

THE ANALYSIS OF SUCCESS 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 first paper, design requirements for SUCCESS 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 SUCCESS HPON characteristics from a viewpoint of various specific network parameters. Finally, a short introduction to the comparison of the SUCCESS and SARDANA HPON networks based on simulation results is presented.

Keywords

HPON network configurator, hybrid passive optical networks, SUCCESS HPON.

1. Introduction

NG-PON systems present optical access infrastructures to support various applications of the many service providers. 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. In the near future, we can expect NG-PON technologies with different motivations for developing 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.

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

The HPON presents a hybrid network as a necessary phase of the future transition from TDM to WDM passive optical networks [1]. Hybrid passive optical networks can be divided into two possible groups. In this paper, we focus on the first one where a change of OLT and ONU equipment is executed and adding of both (WDM and TDM) ONU equipment into a 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 aCESS) HPON can be presented [2], [3]. The SUCCESS HPON network introduces a sequential transition to the pure WDM PON network in 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 DWDM wavelengths; however the TDM ONU transmits signals on CWDM wavelengths. This architecture allows provisioning WDM services at preservation of the backward compatibility with initial/original TDM

subscribers. The exchange of the TDM ONU is necessary. Information can be found in [4].

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 IDE development environment [5], [6], [7], [8]. 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 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 [7]. Then, a specification of parameters and features of the deployed TDM-PON network can be executed. More detailed information can be found in [9].

Three additional dialogue windows with a basic network scheme and short descriptions serve for the specific HPON configuration setup. The interactive window with the SUCCESS HPON description is presented on Fig. 2. For the SUCCESS HPON, a transition is expressed by interactive GIF animations. For their presentation, a free available CPictureEx class is used [10].

The HPON configurator allows simulating and analyzing 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 cal-

Tab. 1: The selection from specifications of HPON optical components.

Symbol	Description	Value
a_{FILTER}	the WDM filter	0, 4 dB
a_{AWG}	the AWG element	5 dB
$a_{50:50}$	the 50:50 power splitter	4, 4 dB
$a_{SPLIT1:N}$	the 1:16 splitter attenuation	14, 1 dB
	the 1:32 splitter attenuation	17, 4 dB
	the 1:64 splitter attenuation	21, 0 dB
a_{TDM-RN}	the TDM node attenuation (including connectors)	1, 5 dB
a_{WDM-RN}	the WDM node attenuation (including connectors)	1 dB

culated and presented. After configuration the SUCCESS HPON network, a number and type of used active and passive components with possibilities for future expanding are presented.

In the HPON network, power relationships are depending on specific network characteristics and applied optical components' parameters. We prefer real attenuation values of optical components utilized in passive optical networks. Some of them are presented in Tab. 1, further optical components together with corresponding attenuation values are presented in [7], [9]. In addition to a distance between the OLT and particular ONU, a number and type of used splitters are included for calculating of the total attenuation for specific network configurations.

3. Design of the SUCCESS HPON Network

The SUCCESS HPON network [2] allows a coexistence of TDM and WDM technologies within one network infrastructure and provides a possibility of the smooth transition TDM subscribers to the WDM. At its architecture, it is possible to utilize up to 17 CWDM wavelengths in all bands for upstream transmitting in TDM stars, the 18th wavelength is utilized for the downstream signal transmission to TDM ONU-s using DWDM multiplexing (a number of wavelengths can be found in Tab. 2).

A distribution of CWDM and DWDM wavelengths in particular transmission bands is introduced in Tab. 2. DWDM wavelengths can be distributed in S-, C- or L-bands. The CWDM channel spacing is fixed to the 20 nm [11], the DWDM channel spacing is variable from 0,2 to 0,8 nm depending on the multiplexing density [12]. After selecting a specific density, the total number of possible DWDM channels is calculated. By decreasing DWDM channel spacing, a negative influence of nonlinear effects presented in the optical transmission medium will be more expressive in real optical transmission networks.

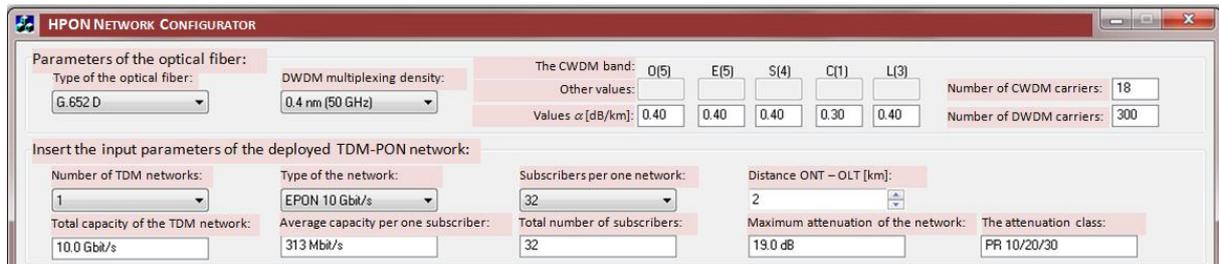


Fig. 1: The cut-out from the main window of the HPON network configurator.

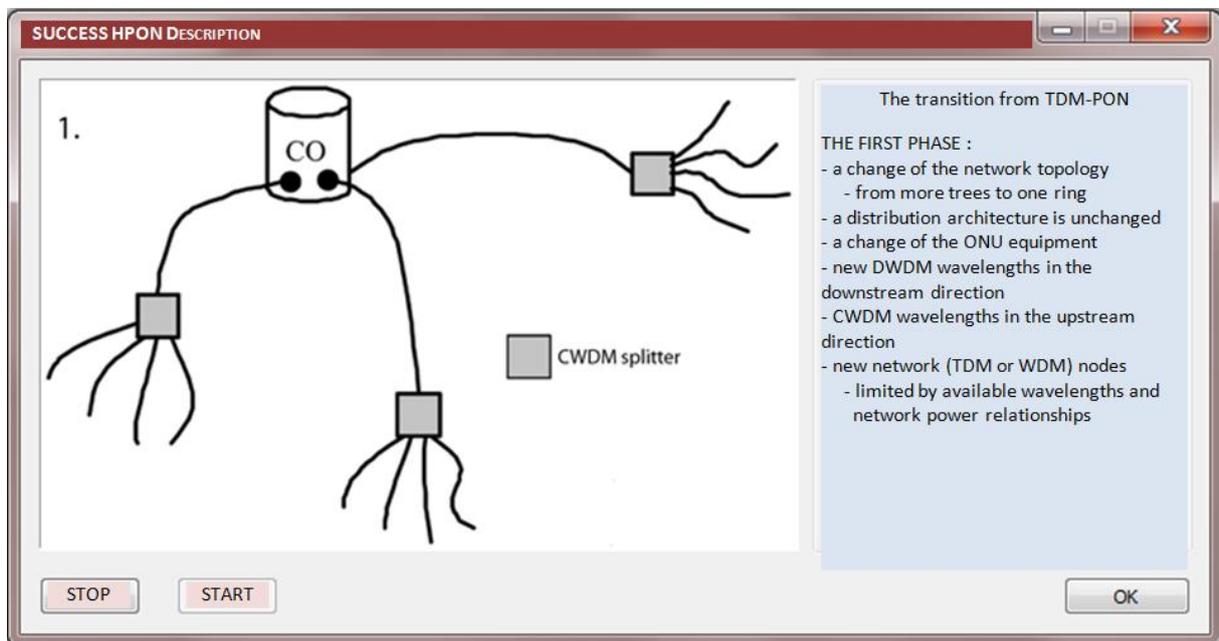


Fig. 2: The description window of the SUCCESS HPON network.

Tab. 2: Numbers of DWDM and CWDM wavelengths for particular transmission bands.

	O	E	S	C	L	SUM
	1260–1360 nm	1360–1460 nm	1460–1530 nm	1530–1565 nm	1565–1625 nm	Σ
DWDM (0,8 nm, 100 GHz)	-	-	50	25	75	150
DWDM (0,4 nm, 50 GHz)	-	-	100	50	150	300
DWDM (0,2 nm, 25 GHz)	-	-	200	100	300	600
CWDM (20 nm)	5	5	4	1	3	18

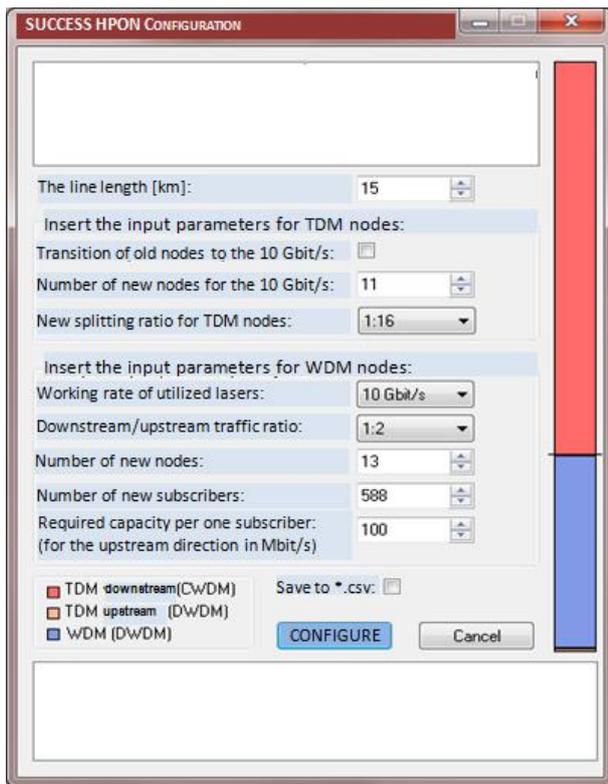


Fig. 3: The configuration window of the SUCCESS HPON network.

As a maximum, 17 TDM stars can be connected. The total number of DWDM wavelengths available for connecting WDM subscribers is decreased by a number of connected TDM nodes, one TDM node per one DWDM channel. In a case of the full DWDM bands availability, a maximum of possible joinable subscribers is acquiring. After connecting more than 11 TDM nodes, CWDM and DWDM bands are overlapping and a number of joinable WDM subscribers together with a total number of joinable subscribers are decreasing. The availability of DWDM and CWDM wavelengths is clearly and transparently displayed using graphical tools (Fig. 3).

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. Characteristics of the SUCCESS HPON configuration with the 1:64 splitting ratio in TDM nodes and utilizing available wavelengths at 25 GHz DWDM channel spacing are presented on Fig. 4. The total number of subscribers (1356) can be reached for 11 TDM nodes. However, as we can see, their attenuation values are exceeded 40 dB. For comparison, attenuation values of WDM nodes are also presented. At the 1:32 splitting ratio in TDM nodes, the total number of subscribers (972) is decreased with lower attenuation values 37,2 dB. At the 1:16 splitting ratio in TDM nodes, the total number of subscribers

(780) is also decreased with still inconvenient lower attenuation values 33,9 dB (Fig. 5).

At this architecture, a number of subscribers is limited by high values of the TDM node attenuation. This high attenuation is caused by longer optical fibers in the ring topology and by inserted losses particular nodes. A solution can be found by placing of optical amplifiers in the RN, however, with limiting utilizable spectral bands and reducing a number of joinable TDM nodes. Moreover, this solution changes a character of passive optical networks to active.

At the SUCCESS network, it is necessary to take into account lower splitting ratios than 1:64 and a smaller number of TDM nodes due to their higher attenuation values. In the SUCCESS network, it is possible to utilize all transmission bands supported by selected optical fibers. However, an adding of optical amplifiers into TDM nodes brings band restrictions. In the SUCCESS HPON, the CWDM multiplexing is utilized at the TDM transmission and this restriction is too high. In the C-band suitable for EDFA amplifications, only 1 TDM node is possible for connecting. In the SUCCESS HPON, WDM nodes have very low values of the attenuation because using AWG elements instead of power optical splitters.

The ring topology allows a selection of the transmitting direction depending on network power arrangement and provides a traffic protection against fiber or node failures.

A comparison of two hybrid passive optical networks – SUCCESS and SARDANA - from various viewpoints will be presented in [9].

4. Conclusion

The intermediate step between TDM and WDM-PON networks is presented by hybrid passive optical networks HPON. The HPON evolution allows using two different approaches. In the first approach, a network combining TDM and WDM-PON elements is created in order to increase a number of subscribers and a reach. In the second one, a smooth transition from TDM-PON to WDM networks is preferred without violation of service provisioning for original TDM subscribers.

In the HPON network configurator, some new features and upgrades for the SUCCESS HPON networks were prepared – the graphical presentation of available wavelength bands, more comfortable design and extension of utilized wavelengths.

Based on output values from this configuration program, it is possible to evaluate various different approaches for building hybrid passive optical networks

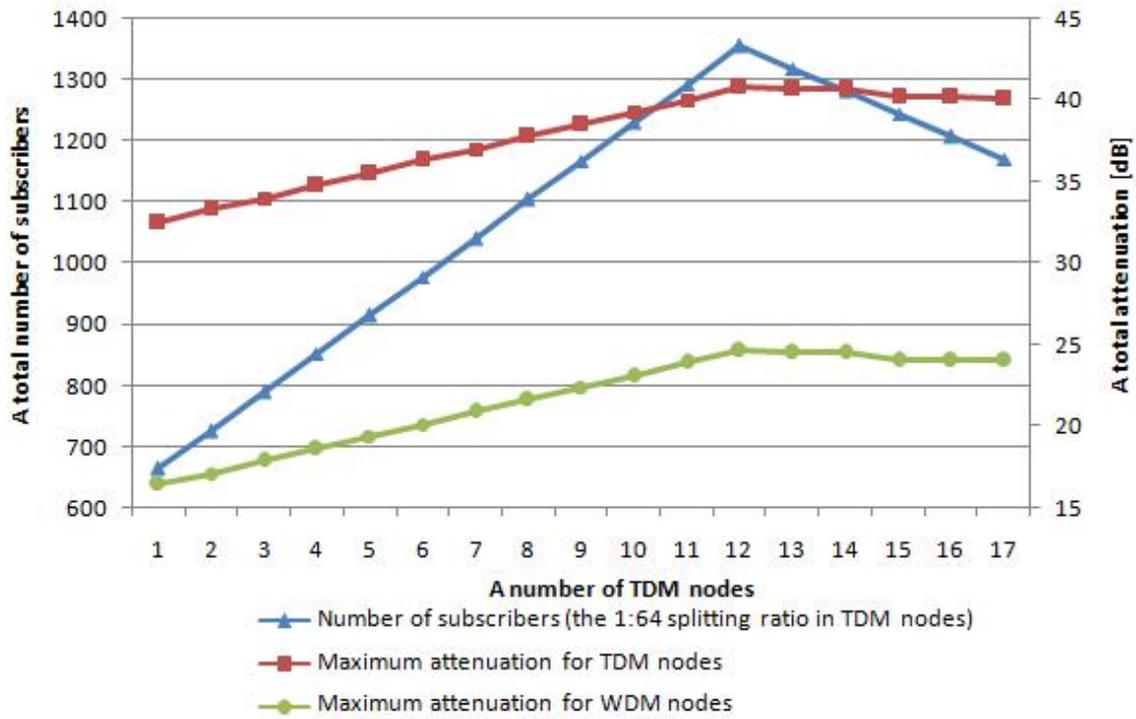


Fig. 4: Characteristics of the SUCCESS HPON network for the 1:64 splitting ratio.

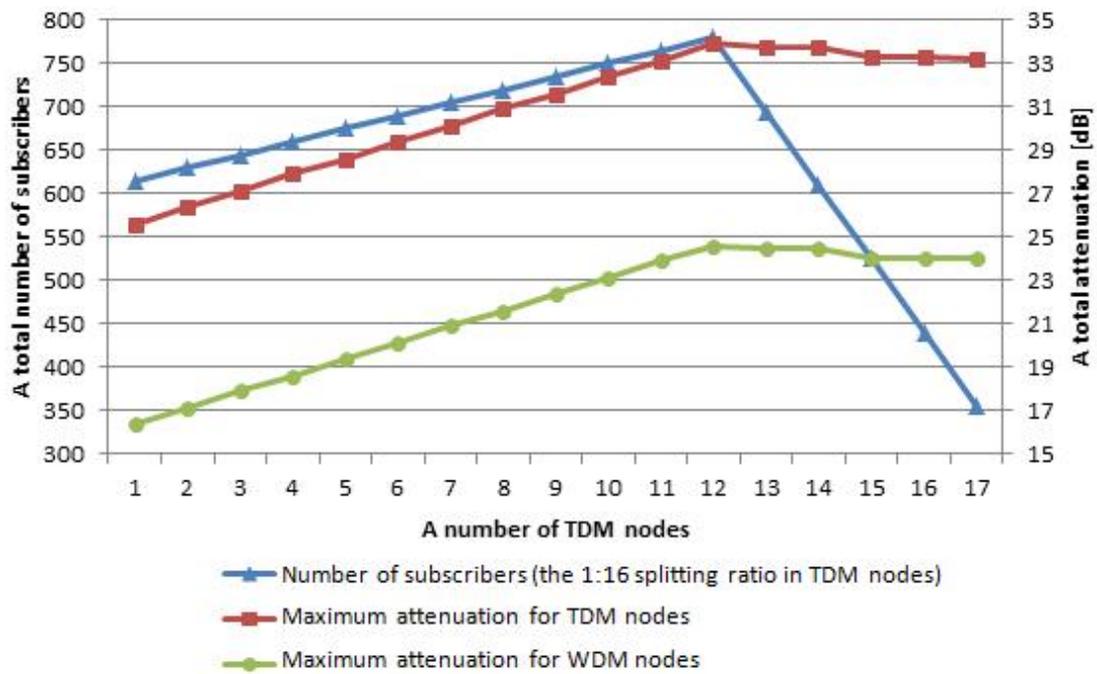


Fig. 5: Characteristics of the SUCCESS HPON network for the 1:16 splitting ratio.

and to compare them from many usable aspects – a number of subscribers, maximum reaches and transmission rates, optical components and technologies.

In these days, the HPON network configurator is not available to download for academic purposes (research). This possibility will be actual after solving the copyright and related rights.

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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] FU-TAI AN, D. GUTIERREZ, KYEONG SOO KIM, JUNG WOO LEE and L.G. KAZOVSKY. SUCCESS-HPON: A next-generation optical access architecture for smooth migration from TDM-PON to WDM-PON. *IEEE Communications Magazine*. 2005, vol. 43, iss. 11, pp. S40–S47. ISSN 0163-6804. DOI: 10.1109/MCOM.2005.1541698.
- [3] KAZOVSKY, Leonid G. *Broadband Optical Access Networks*. Hoboken: John Wiley, 2011. ISBN 978-0-470-18235-2.
- [4] 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.
- [5] 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.
- [6] 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.
- [7] 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.
- [8] 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.
- [9] ROKA, Rastislav. Analysis of Hybrid Passive Optical Networks using the HPON Network Configurator. In: *INTECH 2013 – International Conference on Innovative Technologies*. Budapest: INTECH, 2013, pp. 401–404, ISBN 978-953-6326-88-4.
- [10] 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>.
- [11] ITU-T Recommendation G.694.2. *Spectral grids for WDM applications: CWDM frequency grid*. Switzerland: ITU-T, 2002.
- [12] ITU-T Recommendation G.694.2. *Spectral grids for WDM applications: DWDM frequency grid*. Switzerland: ITU-T, 2002.

About Authors

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.