Sharing of Fibers by Transmission Systems and Open Photonic Transmission Systems

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***Abstract*—The paper addresses motivation for and possible options of fiber-sharing by more transmission systems. Furthermore, the suitability of open photonic transmission systems for this task is described.**

***Index Terms* — DWDM transmission systems, fiber-sharing, open photonic transmission systems, optical communications**

I. Introduction

The usage of fibers for data transmission has multiplied transmission capacities several times and transmission systems have developed from simple and static point-to-point into systems allowing complicated topologies with dynamic addition/removal of channels or whole wave bands. However, deployment of transmission systems is also limited by high prices of new installations or rental of fibers. Fiber-sharing would allow simultaneous operation of more (typically two) transmission systems over single fiber pair. Suitable candidates for fiber sharing are open transmission systems that offer unlimited and full access to the lowest layer of a network (in the sense of the ISO/OSI model [1], [9]).

II. Fiber-sharing by Transmission Systems

A rental of long distance fibers is rather expensive [2]. Another situations can be found where it looks reasonable to run more (typically two) transmission system simultaneously over the same fiber pair. For example, there could be no additional unused fiber pair available. Typically, annualized cost coefficient of a transmission system c_t is lower than the cost coefficient of annual fiber rental c_f. In [2] average c_f of 0.5 EUR/meter/year can be found.

From the same source it can be determined annualized cost coefficient of transmission system (4 year amortization is assumed) c_t about 0.12 EUR/meter/year for commercial transmission systems and from 0.035 to 0.047 EUR/meter/year for open transmission systems. These numbers apply for 10 Gbps transmission system with traditional all optical chromatic dispersion compensation.

Thus it can be stated:

(1) $0 < c_t < c_f$

Obviously, it is more reasonable to operate two systems over a single fiber pair than two systems over two fiber pairs.

(2) $2.c_t + c_f < 2.c_t + 2.c_f$

Mentioned composition (operation of two systems over a single fiber pair) brings only very slightly complicated hardware in comparison with the hardware required for a single fiber bidirectional transmission. The annualized increase in price can be determined as less than 0.0015 EUR/meter/year from [2].

Furthermore, due to gradual exhaustion of the available fiber plant, significant increase in prices of fiber rental between "old" (from years after .com bubble bursts) and "new" rentals can be observed. Where it is necessary to operate multiple (2 or more) transmission systems over a single fiber line, some kind of multiplex must be used. The multiplex obviously causes that the total transmission capacity is divided among the systems and therefore the capacity available for separate systems is decreased. Nevertheless, the present „ordinary" transmission systems offer transmission of 88 channels in C band, each carrying up to 100Gbps of traffic, see for example [3]. Also, transmission in L band (transmission systems for L band are commercially available) offers up to 80 additional channels. Furthermore, efficient amplification for transmission in S band is also under development, see e.g. [4] and commercially available devices can achieve small signal gains up to 30 dB and output powers up to 20 dBm.

Band	Description	Wavelength Range
O band	original	1260 to 1360 nm
E band	extended	1360 to 1460 nm
S band	short wavelengths	1460 to 1530 nm
C band	conventional ("erbium window")	1530 to 1565 nm
L band	long wavelengths	1565 to 1625 nm
U band	ultra-long wavelengths	1625 to 1675 nm

Tab. 1. Transmission bands overview

With a given fiber pair, the first possibility is to multiplex in space. Obvious solution is each fiber from the fiber pair hosts one single bidirectional system, see Fig 1. CESNET has long experience with fiber sharing between directions in single fiber bidirectional transmission systems that are being deployed since 2002. In 2006 the 10 Gbps DWDM bidirectional transmission with no inline equipment has been reported over 210km, see [10]. Today these systems are in operation over more than 900 km of fiber lines.

The isolation of the systems is perfect but the solution is limited to 2 systems only (blue and red on Fig 1.) and the availability of single fiber bidirectional systems is limited due to very small number of vendors able to deliver such systems. The operation principle of a bidirectional system is typically based on sharing transmission spectrum between the two directions and the total transmission capacity of a bidirectional system is only one half of the traditional fiber pair system capacity.

Spatial multiplex can be also achieved in few-mode or multi-core fibers. In these fibers each mode or core carries one data channel. Usage of these fibers is still under research, and many potential challenges must be solved, e.g. cross-talk, splicing, connectors, amplification. For more details see e.g. [12], [13].

The second possibility is to multiplex over the optical frequency spectrum. It allows operation of more systems than two, but brings possible mutual influence between the systems. An intuitive division of the transmission spectrum appears to be a division according transmission bands where the first transmission system uses one band and the second system uses the other band. The mutual influence of the transmission systems is relatively limited as each system uses its own amplifiers, multiplexers and a supervisory channel. Nevertheless, the nonlinear Raman interaction can play its role in transfer of energy from higher frequency to lower frequency channels.

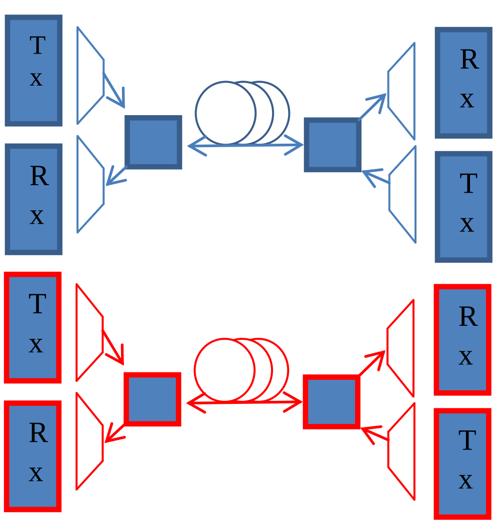

Fig. 1. Two bidirectional transmission systems in operation over fiber pair

A good example can be coexistence of C and L band systems over a single fiber pair. The systems are independent, the just share the same fiber pair. With decreasing available bandwidth in C and L bands, expansion of transmission systems into S band can be expected and, based on this fact, more possibilities of fiber-sharing on the band basis can be expected. See Fig. 2. Supervisory channels of transmission systems are shown with lower powers compared to data channels.

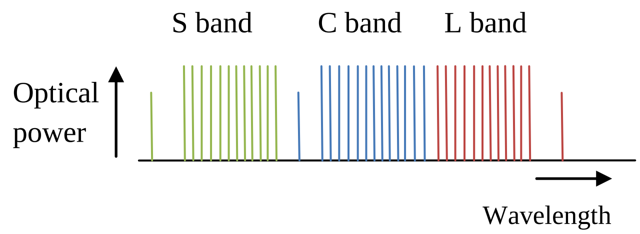

Fig. 2. Possible arrangement of transmission bands including their supervisory channels

Another possible scenario is a division of one transmission band into sub-bands. The mutual influence is of the systems is higher than in the previous case. It can be limited via guard-bands, but they cause waste of bandwidth.

Still another option is spectral interleaving of channels of transmission systems. There is no waste of bandwidth, but the mutual influence, via for example cross phase modulation and four-wave mixing, can be an issue. The last two scenarios represent a subset of a general scenario deploying variable division of the transmission spectra that is emerging with the availability of wavelength selective switching devices working with dynamic spectrum allocation. For this set of scenarios applies that it will be necessary to harmonize supervisory channels of these systems so that they do not collide with each other. The economy of the above described intra-band solution (sub-bands, interleaving and variable apportioning of spectrum inside a band) expressed in CAPEX (capital expenditure) per channel can be worse than in case of apportioning whole transmission bands due to wasted bandwidth.

III. Open Transmission Systems - Research and Technology Transfer

As 'open' here are considered the systems which are free to additional development by users. An equivalent approach applies for open software. The opposite case represents the 'closed' systems typically offered by traditional vendors, where specifications are not publicly available. In case of open systems, important improvements and adding of features can be done by end users (i.e. researchers) or by third parties without any limitations and obstacles. Some parallel can be found in open software systems and it is (or it should be) up to users whether open or closed system is preferred or, in other words, what is more suitable for their ultimate goals. For more details see [11].

The CESNET Association has quite long experience with using dark fibers. The very first intercity link was acquired in 1999 [5]. Since then, CESNET has been aware of importance of full access to dark fibers and its network has been planned with this goal in mind – network should be based on dark fiber wherever possible. This concept was first presented on the Customer Empowered Fiber (CEF) networks workshop [6]. Later, CESNET started development of advanced optical equipment to be deployed on some of CESNET's dark fiber links. The two main reasons were better economy and to secure technological advancement of its network.

The open photonic systems have been in operation since 2004 in the Czech Republic, utilizing over 2660km of dark fibers from the total of over 4000km. They also have been used during international workshops and demonstrations, e.g. [7], where all optical multicast of uncompressed HD streams has been demonstrated. Gradually, many components of transmission and photonic switching systems have been developed [8] and their development still continues.

ACKNOWLEDGMENT

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