Converged Solutions for Next Generation Optical Access

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***Abstract* – This article considers the model of a hybrid passive optical network based on convergent solutions. In order to implement the concept of optical next-generation access to analyse options for building optical networks with OFDM. In order to increase capacity and address the shortcomings of OFDM it proposed to use the method of N-OFDM.**

Keywords: Passive Optical Network, Optical Distribution Network, Optical Access, DWDM, NGOA, N-OFDM, ODN, OFDM, WDM.

I. INTRODUCTION

As known [1], Passive Optical Networks (PON) contains several advantages: minimal use of active equipment; minimizing cabling infrastructure; low maintenance costs; ability to integrate with cable TV; sufficient scalability and density subscriber ports The dominant form of PON in Europe and North America is a Gigabit PON (GPON), and in Asia popular Ethernet PON (EPON) - part of the IEEE 802.3ah (EFM). Typically, PON has a tree topology. In the intermediate units of the tree passive optical splitters for branching ratio of 1:64 or even 1:128 are displayed.

Recently, there is a significant need to improve the capacity by increasing the number of PON subscribers, amount of video content and others. As a result, we can state the fact that existing approaches to classical PON organizations do not satisfy the world tendencies of development of optical access. One of the ways to improve access networks based on optical fibres is to create a hybrid PON, the use of technology "optics over the radio".

Objective: realization of the Concept of optical access next generation of convergent solutions based on "optics over the radio".

II. MAIN

In classical PON to transfer forward and backward using a single channel optical fibres, bandwidth is dynamically shared between subscribers, or two optical fibres – in the case of redundancy. Top-down flow (Downstream, DS) from the central site (Central Office, CO) to subscribers is at a wavelength of 1490 nm and 1550 for video signal in the band of radio frequencies (RF-video), the same as in the networks and cable channels. In up-flow (Upstream, US) from subscribers (wavelength – 1310 nm) resolve conflicts at the expense of arbitration protocols based protocols multiple access time division (Time Division Multiplex, TDMA). They have implemented bandwidth management features, quality of service and others. At the same time, an effective method of delivery, including in terms of cost, on top of existing infrastructure requires IPTV IP-multicast technology. IP-multicast replication makes it possible to allocate? one channel for each audience, in such a way to optimizing the capacity of access equipment. However, the rapid growth of video files on technology Over-the-Top (OTT) overloaded video sharing not only business, but also online. Because OTT – set of unicast, it is impossible to take advantage of efficiency of IP-multicast. Although there is no difference in connection speed between the subscribers of IPTV- or OTT-video channel, the bandwidth access network equipment is significantly overloaded when every spectator gets its own exclusive video channel. All this leads to finding new variations to increase bandwidth of access networks.

Within the concept of next-generation optical access (Next Generation Optical Access, NGOA) for existing PON provides the use of technologies that shown in fig. 1 [2]. Development of technologies for 10G PON and WDM-PON is designed to resolve the issue of restrictions on traffic volumes released. Among the main advantages of WDM-PON should be the following:

- Provide users with dedicated band (no distribution on a competitive basis);
- Signals to subscribers physically isolated;
- Effectively uses of optical fibres;
- Possible significant increase communication range (for example, using arrays of optical waveguides (Arrayed Waveguide Grating, AWG) with low loss instead inefficient in terms of losses in splitters for GPON standard budget of 28 dB can connect subscribers to a distance of about 80 km).

This technology is already showing strong performance in mobile applications (Long Term Evolution, LTE) and scale enterprises applications. With such characteristics "speed/distance" network operators can deliver GE-services to the enterprise without any active equipment between the CO and the end user. The characteristic result is significant savings in capital and operating expenses, as a traditional aggregation and transport nodes can be removed in the architecture of the network, and can be combined with CO (Fig. 2). For mobile LTE small transit waiting time WDM-PON and redundancy transport, combined in the same equipment, represents a very interesting solution with low total cost of ownership (Total Cost of Ownership, TCO).

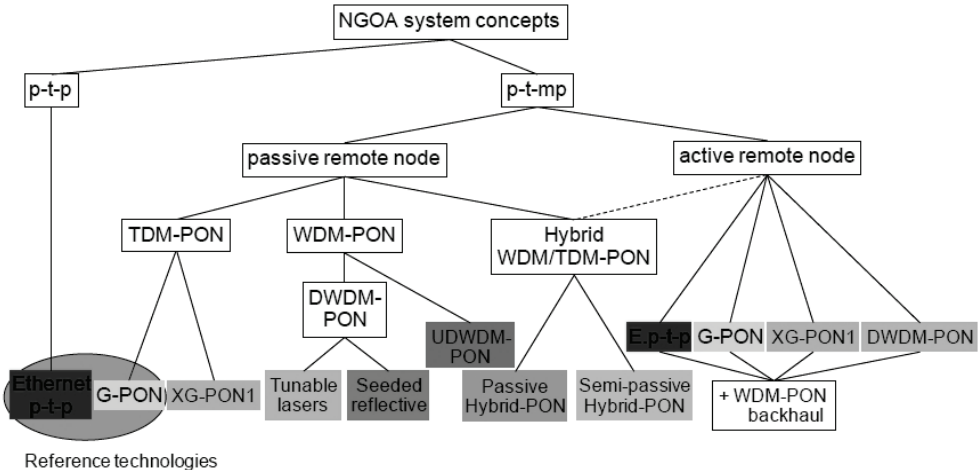

Fig. 1. The concept of NGOA

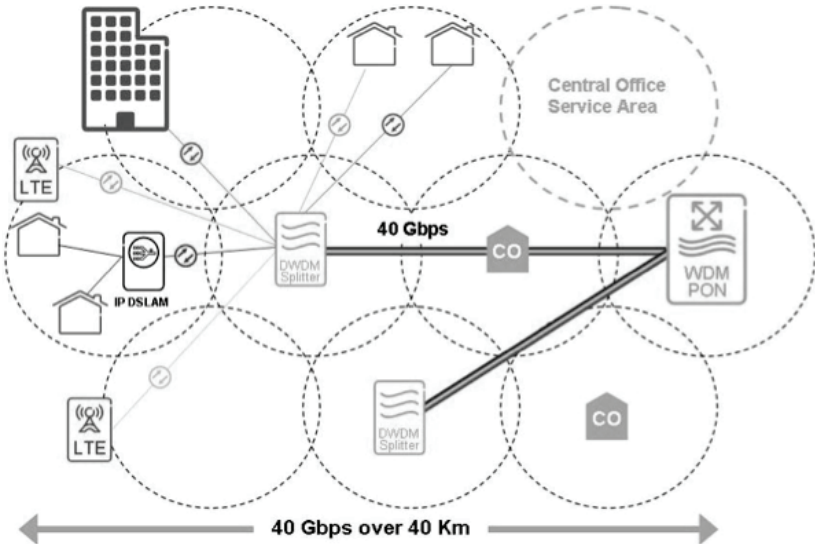

Fig. 2. Distribution units WDM-PON

For the implementation and management of WDM-PON, suitable for the network operator, "colourless" technology WDM-PON must be wool-applicable. This allows anyone to connect ONT where else to PON and automatically tune to the desired optical channel. Currently, there are three pending colourless WDM-PON technology:

- Remotely Seeded;
- Wavelength Reuse;
- Tunnel Lasers.

In turn, the organization "Full Service Access Network» (FSAN) [3] offers two ways of optimization: NG PON1 – for new technologies that are on the existing Optical Distribution Network (ODN); NG PON2 – for new technologies, working on existing ODN – as an option. According to the FSAN, NG PON2 project based on the following realization: with 40G TDM – 40G TDM-PON; PON with Wavelength Division Multiplexing (WDM) – WDM-PON; Orthogonal Frequency Division Multiplexing (OFDM) or variant OFDMA (possibility of dynamic allocation of sub-channels carrying or service users) – OFDMA PON; hybrid WDM-PON, for example: jointly with a 10G TDM.

During the analysis of perspective directions creation NGOA be considered basic:

- Development of technology WDM-OFDM-PON, that provide speed boost and expand coverage radius TDM-PON to 40-60 km;
- Development of converged solutions consolidated "radio over optics", energy/telecommunications, etc.

In optical telecommunication systems increased attention is given to OFDM as a means to overcome various limitations of fiber optic transmission systems (FOTS), for example: the impact of chromatic dispersion, the impact of polarization mode dispersion, the impact of phase self-modulation and others. That is, OFDM is a good candidate to improve the range and transmission speed. Well-known classic NRZ encoding format may not work at large distances at a speed of 10 Gbit/s and above. Compensation for chromatic dispersion along the length of path is sometimes uneconomical.

The OFDM with high information flow is divided into multiple low-speed sub-channels transmitted on orthogonal

bearing [4]. Option scheme of the OFDM signal or coded OFDM (SOFDM), based on the use of inverse fast Fourier transform (FFT), is shown in Fig. 3, 4. The condition of orthogonal sub-channels OFDM is a coincidence bearing with maximum response filters synthesized to the reception-side by the operation of the FFT signal sample. If as a physical channel serves optical carrier, it is modulated in intensity group information signal OFDM [5]. On the receiving side of the optical carrier reaches the photodetector, the load is released electrical group signal flow that comes after amplification in the decoder OFDM.

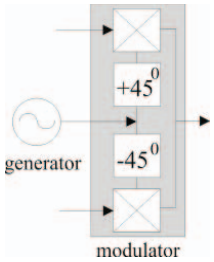

Fig. 3. The modulator for the scheme with decreased formation errors

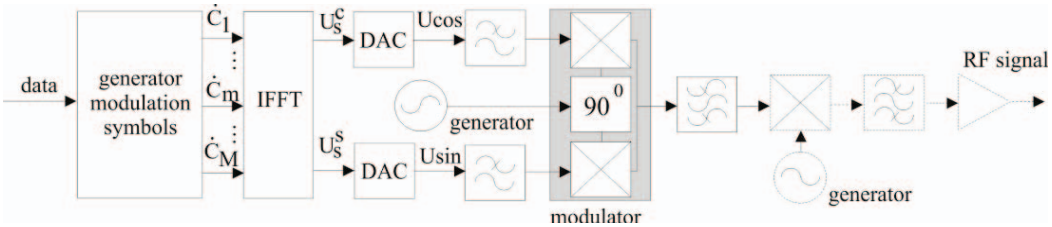

Fig. 4. Scheme of formation OFDM (SOFDM) for transferring party

Thus, modulation factor of optical radiation depends on the number of sub-channels and usually does not exceed 10%. Electronic device frequency compression and watt-ampere characteristic of the laser should be increased linearity over a wide range of levels. Drafted sharing DWDM and coherent optical OFDM (CO-OFDM) with speeds of 100 Gbit/s [6]. In general, the potential OFDM in PON confirmed in a number of projects that are considered in [6-8].

On the basis of the research we can identify the main variants of PON-based converged solutions with OFDM for multi-user:

- OFDMA-PON – different users assigned different orthogonal sub-channels carrying one range;
- OFDMA-TDMA-PON – different users assigned different orthogonal sub-channels and carrying a range of time intervals;
- OFDMA-TDMA-WDMA-PON – different users assigned different orthogonal sub-channels bearing and time intervals and wavelengths.

However, the OFDM is introduced to consider its shortcomings, such as: dependence correct decoding of the shift in frequency, not the best use of the frequency range and especially the use of FFT for forming frequency filters. The main problem of using FFT operation is parasitic phase distortion complex signal amplitudes. These distortions accompany the FFT. When using QAM-modulation algorithms they not reliably decode information. To eliminate restrictions regarding OFDM frequency sealing an approach that is based on the method of non-orthogonal discrete frequency modulation (N-OFDM) where, frequency diversity is not tied to a maximum FFT filter response (Fig. 5) is offered [9]. Attention is drawn to the fact that such a signal at frequency diversity of sub-channels to the width of the filter FFT converted to OFDM-signal. For QAM modulation algorithms sub-channels carrying the information contained in the transmitted message in size quadrature components of signal amplitudes. In this paper, the method of maximum likelihood received optimal evaluation of these components and developed modifications of N-OFDM, for example, without FFT on the receiving side, and others.

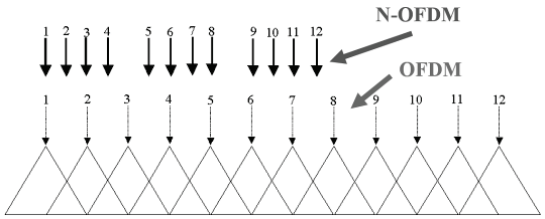

Fig. 5. The arrangement of N-OFDM (OFDM) signal

In general, N-OFDM can increase the bandwidth of optical access. Considering several above mentioned proposed options for hybrid N-OFDM-X-PON (where the symbol "X" – other technologies) using N-OFDM (Fig. 6, 7). To provide smooth upgrade equipment Optical Line Terminal (OLT) to form N-OFDM provides operation with OFDM, which ensures coordination of Optical Network Termination (ONT) or Optical Network Unit (ONU).

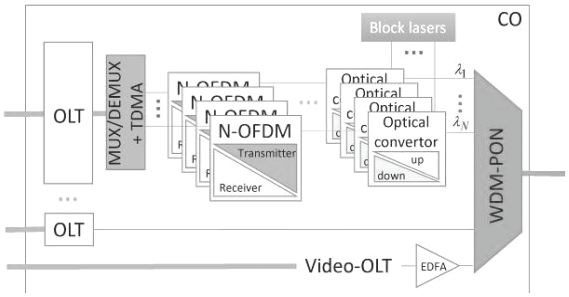

Fig. 6. Structure of CO using N-OFDM

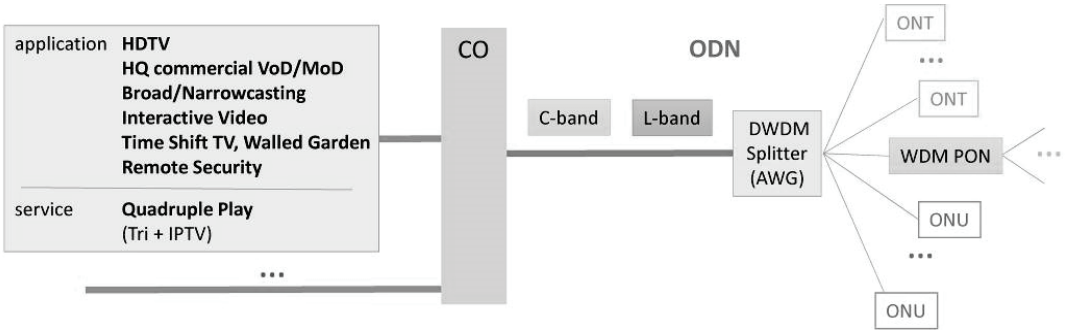

Fig. 7. Option of hybrid N-OFDM-X-PON

In addition, increase the capacity of the proposed hybrid N-OFDM-X-PON at least twice as possible using polarization seal. Currently compaction flow of information through optical carriers having linear polarization, (Polarization Division Multiplexing, PDM) has limited application because of the need no optical anisotropy OJ [5]. Multiplexing is performed using special optical prisms. Removing these limitations is possible by the properties of the signals N-OFDM (OFDM). This problem can be solved in two basic methods of distribution frequency carrier signal dual polarization, shown in Fig. 8. The method ACDP (Adjacent Channel Dual Polarized) involves the use of cut-governmental frequency signals on the orthogonal polarization. As a result, its practical implementation is simpler in technical and algorithmic aspects and isolation between signals of different polarization further enhanced by the frequency-selective action of amplitude-frequency characteristics of the frequency filters. ACDP disadvantages include inefficient use of spectrum range when bearing layout sub-channels N-OFDM (OFDM) in the orthogonal polarization staggered. No such lack denied method of increasing capacity of by using a single polarization decoupling (combined) frequency channel (Co-channel Dual Polar system, CCDP). The impact of the application of CCDP largely determined by factor cross-polarization decoupling (XPD). However, even if the value of this option will be insufficient, the problem of minimizing cross-polarization interference with CCDP can be successfully solved by the introduction of equipment special system suppression cross-polarization interference (Cross-polarization Interference Cancellation, XPIC).

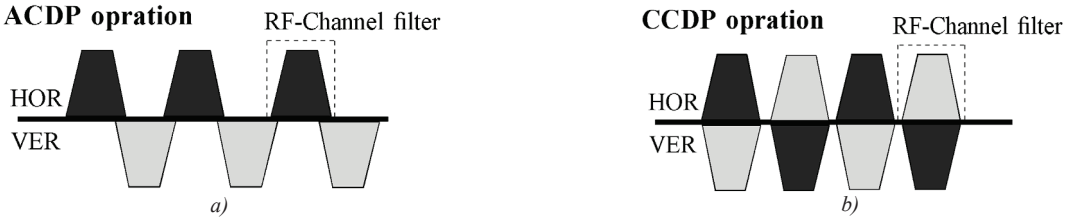

Fig. 8. Methods of alignment of the carrier signal frequency dual polarization: a) – on adjacent frequency channels (ACDP); b) – on the combined frequency channels (CCDP)

III. Conclusions

Within NGOA concept to improve capacity of access networks in the proposed use of convergent solutions "radio over optics" with N-OFDM (OFDM). On the one hand, OFDM is a means of overcoming the impact of chromatic dispersion, intersymbol interference, polarization mode dispersion, phase self-modulation, providing relative intensity noise and others. On the other side, to eliminate restrictions on OFDM frequency compaction an approach based on the method of non-orthogonal discrete frequency modulation (N-OFDM). Thus, the possible introduction of hybrid-N-OFDM-X-PON, based on technology WDM, N-OFDM (OFDM, OFDM), TDM, and others. Further prospective studies aimed at determining the technical aspects for the practical implementation of the proposed model-N-OFDM-X-PON.

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