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Original research article

Design and analysis of hybrid optical distribution network for worst-case scenario of E2-class symmetric coexistence 80 Gbps TWDM NG-PON2 architecture for FTTX access networks

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Abstract

In this paper, we investigated the cost-effective design and validation of E2-class coexistence 80 Gbps symmetric 8 × 8 Time and Wavelength Division Multiplexing (TWDM) NG-PON2 optical access network considering worst-case scenario for the deployment of Fiber-to-the-X (FTTX) access network using hybrid optical distribution network (ODN). Full-service access network (FASN) unanimously agreed and ITU-T G.989.2 described recommendations for TWDM PON NG-PON2 technology to cater to the need of ever-increasing demand for higher bandwidth and data speed beyond 10 Gbps per user through access networks. Wavelength select (WS) and wavelength-routed (WR) ODN for downstream (D/S) and upstream (U/S) channels symmetric coexistence functionality supporting 80 Gbps accommodating GPON and XGS-PON legacy channels i.e.4-TWDM and 4 point-to-point (PtP) WDM channels operating at 1.25/2.5/10 Gbps respectively in D/S and U/S direction with error free higher splitter configuration of 2304 at 20 km, 640 at 40 km, 576 at 60 km. Precise calculations are done to ensure 11 dBm and 9 dBm ODN launch power (PT_{ODN}) to implement worst-case scenario for symmetric E2-class TWDM NG-PON2 network. Calculated inter-channel cross-talk (Cc) is -33.57 dB/-34.74 dB and corresponding cross-talk power penalty (Pc) is 0 dB for D/s and U/S channels respectively. Simulation results demonstrated and verified with the recommendations

made in ITU-T G.989.2 confirmed that the proposed network configuration supports extended to reach upto 60 km in D/S and 80 km in U/S direction delivering incremental receiver sensitivity (Rxs) as -34.40/-34.40/42.21 dBm and -34.11/-37.25/-33.37 dBm, ODN path loss 29.40 dB.

Introduction

Gigabit access networks are enabled and FTTX services are delivered to subscribers due to impressive advancement in fiber-optic and access network technology. As the broadband services are pushing towards gigabits services in the range of 1–10 Gbps per channel or subscriber, the legacy GPON network capable of supporting 2.5 Gbps in D/S and up to 1.25 Gbps in an upstream (U/S) direction, will be limited due to increasing subscribers and use of single wavelength as a channel to deliver next-generation applications and services on existing access networks for multiple users in a family. Further, when GPON is shared with 32 or 64 users, then it will support less than 39–78 Mbps data rate per user [10]. To support next-generation applications based on 5 G, internet of things (IoT), Machine learning and artificial intelligence (AI) not limited to E-governance of smart cities, healthcare, manufacturing, robotics, educational institutes, universities, agriculture, entertainment and gaming services also known as FTTX services, it is expected that the minimum bandwidth required per user would be 100 Mbps. [[10], [11], [12]]. Netflix itself proposing requirement of 25 Mbps for ultra-high-definition (U-HD) quality videos on single node or channel. Internet service providers (ISP) will have to adopt techno-commercially viable solution proposed by ITU-T G.989 (2014/2015/2019) series and accepted by FSAN i.e. TWDM NG-PON2 multi-wavelength high speed access network, accommodating entire existing legacy access network infrastructure along with high speed multi wavelength network using WDM technology. TWDM NG-PON2 enable high speed access network, meets the future bandwidth requirements of the access network data rate of 10 Gbps and more. Other technological options like Code Division Multiple Access PON (OCDMA-PON), Orthogonal Frequency Division Multiplexed PON (OFDM-PON) we also considered for future access networks. But TWDM-PON is more suitable and widely accepted network architectures by FSAN due to ease in migration and up-gradation from existing GPON/XGS-PON access networks from ISP's and subscriber's point-of-view also. It is expected that the aggregate data rate supported by TWDM-PON should be 40 Gbps by arranging 4 × 10 XGS-PON wavelengths and extendable upto 80 Gbps by arranging 8 × 10 XGS-PON wavelengths in D/S and 2.5 × 4 i.e.10 Gbps or 2.5 × 8 i.e. 20 Gbps in an U/S direction [3]. Other configurations supporting different data rates per channel in TWDM NG-PON2 network are 10/10 Gbps symmetric, 10/2.5 Gbps asymmetric and 2.5/2.5 symmetric. On the basis of data rate supported by NG-PON2, ODN launch power, ODN power loss and receiver sensitivity, ITU-T G.989.2 has defined four classes of NG-PON2 network as N1, N2 E1 and E2 extending upto 20 km and 40 km represented as DD20 and DD40 network. [5,13]. In the proposed paper, we successfully designed, simulated, demonstrated and investigated implementation of hybrid ODN i.e. WS-ODN for D/S channels WR-ODN for U/S channels for E2-class coexistence symmetric 8-channel TWDM NG-PON2 network supporting 1.25/2.5/10 Gbps data rate in D/S and U/S direction accommodating splitter ration 2304 at 20 km and 576 at 60 km with inter-channel crosstalk (Cc) -33.57 dB and -34.74 dB for D/S –U/S channel introducing 0 dB cross talk penalty (Pc) at 2.09 dB maximum differential power difference (dmax) for ONUs at 29.40 dB ODN path loss well within the acceptable range recommended by ITU-T G.989.2 [12]

Section snippets

Schematic of coexistence symmetric E2-class TWDM NG-PON2 FTTX access networks

ITU-T G.989.2 has defined parameters such as launch power per transmitter ($P_{TX\lambda}$), ODN path loss (P_{LODN}) and minimum acceptable receiver sensitivity for different data rates for D/S and U/S channels to ensure the specific class of NG-PON2 networks shown in Table 1 [13]

The proposed E2-classTWDM NG-PON2 carries the flexibility to accommodate legacy GPON, 10GPON, 10EPON, and XGS-PON networks with NG-PON2 network known as the coexistence approach as shown in Fig. 1. This is the reason TWDM is a…

OLT transceiver simulation setup

OptiSystem-16 is OptiSystem is an innovative and powerful design software that enables engineers to define, design, simulate and analyze fiber optical communication systems (FOC). It provides libraries of transmitters, fiber channels, receivers, active and passive optical components such as splitters add-drop multiplexers, fork, amplifiers, test and measurement instruments such is WDM analyzer, BER analyzer, optical and electrical power meters useful for design, test and analysis of FOC. Fig. 2 …

Simulation results and network parameters calculations and analysis

The maximum ODN path loss obtained is 29.40 dB which is much less than the maximum ODN power loss recommended by ITU-T G.989.2 i.e. 35 dB. This enables accommodation of a higher configuration of the splitter to connect more subscribers to NG-PON2 network. Fig. 5(a) and (b) represents L-band and C-band D/S and U/S channels spectrum at the output of WDM mux acting as

CEx. The wavelengths used for D/S transmission are as shown in Table 2 for the proposed 8 × 8 TWDM NG-PON2 network. Channel spacing …

Conclusion

Defining the class of TWDM NGPON2 network is most important step in the design and analysis of NG-PON2 network. We successffully demonstrated design process, simulated symmetric bidirectional coexistence E2 - class 8 × 8 TWDM NG-PON2 for worst-case scenario optical access network for FTTX applications. Further, we analyzed and verified the performance parameters such as ODN launch power which defines specific class of NG-PON2 network i.e. PT_{ODN}, ODN power loss, receiver sensitivities (Rexes) of …

Declaration of Competing Interest

The authors report no declarations of interest.…

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…While, due to the lower receiver sensitivity delivered and less channel transmitter power for 2.5 Gbps PtM XGS-PON D/S channels, the power budget and subsequently splitter budget is affected by more than 5 dB compared to other D/S channel. Fig. 10 describes the relationship between splitter power budget achieved for link distance and Fig. 11 represents variation between of splitter configuration supported by λ1, λ4 and λ5 1.25/2.5/10 Gbps D/S channel respectively between 20.011 and 50.011 km [19]. Table 9 summarizes the key attributes of the proposed simulated network with the expected parameters for NG-PON2 defined by [22]….

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