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Analytical modeling and impact analysis on multichannel symmetric optical and wireless NG-PON2 networks of CD, SPM, XPM and FWM impairments

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Abstract

A conceptual model for optical wireless (OW) interfacing with NG-PON2 access network is analyzed using N1-class backbone optical distribution and OW free-space optics (FSO) channels in the frontend to connect ONUs to symmetric 1.25/2.5/10 Gbps channels incorporating Time and Wavelength Division Multiplexing (TWDM) technique to deliver applications and services based on Fiber-to-the-X (FTTX), IoT and 5G technologies. We successfully demonstrated the design and analysis of ODN channel attributes supporting coexistence approach in contiguous with fiber channel linear and nonlinear impairments (LNI), and atmospheric attenuations β due to haze, dry particles inside the premises for high-speed OW channel for indoor applications along with optimization of hybrid N1-power budget class distributing configuration propagating multi-channel (MC) OW-FSO TWDM NG-PON2 configurations supporting symmetric configuration. Multichannel input power is calculated to optimize up/down link spectrum ODN power to 4 and 3 dBm respectively at worst-case scenario accommodating eight symmetric channels. Simulation results achieved at 50.011 km in either direction are −41.85/−36.67/−39.04/ dBm and −33.63/−42.78/ −37.92 dBm receiver sensitivities supporting 448 splitter configuration at 50.011 km, FWM efficiency is 1.65e-52 and FWM component power at as low as −53 to −54 dB in conjunction with CD, SPM, XPM, and FWM LNI for spectrum in either directions.

Introduction

As we are moving towards smart homes, offices and educational environment, work-from-home scenario for corporate and executives, remotely assisted and interactive surgeries in hospitals, internet-of-things (IoT) enabled public and private services and applications, incorporating of virtual reality (VR) and augmented reality (AR) contents in e-commerce, media, entertainment, education sectors and industries are pushing the need for access networks with higher bandwidth capacity. Due to extensive access to high resolution audio, video interactive contents, online gaming and communication between connected devices enabling IoT networks will generate approximately 396 Exabytes of digital data per month on the access network by 2022. Extensive utilization of Artificial Intelligence (AI) and Machine Learning (ML) technologies to deploy IoT enabled smart cities will require to connect around 15 Billion connected devices, many of them will require mobility features. It is expected that global traffic between machines and connected device will grow at compound annual growth rate (CAGR) of 47% by 2022 [COSCO-22].

The attributes of future access networks like supporting growing bandwidth demand by users i.e.in the range of 500 Mbps per user to access 4K video contents on the move, network reliability, availability and resilience can be served by combination of TWDM NG-PON2 optical and wireless (OW) FSO channels to support the services and applications based on FTTX, IoT, and 5G technologies [6], [7], [8]. MC-OW-FSO-TWDM NG-PON2 access networks can be conFig.d to connect multi-gigabit dedicated PtP channels single dedicated corporate subscriber, IoT and 5G services and application servers using PtP WDM links and multiple subscribers using TWDM GPON and TWDM XGS-PON channel e.g. apartments or university campus scenario with symmetric 1.25/2.5/10Gbps configurations [1], [2], [3]. TWDM-PON technology has outplayed OCDMA-PON and OFDM-PON options and unanimously approved by FSAN and protocols outlined in ITU-T G.989.2 (2014 and 02/2019). It is also a cost-effective option from internet service provider's (ISP) point of view to consider and utilize existing legacy Gigabit networks GPON, 10GPON, 10GE-PON and symmetric 10 GPON (XGS-PON) infrastructures. This leads to the development of a coexistence access network supporting symmetric 1.25/2.5/10Gbps channels. [4], [9], [11]. Further, the advantage of mobility is introduced in the FTTX networks by incorporating OW based NG-PON2 multi-gigabit access network serving applications like FTTX, IoT and 5G. An OW FSO channel operates in the line-of-sight (LOS) mode is suitable for implementation for indoor as well as outdoor environmental conditions [10], [14], [15]. License-free OW spectrum, swift integration with optical channel, gigabit line rate, low power consumption, easy installations, electromagnetic-interference free transmission, safety etc. are the key features offered by OW FSO channel. This makes the proposed MC-OW-FSO-TWDM NG-PON2 network an attractive option to utilize the maximum bandwidth of single mode fiber (SMF) channel in the distribution network and incorporating mobility feature using OW FSO channels supporting symmetric 1.25/2.5/10Gbps channels. The analytical modeling and optimization process adopted for the proposed network has delivered incremental receiver sensitivities of −41.85/−36.67/−39.04dBm and −33.63/−42.78/−37.92dBm at acceptable BER in the

range of 10^{-14} to 10^{-10} for D/L and U.L channels respectively, supporting 448 splitter configuration at 50.011 km. With FWM efficiency of 1.65e-52 and FWM component power as low as −53 to −54 dB has introduced −31.16 dB/−29.25 dB crosstalk among the channels with 0 dB power penalty in conjunction with CD, SPM, XPM, and FWM LNI for spectrum in either directions.

Section snippets

OW-FSO NG-PON2 access networks

The proposed multichannel OW-NG-PON2 access network in Fig. 1 is implemented using N1-power budget class ODN is a flexible access network accommodating legacy GPON, XGS-PON, and WDM PtP channels supporting symmetric 1.25/2.5/10 Gbps coexistence channels approach [1], [6], [16] to support for the services and applications from different operators, cloud network etc. on the same ODN. The schematic consists of different interfaces like sender network interface (SNI), sender-receiver channel pair…

OW-FSO NG-PON2 OLT transceiver simulation setup

OptiSystem-18 is the latest and updated version of an innovative optical design and analysis simulation software that enables design and analysis of optical communication (OC) systems. Optisystem consists of a component library and sub-libraries of active and passive components and latest test measurement equipment. An array of multi-channel transmitters and receivers are implemented at OLTs transceivers for symmetric channel pair (CP) of PtM and PtP channels respectively as shown in Fig. 2.

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Simulation analysis of parameters of symmetric channels

Simulation results of OW FSO channels are achieved in conjunction with CD, SPM, XPM, and FWM LNI between 20.011 and 50.011 km. As depicted in Fig. 5(a) and (b), multichannel DS-US symmetric channel spectrums launched on L and C- band post coexistence element CEx. Channel spacing Δf = 100 GHz to limit the interchannel crosstalk Cc and power penalty Pc. The end-to-end OW FSO link is tested for 20.011–50.011 km. It is noted that the differential dmax is 5.18 dB and 6.35 dB down and upstream…

Conclusion

An optical wireless (OW) channel configuration is demonstrated addressing last-mile connectivity

of high-speed access networks for next generation FTTX, IoT, and 5 G services and applications. We successfully demonstrated optimization of N1-power budget class ODN to mitigate fiber channel impairments in coexistence approach with symmetric λ1, λ4 and λ5 1.25/2.5/10 Gbps D/S PtM TWDM GPON, PtM TWDM XGS-PON and WDM PtP D/S OW FSO channels up to 50.011 km link distance considering worst-case…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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