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A FEASIBLE SOLUTION FOR LONG-REACH NEXT GENERATION PASSIVE OPTICAL NETWORK (LR-NGPON)

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ABSTRACT: To overwhelm the issue of limited range of transmission span in traditional passive optical network (PON), we have proposed and designed a long-reach NGPON system, which supports 40Gbps Differential Quadrature Phase Shift Keying (DQPSK) downstream and 20Gbps Return-to-Zero On-off Keying (RZ-OOK) re-modulated upstream. After investigation of proposed design in simulation for 70 Km long-reach NG-PON, transmission performance has been evaluated through Bit error rate (BER) and received power on the basis of increasing splitter ratio for large number of customers. Simulative Results validate that proposed design is a feasible solution for high data rate transmission and long distance coverage with higher splitting ratio to accommodate large number of customers in Larger Metropolitan Area Networks (MANs).

Key words: Long-reach PON , NG-PON, DQPSK, RZ-OOK, split ratio.

INTRODUCTION

Deployment of high capacity access network is ultimate choice due to challenges of drastic growth of bandwidth and number of customers' day by day. To cope up with these issues many solutions have also been proposed by researches, however Passive Optical Networks (PONs) is considered as a promising candidate due to enormous development optical fiber communication. However, there are few limitations in existing passive optical networks such as power splitters are used to share the bandwidth among customers due to which substantial optical power is dropped at the receiver. This decrease in received power either restricts the number of users or reduces the transmission span (Martínez et al., 2016), which are indispensable elements for the expansion of existing metropolitan area network (MAN) (Gao et al., 2018) and convergence with 5G wireless networks for backhaul support (Du et al., 2018). However, these problems can be effectively resolved by selection of right choice of PON standards, modulation techniques, amplifiers and other important parameters. Therefore, in this section we will discuss evaluation of PON in detail.

Due to point-to-point, high data-rate, low cost, extraordinary services and quality supportive features, passive optical network (PON) is front-runner in next generation access systems. In roadmap of Full Service Access network (FSAN), various standards of PON have been proposed to meet the high data rate demand and termed as next generation passive optical networks NG-PON (Yin et al., 2018). Till now, ITU-T and IEEE have recommended many standards of PON such as APON (i.e. ATM-PON), BPON (i.e. Broadband-PON), EPON (i.e. Ethernet-PON), GPON (i.e. Gigabit-PON), XGPON (i.e. Extended GPON), 10GEPON (i.e. 10 Gigabit Extended GPON), NG-PON 1 (i.e. Next Generation-PON 1) and the recent NG-PON 2 (i.e. Next Generation-PON 2) have been introduced (Abbas et al. 2016). Similarly, Comparative analysis of PON standards on the basis of data rate in upstream as well as downstream is depicted in Figure 1.

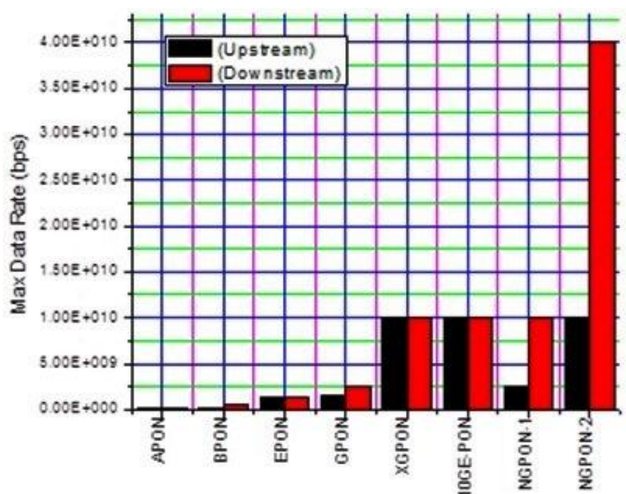

Figure 1: Comparison of various PON architectures on the basis of Max Data Rate Support

Mostly these PONs are based on Advanced modulation formats such as RZ-DQPSK with On-Off keying (OOK) (Khan et al., 2019), DQPSK with IRZ, RZ-DQPSK with DCF (Memon et al., 2017), Carrier suppressed RZ CSRZ-QDPSK (Naqshbandi and Jha, 2016), three different techniques of DPSK, WDM PON with SOA amplifier and recently proposed 40Gbps DQPSK based NGPON2 techniques (Parajuli and

Udvary, 2018). Although high data rates and large number of users can be supported in latest versions of PON but due to limited transmission span these are not feasible for deployment in long distance access network. Therefore, researchers have also introduced long-reach PON to cope up the demands of upcoming metropolitan area networks (MAN) such as Optical OFDM for Downstream Transmission in Long-Reach PON (Pandey and Goel, 2017) long-reach OFDMA PON technique is distance adaptive centered OFDM-PON Downstream Transmission using m-QAM-Mapped OFDM Signal long-reach PON system established on directly modulated transmitters and simple polarization independent coherent receiver (MD 2013) Experimental Demonstration of Redundant Long-Reach PON, Long-Reach Wavelength-Routed TWDM PON and Long-Reach PON Based on SSB Modulated Frequency-Shifted QAM. However, effectiveness of these long-reach PON techniques are also compromised due to comparatively complex design, low data rate transmission or low split ratio to facilitate higher number of customers.

In this research work, we have proposed and design long-reach NG-PON system which is feasible for 70 Km transmission range. We employed 40 Gbps DQPSK downstream and 20 Gbps OOK upstream data rates supporting higher split ratio. To cope up the transmission impairment FBG is used and EDFA amplifier are used in both directions. Simulation results also verify that high data rate transmission for minimum 64 customers can be achieved successfully with satisfactory transmission performance which to cope up the challenge of next generation PON deployment in Large Metropolitan Area Network (MAN).

MATERIALS AND METHODS

Proposed architecture is shown in the Figure 2, In downstream transmission 40 Gbps differentially precoded pseudo random generator (PRBS) generated signal is modulated by using Mach-Zehnder modulator MZM-1 and MZM-2 with optical carrier generated from 193.1 THz frequency Laser with 1mW (0 dBm) power.

The output produced from modulators is 40 Gbps DQPSK signal which has two bits per symbol. In fact, DQPSK is most popular technique for high data rate, multi-level transmission and due to its constant envelope DQPSK performs considerable enhanced against polarization mode dispersion (PMD) and nonlinear properties. In order to extend traditional PON into long-reach PON the signal is transmitted over 70 km fiber. Due to attenuation losses and chromatic dispersion in fiber the signal is deteriorated therefore to restore the signal in normal condition Erbium doped Fiber Amplifier (EDFA) is employed to amplify the signal then Ideal Dispersion Compensation Fiber Bragg Grating (FBG) is used to control dispersion and reflection of transmitted signal. Dispersion causes the deterioration of transmission performance of optical fiber, due to these different forms of dispersion, compensators are used to improve the transmission power in optical fiber. Subsequently FBG is employed for dispersion compensation due to its low insertion loss and cost. To increase the number of customer high ratio splitter is used and we have chosen up to 1:64. At the Optical network unit (ONU), the received DQPSK signal is processed through two balanced detectors and two Mach-Zehnder delay interferometers (MZDI) via coherency realization through $\pi/4$ and $-\pi/4$ phase shift with a delay T.

For upstream transmission at ONU, received signal from downstream is used as a carrier to re-modulate with RZ-OOK via MZM-3 having 20 Gbps data rate. This signal is transmitted in the direction of OLT receiver through optical fiber span of 70Km. As already discussed at this large length attenuation and dispersion effects optical signal and similarly EDFA and ideal dispersion FBG are used to restore signal at its normal state. Then upstream OOK signal received at OLT is recovered through PIN photodiode. Finally, transmission performance of downstream and upstream are analyzed with the help of BER analyzers.

Simulation Setup: Optisys 7.0 software is used in simulation design and the snapshot of simulation of planned design of PON is shown in Figure 3 and all associated specifics such as frequency, channel spacing, launched power, data rate and specification of single mode fiber (SMF) are described in the Table-1.

As per simulation setup 40Gbps DQPSK modulated downstream signal is generated with the help of two Mach Zehnder modulators (MZM) and pre-coded data. Then the signal of 15 db gain is transmitted over 70 Km fiber. To overwhelmed transmission losses and fiber nonlinearity special effects Fiber Bragg Grating (FBG) is placed to mitigate the the effect of dispersion in both directions. At ONU, power splitter is used to separate the signal in two portions: one received at receiver and other is used as carrier signal for upstream transmission of data. Furthermore, to recover data from DQPSK signal, Mech-Zehnder Delay interferometer (MZDI) and balanced detector are used. This system is active at receiver in two times, first is In-phase (I) and the other is for Quadrature-phase(Q) of DQPSK signal. The received signal will be analyzed through Bit-error-rate analyzer to confirm effective transmission of data. From customer side, 20 Gbps data is re-modulated through MZM and transmitted towards OLT though 70 Km fiber with EDFA and FBG. A single photo detector is used to detect OOK signal at OLT as shown in Figure 3.

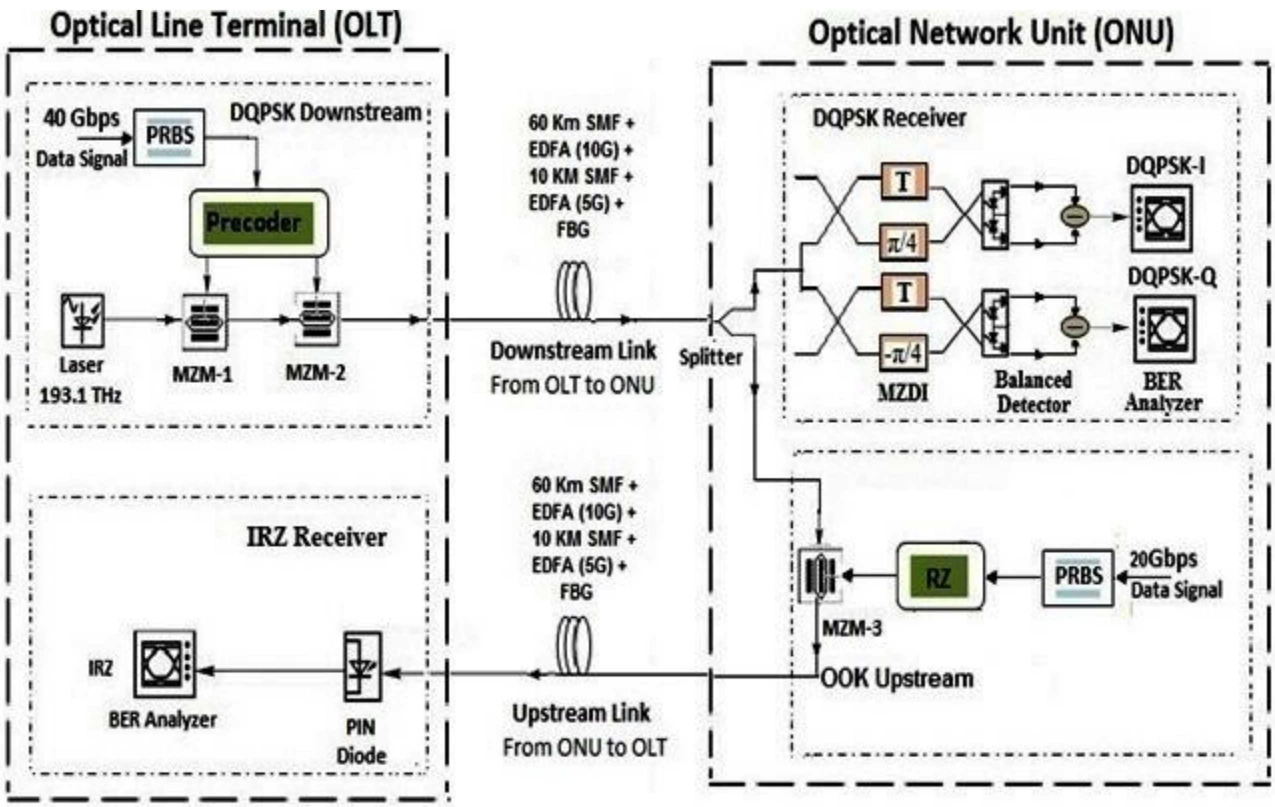

Figure 2: Architecture of proposed High Data-Rate Long reach NG-PON.

RESULTS AND DISCUSSION

In the Figure 4 and Figure 5, it can be observed that eyes diagrams of DQPSK downstream and RZ-OOK upstream are widespread and clear which specifies that both have good transmission performance in proposed long-reach NGPON. Moreover, smooth constellation Diagram of DQPSK downstream ensures good transmission as shown in Figure 6.

Table 1: Simulation Deign Parameters.

Parameters	Values
Laser Launched Power	0 dB
Laser transmitted Frequency	193.1 THz
Length of Fiber Span	70 (60+10) Km
Coefficient of Attenuation	0.2 dB.Km^{-1}
Dispersion Slop	0.075 ps.nm^{-2}(Km)
Coefficient of Nonlinear Index	2.6x10^{-20}
Dispersion effect	16.75 ps.nm$^{-1.(}$Km)
Effective Area of fiber core	80 um^{2}

Analysis of Received Power vs Split Ratio of DQPSK Downstream and OOK upstream in proposed LR NGPON are described in Figure 7 and Figure 8 correspondingly. Here, it can be noticed that numbers of customer can be increased through increasing split ratio but subsequently the received power is also dropped. Downstream DQPSK has still enough power margin with its receiver sensitivity (around -37 dBm) therefore it can be further split to support upto 1000 customers. However, OOK in upstream can work up to 64 split ratio as it has low receiver sensitivity (around 22 dBm) as compared to DQPSK.

Similarly, analysis of bit error rate (BER) vs Split Ratio of DQPSK Downstream and OOK upstream in proposed LR NGPON are described in Figure 9 and Figure 10 respectively. Now, again it can be observed that increasing split ratio causes in ceasing BER value. In continuation of DQPSK analysis with respect to received power, Downstream DQPSK signal can support up to 1000 customers at low BER value. However, OOK in upstream can support up to 64 customers at low BER value as compared to DQPSK modulated downstream.

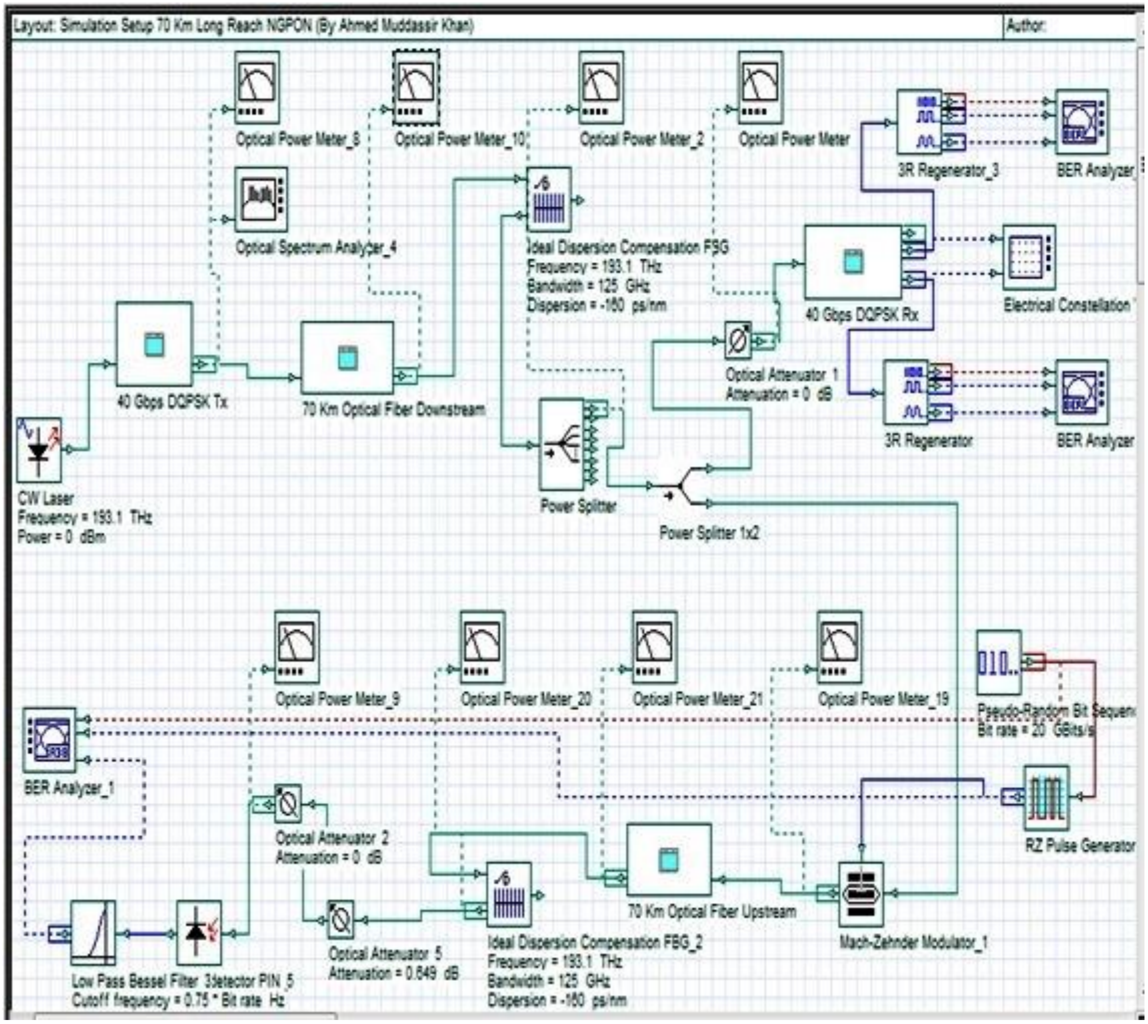

Figure 3: Simulation Setup of Long-reach NG-PON Proposed Design.

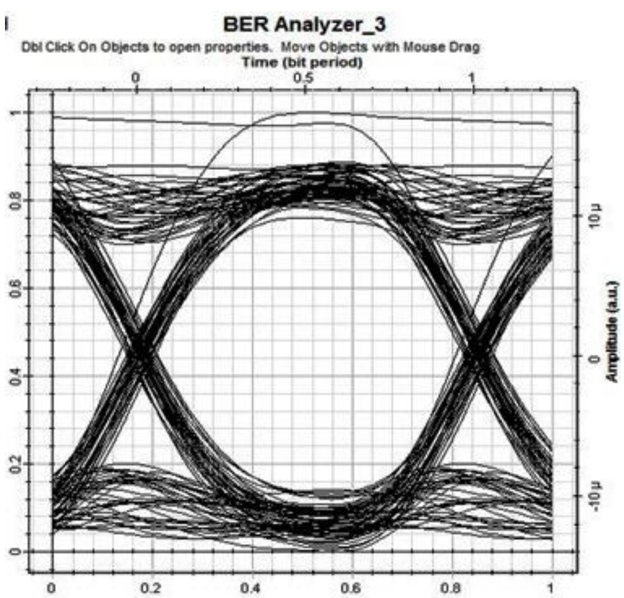

Figure 4: Eye diagram for DQPSK Downstream in proposed Long-reach NGPON.

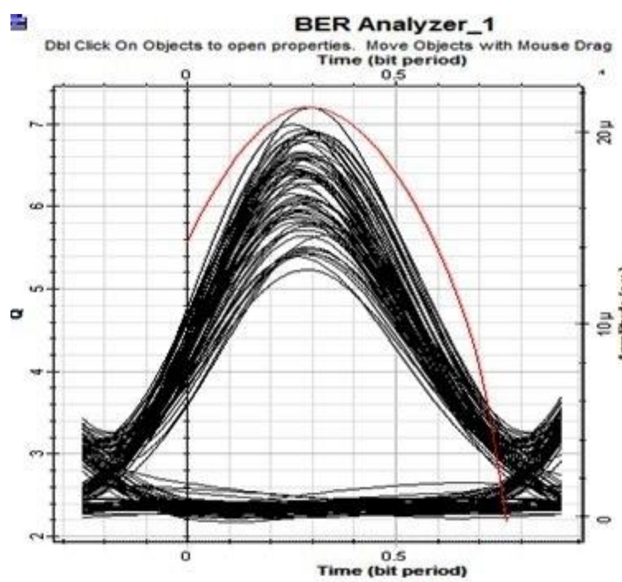

Figure 5: Eye diagram for OOK Upstream in proposed Long-reachNGPON.

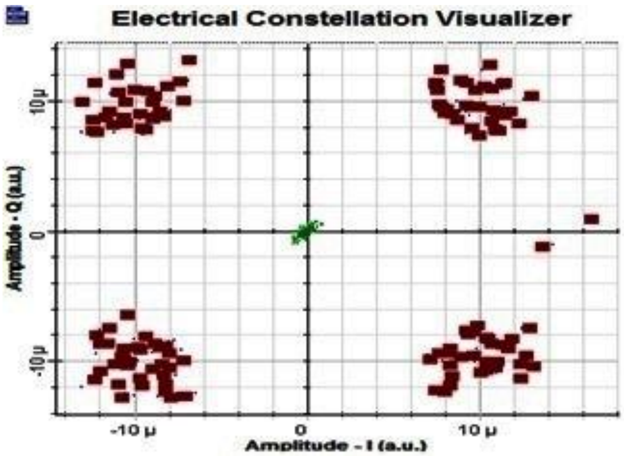

Figure 6: Constellation Diagram of DQPSK downstream in proposed.

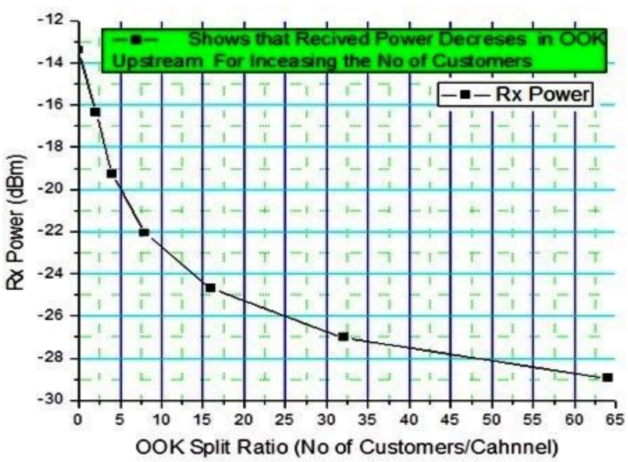

Figure 7: Analysis of Received Power vs Split Ratio of DQPSK Downstream in proposed LR NGPON.

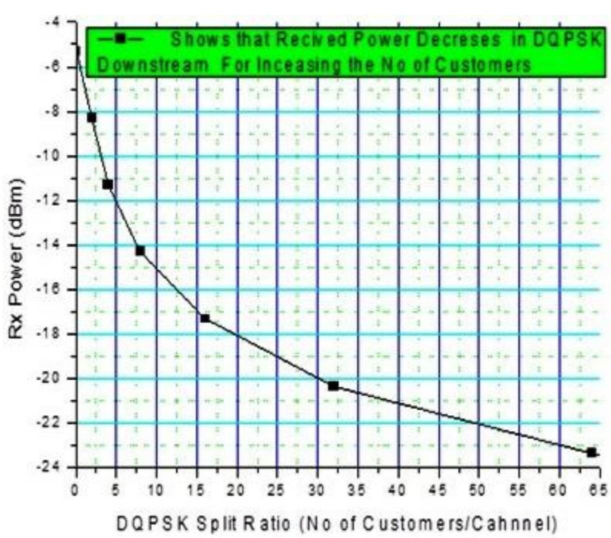

Figure 8: Analysis of Received Power vs Split Ratio of OOK Upstream in proposed LR NGPON.

Figure 9: Analysis of Bit error rate vs Split Ratio of DQPSK Downstream in proposed LR NGPON.

Figure 10: Analysis of Bit error rate vs Split Ratio of OOK Upstream in proposed LR NGPON.

Conclusion: We proposed and design 40 Gbps DQPSK downstream and 20 Gbps OOK upstream based NG-PON and which supports 1:64 and higher split ratio. Furthermore, in this long-reach NG-PON, transmission range is extended up to 70 Km with the help of EDFA. Ideal dispersion FBG is also used to control dispersion in transmission in both directions. Simulation results also validate that successful transmission of high data rate for 70 Km for can support minimum 64 customers with acceptable receiver sensitivity. Hence, proposed long-reach NG-PON provides a feasible solution for the demands of high bandwidth, extended reach and large number of customers in future metropolitan area networks (MANs).

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