Optical Last Miles for Research and Education in the Czech Republic

Jan Radil, Lada Altmannová, Ondřej Havliš, Miloslav Hůla, Stanislav Šíma, Josef Vojtěch
Optical Networks Department
CESNET, Association of Legal Entities
Praha, Czech Republic
jan.radil@cesnet.cz, lada.altmanova@cesnet.cz, ondrej.havlis@cesnet.cz, miloslav.hula@cesnet.cz, stanislav.sima@cesnet.cz, josef.vojtech@cesnet.cz

***Abstract* — There are compelling reasons for building networks which are future-proof, scalable, and which will be able to accommodate power users with special needs in the future. However, while the backbone networks are typically ready for new trends such as coherent systems, the situation with access networks is different, often for economic reasons. In this article, we present a cost-effective solution based on open equipment which can be advantageous even outside the academia, research and education ecosystems. As an example, we describe our use of the Czech Light® family of devices within the central region of the CESNET's production network.**

Keywords – optical fiber network; metropolitan area network.

I. Introduction

National research and education networks (NREN) provide connectivity for universities, research centres and other advanced users. Their backbone networks use dense wavelength division multiplexing (DWDM) coherent transmission systems rather routinely, and the data rates of 100 Gb/s are quite common. Successful 1 Tb/s trials have been performed in networks where dark fibers are abundant and available for experiments [1] [2].

This transmission capacity situation is rather different in access parts of the networks. The DWDM systems are not deployed commonly and transmission speeds are usually limited to 10 Gb/s. Sometimes the legacy time division multiplexing (TDM) technology is still used. This stark contrast with the backbone networks is often caused by economic reasons as upgrades are not conducted that often.

Moreover, there are certain new scientific applications with rather special requirements. Examples of these are an accurate time transfer, or a very stable frequency transfer. For these applications, increasing the transmission speeds to 100 Gb/s or even 1 Tb/s are not important and will not help when such applications are deployed [3]. The reason for this constraint is that the time and/or frequency transfer is not about 'big data' transfers, but rather about stable and very low jitter. An accurate time transfer uses speeds well below 1 Gb/s. A transmission of stable frequency consists of a so called continuous wave (CW) signal, i.e., a signal without any modulation because the frequency of photons is the useful property of the transmitted information.

Very accurate time and ultra-stable frequency are crucial for many fields, for example sensing, metrology, navigation, geodesy, radio-astronomy, Earth surveying, seismology, fundamental physics, etc. The increased interest in the all-optical time and frequency transfers are manifested by the EU joint research project NEAT-FT [4].

Unfortunately, technical issues may arise when high speed coherent systems and time/frequency applications are operated together over a shared fiber infrastructure with regular data over DWDM [5].

In this contribution, we will describe some practical examples that show how CESNET has been able to overcome these economical and technical issues.

II. Optical Last Miles Issues

The issues related to last miles are well-known and all operators have learned to deal with them. Sometimes Last Miles have been dubbed as First Miles to emphasize their importance for high speed optical networking. In an NREN ecosystem, the last miles' problems cannot be solved by means of wireless networking because capacity (or bit rate) is not large enough for big demanding applications. With the higher bit rates, one has to utilize higher carrier frequencies, but their reach decreases significantly.

One example of such demanding application can be the ultra-high definition video transmission required for medical applications [6]. Moreover, new applications such as hard real-time controls require very low and constant jitter which can be satisfied successfully with an optical fiber [7]. Real-time network services are needed for an interaction with external processes, in other words for any processes running outside the network. Examples of these use cases include collecting data from remote sensors or telescopes, or remote machine control. The importance of these topics can be found, for example, in the Strategy document for the pan-European network GÉANT for the 2020 time frame [8].

To provide new opportunities for the research, education and scientific community, CESNET has developed new equipment – the Czech Light® family of advanced photonic devices. All of the Czech Light® devices are open. The word 'open' means that third parties are allowed to modify the Czech Light® devices, so it is easy to deploy them in new networking scenarios. The Czech Light® devices can be also customized by power

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end users, e.g., by augmenting them with a custom, specific control software. This is usually not possible with equipment from traditional big vendors.

III. CESNET SOLUTIONS FOR THE LAST MILES

Dark fibers have been used in the CESNET network for many years. The first dark fiber was lit back in 1999, with Packet over SONET (PoS) technology with 2.5 Gb/s speed. At that time electro-optical regenerators for SONET/SDH were the primary option for extending the reach. Later on, optical amplifiers started to emerge, especially when optical gigabit Ethernet was deployed in metropolitan (MAN) and even wide area networks (WAN).

The Czech Light® optical amplifiers (CLA) have been developed by CESNET to overcome limitations of the then-available optical equipment. The most significant drawback of contemporary commercial offerings was the lack of standardized monitoring capabilities. Support for the de-facto standard Simple Network Monitoring Protocol (SNMP) was one of the key requirements for practical deployment for any NREN or Internet Service Provider (ISP).

The Czech Light® amplifiers are based on commercially available modules of Erbium doped fiber amplifier (EDFA). The Czech Light® family of devices also include reconfigurable add-drop multiplexers (ROADM), wavelength selective switches (WSS) or tuneable dispersion compensators (TDC). All of these devices consist of the optical module, an embedded Linux system, and essential control electronics. The Czech Light® devices are housed in a standard rack chassis of size 1U or 2U, and can be customized on demand.

Various Czech Light® products are protected by several patents in the EU [9] and within the US [10] [11] [12].As of 2015, the Czech Light® equipment is used on 4890 km of the CESNET networks, including 2012 km of bidirectional single-fiber transmission.

Figures 1 to 4 show the up-to-date situation with Czech Light® equipment deployed in some of the important optical last miles in the central area around Prague (Praha).

Fig. 1 shows a bidirectional single fiber line between Praha and Dolní Břežany, where the Extreme Light Infrastructure (ELI) is located. This design features so called one-side amplification, where an active device is located at one end of a fiber line only. In this case it is one optical amplifier Czech Light® with two independent modules, one serving as a power amplifier (booster) and another one serving as a preamplifier.

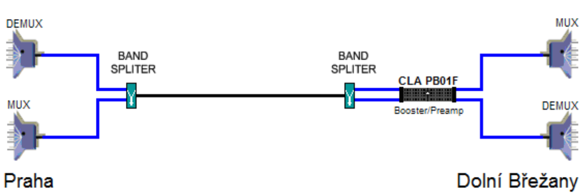

Figure 1. Bidirectional single fiber line Praha-Dolní Břežany.

Fig. 2 shows a standard fiber line between Praha and Řež, a site of numerous research centres and institutions.

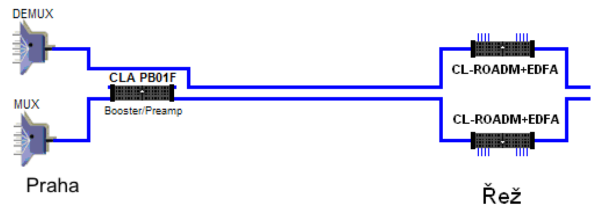

Figure 2. Standard fiber line Praha-Řež.

Fig. 3 shows the ring Praha-Řež-Jenštejn-Praha which is used to increase reliability of a critical part of the network. Both remote locations are hereby reachable from two geographically different directions. Within this path, only the Řež-Jenštejn segment is built on a bidirectional single-fiber line. Both end of the fiber in Praha terminate at the same physical location.

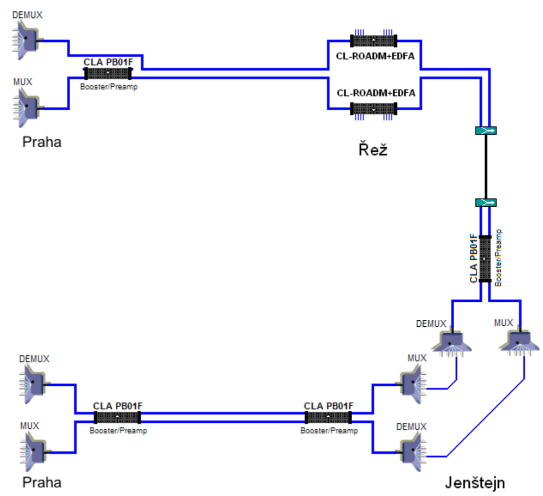

Figure 3. The ring Praha-Řež-Jenštejn-Praha.

Fig. 4 shows the ring Praha-Krč-Vestec-Dolní Břežany-Praha for ELI and BIOCEV. Vestec hosts the Biotechnology and Biomedicine Centre (BIOCEV) of the Academy of Sciences and Charles University. The entire ring is built upon bidirectional single-fiber segments. Both ends of the fiber ring in Praha terminate at the same physical location.

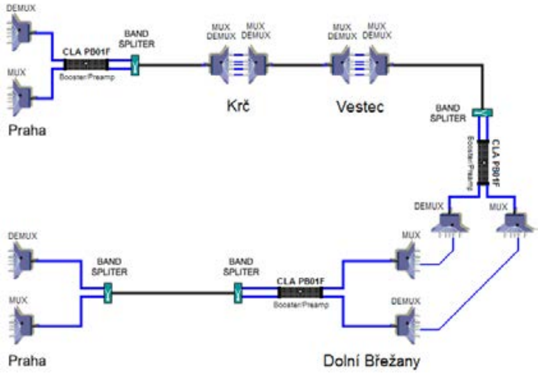

Figure 4. The ring Praha-Krč-Vestec-Dolní Břežany-Praha.

Figures 3 and 4 also demonstrate the deployment of multiple Czech Light® ROADMs. These optical last miles based on the Czech Light® equipment therefore support dynamic, on-demand reconfiguration in response to a remote command. This feature allows CESNET to better optimize usage of its fiber pool as future requests for circuits arrive. As an additional reference, Fig. 5 shows the schematic topological runs of the two described dark fiber rings, with a major part of their length being deployed over bidirectional single fiber lines.

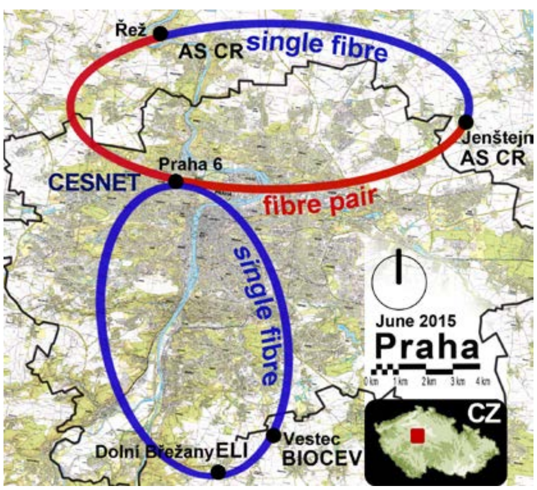

Figure 5. Schematic topology of dark fiber rings.

IV. CONCLUSION

In this paper, we presented the feasible technical solutions of the optical last miles used in the Czech NREN CESNET. The added value of the CESNET solutions is twofold: economic feasibility allowing for higher transmission capacity and openness allowing for deployment of new applications without any restrictions.

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