

# THE ANALYSIS OF SARDANA HPON NETWORKS USING THE HPON NETWORK CONFIGURATOR

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**Abstract.** NG-PON systems present optical access infrastructures to support various applications of the many service providers. In the near future, we can expect NG-PON technologies with different motivations for developing of HPON networks. The HPON is a hybrid passive optical network in a way that utilizes on a physical layer both TDM and WDM multiplexing principles together. The HPON network utilizes similar or soft revised topologies as TDM-PON architectures. In this second paper, requirements for the SARDANA HPON networks are introduced. A main part of the paper is dedicated to presentation of the HPON network configurator that allows configuring and analyzing the SARDANA HPON characteristics from a viewpoint of various specific network parameters. Finally, a short introduction to the comparison of the SARDANA and SUCCESS HPON networks based on simulation results is presented.

## Keywords

*HPON network configurator, hybrid passive optical networks, SARDANA HPON.*

## 1. Introduction

NG-PON technologies can be divided into two categories. The NG-PON1 presents an evolutionary growth with supporting the coexistence with the GPON on the same ODN. The coexistence feature enables seamless upgrade of individual customers on live optical fibers without disrupting services of other customers. The NG-PON2 presents a revolutionary change with no requirement in terms of coexistence with the GPON on the same ODN.

The HPON presents a hybrid network as a necessary phase of the future transition from TDM to WDM passive optical networks [1]. It can be divided into two

possible groups. In the first one, a change of OLT and ONU equipment is executed and adding of WDM and TDM ONU equipment into a common network architecture is allowed by using specialized remote nodes that utilize either power splitters or AWG elements. In the second one, preservation of TDM access networks combined with the DWDM technique is predicted. For both approaches, various solutions were proposed.

At the SARDANA (Scalable Advanced Ring-based passive Dense Access Network Architecture) design [2], [3], [4], a scope is to create a modular network and to enable service provisioning for more than 1000 subscribers at distances up to 100 km. It is considered a remote pumped amplification using EDFA principles and utilization of the colourless 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 colourless, they don't contain any optical source. Transmitting from the ONU is based on the RSOA by means of the re-modulation of received signals. The SARDANA network allows connecting a large number of subscribers either on smaller distances in populous urban areas or in larger geographical areas with a small population. Information can be found in [5].

## 2. Simulation of HPON Networks

Our simulation model for comparing possibilities of various passive optical access networks is created by using the Microsoft Visual Studio 2008 software in the

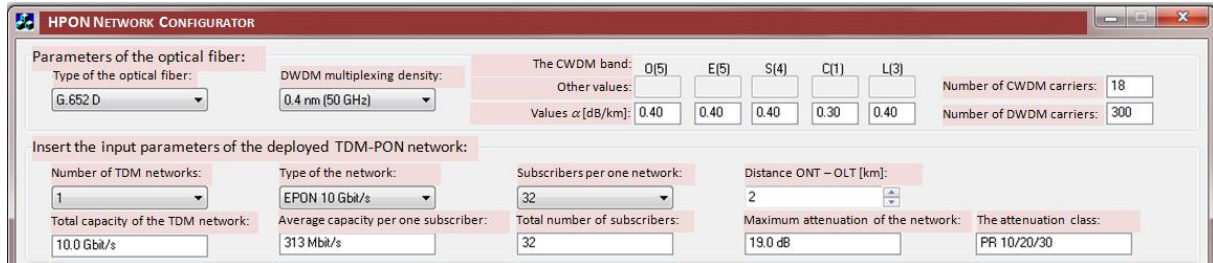


Fig. 1: The cut-out from the main window of the HPON network configurator.

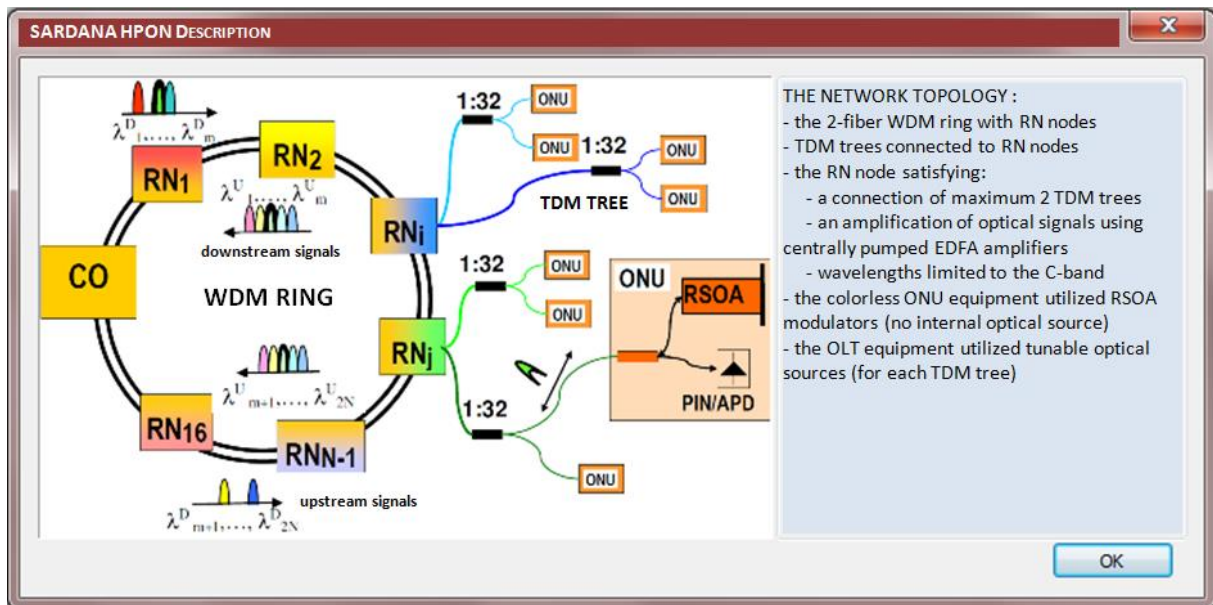


Fig. 2: The description window of the SARDANA HPON network.

IDE development environment [6], [7], [8], [9]. There exist possibilities for the graphical interface created by using the MFC (Microsoft Foundation Class) 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 configurator is shown on Fig. 1.

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 of 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 [8]. Then, a specification of parameters and features of the deployed TDM-PON network can be executed. More detailed information can be found in [10].

Three additional dialogue windows with a basic network scheme and short descriptions serve for the specific HPON configuration setup. The description window with the SARDANA HPON network topology is presented on Fig. 2. For presentations of GIF animations related to the SARDANA HPON, a free available CPictureEx class is used [11].

The HPON Configurator allows to simulate and analyze a transition from TDM-PON networks to HPON networks and to compare three different approaches to hybrid networks. After inserting input parameters of TDM-PON networks, these parameters are evaluated and 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 are calculated and presented. After configuration the SARDANA HPON network, a number and type of used active and passive components with possibilities for future expanding are presented.

### 3. Design of the SARDANA HPON Network

The SARDANA network architecture is created by the two-fiber ring with connected remote nodes RN

that ensure bidirectional signal amplification and dropping/adding of DWDM wavelengths for particular TDM trees. There is a possibility for connection of 2 TDM trees to 1 RN, so a total number of utilized wavelengths (and thus also TDM trees) is double of a number of remote nodes. A transmission in both directions is limited to the C-band due to the operational bandwidth of used EDFA amplifiers. A number of joinable TDM trees is derived from the density of DWDM channel spacing and from a derivable number of wavelengths in the C-band. At the network deployment, a support for the 1G (EPON, GPON) and 10G (10G-EPON, XG-PON) recommendation is expected.

The interactive window with the SARDANA HPON configuration is presented on Fig. 3.

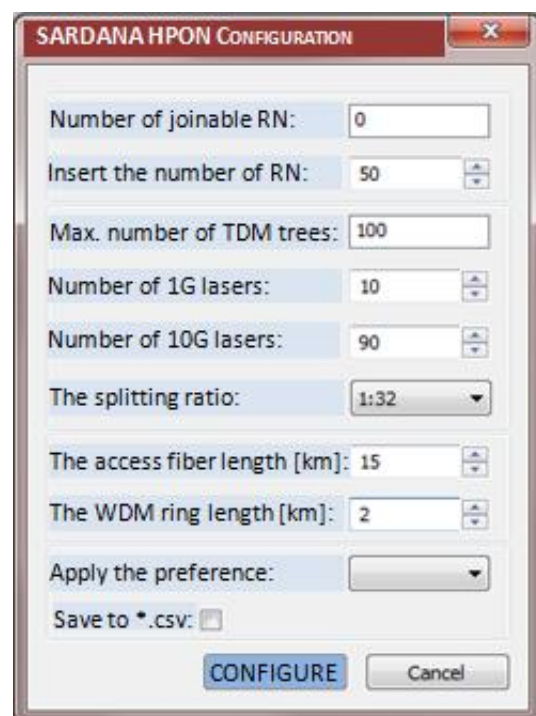


Fig. 3: The configuration window of the SARDANA HPON network.

At the configuration, it is possible to set network parameters manually or by using default values from the Tab. 1 [12]. Variables are expressing the ring length LRING, the access fiber length LACCESS, a number of remote nodes N and the splitting ratio of power optical splitters K. These default values present model cases from populous areas (Urban) up to geographically large areas (Rural).

The HPON configurator allows a calculation of the total number of subscribers U given by following relation:

$$U = 2.N.K \quad (1)$$

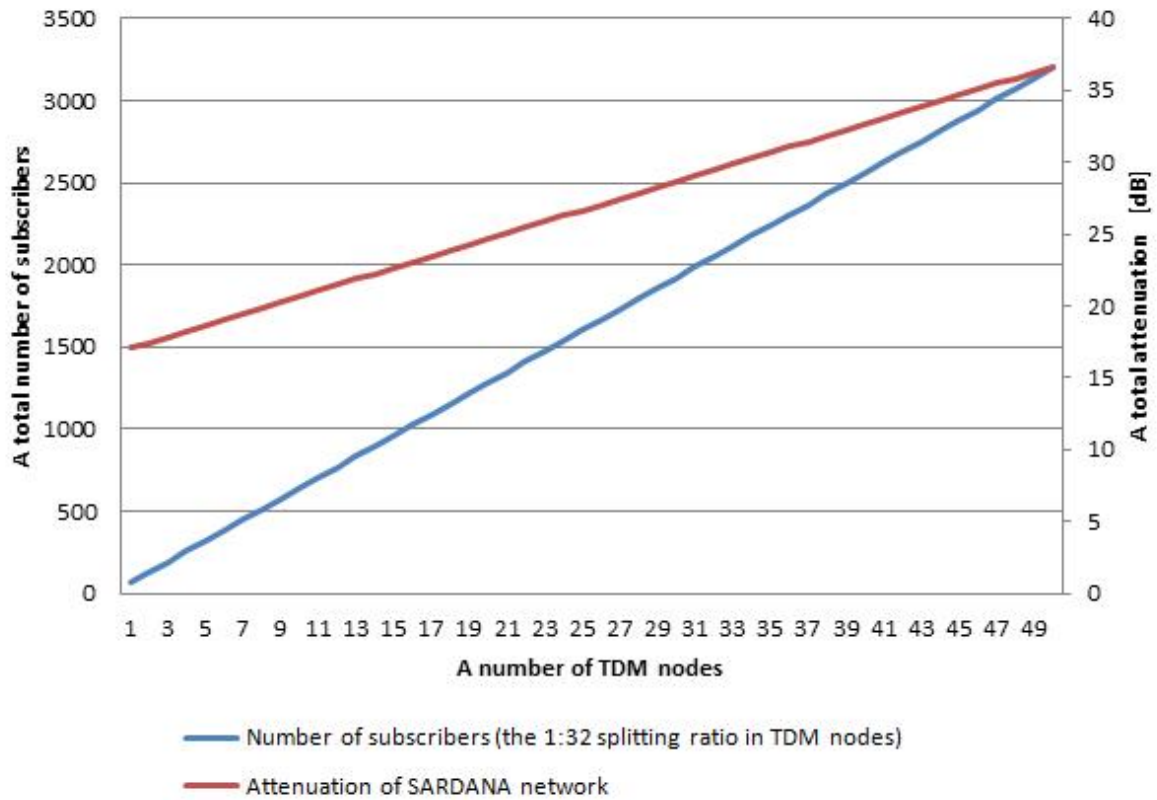


Fig. 4: Characteristics of the SARDANA HPON network for the 1:32 splitting ratio.

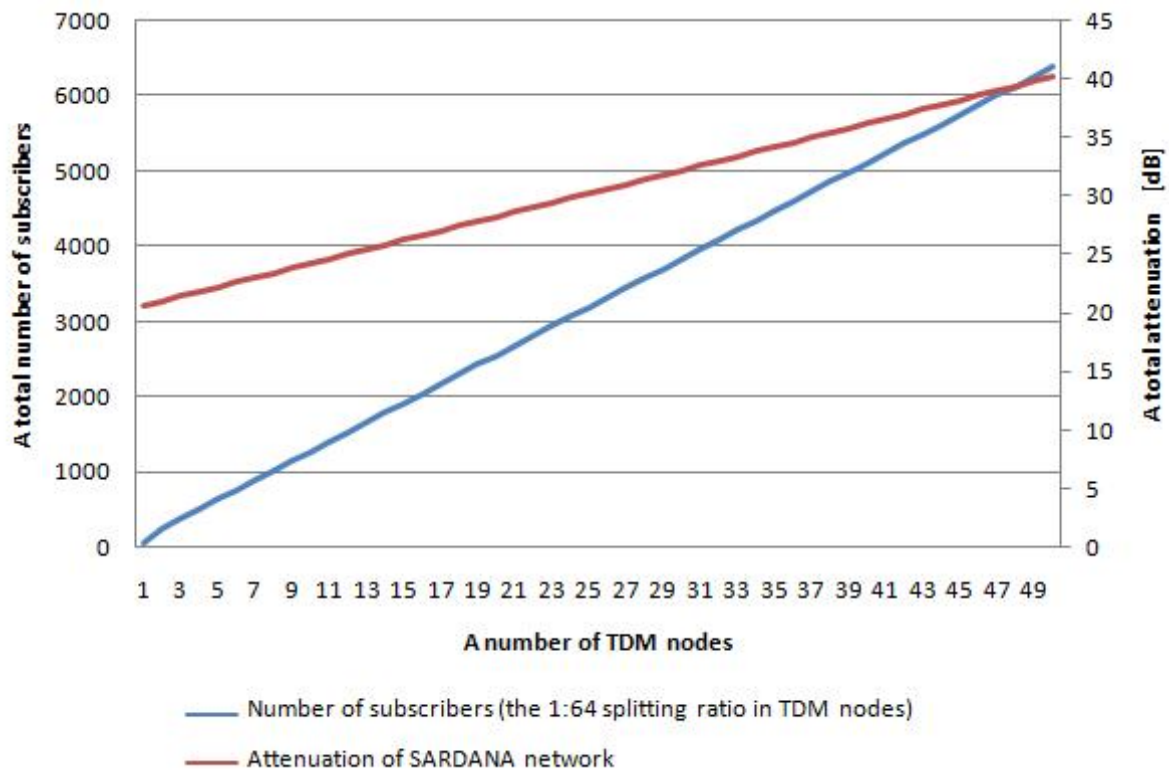


Fig. 5: Characteristics of the SARDANA HPON network for the 1:64 splitting ratio.

**Tab. 1:** Default values for model cases.

| Model case | $L_{RING}^*$<br>[km] | $L_{ACCES}^*$<br>[km] | N  | K      |
|------------|----------------------|-----------------------|----|--------|
| Urban 1    | 17                   | 3                     | 16 | 1 : 64 |
| Urban 2    | 10                   | 10                    | 16 | 1 : 32 |
| Metro      | 50                   | 10                    | 8  | 1 : 32 |
| Rural      | 80                   | 20                    | 8  | 1 : 16 |

**Tab. 2:** Maximum values of network subscribers based on the DWDM spacing and the splitting ratio.

| The splitting ratio K |    | 1:16         | 1:32 | 1:64 |
|-----------------------|----|--------------|------|------|
| DWDM spacing<br>[nm]  | N  | TDM<br>trees | U    | U    |
| 0,8                   | 12 | 24           | 384  | 768  |
| 0,4                   | 25 | 50           | 800  | 1600 |
| 0,2                   | 50 | 100          | 1600 | 3200 |

where  $K$  is the splitting ratio of power optical splitters and  $N$  is a number of remote nodes. A maximum number of joinable remote nodes  $N$  is depending on the DWDM multiplexing type (Tab. 2).

For this presentation, following parameters were selected: the ITU-T G.652 D optical fiber, the 0,2 nm DWDM channel spacing, the ring length 15 km, the access fiber length 2 km. A calculation of the total network attenuation comes out from features of components utilized in remote nodes, a number of remote nodes, a type of couplers and characteristics of the selected optical fiber. Following graphs (Fig. 4 and Fig. 5) represent dependencies of the total number of subscribers and the attenuation on the number of remote nodes in the connected network.

The SARDANA is a modular network with possibilities for connecting a large number of subscribers at acceptable attenuation values. These can be reached by placing of centrally pumped optical amplifiers into remote nodes. By this way, it is possible to increase a reach up to 30 km compared with common PON networks without utilization of the optical amplification. For a specific type of the EDFA amplifiers, the gain can be determined from minimum 10 dB to higher values in the simulation program. In a real network, gain values can be accommodated according to the length of optical fibers and to power characteristics of pumped lasers. The hybrid SARDANA network combines features of metropolitan and access networks to acquire maximum utilization of current technologies.

A comparison of two hybrid passive optical networks – SARDANA and SUCCESS - from various viewpoints will be presented in [10].

## 4. Conclusion

Hybrid passive optical networks HPON presents the intermediate between TDM and WDM-PON networks

with two different purposes/approaches. The first one is a creating of the network combining TDM and WDM-PON elements in order to increase a number of subscribers and a reach. The second one is an occasion for a smooth transition from TDM-PON to WDM networks without violation of service provisioning for original TDM subscribers.

In the HPON network configurator, some new features for the SARDANA HPON networks were prepared – the selection of transmission parameters utilized optical fibers, various wavelengths spacing at the DWDM multiplexing, a list of available transmission channels for DWDM and CWDM multiplexing, the presentation of available attenuation classes for the original TDM network. At the SARDANA configuration, it is not possible to select or insert incorrect values. For this case, a reason of actual limitation is presented.

Based on output values from this configuration program, it is possible to evaluate various different approaches for building hybrid passive optical networks and to compare them from many usable aspects – a number of subscribers, maximum reaches and transmission rates, optical components and technologies.

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## References

- [1] PETKO, Ladislav. G-PON Migration to New Technologies. In: *OK 2012 – 15th Conference and Exhibition on Optical Communications*. Praha: ActionM, 2012. ISBN 978-80-86742-36-6.
- [2] LAZARO, J. A., J. PRAT, P. CHANCLOU, G. M. Tosi BELEFFI, A. TEIXEIRA, I. TOMKOS, R. SOILA and V. KORATZINOS. Scalable Extended Reach PON. In: *OFC/NFOEC 2008 - 2008 Conference on Optical Fiber Communication/National Fiber Optic Engineers Conference*. San Diego: IEEE, 2008, pp. 1–3. ISBN 978-1-55752-856-8. DOI: 10.1109/OFC.2008.4528488.
- [3] PRAT, J., J. A. LAZARO, P. CHANCLOU, R. SOILA, P. VELANAS, A. TEIXEIRA, G. TOSI

- BELEFFI, I. TOMKOS, K. KANONAKIS. Passive Optical Network for Long-reach Scalable and Resilient Access. In: *ConTEL 2009. 10th International Conference on Telecommunications*. Zagreb: IEEE, 2009, pp. 271–275, ISBN 978-953-184-130-6 .
- [4] KAZOVSKY, Leonid G. *Broadband Optical Access Networks*. Hoboken: John Wiley, 2011. ISBN 978-0-470-18235-2.
- [5] PETER, Juraj. *The Analysis of the Hybrid PON Utilization in the Optical Access Network*. Bratislava, 2012. Diploma Thesis. Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava.
- [6] ROKA, Rastislav. The Designing of Passive Optical Networks using the HPON Network Configurator. *International Journal of Research and Reviews in Computer Science IJRRCS*. 2010, vol. 1, no. 3, pp. 38–43, ISSN 2079-2557.
- [7] ROKA, Rastislav. The extension of the HPON network configurator at designing of NG-PON networks. In: *34th International Conference on Telecommunications and Signal Processing (TSP 2011)*. Budapest: IEEE, 2011, pp. 79–84. ISBN 978-1-4577-1410-8. DOI: 10.1109/TSP.2011.6043768.
- [8] ROKA, Rastislav. The Designing of NG-PON Networks Using the HPON Network Configuration. *Journal of Communication and Computer JCC*. 2012, vol. 9, no. 6, pp. 669–678. ISSN 1548-7709.
- [9] ROKA, R. and S. KHAN. The Modeling of Hybrid Passive Optical Networks using the Network Configurator. *International Journal of Research and Reviews in Computer Science IJRRCS*. 2011 - Special Issue, pp. 48–54, ISSN 2079-2557.
- [10] ROKA, Rastislav. Analysis of Hybrid Passive Optical Networks using the HPON Network Configurator. In: *INTECH 2013 – International Conference on Innovative Technologies*. Budapest: INTECH International Conference on Innovative Technologies, 2013, pp. 401–404, ISBN 978-953-6326-88-4.
- [11] BYKOV, O. Code Project. *The CPictureEx Class* [online]. 2001. Available at: <http://www.codeproject.com/Articles/1427/Add-GIF-animation-to-your-MFC-and-ATL-projects-wit>.
- [12] JONG HOON LEE, KI-MAN CHOI, JUNG-HYUNG MOON and CHANG-HEE LEE. Seamless Upgrades From a TDM-PON With a Video Overlay to a WDM-PON. *Journal of Lightwave Technology*. 2009, vol. 27, iss. 15, pp. 3116–3123. ISSN 0733-8724. DOI: 10.1109/JLT.2008.2006861.

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**Rastislav ROKA** was born in Sala, Slovakia on January 27, 1972. He received his M.Sc. and Ph.D. degrees in Telecommunications from the Slovak University of Technology, Bratislava, in 1995 and 2002. Since 1997, he has been working as a senior lecturer at the Institute of Telecommunications, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava. Since 2009, he is working as an associated professor at this institute. At present, his research activity is focused on the signal transmission through metallic access networks by means of xDSL/PLC technologies and through optical transport and access networks by means of WDM and TDM technologies using various techniques of the optical signal processing. A main effort is dedicated to effective utilization of the optical fiber's transmission capacity by using DBA/DWA algorithms.