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Symmetric 80 Gbps Next Generation Passive Optical Network Stage Two NG-PON2

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Abstract

In this research, a design of a symmetric 80 Gbps Passive Optical Network that meets the requirements of Next Generation Passive Optical Network Stage Two (NG-PON2) is proposed. According to The Full-Service Access Network (FSAN), The Time and Wave Length Division Multiplexing (TWDM) is chosen as the best solution to implement NG-PON2. TWDM network of NG-PON2 can be implemented in many wavelength plans to replace or co-exist with previous PON technologies. The proposed design was simulated taking into consideration the practical parameters of existing systems, the results shows that the system is reliable for implementation for 80 Gbps bitrate utilizing 8 pairs of wavelengths transmitted over 40 Km and distributed and received by 128 users with acceptable data rate.

Keywords:
NG-PON2,
TWDM-PON,
FSAN,
FTTH,
Tunable Transmitters and Receiver.

1. Introduction:

The great growth in user demand for bandwidth due to today's network applications, stir the competition between network carriers to meet the user demands. Network companies can measure user requirements by counting the traffic passing through network nodes and using statistical data analysis they can predict the future traffic requirements which are vital for planning network upgrades smoothly to meet the everyday increase in traffic through the network. This urges the telecommunications companies to upgrade their networks to meet the future needs for users. FSAN began studies to assess needs in late 2010, they concluded that there is a great gap between user needs and the bandwidth offered by the 10 Gbps capable Passive Optical Network (10G-PON known as XG-PON) technologies. A system proposal for Next Generation- Passive Optical Network (NG-PON) stage 2 was commenced in 2011 (Santa Clara, July 16, 2012). Among other solutions Time and Wavelength - Passive Optical Network (TWDM-PON) technology was recommended at the April 2012 meeting as a primary solution to design and implement NG-PON2. The network design achieves main design objectives like available bandwidth, network reach and cost (Nowak & Murphy, 2005).

Figure 1 shows the time line for network standards from the first telephone line modem to the recent and future standards explaining the capacity increase.

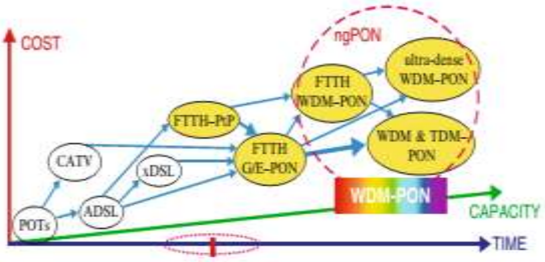

Figure 1 *Access Network Evolution*

2. Literature Review:

The everyday increasing traffic demand motivate the telecom companies to develop new standards that meet customer future needs that is coexist with and gradually replaces older DSL technologies.

2.1. PON architecture:

PON consists mainly of an optical Line Terminal (OLT), several Optical Network Terminal (ONT) or Optical Network Units (ONTs) and Optical Distribution Network (ODN) that connects OLT and ONUs as shown in Figure 2 (Shaik & Patil, 2005).

Figure 2 *PON architecture* [28]

2.2. Advantages of PON:

The advantages of PON are cost effective implementation due to shared optical link and no need for backup battaries and un-interrubtable power supply, very low energy consumption due to passive components and low attenuation of fiber cables, Longer distance between CO and customers sharing the same trunk as a result of the very low attenuation of fiber cable, nore signals in one fiber to cabienet allows for very dense CO equibement, nuch higher bandwidth per user, As point to multi point allows for downstream vedio broadcasting and no need for multiplexing or demultiplexing componetns in cabients (Kramer, 2005).

2.3. PON Evolution:

Passive Optical Networks is a protocol transparent technology that passed many steps toward NG-PON2.There are different PON technologies from FSAN, ITU-T and parallel efforts by IEEE (Hajduczenia & da Silva, 2009). There are many implementations of PON technology, like Asynchronous Transfer Mode (ATM) over Passive Optical Network (APON) standardized as G.983.1and G.983.2 at the year 1995 with 155 Mbps upstream and 155 Mbps downstream , Broadband Passive Optical Network (BPON) with standards G.983.3 to G.983.5 (Kaminow, Li, & Willner, 2010) at the year 2000 rising the data rates to 625 Mbps downstream, Gigabit Passive Optical Network (GPON) with 2.5 Gbps downstream and 1.25 Gbps upstream standardized at the year 2001 as G.984.1 to G,984.4 (Walid & Chen, 2010) and new amendments added at the year 2006, Ethernet Passive Optical Network (EPON) is standardized by IEEE at the year 2001 as IEEE 802.3ah (Dutta, Dutta, & Fujiwara, 2003) to support symmetric 1Gbps upstream and downstream, Gigabit Ethernet Passive Optical Network (G-EPON), 10 Gigabit Ethernet Passive Optical Network (10G-EPON) increased the upstream and downstream data rates to 10 Gbps and standardized as IEEE 802.3av at the year 2007 ,NG-PON1(Kani et al., 2009) and NG-PON2. The PON evolution is shown in Figure.

The new approach, NG-PON2, will increase PON capacity to at least 40 Gbps and deliver services of 1 Gbps or more with platforms and standards that could be deployable in 2015 (see Figure 3). It is designed to meet a broad range of communication needs, including business and mobile backhaul applications as well as residential access. The advantages of NG-PON2 is that it can support increased capacity, higher light-to-port ratios, improved interoperability and enhanced services (Santa Clara, July 16, 2012)

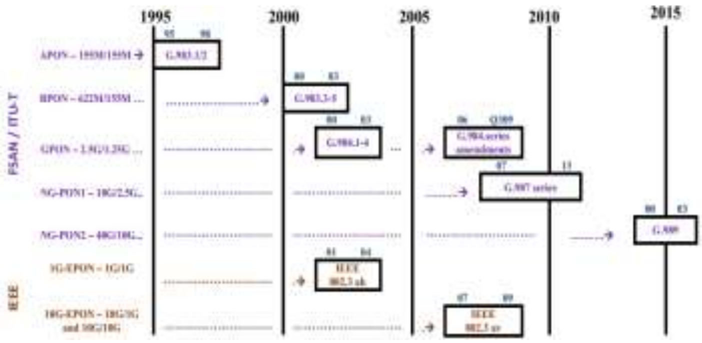

Figure 3 *PON Evolution*

3. NG-PON2:

The NG-PON2 is a project guided by FSAN initiated at April 2012 with time period of project extends to 2020. The main goals of project are defined according to vision of FSAN but the researchers compete to add their designs to the project. So there are many designs can be implemented. The novelty aspects in this research are:

- Data Rate increased to 80 Gbps (started at 40 Gbps then increased the rate with design tradeoff between data rate and cost of implementation to maximum number of users.

- The number of users shareing the same fiber link increased to 128.

4. Tunable Transmitters and Receiver

The implementation of TWDM NG-PON2 network is a great challenge as the tunable transceivers technology is still evolving with currently high cost that limits spreading this technology but this will change in the near future. The tunable transmitter and receiver of the ONU request wavelength from the OLT that assigns the ONU free wavelength in three-way hand shake as shown in Figure 4.

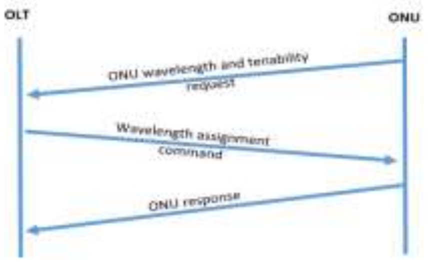

Figure 4 *Wavelength management*

4.1. Tuneable Transmitter:

Tunable transmitters or tunable lasers is a challenge in the development of future ultra-high data rate networks. The transmitter can by fixed-tuned or dynamically-tuned. In previous generations of PON, many researchers studied wavelength tuning. Tuning in both time and wavelength is a promising technology for flexible NG-PON design. There are many wavelength tuning techniques like: External cavity tunable lasers, Two-section tunable distributed Bragg reflector tunable laser diodes, Three-section tunable distributed Bragg reflector tunable laser diodes and one or two dimensional laser diode array (DeCusatis, 2013).

4.2. Tuneable Receiver:

It is vital to strictly select desired wavelength for data reception. The tunable receivers or Tunable Optical Filters (TOF) uses externally controlled electric signal to tune filter to selected wavelength with the following specifications; wide tuning range, fast tuning, constant gain, narrow bandwidth and stability against temperature variations. There are many examples of tunable filters like the Fabry-Perot interferometer, the Bragg reflector, Dielectric thin-film interference, the Acousto-optic tunable optical filters (AOTFs), Tunable Mach-Zehnder filter, Absorption filters, Hybrid filters that combines different filter types. These types of filters vary in their characteristics and hence can be used for different applications. as a comparison between prescribed filters, it is found that acousto-optic and fabry-perot filter are better suited for a large number of channels applications, while electro-optic and semiconductor filters are better suited for fast tuning applications (Kartalopoulos, 2000).

5. 80 GB/S TWDM-PON System Design:

The 80 Gbps network can be implemented by stacking eight XG-PONs as shown in Figure 5 with eight downstream wavelengthsfor downstream data and upstream wavelengths for upstream data.

The data signals from each Internet Service Provider (ISP) is sent to the approprate OLT, then the data modulates the light signal with downstream light signal with wavelength specified by the MAC layer protocol, the data from each transmitter are combined by WDM mux then lunched to the optical fiber for transmission and reach the passive splitter for distribution to users ONUs.

In the upstream direction the user data modulates the upstream light signal with wavelength and time slot specified also by MAC layer protocol, wavelength and time slot are Negotiated through link setup.

The network design is implemented and tested using optiwave optisystem design tool for 80 Gbps distributed and serving 64 users.

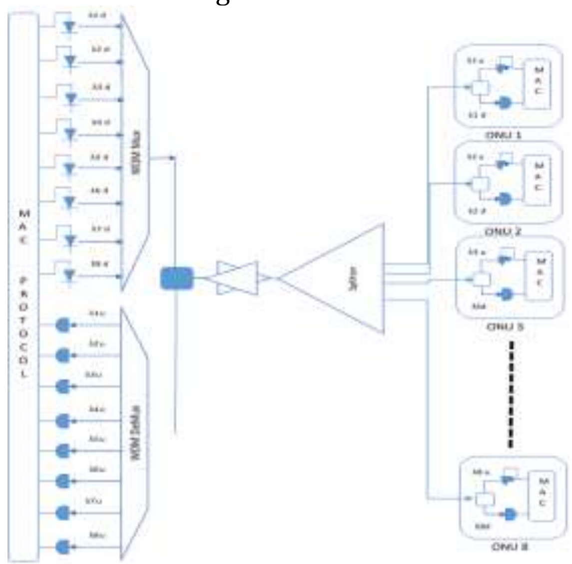

Figure 5 *80 Gbps TWDM NG-PON2 system architecture*

TWDM OLT is impelemented by stacking eight XGPONs transievers of aggregate 80 Gbps.

OLT optical transmitter (see Figure 6) consists of Pseudo-Random Bit Sequence (PRBS) Generator that generates the data stream to be transmitted followed by NRZ Pulse Generator. The line coded data modulates the optical light generated by CW Laser externally using Mach-Zehnder Modulator.

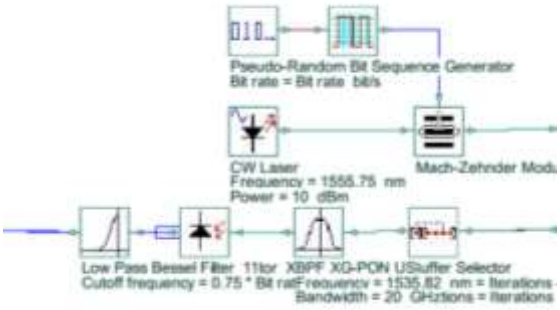

Figure 6 *OLT for 10G-PON*

Optical transmitters are multiplexed using AWG that works as multiplexer while received optical signal is demultilexed using AWG that works as demultiplexer and distribute each optical wavelength to its destination OLT receiver.

Optical distribution network (ODN) consists of two stages of power splitters; 1:8 passive splitter / combiner followed by 1:16 splitter / combiner to get 128 split ratio can be upgraded to 256 split ratio using either 1:16 followed by 1:16 or 1:8 followed by 1:32 taking into consideration power pudjet calulations.

Optical Network Terminal consists of tunable transmitter and reciever, the transmitter consists of WDM transmitter that can tune to required upstream wavelength and uses two stages of Dynamic Y select for dynamic time slot management to transmit burst of data only in the required time slot of transmission (see Figure 7). Time slot assignement is controlled by OLT.

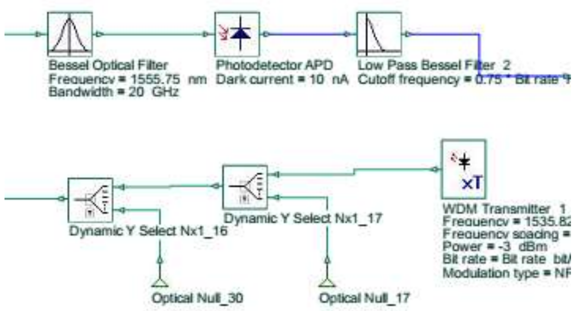

Figure 7 *ONU Unit*

In the network design in this thesis work 16 ONUs share the same wavelength and but with different time slots, according to split ratio of the second splitter stage the ONUs are connected to the splitter.

The formula for the Dynamic Y Select 1 for 16 time slots is given by (Luo et al., 2013)

$$\text{Switching Event Time} = \text{TimeSlot} \times \frac{1}{\text{Bit rate}} \times \frac{\text{Sequence length}}{16}$$

The formula for the Dynamic Y Select 2 is given by

$$\text{Switching Event Time} = \text{TimeSlot} \times \frac{1}{\text{Bit rate}} \times \frac{\text{Sequence length}}{16} \times \frac{\text{Time window}}{16}$$

For Bitrate of 10 Gbps and Sequence length 256 bit and 25.6 ns time window the switching event was calculated to divides the 10 Gbps data loaded to the optical light signal shared by 16 user so the 80 Gbps implementation serves 128 user with the same data rate. Both systems can serve more users with less than 640 mbps taking into consideration the power budjet for higher split ratio.

6. Results (80 Gbps TWDM-PON):

The 80 Gbps TWDM-PON design is tested for variable parameters that shows good results for feasible implementation for wavelength 1600.6 nm at distance 40 Km; the measured values are 16.1366 Quality Factor (Q-Factor) as shown in Figure 8, 6.18 e-59 Minimum Bit Error Rate (BER) as shown in Figure 9, Eye diagram with opening showing height and width for good decision of incoming bits conclude that the system downstream is reliable, feasible and can be implemented without any problems.

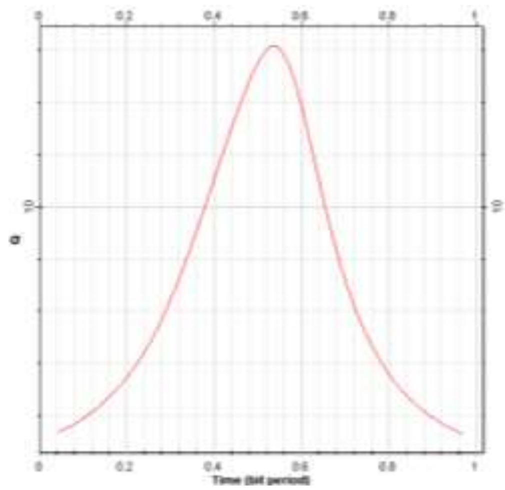

Figure 8 *Q Factor for 1600.6 nm downstream at 40 Km*

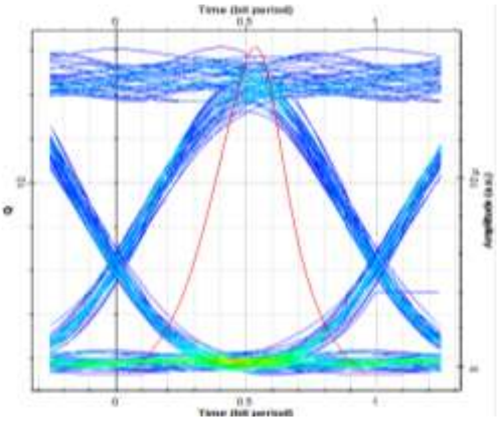

Figure 9 *Eye Diagram for 1600.6 nm downstream at 40 Km*

Figure 10 shows the receiver sensitivity for 1600.6 nm wavelength at distances Back to Back (B2B), 10 Km, 20 Km, 30 Km and 40 Km, it is clear that the system has acceptable value of BER at input power of 6 dBm lunched in the OLT transmitter at 40 Km reach while it can be accomplished for less than 40 Km reach with less laser power at OLT transmitter. While Figure 11 shows that using any of the eight wavelengths of transmitted by 80 Gbps TWDM-PON gets almost the same results.

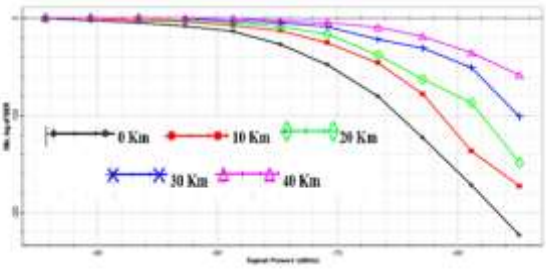

Figure 10 *Receiver sensitivity for 1600.6 nm*

The 80 Gbps TWDM-PON system has the same behavior as 40 Gbps system but it suffers some degradation for the downstream wavelengths 1604.88, 1605.74, 1606.6 nm as shown in Figure 11, but the system is still reliable to be implemented with out risk.

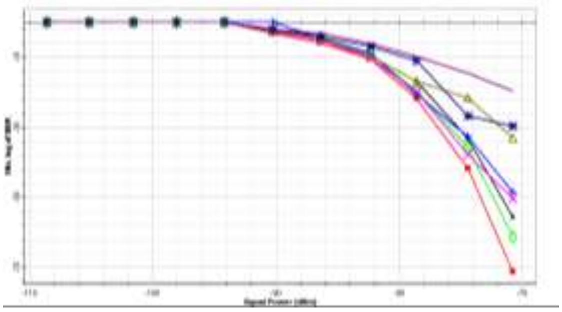

Figure 11 *Receiver sensitivity at 40 Km for various wavelengths*

7. Conclusion:

TWDM NG-PON2 is a promising technology since it offers user requirements for bandwidth and attractive for service providers because of the advantage of saving their investements as TWDM reuses existing distribution network.

TWDM-PON inherits the advantages of PON networks as it does not need power in the distribution planet so it is considerd green technology at the same time it reduces the costs of network design, implementation, operation and maintenance.

In this research a TWDM-PON system is designed , implemented and tested using optisystem 13. The results of modular design proved that TWDM-PON has a wide range of advantages that will make it the best solution for next generation optical access networks as it can coexist with previous technologies for smooth upgrade option and can totally replace previous technologies.

The 40 Gbps network can serve 64 users with 640 Mbps dedicated bandwidth for each while the 80 Gbps can serve 128 users with the same user bandwidth. With the power penalty availiable the same network design can be extended to eighter increase the reach distance or duplicate split ratio to increase the number of users sharing the same fiber with minimum risk.

TWDM-PON is transperent technology as it can support varity of MAC address protocol standards.

References:

DeCusatis, C. (2013). *Handbook of fiber optic data communication: a practical guide to optical networking*. New York: Academic Press.

Dutta, A. K., Dutta, N. K., & Fujiwara, M. (2003). *WDM technologies: Passive optical components* (Vol. 1). New York: Academic press.

Hajduczenia, M., & da Silva, H. J. (2009). *Next generation PON systems-Current status.* Paper presented at the 11th International Conference on Transparent Optical Networks, Portugal: University of Azores.

Kaminow, I., Li, T., & Willner, A. E. (2010). *Optical fiber telecommunications VB: systems and networks*. Elsevier.

Kani, J.-i., Bourgart, F., Cui, A., Rafel, A., Campbell, M., Davey, R., & Rodrigues, S. (2009). Next-generation PON-part I: Technology roadmap and general requirements. *IEEE Communications Magazine, 47*(11), 43-49.

Kartalopoulos, S. (2000). *Introduction to DWDM Technology*. USA: IEEE Press.

Kramer, G. (2005). *Ethernet passive optical networks*. New York: McGraw Hill Professional.

Luo, Y., Zhou, X., Effenberger, F., Yan, X., Peng, G., Qian, Y., & Ma, Y. (2013). Time-and wavelength-division multiplexed passive optical network (TWDM-PON) for next-generation PON stage 2 (NG-PON2). *Journal of Lightwave Technology, 31*(4), 587-593.

Nowak, D., & Murphy, J. (2005). *FTTH: The overview of existing technologies.* Paper presented at the OPTO-Ireland, Ireland.

Santa Clara, C. (2012, July 16). *Next Generation PON Task Group*. from: http://www.fsan.org/task-groups/ngpon/

Shaik, J. S., & Patil, N. (2005). FTTH deployment options for telecom operators. *Sterlite Optical Technologies Ltd., White Paper*, 1-9.

Walid, A., & Chen, A. (2010). Self-adaptive dynamic bandwidth allocation for GPON. *Bell Labs Technical Journal, 15*(3), 131-139.

الجيل القادم الثاني من شبكات الاتصالات البصرية السلبية المتماثلة بسرعة 80 جيجابت في الثانية

يهدف هذا البحث لتصميم شبكة ألياف ضوئية تلبي متطلبات المرحلة الثانية من الجيل القادم من شبكة الألياف الضوئية. حيث سيتم عمل محاكاة للتصميم المقترح باستخدام النسخة الأخيرة من برنامج Optisystem حسب القيم والمتغيرات الحقيقية للأجهزة الموجودة قيد الاستخدام في شركات الاتصالات.

حسب منظمة FSAN وهي عبارة عن مجموعة مكونة من 85 شركة من شركات ومزودي خدمات الاتصالات في العالم, فان نظام التجميع في مجالي الزمن والطول الموجي قد تم اختياره في شهر أبريل 2012 كأفضل الحلول المطروحة لتصميم المرحلة الثانية من نظام الجيل القادم لشبكات الاتصالات الضوئية السالبة NG-PON2.

قادت منظمتا FSAN وITU-T الجهود لتحديد احتياجات عرض النطاق لمستخدمي الشبكة والتخطيط المسبق لترقية الشبكات بالمرونة اللازمة التي توفر احتياجات مستخدمي الشبكة مع أقل تكلفة مع توفير خيارات متعددة لعرض النطاق الذي يمكن أن يحصل عليه المشترك بحيث يدفع تكلفة الخدمة التي يتلقاها ويمكن للمشترك الانتقال لسرعة أعلي بمقابل أعلي حسب احتياجات المشترك ورغباته.

في هذا البحث تم تحديد أهداف اضافية لتحقيها بتصميم نظام مبني علي النمذجة بحيث يمكن مضاعفة وحدات النموذج لمضاعفة عرض النطاق 40 Gbps إلي 80 Gbps أو أكثر. كما تم استعراض أكثر من مخطط لمجال الأطوال الموجية المستخدمة ومقارنة النتائج لتوضيح مزايا وعيوب كل من هذه المخططات.

كلمات مفتاحية:
شبكة ألياف ضوئية،
المرحلة الثانية من الجيل القادم من شبكة الألياف الضوئية،
نظام التجميع في مجالي الزمن والطول الموجي.