Analysis of Possible Exploitation for Long Reach Passive Optical Networks

Rastislav Róka
Institute of Telecommunications, Slovak University of Technology, Ilkovičova 3, 812 19 Bratislava, Slovakia

Keywords: LR-PON Network, HPON Network Configurator, EPON, 10G-EPON, GPON and XG-PON Implementations.

Abstract: For the expansion of networks based on optical transmission media, it is necessary to have a detailed knowledge of advanced implementations for passive optical systems used in the access network. This contribution shortly discusses possible scenarios of exploitation for hybrid passive optical networks. A main part is focused on characteristics of the HPON network simulation environment and on results from simulation experiments related to the Long Reach Passive Optical Network effective utilization for various higher layers.

1 INTRODUCTION

Next Generation Passive Optical Networks (NG-PON) present optical access infrastructures to support various applications of many service providers. In the near future, we can expect NG-PON technologies with different motivations for developing Hybrid Passive Optical Networks (HPON). The HPON is a hybrid network in a way that utilizes on a physical layer both Time- (TDM) and Wavelength- Division Multiplexing (WDM) principles together (Róka, 2012). Moreover, the HPON presents a hybrid network as a necessary phase of the future transition from TDM to WDM passive optical networks (Peťko, 2012). Possible exploitation of hybrid passive optical networks can be divided into four probable scenarios:

- In the first case, the WDM/TDM PON network represents a hybrid network based on the combined WDM/TDM approach. The WDM/TDM PON architecture associates several smaller TDM networks into one large network, where each TDM network utilizes specific wavelength for communication with the Optical Line Terminal (OLT). A number of subnetworks depends on a number of Array Waveguide Gratings (AWG) ports, when every subnetwork can utilize different splitting ratio.
- In the second case, a change of OLT and ONU equipment is executed and adding of both (WDM and TDM) Optical Network Unit (ONU) equipment into common network architecture is allowed by using specialized remote nodes that utilize either passive optical power splitters or AWG elements. By this way, a smooth transition from TDM to WDM networks is allowed. As an example, the SUCCESS (Stanford University aCCESS) HPON can be presented (An, 2005; Kazovsky, 2011). The SUCCESS HPON network introduces a sequential transition to the pure WDM PON network in a compliance with the TDM and WDM technology coexistence. The hybrid SUCCESS architecture comprises the ring topology for the WDM transmission. It contains two types of Remote Nodes (RN) for the WDM or TDM star connections. The WDM RN is created from AWG elements, the TDM RN from optical power splitters. The OLT terminal generates signals for both WDM and TDM ONU units by means of Dense WDM (DWDM) wavelengths; however the TDM ONU transmits signals on Coarse WDM (CWDM) wavelengths. This architecture allows provisioning WDM services at preservation of the backward compatibility

Róka R..
Analysis of Possible Exploitation for Long Reach Passive Optical Networks.
DOI: 10.5220/0005054101950202
In *Proceedings of the 4th International Conference on Simulation and Modeling Methodologies, Technologies and Applications* (SIMULTECH-2014), pages 195-202
ISBN: 978-989-758-038-3

with initial/original TDM subscribers. The exchange of the TDM ONU is necessary. Information can be found in (Róka, 2014).

- In the third case, a scope is to create a modular network and to enable service provisioning for more than 1000 subscribers at distances up to 100 km using the SARDANA (Scalable Advanced Ring-based passive Dense Access Network Architecture) design (Kazovsky, 2011; Lazaro, 2008). It is considered a remote pumped amplification using Erbium Doped Fiber Amplifier (EDFA) principles and a utilization of the colorless ONU units at subscriber side. Also, the backward compatibility with existing 1G-PON networks and a support for standardized 10G-PON networks are considered with 100-1000 Mbit/s transmission rates per one subscriber. The PON fiber topology is creating by two main parts – the WDM ring with the central office and remote nodes, TDM trees connected to particular remote nodes. The WDM ring consists of two optical fibers – one per direction. A key element of the network is the RN. Used ONU units are colorless; they don't contain any optical source. Transmitting from the ONU is based on the Reflective Semiconductor Optical Amplifier (RSOA) by means of the re-modulation of received signals. The SARDANA network allows connecting a large number of subscribers either on smaller distance in populous urban areas or in larger geographical areas with small population. Information can be found in (Róka, 2014).
- In the fourth case, the Long Reach Passive Optical Network (LR-PON) architecture utilizes active components in an outside plant (Prat, 2009). A network reach can be extended up to 100 km and can be utilized various type of optical amplifiers – EDFA, RAMAN, SOA. A network attenuation depends on a type of optical fibers, on a selected TDM network, on a number of connected subscribers and on a distance OLT–ONU.

In this paper, analysis of possible exploitation for only Long Reach Passive Optical Networks is presented. Also, effective utilization of the LR-PON for various higher layers of the Open Systems Interconnection (OSI) model is examined and verified. Analysis of other hybrid passive optical networks using the HPON Network Configurator can be found in (Róka, 2013).

2 THE SIMULATION ENVIRONMENT FOR HPON NETWORKS

Our simulation model for comparing possible exploitations of various scenarios in real access networks is created by using the Microsoft Visual Studio 2008 software in the IDE development environment (Róka, 2011, 2012, 2013). There exist possibilities for the graphical interface created by using the Microsoft Foundation Class (MFC) library for the C++ programming language. The simulation model has one main dialogue window for simulating a transition from TDM-PON to HPON networks. It allows comparing principal approaches for configuring of hybrid passive optical networks. A cut-out from the main window of the HPON Network Configurator is shown on Fig. 1.

The HPON simulation environment is working in several steps:

1. Setting parameters of the optical fiber – a type of the optical fiber (according to the ITU-T), the DWDM multiplexing density.
2. Evaluating optical fibers – standard or inserted specific attenuation values in [dB/km], a calculation of numbers of CWDM and DWDM carrier wavelengths.
3. Inserting input parameters of the TDM-PON network - a number of TDM networks, a type of the network, a number of subscribers per one network, a distance between the ONT and the OLT.
4. Evaluating input parameters – a calculation of the total transmission capacity of the TDM network together with the average capacity per one subscriber, the total number of subscribers and the maximum attenuation of the TDM network; also, the attenuation class is presented. This step is terminating with the selection of detailed hybrid PON configuration design.

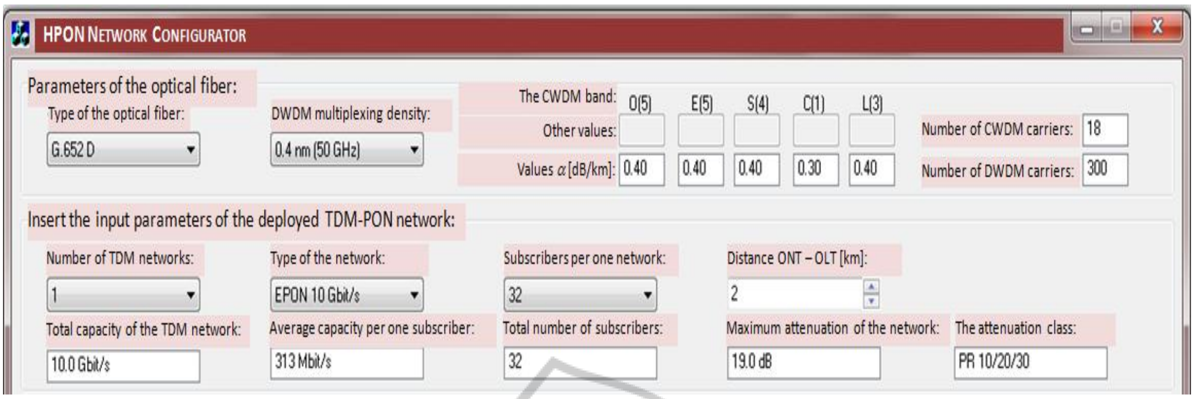

Figure 1: The cut-out from the main window of the HPON Network Configurator.

5. Setting input parameters for the hybrid PON configuration – based on the stored TDM-PON network data and selecting one from HPON types.
6. Application input parameters and specific network parameters of the HPON configuration (the total capacity of the hybrid network, the total number of subscribers, the average capacity per one subscriber, the maximum attenuation of the hybrid network between the OLT and the ONT, a number and type of used active and passive components) with summing up a type and number of deployed optical components and presenting possibilities for future expanding of hybrid HPON network types.

At first, a selection of the optical fiber's type and the DWDM multiplexing density can be executed. A selected type of the optical fiber is presented by the specific attenuation values and by a number of transmission bands. These values correspond to various ITU-T recommendations – ITU-T G.652 A, G.652 B, G.652 C, G.652 D, G.656, G.657 – and, if available, measuring data can be inserted in the "Other values" option. Then, specific attenuation coefficients are used for calculating the optical fiber`s attenuation in corresponding bands in specific network configurations. Also, a total number of CWDM and DWDM carrier wavelengths for particular bands is presented. The relationship between numbers of available wavelengths at various channel allocations is introduced in (Róka, 2012).

Following, a specification of parameters and features of the deployed TDM-PON network is presenting. More detailed information about analysis of various hybrid passive optical networks using the HPON Network Configurator can be found in (Róka, 2013).

3 POSSIBILITIES OF THE LR-PON NETWORK

In the latest scenario of the possible HPON exploitation, the Long Reach PON utilizes moreover active components (optical amplifiers) that can extend a network reach or improve splitting ratio in remote nodes. The Long Reach PON window is opened (Fig. 2). In the HPON Network Configurator, options for selecting a higher splitting ratio (1:128 and more) are supplemented as a special feature of the LR-PON. When one of higher splitting ratios of subscribers per network is selected, options for configuration of other hybrid passive optical networks - WDM/TDM PON, SUCCESS HPON and SARDANA HPON - are automatically deactivated because they don't support this selected splitting ratio. For this case, an option for the Long Reach PON configuration is only active.

Possibilities for new configuration of this LR-PON network are very similar to the hybrid WDM/TDM PON network configuration. One option for selecting of specified optical amplifiers type is supplemented as a main factor that distinguished the LR-PON from other passive optical networks (Fig. 3).

In the LR-PON network, a selection from three types of optical amplifiers – Erbium Doped Optical Amplifier (EDFA), Raman Amplifier (RAMAN) and Semiconductor Optical Amplifier (SOA) – located in the OLT is possible.

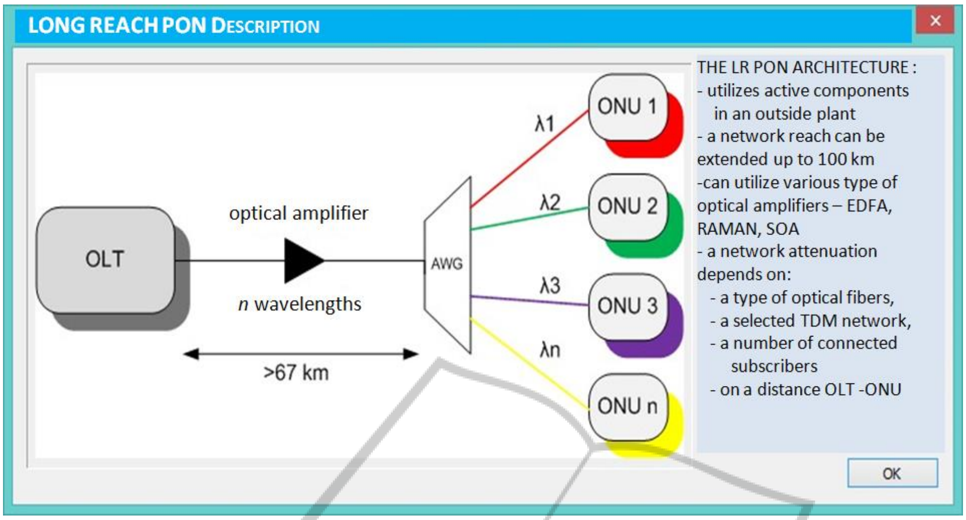

Figure 2: The opening window of the Long Reach PON network approach.

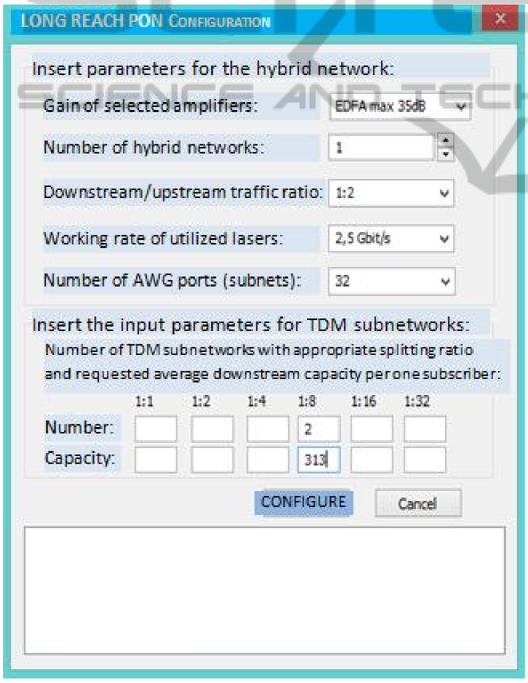

Figure 3: The Long Reach PON network configuration window.

These optical amplifiers have various features and characteristics and different values of the optical amplification (gain)

In the LR-PON network, a selection from three types of optical amplifiers – Erbium Doped Optical Amplifier (EDFA), Raman Amplifier (RAMAN) and Semiconductor Optical Amplifier (SOA) – located in the OLT is possible. These optical amplifiers have various features and characteristics and different values of the optical amplification (gain). Options of appropriate optical amplifiers type are depending on specified network configurations. In a case of mismatched network configuration or/and parameters setting, error messages are presented in the bottom part of the LR-PON configuration window (Fig. 3). A summary of selected parameters for mentioned optical amplifiers is introduced in Table 1.

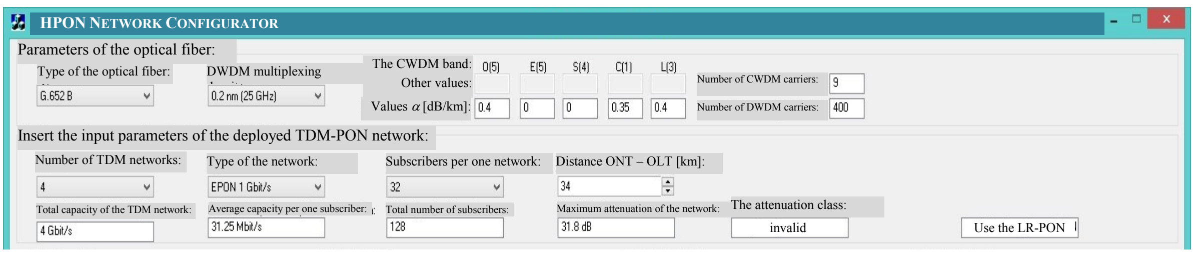

Figure 4: The window with the EPON input parameters.

Table1: Parameters of optical amplifiers in the LR-PON networks.

Features	EDFA	Raman	SOA
Gain [dB]	up to 35	up to 25	up to 30
Wavelength band [nm]	1530 – 1560	1280 – 1650	1280 – 1650
Noise figure [dB]	5	5	8
Cost	medium	high	low

4 RESULTS OF SIMULATION EXPERIMENTS

For higher layers of the OSI model, there exist different implementations for deployed TDM-PON networks. First, the GPON (Gigabit-capable PON) option based on the FSAN initiative was standardized as the ITU G.984 in 2003 (ITU-T, 2008). Second, the EPON (Ethernet PON) option independent on previous one based on the Ethernet protocol was standardized as the IEEE 802.3ah in 2004 (IEEE, 2004). The GPON works with higher downstream/upstream rates than the EPON, moreover has better network performance relationships for connecting higher number of subscribers and for longer distances.

Latter recommendations are IEEE 802.3av (IEEE, 2009) and ITU-T G.987 (ITU-T, 2010, 2012). The 10G-EPON works at 10 Gbit/s rates. Besides another features, various attenuation classes are defined for higher splitting ratios and for longer distances. Depending on selected attenuation classes, demands for the optical laser in the OLT and receivers in ONUs are specified for the downstream signal transmission. Reciprocally, options for utilization of optical lasers in ONUs and the receiver in the OLT are characterized for the upstream signal transmission.

The XG-PON also works at 10 Gbit/s rates. Besides another features, changes of attenuation classes comparing to the GPON are realized due to overrun original attenuation classes by using the WDM filter and different wavelengths. There are standardized 2 Nominal attenuation classes and 2 Extended attenuation classes.

Except above-mentioned case with the higher splitting ratio of subscribers, options for configuration of other hybrid passive optical networks - WDM/TDM PON, SUCCESS HPON and SARDANA HPON - are automatically deactivated also in a case of overrunning the maximum network attenuation value. This value is depending on the optical fibers' type, the network type, a number of subscribers and the OLT-ONT distance. Also for this case, only a challenge for the Long Reach PON configuration is appearing. On Fig. 4, we can see a cut-out from the main window of the HPON Network Configurator with EPON input parameters for the deployed TDM-PON network.

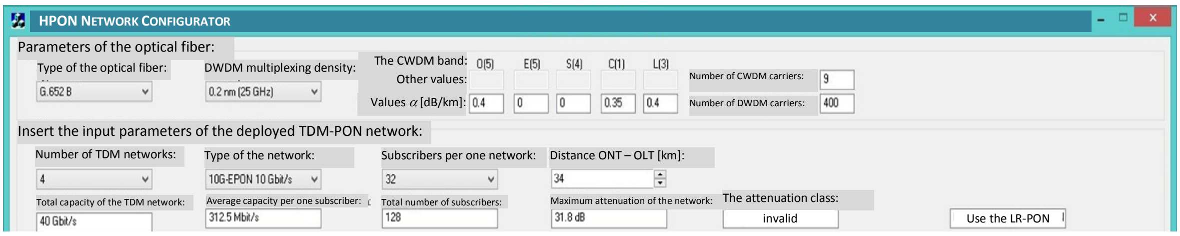

Figure 5: The window with the 10G-EPON input parameters.

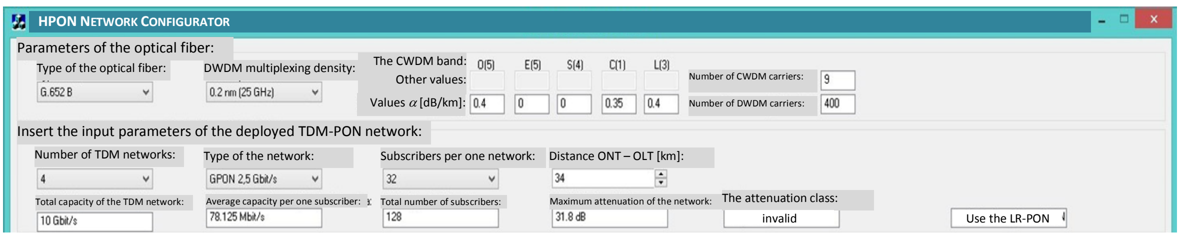

Figure 6: The window with the GPON input parameters.

Affiliated with these parameters, limits of exploitation for the LR-PON are presented on Fig. 8, where the blue line is reserved for the G. 652 A optical fiber and the red line is assigned for others (G. 652 B, G. 652 C, G. 652 D, G. 656, G. 657) with identical attenuation values.

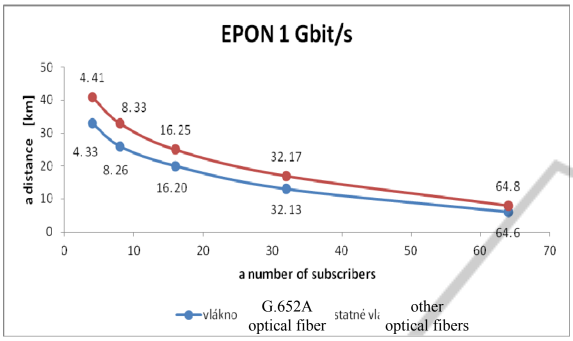

Figure 8: Limits for the Long Reach PON utilization for the EPON 1 Gbit/s.

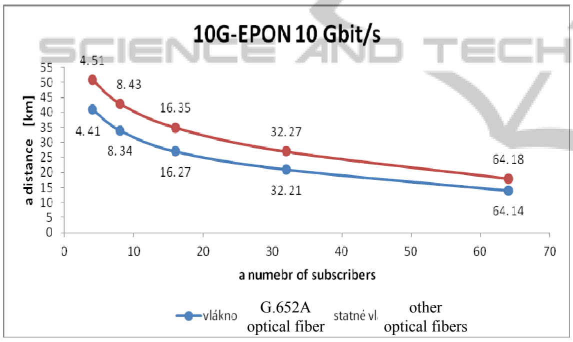

Figure 9: Limits for the Long Reach PON utilization for the 10G-EPON 10 Gbit/s.

In a case of the 10G-EPON network, affiliated with its input parameters (Fig. 5), limits of exploitation for the LR-PON are presented on Fig. 9. As can be seen, distances are longer than at the EPON due to adapted attenuation classes of the latter10G-EPON network in spite of its higher transmission rates.

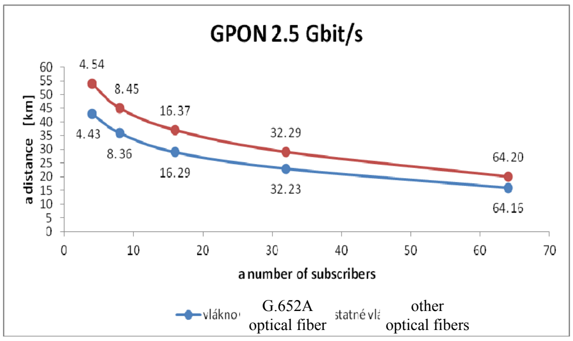

Figure 10: Limits for the Long Reach PON utilization for the GPON 2,5 Gbit/s.

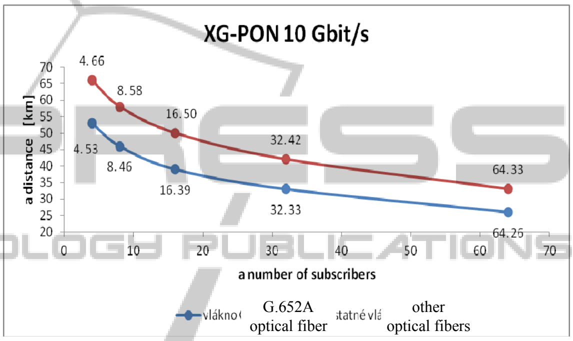

Figure 11: Limits for the Long Reach PON utilization for the XG-PON 10 Gbit/s.

In a case of the GPON network, affiliated with its input parameters (Fig. 6), of exploitation for the LR-PON are presented on Fig. 10. As can be seen, distances are longer than at the EPON due to better performance relationships of the GPON network in spite of its higher transmission rates.

In a case of the XG-PON network, affiliated with its input parameters (Fig. 7), limits of exploitation for the LR-PON are PON are presented on Fig. 11. As can be seen, distances are the longest between considered implementations of the deployed TDM-PON network due to more precisely adapted attenuation classes in spite of its higher transmission rates.

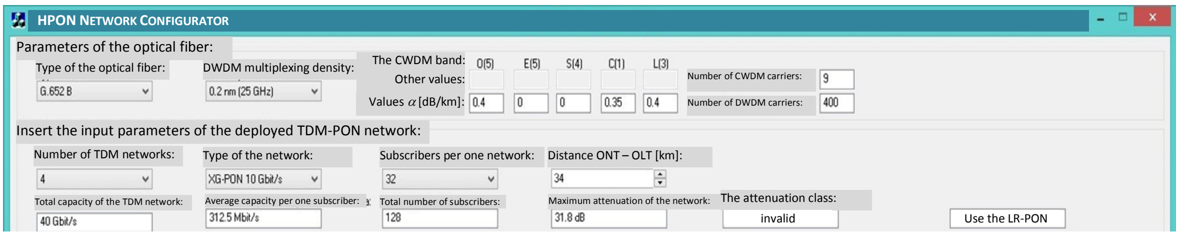

Figure 7: The window with the XG-PON input parameters.

On Fig. 12, a comparison of limits for employment of the Long Reach PON is presented for particular PON networks and for various types of optical fibers.

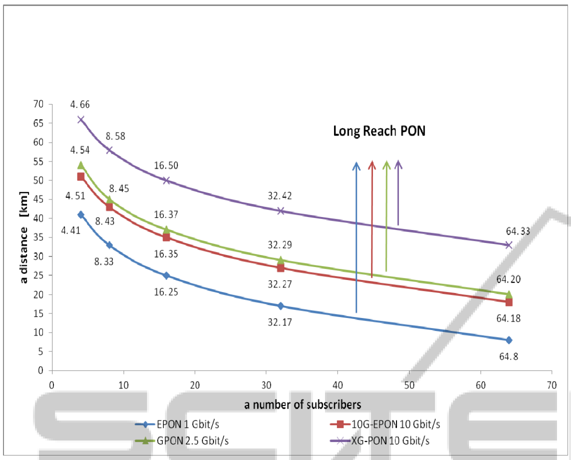

Figure 12: The comparison of limits for the Long Reach PON utilization for particular PON networks.

5 CONCLUSIONS

For given environment of the LR-PON networks, different implementations for higher layers of the OSI model in the deployed TDM-PON network were compared. From presented results, the XG-PON network with the 10 Gbit/s transmission rates can reach qualitative better values. However, using of concrete implementation (EPON, 10G-EPON, GPON, XG-PON) for higher layers is depending on many factors, for example the distance between OLT and particular ONUs in km, the total number of subscribers, the maximum attenuation of the network and the attenuation class.

6 FUTURE WORK

In the near future, possibilities of the HPON Network Configurator will be expanded into the area of mutual comparison for deployed optical components and possible expansions of four probable scenarios of hybrid passive optical networks. Moreover, extensions related with the traffic protection and restoration for each particular HPON network type will be proposed and prepared.

Inseparable part of the future work is searching for appropriate and competent results of scientific and industrial projects for preparing valuable comparative evaluation.

ACKNOWLEDGMENT

This work is a part of research activities conducted at Slovak University of Technology Bratislava, Faculty of Electrical Engineering and Information Technology, Institute of Telecommunications, within the scope of the project KEGA No. 039STU-4/2013 “Utilization of Web-based Training and Learning Systems at the Development of New Educational Programs in the Area of Optical Transmission Media”.

REFERENCES

Róka, R., May 2012. Fixed Transmission Media. In: *Technology and Engineering Applications of Simulink, InTech, Rijeka (Croatia), ISBN 978-953-51-0635-7.*

Peťko, L., October 2012. G-PON Migration to New Technologies. In: *OK 2012 - 15th Conference and Exhibition on Optical Communications, Praha (Czech Republic), ISBN 978-80-86742-36-6.*

An, F. et al., November 2005. SUCCESS-HPON: A Next-Generation Optical Access Architecture for Smooth Migration from TDM-PON to WDM-PON. In: *IEEE Communications Magazine, Vol.43, No.11, pp. S40-S47.*

Kazovsky, L., 2011. Broadband optical access networks: emerging technologies and optical-wireless convergence. In: *Wiley-Interscience, Hoboken, N.J. ISBN 978-047-0182-352.*

Róka, R., 2014. Broadband NG-PON Networks and their Designing using the HPON Network Configuration. In: *Convergence of Broadband, Broadcast and Cellular Network Technologies, IGI Global - in the printing process.*

Lazaro, J. et al., 2008. Scalable Extended Reach PON, Optical Fiber Communication. In: *OFC/NFOEC 2008 - National Fiber Optic Engineers Conference, pp. 1-3.*

Prat, J. et al., 2009. Passive Optical Network for Long-reach Scalable and Resilient Access. In: *ConTEL 2009 - 10th International Conf. on Telecommunications, pp. 271-275.*

Róka, R., August 2011. The Extension of the HPON Network Configurator at Designing of NG-PON Networks. In: *TSP 2011 – 34th International Conference on Telecommunications and Signal Processing. Budapest (Hungary), pp. 79-84, ISBN 978-1-4577-1409-2.*

Róka, R., June 2012. The Designing of NG-PON Networks Using the HPON Network Configuration. In: *Journal of Communication and Computer JCC, Vol.9, No.6, pp. 669-678, print ISSN 1548-7709, online ISSN 1930-1553.*

Róka, R., September 2013. Analysis of Hybrid Passive Optical Networks using the HPON Network Configurator, In: *INTECH 2013 – International Conference on Innovative Technologies. Budapest (Hungary), pp. 401-404, ISBN 978-953-6326-88-4.*

Róka, R., Special Issue 2013. The Analysis of SUCCESS HPON Networks using the HPON Network Configurator. In: *Advances in Electrical and Electronic Engineering AEEE, Vol.11, No.5, pp. 420-425, ISSN 1336-1376, E-ISSN 1804-3119.*

Róka, R., December 2013. The Analysis of SARDANA HPON Networks using the HPON Network Configurator. In: *Advances in Electrical and Electronic Engineering AEEE, Vol.11, No.6, pp. 522-527, ISSN 1336-1376, E-ISSN 1804-3119.*

ITU-T Recommendation G.984.1, March 2008. *Gigabit-capable passive optical networks (GPON) - General characteristics.*

IEEE Standard 802.3ah, 2004. *Telecommunications and information exchange between systems - Local and metropolitan area networks— Specific requirements - Part 3: CSMA/CD Access Method and Physical Layer Specifications Amendment.*

IEEE Standard 802.3av, 2009. *Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements Part 3: CSMA/CD Access Method and Physical Layer Specifications Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks*.

ITU-T Recommendation G.987.1, April 2012. *10-Gigabit-capable passive optical networks (XG-PON) - General requirements.*

ITU-T Recommendation G.987.2, October 2010. *10-Gigabit-capable passive optical networks (XG-PON) - Physical media dependent (PMD) layer specification.*