasted over passive splitter to all ONU/BSs with the standard optical power budget parameters [5]. At each ONU/BS a tuneable optical band-pass filter with 50 GHz bandwidth is used to select a wavelength which is then detected by an avalanche photodetector (APD) followed by RF down-conversion to result to the transmitted WiMAX channels.

EVM figures at ONU/BS1 antenna input are then plotted in Fig. 1(c) as a function of the Mach-Zehnder modulator (MZM) RF drive power in the OLT displaying a figure below the -30 dB limit at distinctive drive powers as dictated by the WiMAX standard with 64-QAM modulation. Similar results were obtained for the WiMAX channels transmitted on λ^{d}_{2}=1554.13nm. In addition, BER curves, as shown in Fig. 2, for the 3.4GHz and 3.5GHz WiMAX channels dropped to two ONU/BSs on different wavelengths and transmitted initially over an AWGN channel demonstrate equal performance as well as 4 dB power penalty, at a required by the standard, BER of $1E^{-6}$. For non-line-of-sight wireless path a further power penalty is monitored as expected due to the exclusion of wireless channel coding to represent the worst case scenario for both cases.

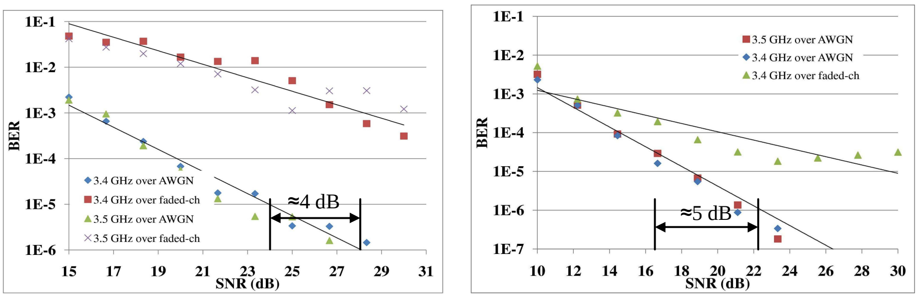


Fig. 2. BER performance for 3.4GHz and 3.5 GHz WiMAX channels (a) downstream and (b) upstream channels

In upstream, following reception at the ONU/BS1, the WiMAX channels are directly modulating VCSEL array at 1553.33nm with a constant output power level of +1.2 dBm [4]. After fibre transmission the optical signal is then routed through the I/O port of the DAWG and through the corresponding circulator to the destination receivers in the OLT. The BER estimates, shown in Fig. 2(b), for an AWGN channel, displayed similar power penalty as in downstream, demonstrating successful application of VCSEL arrays for the integrated optical/wireless network.

4. Conclusions

A novel network architecture featuring wireless transmission by means of FDM over multi-wavelength splitter PONs for enhanced network scalability is described. Assuming the application of a 40-port commercially available DAWG and 16 ONU/BSs per PON with minimum 50 users per WiMAX sector, more than 96000 wireless users can be served by the proposed network. The obtained results demonstrate EVM figures below -30 dB, complying with the WiMAX standard while successful transmission of standard WiMAX rates has been demonstrated bidirectionally with the applications of long-wavelength VCSEL arrays upstream.

5. References

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