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COFFEE – COHERENT OPTICAL SYSTEM FIELD-TRIAL FOR SPECTRAL EFFICIENCY ENHANCEMENT

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Abstract—The scope, aims, and contributions of the COFFEE project for spectral efficiency enhancement and market exposure are presented.

Index Terms—Time Frequency Packing, Nonlinearity mitigation, multi-user receiver.

I. PRESENTING COFFEE

Every telecom bandwidth provider would like to maximize its investment in already installed optical fibre links before replacing them with new types of fibres or overlaying another link. Spectral efficiency (b/s/Hz) characterizes the optimum utilization of spectral resources and defines overall transmission capacity of a link. The COFFEE project aims at demonstrating, through field trial experiments, the coherent optical data transmission of a single superchannel at the high capacity of 1Tbps using a reduced bandwidth (<200 GHz) over long-haul testbed routes. In order to fulfil such requirements, innovative techniques, already developed in laboratory, is being introduced in a field trial environment. Time-Frequency Packing (TFP) is used to increase the spectral efficiency [1]. With respect to other commonly used techniques like orthogonal frequency division multiplexing (OFDM) and M-ary quadrature amplitude modulation format (M-QAM), TFP can guarantee for lower transceiver complexity and bandwidth requirements, higher tolerance with respect to fibre propagation nonlinearities, reduced power consumption, and larger flexibility. Channel shortening (CS) [2], enhanced split step Fourier Method (ESSFM) [3], and multi-user processing are key enabling techniques [4] for these features. The implementation of such advanced techniques represents a strong innovation in the area of telecommunications, and the use of GÉANT infrastructures also pushes the relevance of the COFFEE objectives toward market visibility. GÉANT installed link between Milan and Finkenstein shown in Fig. 1 is being used to evaluate the 1Tbps transceiver prototypes in a real network infrastructure.

Figure 1: Milan-Finkenstein 675Km link for Tbps field trial

II. UNDERSTANDING SPECTRAL EFFICIENCY AND INFORMATION CAPACITY

Most of currently installed transmission links in core networks carry 10Gbps OOK channels on the ITU-T fixed grid occupying 50GHz or 100GHz of spectrum. In the past few years 40Gbps and 100Gbps channels have also been installed to increase the overall link capacity. To ensure the optimum utilization of spectrum the ITU-T G.694.1 flex-grid standard [5] has been defined allowing 12.5GHz spectral slices. Figure 2 shows different data rate channels along with their spectral occupancies. Table I shows how optimized use of spectral resources increases the overall link capacity for different channels.

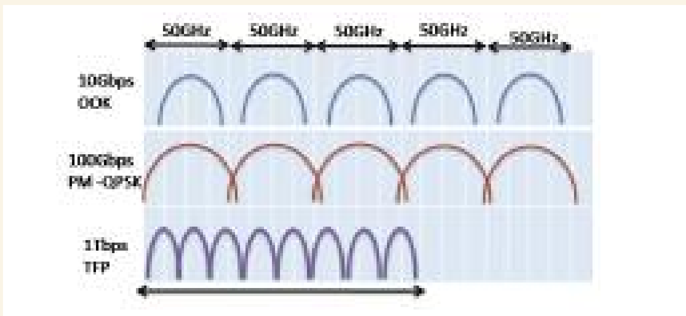

Figure 2: Different data rate channels and spectral occupancy. Each column represents a 12.5GHz flex-grid slice.

III. LINK DESCRIPTION

The fibre optic link chosen for the field trial connects Milan, Italy and Finkenstein, Austria over a length of 675km. The link consists of ten spans of ITU-T G.655 fibre with lengths between 45 and 80km, with amplification provided by Erbuim Doped Fibre amplifiers (EDFAs) as shown in Fig 1. The installed fibre is Corning LEAF on all spans, with a short length of 13km of G.652 Corning fibre. Alcatel 1626LM DWDM equipment is installed in all the nodes.

Data Rate	No. of 12.5GHz slices	Occupied BW (GHz)	No. of Channels in C-Band	Total C-Band Capacity (Tbps)
10Gbps OOK	4	50	80	0.8
100Gbps PM-QPSK	4	50	80	8
1Tbps TFP	13	162.5	24	24

TABLE I. Different data rates and total C-band capacity

IV. NETWORK EMULATION IN LAB

Three nodes of Alcatel LM1626 equipment were installed and re-commissioned in the CNIT lab to characterize each component of a node and to emulate the network conditions before making the actual field trial. The network emulation helped to understand the compatibility issues with 1Tbps transceiver and node component parameters such as the gain of amplifiers were optimized. Moreover, the amplifier loop back configuration at Finkenstein was also ascertained after evaluating different possible configurations.

V. ENHANCING THE SPECTRAL EFFICIENCY- KEY COFFEE CONTRIBUTIONS

The overall transmission capacity of a link can be increased by transmitting more bits per second per Hz of spectrum. But as we place channels closer to each other we increase the inter-channel interference (ICI) degrading transmission performance. TFP employs several innovative techniques to mitigate ICI and other linear and non-linear impairments and thus allows reduction of the spacing between different channels. Figure 3 shows three 160Gbps PM-QPSK channels packed together in 63GHz bandwidth using TFP. Table II shows achieved transmission distance for different spectral bandwidths of a 1Tbps superchannel consisting of 8 sub-channels.

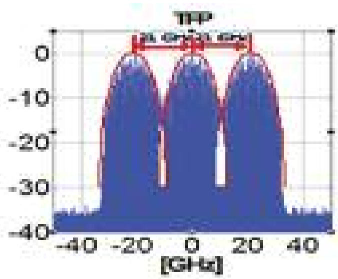

Figure 3: Three adjacent PM-QPSK channels in 63GHz using TFP

No. of sub-channels	Occupied BW (GHz)	No. of 12.5GHz Slices	Distance (Km)	Spectral Efficiency (b/s/Hz)
8	162.5	13	760	6.24
8	175	14	1520	5.80
8	200	16	1900	5.07

TABLE II. Achieved Transmission distances for different spectral bandwidths for 1Tbps PM-QPSK superchannel

In the COFFEE project, a discrete time model of the transmission channel has been derived to evaluate propagation over the link through simulations using a numerical tool built in CNIT. Both linear and nonlinear channel models have been implemented. The key techniques incorporated in TFP in the scope of the COFFEE project include:

- Channel Shortening [2].
- Nonlinear Impairment Mitigation [3].
- Multiuser processing at the receiver [4].

The system performance both in a single user and multi-user scenario has been tested and optimised by emulating the Milan–Finkenstein fibre optic link with a re-circulating loop in the lab. Use of multi-user processing will reduce the penalty due to ICI, and thus will enable a more tight binding of optical sub-channels.

VI. FUTURE PLANS

Based on system optimizations achieved in the lab, a field trial is now under way. As a fundamental outcome within the GN3plus community the COFFEE project allows to build expertise in innovative transmission techniques for next generation optical networks.

ACKNOWLEDGMENT

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