

Entirely Passive Remote Node Design And System Architecture For Bus Topology Based 80Gbps Symmetrical NG-PON2

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Abstract

The next generation passive optical network stage 2 (NG-PON2) is a broadcast network in which a large number of optical network units (ONUs) can be served using various network topologies. In this paper, a purely passive remote node (RN) design based on fiber bragg grating (FBG) is presented for the bus topology of a high split NG-PON2 system. The performance of the proposed node has been analysed for a symmetric 80 Gbps NG-PON2 system serving 1024 ONUs in terms of bit error rate (BER) and optical signal to noise ratio (OSNR). The working of the proposed node has been explained with the optical frequency spectrums for downstream and upstream signals. The observed OSNR levels for the ONUs operating at the 1st RN is 84.8743dB which decreases to 75.7973dB for the ONUs connected to the 8th RN. The BER level $< 10^{-9}$ for both upstream and downstream confirms the correct working of the proposed node in the NG-PON2 system.

I. Introduction

A passive optical network (PON) is a fiber to the home (FTTH) point to a multipoint network that provides high data rate service to end-users [1], [2]. The optical distribution network (ODN) in the PON consists of passive components like optical power splitters, optical fiber, couplers, etc.[3]. According to the ITU-T standards, NG-PON2 technology should outperform existing PON technologies in ODN compatibility, bandwidth, capacity, and cost-efficiency [4]. As per the G.989.2 recommendation of ITU-T, time and wavelength division multiplexing PON (TWDM-PON) is the best hybrid multiplexed technique for NG-PON2. TWDM utilizes the bandwidth of optical fiber efficiently. The NG-PON2 is a broadcast network, and a large number of ONUs can be served using various network topologies. These topologies are the arrangement or mapping of the links, nodes, etc. of a network. The operational and maintenance cost depends on the network topology, so for every requirements there exists a most suitable topology [5].

J. Prat et. al proposed an architecture and node design for the hybrid operation of the ring-tree wavelength division multiplexing/time division multiplexing passive optical network (WDM-TDM-PON). In their work, they used optical add-drop multiplexers (OADMs) for dropping the downstream wavelength and adding the upstream wavelengths. They utilized WDM for the ring implementation and TDM in the star topology [6]. P. Lafata et. al proposed the use of a secondary optical line terminal (OLT) in a dual fiber ring topology system. Although the proposed ring-based architecture protects in case of fiber cut or equipment malfunction. However, the cost involved in keeping and additional OLT and dual fiber is quite high [7].

B. Chen et. al. also proposed a similar approach of using ring topology. Their method was based on single fiber ring topology which reduces the cost as compared to dual fiber ring. However, they used active components in the remote node for the switching function which is undesirable [8]. Rafael Sánchez et. al compared Gigabit passive optical network (GPON), 10G-PON (XG-PON), WDM-PON, and TWDM-PON for provisioning 1 Gbps symmetrical data rate service to the end-users. They found that for a green mile solution provisioning up to 5000 users, all these technologies are capable. However, as the number of

users and their activity increases, only TWDM based optical system is capable enough for guaranteed 1Gbps symmetrical access [9].

L. Pavel et. al used the dual OLT scheme to provide services to the ONU from both directions (Clockwise direction and Anti-clockwise direction) for bus and ring topology. With this approach the ONUs can easily be switched between OLTs by adapting the transmission direction in case of fiber failure. The data rates considered in this work were conforming to GPON norms. They used dual fiber in their system for link protection. But there is a limitation, both OLTs transmit data at the same time for both directions. Because of that the signals coming from OLT1 interfere with signals coming from OLT2 and vice versa [10]. S. M. Idrus et. al experimentally investigated the 25Gbps NG-PON system's performance for a 25 km reach by employing a differential phase-shift keying (DPSK) signal at downstream transmission and its conversion to optical duobinary modulation format at the ONU receiver. The receiver sensitivity of -29 dBm was observed for BER less than 10^{-5} with a 1:64 split ratio [11].

A low-cost 40 Gbps TWDM PON was investigated by Bart Moeneclaey et. al using electrical duobinary modulation (EDM) format at the downstream transmission. They achieved a power budget of 23.6 dB with forward error correction (FEC) and BER level of 10^{-3} with a 20 km system reach [12]. Many researchers have analysed the performance of PON for various network topologies. Sanjeev Dewra et.al have investigated the performance of the system by deploying different optical network topologies in the presence of a hybrid optical amplifier. They reported that bus topology supports 18 nodes for a minimum signal input power of -20 dBm, ring topology supports 30 nodes for -30 dBm input power at 10 Gbps data rate with 30 km reach between successive nodes in the presence of hybrid amplifier. However, they found in hybrid topology that the number of nodes supported for bus topology is 6 and for the ring, it is 10 at -20 dBm signal input power [13].

Chung-Yi Li et. al proposed a novel tree-based add/drop multiplexer (TOADM) for TWDM NG-PON2. They used two four-port optical circulators (OCs), one three-port OC, and two FBGs passive components to place at any selected location along with transmission fiber to multiplex and de-multiplex optical wavelengths. Through experimental results, they observed that the insertion loss of the proposed device is less than a 1×2 optical splitter in downstream and upstream directions [14]. From the literature review, it is observed that the selection of network topology plays an important role in the broadcast access network. Also, the previous works are limited to low data rate and fewer users. NG-PON2 network can extend the network capacity to 40 Gbps or 80 Gbps by employing multiple optical carriers and the TWDM concept [15].

In our previous work, we have analysed the feasibility of symmetric 80Gbps NG-PON architecture. The analysed TWDM based architecture was based on the star topology where 64 ONUs were connected to OLT for symmetrical data rates. From the results, it has been observed that the presented system works well up to 65 km system length [16]. In our other previous work, the performance of star topology based NG-PON2 high split for 80 Gbps data rate with duobinary modulation format and with avalanche photodiode (APD) receiver was achieved [17]. In this paper, we are proposing the bus topology-based

architecture for 80Gbps NG-PON2 with 1024 users. To make ODN entirely passive, an RN is designed based on FBG which reflects a portion of the wavelength band out of the incoming signal and it does not affect other wavelengths. In the proposed RN the FBG is used to separate upstream wavelengths from the downstream wavelengths to avoid crosstalk. The paper is organised into four sections. The introduction and related literature are presented in the first section. The simulation architecture of the bus topology-based NG-PON2 system with the proposed node design is described in section two. The obtained results are discussed in section three. In the section four the conclusions from the result are made and at the end of the paper cited references are listed.

ii. Simulation Architecture Of 80gbps Ng-pon2 With Bus Topology

In the present work, the proposed RN design and the 80 Gbps symmetrical NG-PON2 network provisioning 1024 ONUs is simulated in the Optisystem v.13 software. The simulation setup is shown in figure 1. The wavelength assignment scheme is used as per the ITU-T recommendations for NG-PON2 [5]. Eight wavelengths starting from 1596 nm with 0.8 nm channel spacing are multiplexed at the central office (CO) for downstream. For the downstream signals labels from λ_1 to λ_8 are used. The λ_1 is 1596 nm and the downstream wavelength assigned to the n^{th} RN can be calculated by the following equation.

$$\lambda_n = \lambda_1 + (n-1) \times 0.8 \text{ nm} \quad \dots\dots(1)$$

Each wavelength carries a 10 Gbps data rate that makes the system capable of 80 Gbps data rate service. The multiplexed data is transmitted over single-mode fiber (SMF). PON is a point to the multipoint network so the data is broadcast using a bus topology near the user premises. In this topology, all ONUs are connected to a common transmission fiber. The data to the dedicated groups of ONUs is transmitted in the network as per the assigned wavelengths. In this way, the data transmission between every ONU and OLT takes place over the same primary fiber. For upstream transmission, eight wavelengths (λ_9 - λ_{16}) starting from 1524 nm to 1529.6 nm with 0.8 nm channel spacing are used in the system. The first upstream wavelength λ_9 of 1524 nm is assigned for upstream from the ONUs of RN1. The dedicated upstream wavelength for the ONUs operating at the n^{th} RN can be calculated by the following generalized equation.

$$\lambda_{n+8} = \lambda_9 + (n-1) \times 0.8 \text{ nm} \quad \dots\dots(2)$$

In the bus topology, RNs connect the clusters of ONUs with the OLT. The RN should be designed in such a way that it should allow simultaneous flow of downstream data to all ONUs and flow of upstream data from the node under consideration and all other nodes can pass through it towards OLT.

Each upstream wavelength carries a 10 Gbps data rate similar to the downstream. Each ONU can transmit its upstream data as per the assigned time slot, for this TWDM scheme is used. Equal time slots are allocated to each ONU. Since the NG-PON supports TWDM, The ONU connected to a common RN

transmit their upstream data on a common upstream wavelength but in different time slots. Figure 2 shows how the upstream is assigned to a cluster of ONUs with the dedicated time slots. The dynamic Y switch 1 and dynamic Y switch 2 marks the start time and end time to the assigned slot dedicated to 1st ONU. A parameter named “Timeslot” is defined to allow the static time slot to each ONU. Considering the complexity of the simulation, the “Timeslot” parameter values from 0 to 7 are assigned to eight ONUs of every RN. “Timeslot” value is 0 for the first ONU; it is 1 for the second ONU, and so on it is 7 for the 8th ONU, other ONUs are assumed to be in off state. The following equations mark the start time and end time of the slot allocated to any ONU.

$$Start\ time = Time\ Slot \times \left(\frac{1}{Bit\ rate} \right) \times \frac{Sequence\ length}{8}$$

.....(3)

$$End\ time = Time\ Slot \times \left(\frac{1}{Bit\ rate} \right) \times \frac{Sequence\ length}{8} + \frac{Time\ window}{8} \quad \text{.....(4)}$$

For the simulations, the “Bit rate” of 10 Gbps, the sequence length of 256 bits, and a time window of 56.6×10^{-9} seconds is set. The combined data frame is obtained after combining the power from every input to the power combiner.

Then passive power combiner combines the upstream data coming from each group of ONUs. The combined data is transmitted towards OLT through AWG over the same SMF that was carrying the downstream traffic. At the OLT receiver, all upstream wavelengths are de-multiplexed and received. The correct reception at Rx1 confirms the successful reception of upstream data at OLT sent by ONUs connected to RN1. Similarly, the Rx8 receives the upstream of all ONUs sharing upstream wavelength dedicated to RN8. For the amplification of downstream signals, a Raman pump of 1535 nm is also sent from the OLT to compensate for the loss. The simulation parameters are listed in table 1.

Table1: Simulation Parameters for Symmetric 80 Gbps TWDM PON

NAME	VALUE
SMF1	20 km
SMF2- SMF8	1 km
Total Bit rate (Upstream/Downstream)	80 Gbps
Split per wavelength	128
Total Number of ONUs	1024
Number of wavelengths (Downstream)	8 (1524-1529.6) nm
Number of wavelengths (Upstream)	8 (1596-1601.6) nm
Channel spacing (Upstream/Downstream)	0.8 nm

iii. Rn Design Using Fbg For 80gbps Twdm Based Ng-pon2 With Bus Topology

In this work, RN design has been proposed for high split NG-PON2 downstream transmission using bus topology which also supports multi-wavelength upstream. We have deployed eight wavelengths for downstream transmission in this work, so a fixed downstream wavelength is allocated to each RN. The structure of n^{th} generalized RN_n is presented in figure 3 to explain how downstream and upstream wavelengths pass through the node, here n is the node number which is 1 to 8 in this case. The downstream wavelengths from λ_n to λ_8 enter the n^{th} RN from the left port. The λ_n is dropped with the FBG tuned to reflect λ_n out of these wavelengths. The downstream data stream is provided to every ONU connected with n^{th} RN with the reflected wavelength λ_n . The remaining downstream wavelengths from λ_{n+1} to λ_8 pass through the FBG and are routed to the RN_{n+1} . Similarly, the upstream data of all ONUs connected to n^{th} RN is generated at wavelength. The upstream wavelength λ_{n+8} of n^{th} RN gets coupled with λ_{n+9} to λ_{16} upstream wavelengths which are coming from RN_{n+1} . All these wavelengths from λ_{n+8} to λ_{16} are propagated towards the RN_{n-1} . The RN_{n-1} will further add its allocated upstream wavelength, and an upstream path is established between every ONU and OLT. In this way, the proposed RN can connect downstream and upstream transmission link between the ONUs and OLT. The proposed RN design is used in the simulation architecture shown in figure 1. To verify the operation of the proposed RN, the optical spectrum diagrams have been obtained.

The obtained spectrum of all transmitted downstream signals from the OLT is shown in figure 4. It can be seen from the spectrum that eight downstream wavelengths starting from 1596 nm with a channel spacing of 0.8 nm have the same optical power. This signal propagates through the optical fiber and

reaches RN1, the FBG in the first RN is tuned to reflect 1596 nm downstream wavelength. The reflected $\lambda_1 = 1596$ nm signal is received by the cluster of ONUs operating on the RN1.

The observed spectrum of the received wavelength at the ONU connected to RN1 is shown in figure 5. The peak of the 1596 nm signal justifies the reception of the correct assigned wavelength. Although the other downstream signals are also present in the reflected spectrum. But their power is relatively lower than the 1596 nm.

After reflection of λ_1 at RN1, the remaining downstream wavelengths get transmitted to RN2. The second RN is accepting the unreflected part of the signal crossed through RN1. The spectrum of signal reached RN2 is shown in figure 6. From the spectrum, it can be observed that the signal level of 1596 nm allocated to RN1 is much attenuated as compared to other signal wavelengths and λ_2 - λ_8 wavelengths are received in RN2. It can be concluded from figure 4, figure 5 and figure 6 that the wavelength assigned to the particular RN is being correctly received at the ONUs and the remaining wavelengths are passed on to the subsequent RNs.

To further explain the working of the proposed design we have chosen to show the optical spectrum for first, fifth and eighth RN. The spectrum reaching the RN5 is shown in figure 7, it is evident that the first four RNs have dropped their assigned wavelengths and the wavelengths assigned to the RN5-RN8 are still available. The fifth RN is tuned to drop λ_5 wavelength of 1599.2 nm. The operation of the RN5 is similar to the operation of RN1 which is explained above. The received downstream spectrum at the ONU connected to RN5 is shown in figure 8.

After the reflection of 1599.2 nm at RN5, the spectrum should contain the remaining downstream wavelengths assigned to RN6, RN7 and RN8 which are 1600 nm, 1600.8 nm and 1601.6 nm. The spectrum at the output of RN5 is shown in figure 9. It can be seen that the wavelengths assigned to the first 5 nodes are much attenuated, and wavelengths assigned to RN6, RN7 and RN8 are still having higher power. This way a downstream wavelength is dropped at each RN and connectivity of all the eight RNs to the OLT is established. The signal received at the ONU connected to the eighth RN is shown in figure 10.

Eight upstream wavelengths starting from 1524 nm with 0.8 nm channel spacing have been assigned to eight sets of ONUs connected to eighth RNs. The upstream wavelengths are chosen as per the dedicated wavelength plan by ITU-T for NGPON-2 [5]. Since the notation of $\lambda_1 - \lambda_8$ is used for downstream signals, the names $\lambda_9 - \lambda_{16}$ are given to the upstream wavelengths. During upstream each cluster of ONU connected to an RN generates an upstream signal at the wavelength allocated to that RN. The RN_{n+1} send the upstream signal containing $\lambda_{n+9} - \lambda_{16}$ to the RN_n node. The RN_n adds its upstream wavelength λ_{n+8} generated by the ONUs connected to it. And thus the RN_n sends the $\lambda_{n+8} - \lambda_{16}$ upstream wavelengths towards RN_{n-1} . This way the OLT receives all the upstream wavelengths from $\lambda_9 - \lambda_{16}$. The upstream spectrum diagrams of signals received by the RN5 from RN6 and the upstream signal transmitted by RN5 to RN4 are shown in figure 11 and figure 12. Similarly, the Upstream spectrum containing data of ONUs of

all RNs is shown in figure 13. This signal is demultiplexed at the OLT and the BER has been evaluated. There are some four wave mixing signals which can be seen in figure 13. However, their power level is very small, so they do not have any effect on the system performance.

IV. Result And Discussion

The performance of a system has been analysed by observing the BER and OSNR for each RN. As the RN1 is closest to the OLT, it is expected that the performance will degrade as we will move from RN1 towards RN8 to the OLT. For this, it is necessary to assess the entire system's performance (for all RNs). The observed BER for all the RNs is plotted in figure 14.

The graph shows that the RN1 which operates at 1596 nm wavelength performs best and the BER increases for the subsequent RNs as we move away from OLT. The BER below 10^{-9} level for all the wavelengths is suggesting that the BER for downstream at all the 1024 ONUs is under acceptable limits. The received power at the RN1 is -22 dB and the power decreases as the distance of RN increases from OLT. The received power at the 8th RN decreases to -28 dB. This is the reason why the BER comes better for the 1st RN and the BER increases for every next RN.

The eye diagrams are also considered in this analysis, the eye diagrams for the ONUs connected to various RNs are shown in figure 15. From the eye diagrams, it can be observed that the eye degradation is there if we move from RN1 towards RN8.

The degradation of the signal quality at the ONUs connected to all the RNs has been measured in form of OSNR of the signal received. The variation of OSNR for the ONUs connected to various RNs is shown in figure 16. The OSNR decreases as the distance between OLT and RN increases. The OSNR at the RN1 is highest and as the signal propagates through various RNs and fibers the OSNR decreases. The increase in BER which is shown in figure 14 is the result of this OSNR decrease as we move towards the farthest RNs. The OSNR level of 84.8743dB was observed at the ONU connected to the RN1, it decreases to 75.7973dB at the ONU connected to RN8.

The system performance is also investigated for the upstream transmission. The wavelengths are according to the NG-PON2 specifications. The wavelength range used for upstream is from 1524 nm to 1529.6 nm with 0.8 nm channel spacing. TWDM technique is used in upstream transmission. As each group of ONUs are sharing the same wavelength, each ONU transmits their data using the TDM technique.

As it can be seen from figure 13 the power of the upstream signal wavelength $\lambda_0 = 1524$ nm is highest as it is nearest to the OLT, and the upstream wavelengths of other RNs are crossing fiber segments and nodes therefore a power reduction is there. The effect of the decrease of the power of the upstream signal coming from farthest ONUs can be seen from figure 20 which is showing the BER observed at the OLT. The 1524 nm upstream wavelength (from RN1) is providing a $BER < 10^{-35}$. Whereas, the BER increases as

the distance of RN from OLT increases. The BER of the upstream signal λ_{16} (1529.6 nm) sent by RN8 is barely acceptable with BER of the order of 10^{-9} . This problem for high BER in case of farthest RNs can be eliminated by using the higher upstream power of the ONUs or by providing amplification to the upstream signals.

V. Conclusion

In this paper, an RN design based on FBG has been proposed for the bus topology of the NG-PON2 system. The performance of NG-PON2 is investigated with the proposed RN design. The BER for downstream transmission is observed below 10^{-9} level for all RNs. It suggests that the BER values for all 1024 ONUs operating in the system are under acceptable limits. A -22 dB power is received at the ONUs working on RN1 and it is observed that the signal power decreases as the distance between RN from OLT increases. The received power at the ONUs of 8th RN decreases to -28 dB. The variation of OSNR for the ONUs connected to every RNs is also obtained. The OSNR decreases as the distance between OLT and RN increases. The observed OSNR levels for the ONUs operating at the 1st RN is 84.8743 dB which decreases to 75.7973 dB for the ONUs connected to the 8th RN. The BER for all the upstream wavelengths is found acceptable (below 10^{-9} level). For the upstream from the first RN, BER observed is $<10^{-35}$. The BER for upstream increases as the distance of RN from the OLT increases. The BER of the upstream signal λ_{16} sent by RN8 is barely acceptable with a BER value of the order of 10^{-9} . The acceptable BER ($<10^{-9}$) for both upstream and downstream validates the correct operation of the proposed remote node in 80 Gbps symmetrical NG-PON2.

Declarations

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References

- [1] A. Usman, N. Zulkifli, M. R. Salim, K. Khairi, and A. I. Azmi, "Optical link monitoring in fibre-to-the-x passive optical network (FTTx PON): A comprehensive survey," *Opt. Switch. Netw.*, vol. 39, p. 100596, 2020.
- [2] A. Usman, N. Zulkifli, M. R. Salim, K. Khairi, and A. I. Azmi, "Optical link monitoring in fibre-to-the-x passive optical network (FTTx PON): A comprehensive survey," *Opt. Switch. Netw.*, vol. 39, p. 100596, 2020.

- [3] D. Nasset, "PON Roadmap [Invited]," *J. Opt. Commun. Netw.*, vol. 9, no. 1, pp. 71–76, 2017.
- [4] R. Kaur and S. Singh, "Polarization multiplexing and hybrid modulation based bandwidth efficient NG-PON2 coexisting GPON and XG-PON," *J. Opt. Technol.*, vol. 88, no. 4, pp. 196–201, 2021.
- [5] ITU-T, "40-Gigabit-capable passive optical networks 2 (NG-PON2): Physical media dependent (PMD) layer specification," *ITU-T Recomm. G.989.2*, vol. 2, 2014.
- [6] J. Prat, J. Lazaro, P. Chanclou, and S. Cascelli, "Passive OADM Network Element for Hybrid Ring-Tree WDM / TDM-PON," in *35th European Conference on Optical Communication, Vienna, Austria*, pp. 23–24, 20–24 September, 2009.
- [7] P. Lafata and J. Vodrazka, "Simulation of ring-based passive optical network and its experimental verification," *Elektron. ir Elektrotehnika*, vol. 19, no. 5, pp. 93–98, 2013.
- [8] B. Chen and C. Gan, "Novel architecture of WDM-PON based on single-fiber ring topology featuring protection and dynamic wavelength assignment," *Opt. Int. J. Light Electron Opt.*, vol. 124, no. 3, pp. 234–237, 2013.
- [9] R. Sánchez, J. A. Hernández, J. M. Garcíá, and D. Larrabeiti, "Provisioning 1 Gb/s symmetrical services with next-generation passive optical network technologies," *IEEE Commun. Mag.*, vol. 54, no. 2, pp. 72–77, 2016.
- [10] L. Pavel, "Novel protection strategies for passive optical networks based on ring and bus topologies," *Trans. Emerg. Telecommun. Technol.*, vol. 26, no. 9, pp. 1131–1153, Sep. 2015.
- [11] S. M. Idrus, S. U. Rehman, N. Zulkifli, F. Iqbal, and A. Kanno, "Demonstration of Receiver Generated Optical Duobinary and VSB-NRZ for Next-Generation PON," *IEEE 7th Int. Conf. Photonics (ICP), Kuah, Malaysia*, pp. 1–3, 9–11 April, 2018.
- [12] B. Moeneclaey *et al.*, "40-Gb/s TDM-PON Downstream Link With Low-Cost EML Transmitter and APD-Based Electrical Duobinary Receiver," *J. Light. Technol.*, vol. 35, no. 4, pp. 1083–1089, 2017.
- [13] S. Dewra and R. S. Kaler, "Performance analysis of optical network topologies in the presence of hybrid optical amplifier," *Optoelectron. Adv. Mater. Rapid Commun.*, vol. 11, no. 1–2, pp. 54–58, 2017.
- [14] C. Y. Li, C. H. Chang, Z. G. Lin, and Z. Y. Cheng, "Optical add/drop multiplexer for tree-based passive optical networks," *Opt. Fiber Technol.*, vol. 54, pp. 102121 (1–4), Jan. 2020.
- [15] ITU-T, "40-Gigabit-capable passive optical networks (NG-PON2): Transmission convergence layer specification," *ITU-T Recomm. G989.3*, vol. 3, 2016.
- [16] R. Kaur and S. Singh, "A Time and Wavelength Division Multiplexing based Next Generation Passive Optical Networks Provisioning 80Gbps Symmetrical Access Rate," in *International Conference on Recent*

[17] R. Kaur, S. Singh, and M. L. Singh, "Power budget calculations of high-speed twdm based next-generation passive optical network for different data types," *Optoelectron. Adv. Mater. Rapid Commun.*, vol. 15, no. 1–2, pp. 39–48, 2021.

Figures

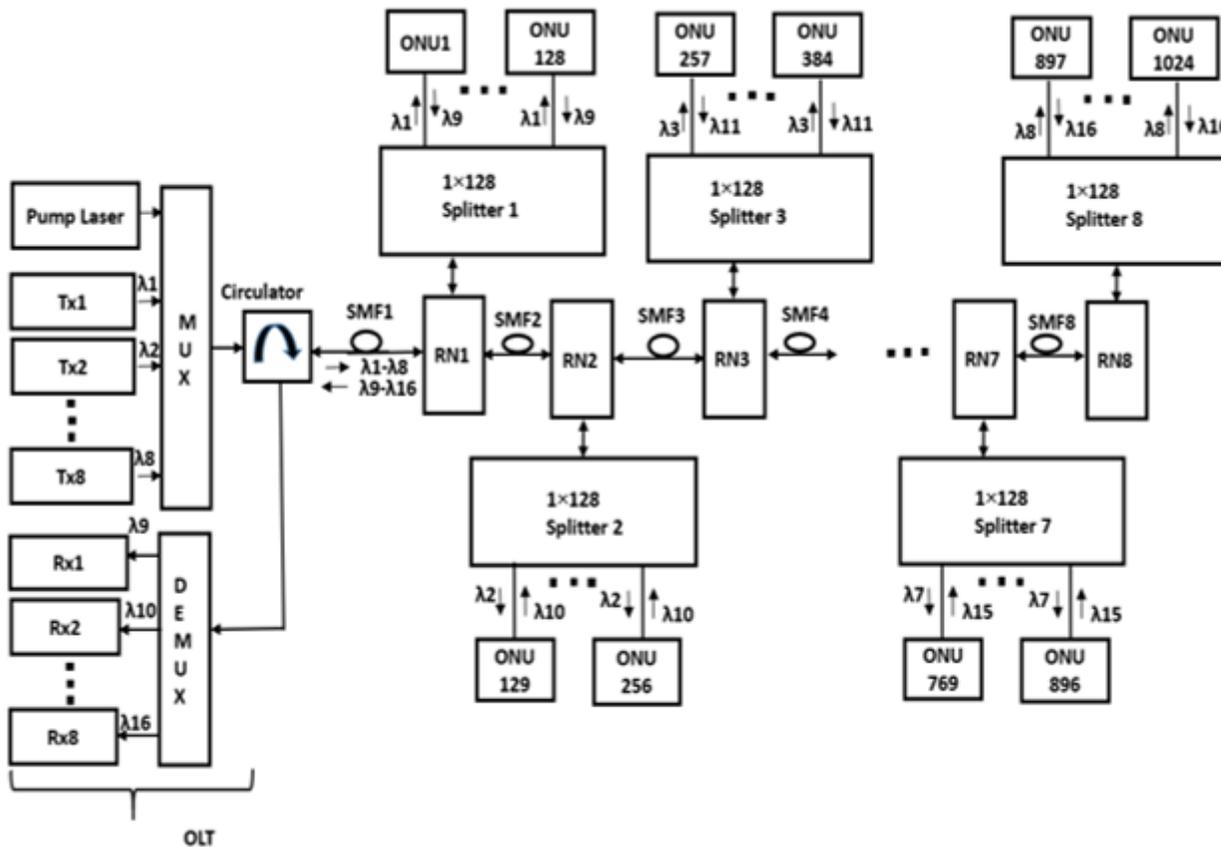


Figure 1

Simulation Architecture of 80 Gbps NG-PON2 with Bus Topology

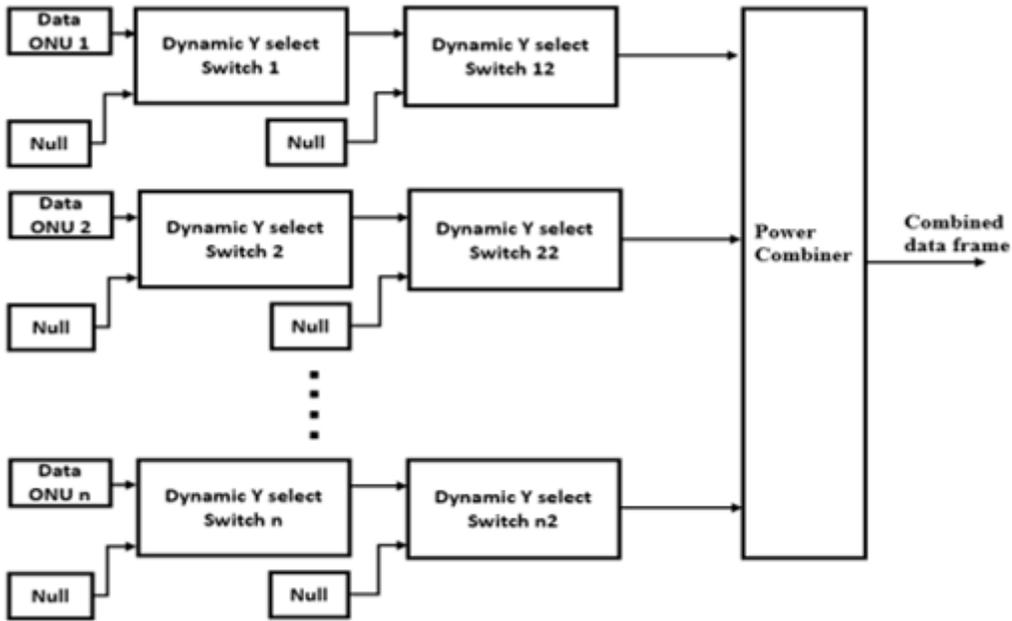


Figure 2

Combined Data Frame Formation from Individual data of ONUs.

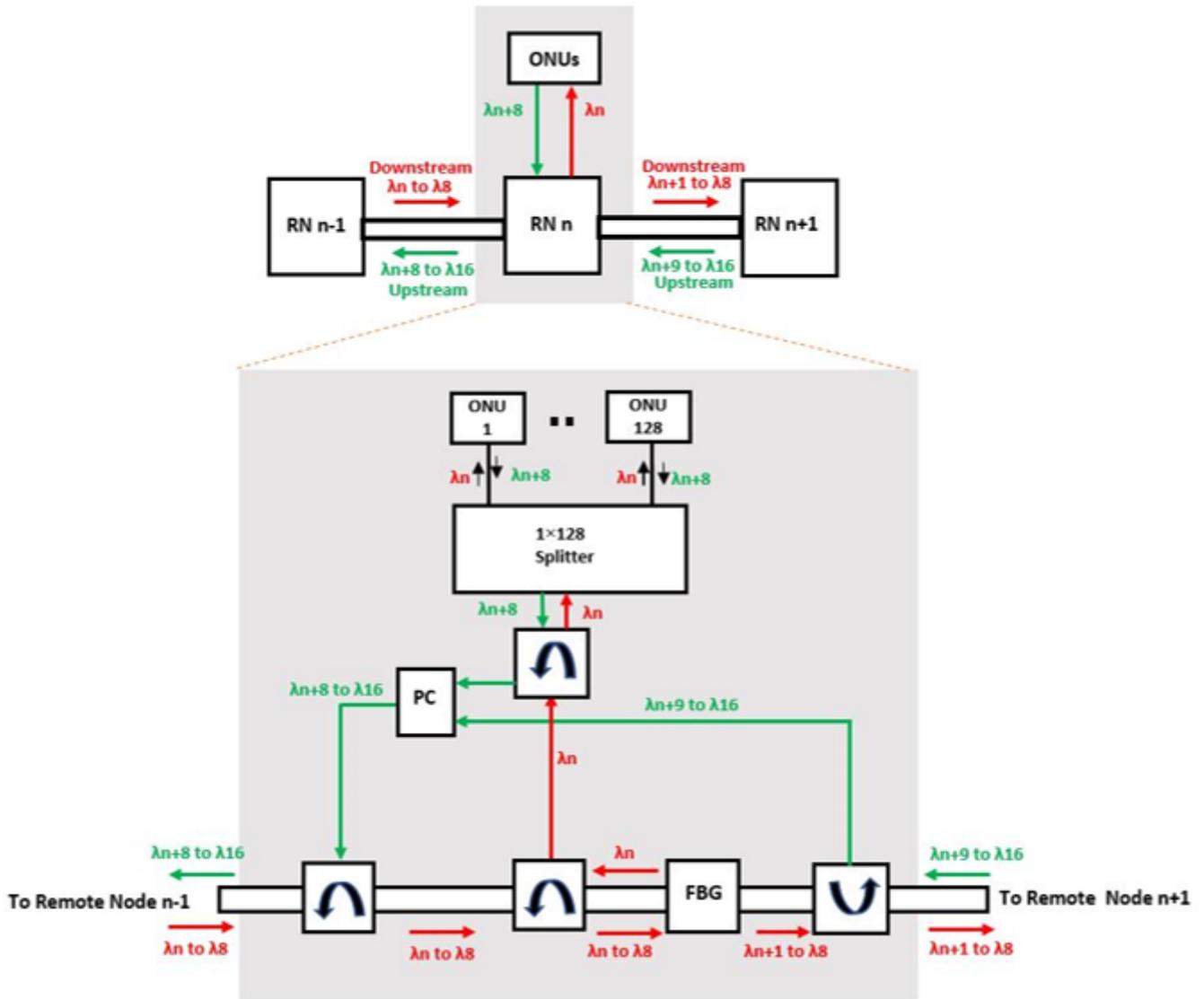


Figure 3

Design of FBG based nth Remote Node for Bus Topology in NGPON-2

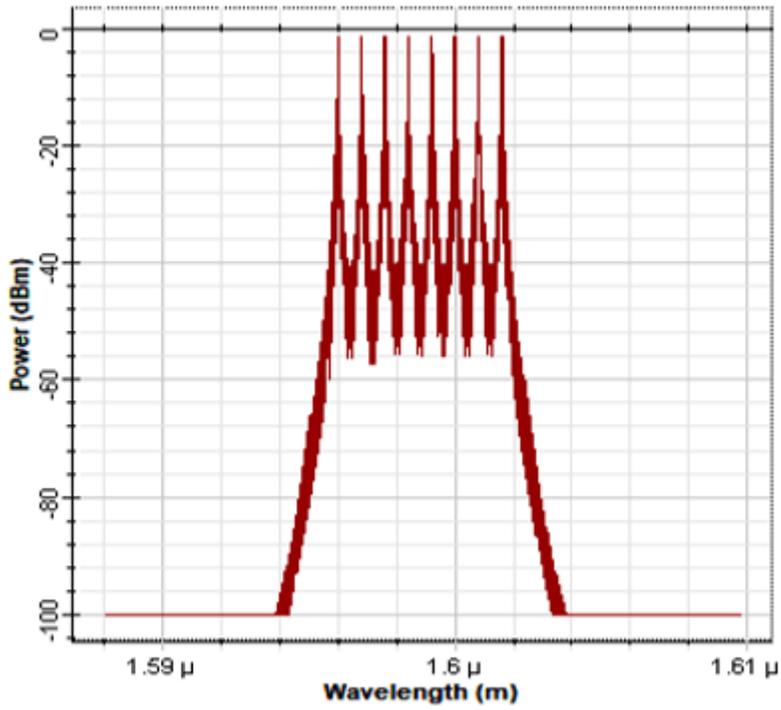


Figure 4

Transmitted downstream signal spectrum from the OLT

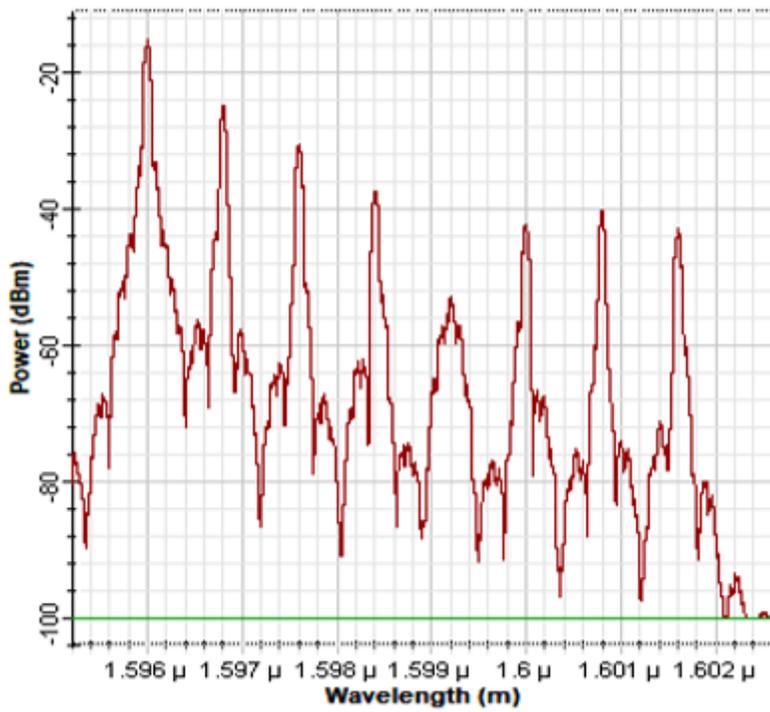


Figure 5

Optical spectrum received at the ONU connected to RN1

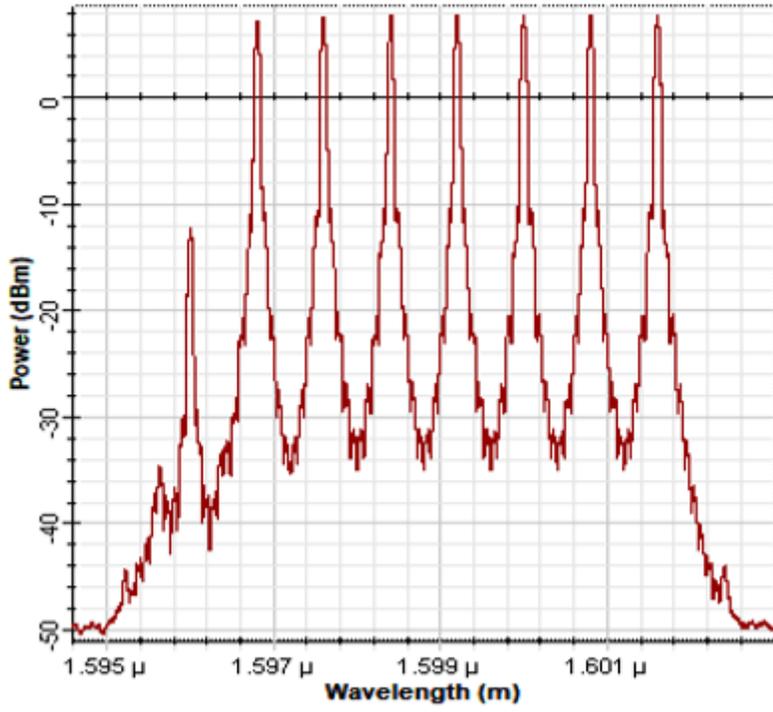


Figure 6

Optical spectrum of downstream signal reached the input of RN2

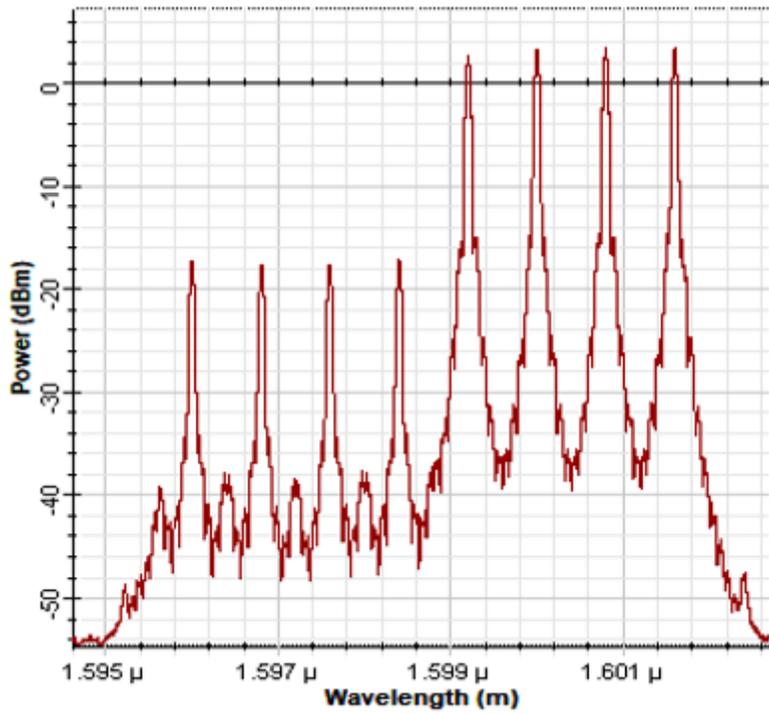


Figure 7

Optical spectrum at the input of RN5

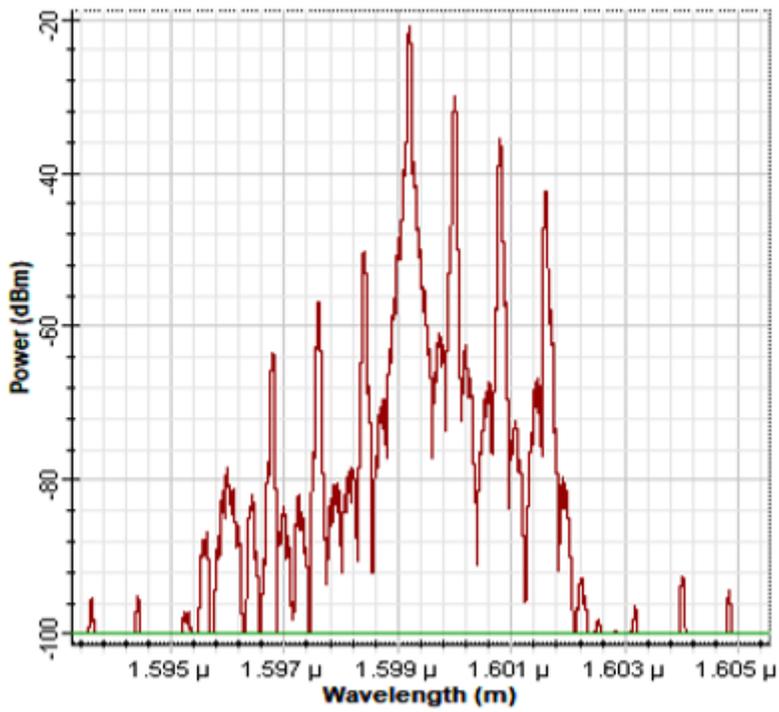


Figure 8

Optical spectrum received at the ONU connected to RN5

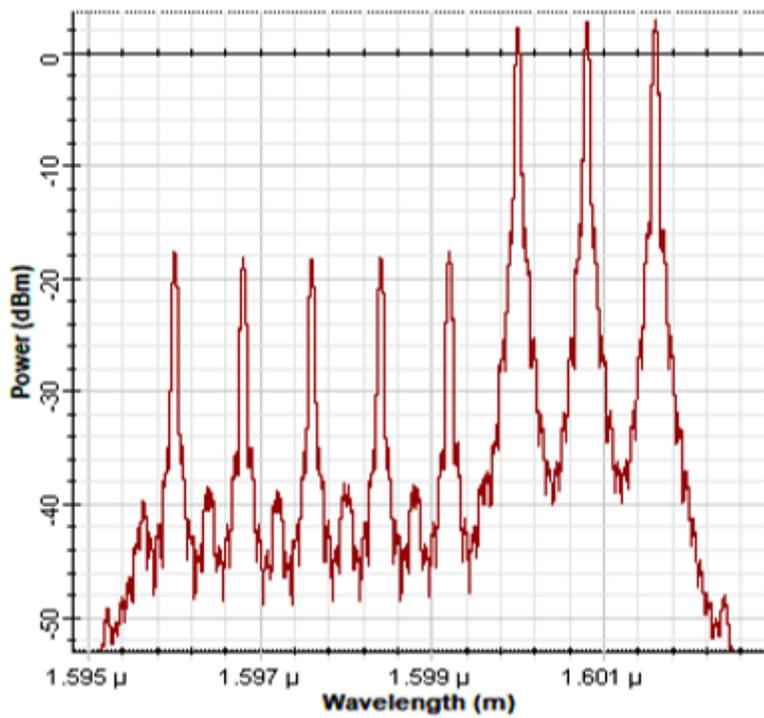


Figure 9

Optical spectrum at the input of RN6

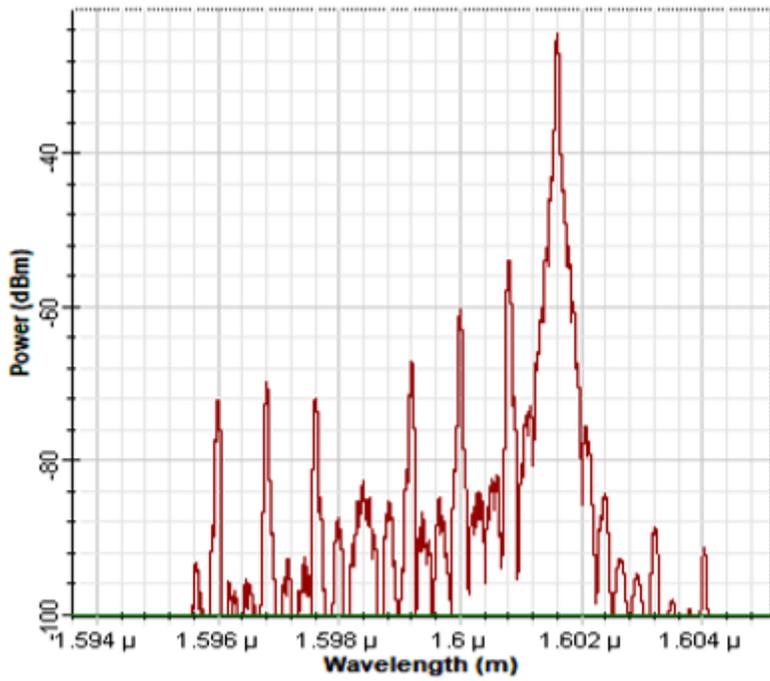


Figure 10

Optical spectrum received at the ONU connected to RN8

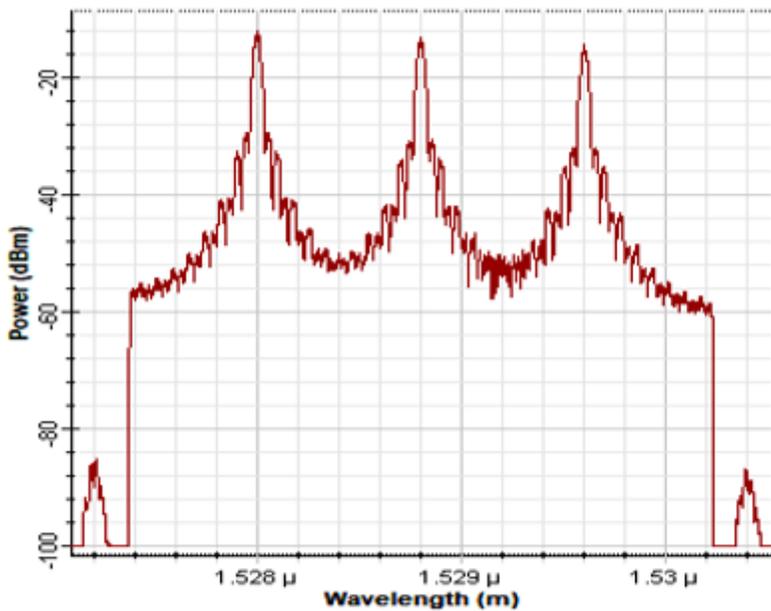


Figure 11

Optical spectrum of the upstream signal received by RN5 from RN6

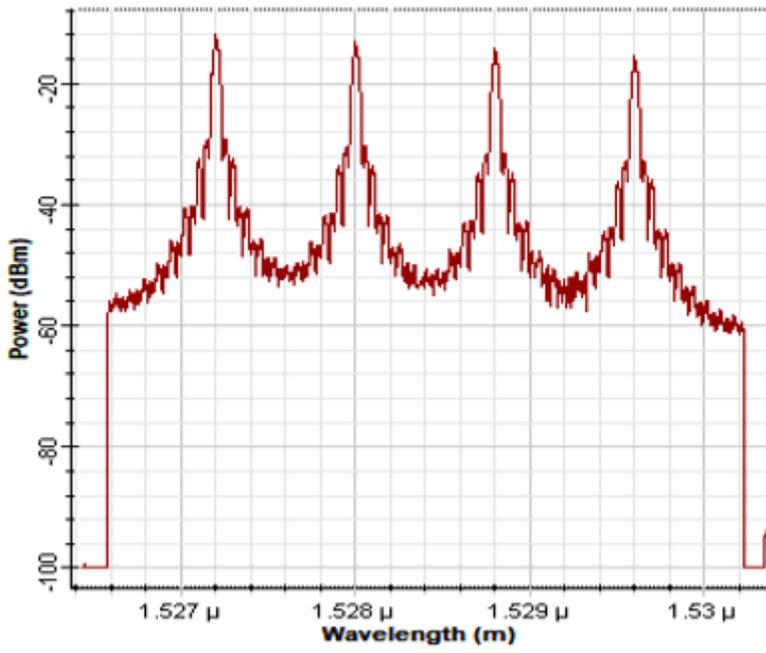


Figure 12

Optical spectrum of the upstream signal Sent by RN5 to RN4

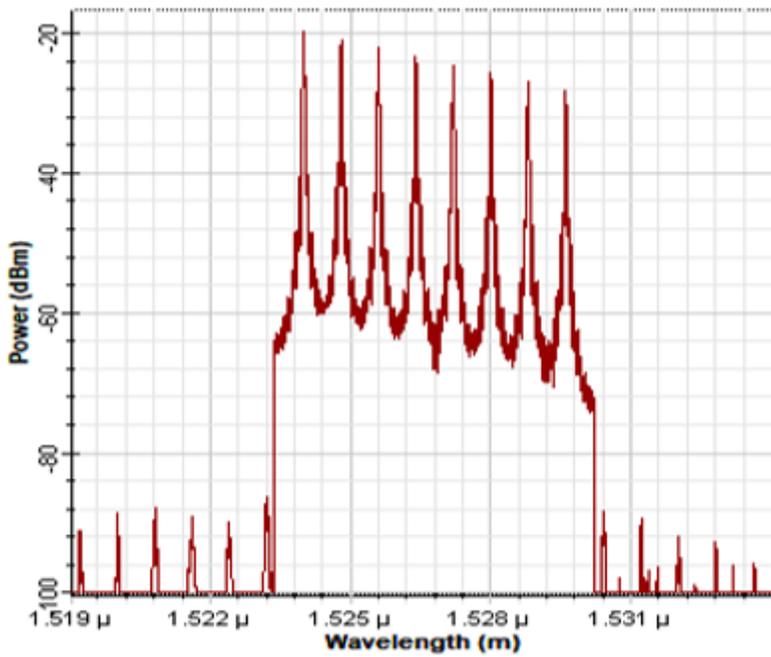


Figure 13

Optical spectrum of the upstream signal received at OLT

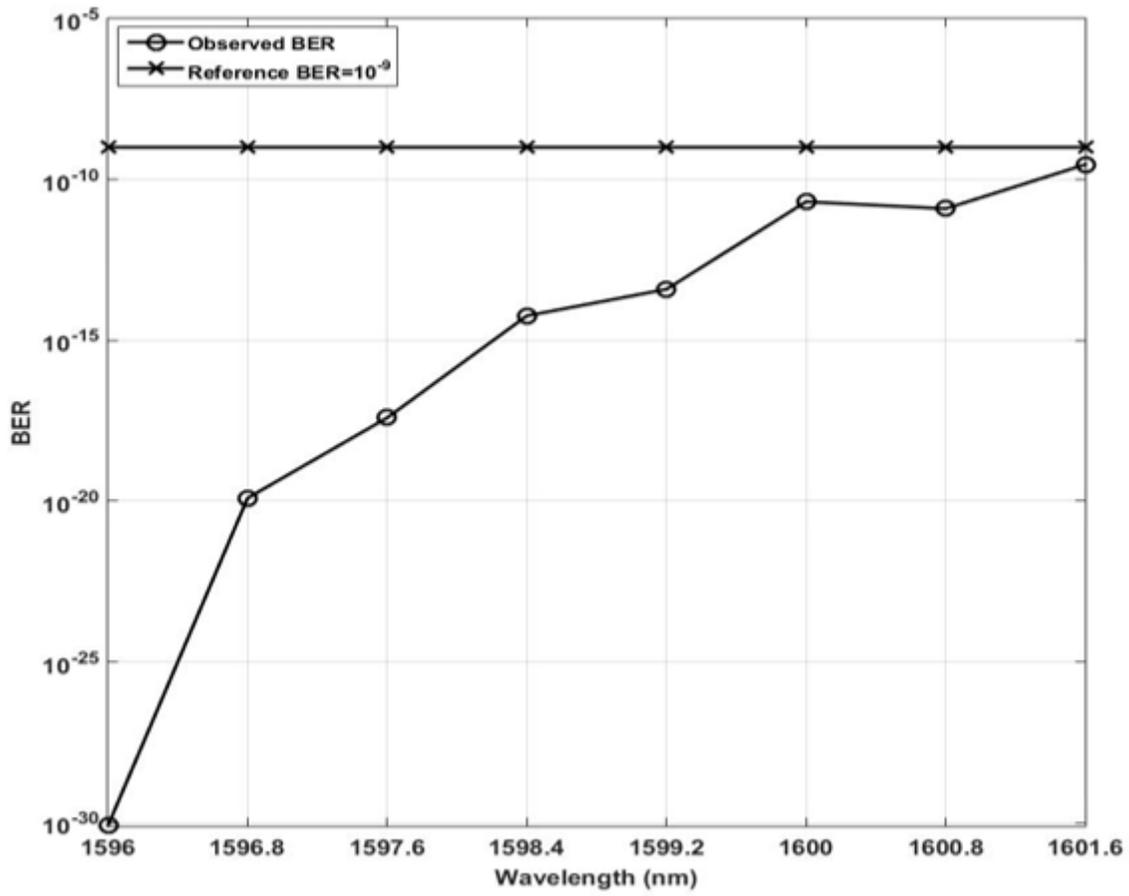


Figure 14

BER at All RNs for Downstream in Bus Topology using FBG

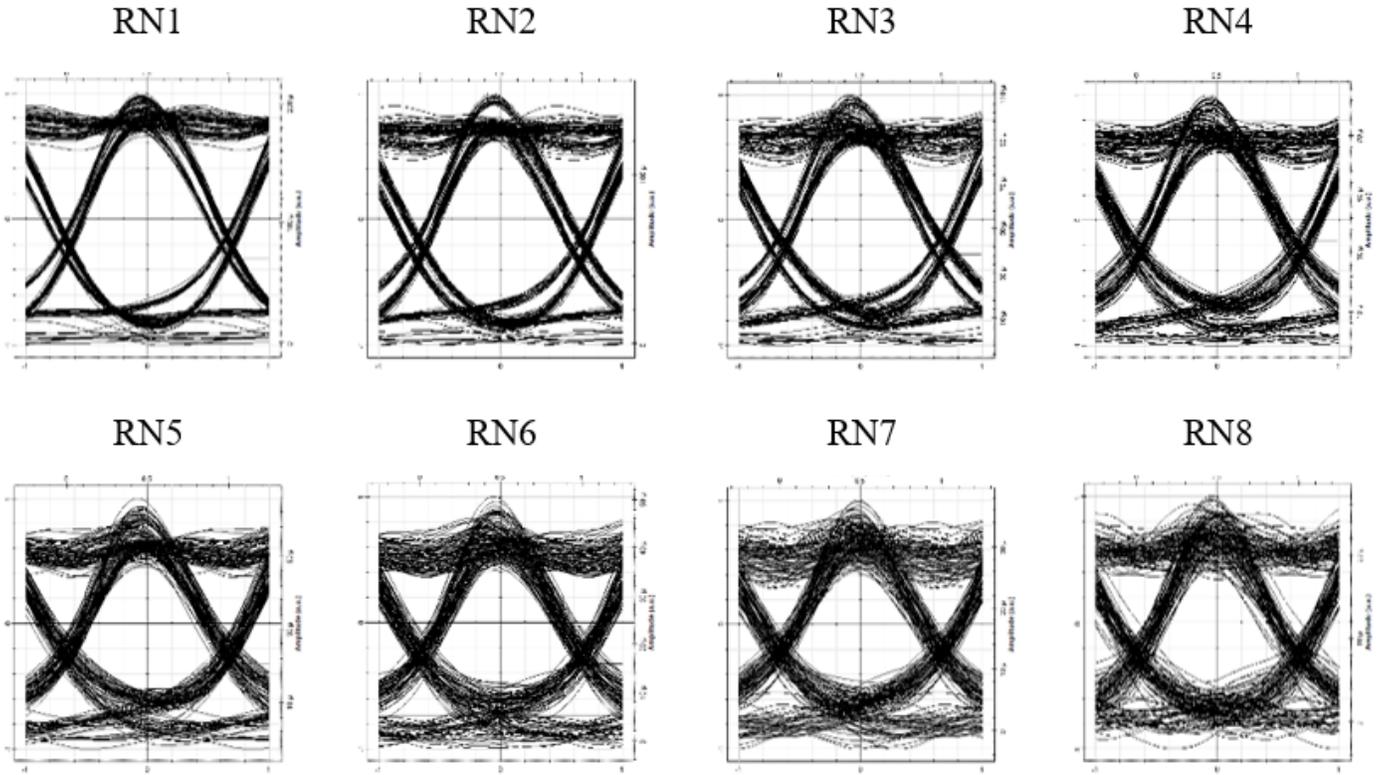


Figure 15

Eye diagrams for the ONUs connected to different remote nodes

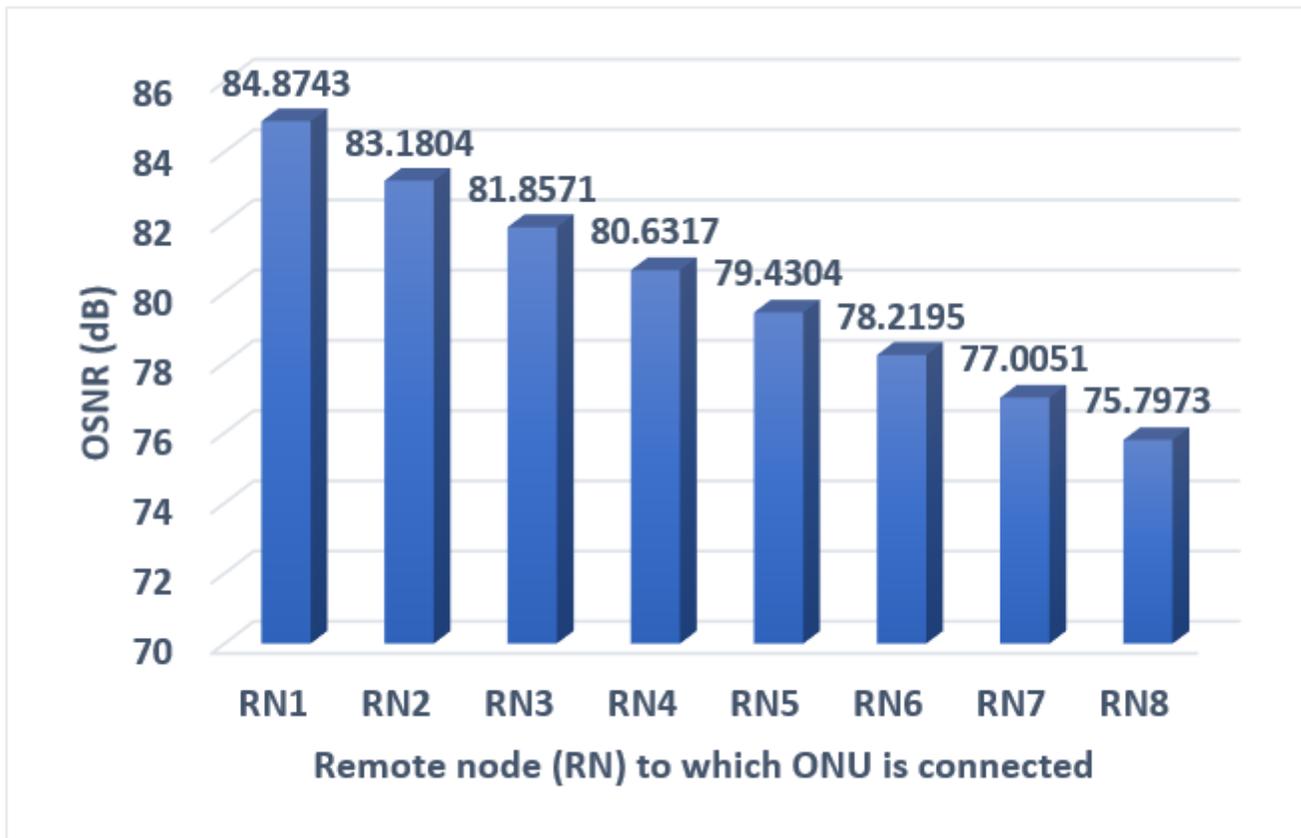


Figure 16

OSNR vs Location of ONU in the system

Image not available with this version

Figure 17

Image not available with this version

Figure 18

Image not available with this version

Figure 19

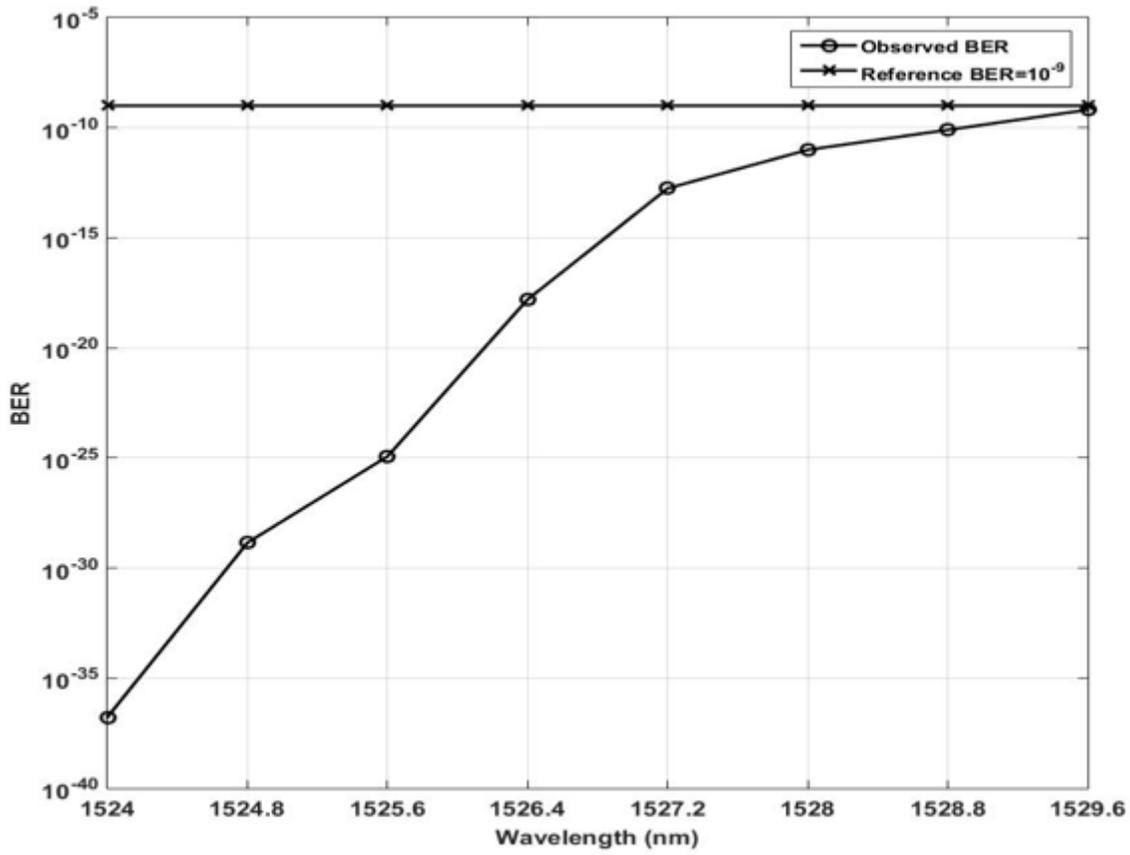


Figure 20

BER observed for the upstream signals coming from all RNs at OLT