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Field Trial of 40 Gb/s Optical Transport Network using Open WDM Interfaces

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Abstract

An experimental field-trail deployment of a 40Gb/s open WDM interface in an operational network is presented, in cross-carrier interconnection scenario. Practical challenges of integration and performance measures for both native and alien channels are outlined.

I. Introduction

In optical transport multi-domain networks connections are usually terminated and adapted at the edges of the domains. This digital boundary is a very efficient method for providing carrier class performance, but it binds the network provider to use equipment from a specific vendor. Recently, network operators are increasingly requesting multi-vendor interoperability, resulting in the G.698.X series of ITU-T recommendations (supporting up to 10 Gb/s signals in metro applications). The standards facilitate the deployment of open WDM interfaces, the so-called Alien Wavelengths (AWs) or "black link". AWs are optical signals, originating from a transponder, from a different vendor than the one utilized in the WDM transport segment under consideration. This also means that the WDM transport system was not specifically designed for transporting these signals, even though it may often be capable of carrying them, albeit no guarantees towards the performance can be given. In addition to a new concept for service delivery [1], AWs can be extremely useful as a network expansion strategy [2]. New network segments are not bound to the legacy network's vendor equipment, hence potentially lowering significantly the CAPEX and the OPEX costs [3].

In this field trial, we take a step beyond the state of the art, given by the standardization documents. We deploy and evaluate the performance of a 40 Gb/s DP QPSK open WDM interface within a long-haul dispersion compensated system designed for 10 Gb/s OOK signals as a part of network expansion strategy (multi-vendor inter-carrier connection). The goal of the deployment was to evaluate if an AW can be directly deployed following the standard operational parameters and procedures for the system, and if not, under what conditions such interface can operate satisfactory.

II. Network Setup and Experiments

The deployment of the AW was conducted in the Danish Research and Education Network – Forskningsnettet. It is a regional ring-based network, spanning entire Denmark. There are 9 WSS-based ROADMs and 7 in-line amplifiers, with total length around the ring of 1189.4 km. Each span in the ring is based on standard G.652 fibers and the dispersion is minimized by dispersion compensated fiber in order to accommodate the transport of 10 Gb/s OOK signals. The AW signal was provided by the Danish national telecom operator TDC. The deployment setup was as follows: a 40 Gb/s AW was deployed between 2 native 10 Gb/s signals at 50 GHz spacing along the entire ring. Fig.1 shows a schematic of the local add/drop site. The letters indicate the points where power levels were monitored during the experiment.

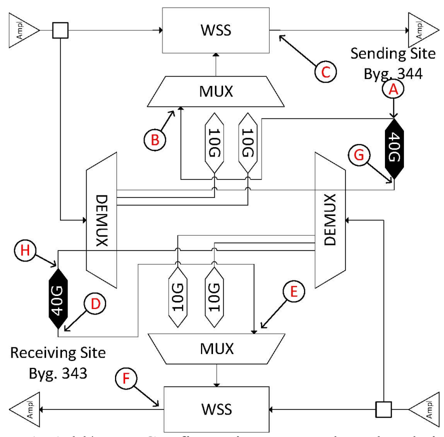

Figure 1: Add/Drop Configuration at Lyngby – local site

In the following experiments, we will describe the integration process and the performance of both the native and the AW signals during this process. The starting point was a deployed AW without neighboring native channels. The AW was provisioned according to the operational specifications for native channels (standard output power levels from the WSS components – points C and F from Fig.1 and standard provisioning procedure for the host system). Table I presents the system parameters and the AW performance at this stage of the experiment.

Table I: Initial AW performance and system parameters

Performance parameters		System parameters	
PreFEC BER	$9*10^{-5}$	$P_{trans\ (point\ A)}$	0.0 dBm
max PreFEC BER	$1*10^{-4}$	$P_{send\ (point\ B)}$	-0.2 dBm
$P_{received\ (point\ H)}$	-17.90 dBm	$P_{out\ (point\ C)}$	-19.0 dBm

A. Adding the 2 native neighboring wavelengths

As seen above, the AW deployment using standard operational specifications and procedures was successful. At this point, the process of adding the native neighboring signals was initiated. The goal was to observe the impact on the AW. Fig. 2 presents the results for the PreFEC BER of the AW signal, when the native signals were added on both sides 50 GHz away. The process was a step-wise deployment, where the native signals was deployed one span at a time. The result shows that the more spans were deployed, the worse the AW performance became. With 2 fully deployed native neighbors the AW's performance was below operational limit. This indicates that in the system under investigation, deploying the AW using standard system parameters in the presence of neighboring channels was impossible. Thus, custom engineering of the deployment was required. The results fundamentally indicate a strong impact of adding the neighboring channels on the performance of the AW. As the power per channel was kept constant during the experiment the observed degradation is attributed to linear or non-linear crosstalk. The AW is using DP QPSK modulation, which is known to be sensitive to phase perturbations, so it is very likely that the crosstalk is caused by cross phase modulation induced on the fibers by the neighboring OOK signals.

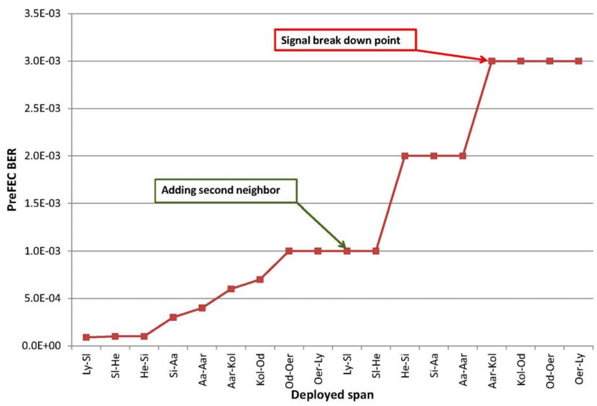

Figure 2: AW performance under native neighbor signal deployment. Neighbors added one at a time in a span-by-span manner.

B. Custom-engineering an operational setup

In order to find suitable operational parameters, several tests were conducted where the power levels of both the alien and the native channels were varied and adjusted. After analyzing the results, an operational setup was established, under which the AW performance was acceptable and the provisioned power levels in the system were acceptable for the network operator.

The provisioned power levels at the exit points from each WSS component on the ring in the final setup are presented in Table II. The power difference between the AW and the native wavelengths was set to 3 dB, where the AW required higher power level. At these operational parameters the performance of the AW was as follows: PreFEC BER = $2*10^{-3}$; $P_{received\ (point\ H)} = -3.0$ dBm (a booster amplifier was installed between the AW transponder and the WDM host system in order to compensate for a 6 dB loss in the optical distribution frame and trunk fiber).

The performances of the native channels were observed via the Channel Margin (CM) measure for both native wavelengths with and without the presence of the AW in the system (see Table III). The CM is a proprietary performance indicator, derived from the calculated Q-factor of the signal (the higher – the better). The results clearly indicate a slight decrease in the CM at the presence of an AW, but with marginal impact on the quality of the native channels.

TABLE II: FINAL POWER LEVELS AT EXIT POINT FROM WSS COMPONENTS (POINT C) FOR BOTH NATIVE AND AW SIGNALS.

Span	$P_{point\ C}$	Span	$P_{point\ C}$	Span	$P_{point\ C}$
1	-22 dBm -19 dBm -22 dBm	2	-18 dBm -15 dBm -18 dBm	3	-18 dBm -15 dBm -18 dBm
4	-18 dBm -15 dBm -18 dBm	5	-22 dBm -19 dBm -22 dBm	6	-22 dBm -19 dBm -22 dBm
7	-18 dBm -15 dBm -18 dBm	8	-22 dBm -19 dBm -22 dBm	9	-22 dBm -19 dBm -22 dBm

TABLE III: CHANNEL MARGINS FOR BOTH NATIVE CHANNELS WITH AND WITHOUT AW AT THE ACCEPTED OPERATIONAL POWER LEVELS.

	CM1 at sending site	CM1at receiving site	CM2 at sending site	CM2 at receiving site
with AW	4.64 dB	5.10 dB	4.17 dB	5.09 dB
w/u AW	4.90 dB	5.90 dB	4.30 dB	5.40 dB

III. CONCLUSIONS

This paper presents an experimental field trial deployment of an open WDM interface within a production network as a network expansion strategy. The goal of the experiment was to gain experience with deploying 40 Gb/s AW (DP QPSK) in a network designed and optimized for 10 Gb/s (OOK) signals.

In this work we took a step beyond the state of the art and the standardization in the field and observed that it is relatively simple and easy to include a 40 Gb/s AW (open WDM interface) in a long-haul operational system, but provisioning of AWs requires more than traditional power management. When native and AW signals are using different modulation formats wavelength planning and use of differential channel power are key issues for systems to support transport of AWs.

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