Applications of optical heterogeneous networks

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***Rezumat**: Datorită evoluției continue a produselor electronice de larg consum și înzestrarea acestora cu conectivitate internet IoT, serviciile se vor digitaliza, devenind accesibile de oriunde și oricând, putând fi folosite pe dispozitive precum telefoane inteligente, tablete, laptopuri si computere, radiouri digitale sau televizoare inteligente. Acest articol demonstrează modalitatea prin care comunicația optică (fibră optică și FSO) poate juca un rol major în realizarea acestor deziderate enumerate mai sus. În acest articol vor fi exemplificate câteva din aplicațiile specifice ale FSO, cu aplicabilitate în rețelele de telecomunicații actuale.*

***Cuvinte cheie:** Fibră optică, comunicaţii optice neghidate, reţele eterogene.*

***Abstract:** Due to the continuous development of electronics consumer and equipping them with internet connectivity (IoT), services will be digitized by becoming accessible from anywhere and any-time, and can be used on devices like smartphones, tablets, laptops and PCs, digital radios or smart televisions. This paper demonstrates how optical communication (fiber and FSO) could play a major role in achieving these goals listed above. This paper exemplifies some of the specific applications of FSO, with actual application in telecommunication networks.*

***Keywords:** Optical fiber, free space optics, heterogeneous networks.*

Optical solutions are represented by fiber optic systems, that have an enormous bandwidth available, and FSO complementary systems with ease of use, installation, operation and integration into existing communications with the benefit in ensuring a significant fraction of the bandwidth of the optical fiber [1], [2].

Specific applications are linked by the FSO ability to provide complementary optical connectivity. Applications can be of type:

- redundant connectivity that can provide backup connections on fiber optic, radio, copper (xDSL, Ethernet).
- providing rescale capacity and connectivity (resizing) networks operating on different trans-mission media (optic, copper). In this regard, FSO interested in connecting metropolitan fiber rings, ROF transmission and interconnection with legacy copper or xDSL evolved in recent gigabit Ethernet networks with the latest revisions.

From a functional perspective, the networks, free space optical connection can be used as point-to-point optical connection (network segments or areas of the network) and support network (backhaul). The intermediate connections between buses and (sub)networks are at the “edge“ of the network (in terms of network hierarchy), which can be, for example, access networks that require connection to the bus [3], [4].

A transparent network, by definition, can route one or more wavelengths from an arbitrary source to an arbitrary destination network located in the same network without conversion, processing and electronic storage thereof in any intermediate point. In contrast,

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opaque networks are in need of (partial) conversion for packet processing (to read headers and routing).

The transfer module used in optical networks is connection-oriented opaque, switching specific circuits. Packet switching requires routing decisions in each node and each packet arrives. This mode involves storing packets, reading and processing headers, which can not be done yet in the optical field. Therefore, packet switching requires the conversion of electrical optical, electrical processing and conversion into optical [5].

Such a network is not optically transparent and has known disadvantages of classical networks: congestion, lower transfer speed, low flexibility. Translucent networks are a combination between two described above. In fact, current networks are mostly translucent because combines the speed and transparency characteristic for optical networks with the possibility of memorizing and routing that is specific to switching circuits [6], [7]. Current optical mesh networks interconnect transparent and opaque sub-networks. The basic element of a transparent optical network is reconfigurable optical multiplexer with insertion / extraction (ROADM).

Conceptually, it contains optical switching matrices and a set (or more) of input/output optical coupling with optical transponders. In the center is the optical matrix (software control) and arms multiplexer input and output meet FO/FSO and the two points of insertion/extraction, A mesh network could be constructed of optical ROADM devices with more than two arms. This provides optical connectivity more complex than bus or ring, and, in general, there may be several optical paths between two ROADM devices.

Among the components of a network may exist possible paths where it is not possible such optical transparency between two components like ROADM. When passing through the transmission medium (fiber, air), modulated optical beam is affected mainly by optical attenuation which means we have loss of power while crossing transmission medium. This can counteract to some extent using EDFA or Raman optical amplifiers. Both amplifies all wavelengths simultaneously traversing transmission medium. An important descriptor of an optical connection is the signal / noise optical OSNR [8], [9]. Any optical beam sent through the environment (air, fiber) has a certain level of noise.

Optical amplification of the optical signal increases the useful signal but at the same time, increase and their own noise level, which make more complicated the estimation of the noise factor OSNR. Optical signal chromatic dispersion transmitted produce analog or digital distortion. An optical pulse lasts more dispersed and reduced amplitude and damaged fronts.

Optical wave propagation channel launched in its initial state of polarization can change the travel distance. Change random polarization is not critical because most photo detectors are insensitive to changes in polarization [9].

This becomes a problem if the incident wave is a short optical pulse. The two polarization components traveling at different speeds, pulse expands in response to random variations of birefringence. FSO is the solution customers broadband connection to the bus (last kilometer access). This technology can be a replacement for conventional radio and fiber optic connections. For short distances (max. 2km), it has the following advantages:

- fast deployment of short-range optical links in urban areas (point-to-point or point-to-multipoint);
- broadband links crossings railways, highways and rivers;
- connections between building companies and institutions;

- quick replacement of cables (copper, fiber) and/or discontinued operations;
- quick setup uses ad-hoc type for seminars, meetings, events;
- connections between different locations and disparate events;
- connections with the subsidiary companies, warehouses;

To provide an attractive valuation metric for FSO networks, we will review the attributes of an ideal broadband access network. One of the basic attributes is in the cost, which includes the following elements:

- lower installation costs and those related to the rate associated with each subscriber;
- low initial costs - for example of a service launch costs for the first subscribers;

In an ideal access network, broadband should provide easy installation and easy return on investment for operators in the shortest possible time period. Another attribute is the capability to offering a high speed for each subscriber separately, leading to the possibility of multiple insurance services. Furthermore, the capacity offered by each subscriber must scale, not only in bandwidth offered a group of subscribers but also for each subscriber individually using this equipment (individual granularity). The ideal optical wireless access network must have an availability of 99.999% and must be able to provide quality optical signal over distances of up to 2 km.

Each broadband access technology offers the advantage in some areas optimum performance for specific applications and implementation strategies. There is no technology that provides optimal performance for all attributes required for any access network. For example, fiber offers massive capacity but it is expensive, and has a long payback time. PON (Passive Optical Networks) represent an attractive alternative due to lower cost per subscriber. The high capacity optical fiber is shared between many users, but time location of the fiber is long and depends on the positions occupied by subscribers. Radio systems also represent an alternative but are limited because of transmission speed, frequency licensing, fading issues, spectrum saturation and congestion in urban areas with high density of transmitters [9], [10].

Optical wireless systems can be easily integrated into existing networks and can access:

- designed to work independently of the protocols used;
- implemented in mesh architecture as the connection point-to-point;
- designed to be compatible with the common monitoring protocols;
- located on roofs or inside (communication window, window, window, roof or roof-roof);
- fast relocation of the equipment, with the change of location or change subscriber access technology.

Given this data, these is an increasingly big area understandable interest in this type of technology that can be implemented in a variety of applications, including telecom operators, providers of telephony, internet and television as well as integrators, network services providers [11].

The benefits of FSO solutions are given short installation times (maximum one day), full-duplex communications for ad-hoc optical connections (redundant or temporary).

With FSO can be made redundant communication connections and can minimize the impact of given fiber or copper cables buried disruption. The solution enables communication recovery for fires, floods, earthquakes or other natural disasters. For networks transiting important data can be provided by design FSO backup solutions, ensuring fast connectivity, or, as necessary, redundant temporary links.

FSO can ensure connectivity of broadband networks and can ensure the transition of various standards such as Wi-Fi (IEEE 802.11), WiMAX (IEEE 802.16), UWB (IEEE 802.15) cellular technology 3G-4G (with reserve for 5G), HFC, DVB-T [9], [10], [12].

Figure 1 is shown how to use the FSO transmission RF signals (video, data, voice). This is achieved by performing conversion from electrical into optical and assigning each service to a wavelength.

To design a system FSO/RoFSO performance can be assessed taking into account the internal and external parameters in Table 1.

ROF technology can be easily implemented in the FSO as an option Gbps connection capacity of different types of networks. This includes the backhaul applications (support network) interconnection of distributed antenna systems and provide easily triple-play services (voice, data and TV).

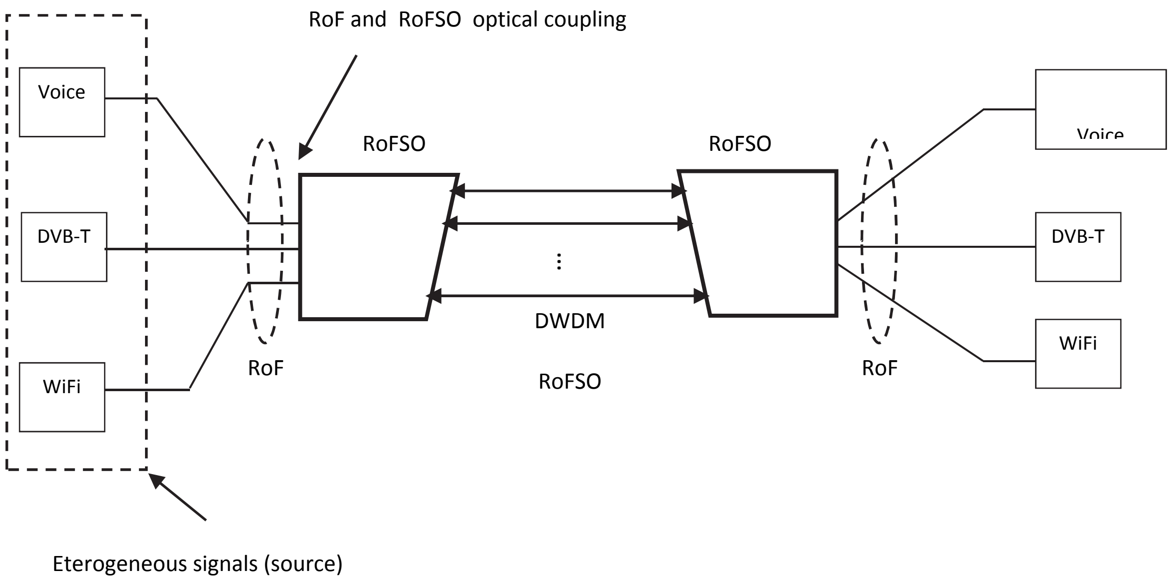

Fig. 1. DWDM RoFSO concept illustration.

Table 1

Assessment of an FSO/RoFSO system [9]

FSO/RoFSO performance	**Internal parameters** (System design parameters FSO/RoFSO)	✓ Optical power ✓ Wavelength ✓ Bandwidth ✓ Divergence angle ✓ Optical losses ✓ BER ✓ SNR ✓ Lens diameter and FOV ✓ Dynamic range ✓ RF efficiency
	External parameters (Non-specific system parameters)	✓ Visibility ✓ Atmospheric attenuation ✓ Scintillation ✓ Working distance (range) ✓ Misalignment losses

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