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40 Gbps communication channels test over the CESNET2 DWDM optical transmission network

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Abstract

This paper describes 40 Gbps communication channels tests over the current CESNET2 10 Gbps DWDM optical transport system between the main CESNET2 PoPs in Praha and Brno. These tests were performed with both ODB (1OC768-ITU/C, also known as Godzilla) and DPSK+ (1OC768-DPSK/C, also known as Godzilla+) modulations. There were several reasons for this experiment:

- Verify the solution for possible deployment of 40 Gbps over the existing DWDM system.
- Compare the performance of both solutions under different conditions.
- Verify the 40-Gbps IPoDWDM technology.

40 Gbps communication channels have been tested on two possible optical paths between Praha and Brno PoPs, also called South and North paths. The basic 2-way fiber lines parameters are:

- Southern path: length =299 km, OSNR=~15 dB, residual CD=153/153 ps/nm, average PMD=2.13 ps/$\sqrt{\text{km}}$ (for both fibers), mix of G.655/G.652
- Northern path: length =462 km, OSNR=~15 dB, residual CD=324/424 ps/nm, average PMD=2.13 ps/$\sqrt{\text{km}}$ (for both fibers), G.652 only.

The PMD values were not measured for all used fibers, but all the values were estimated from CTP (Cisco Transport Planner) simulation. The Southern path was verified for 40-Gbps transmission by Cisco optical engineers in Monza.

Keywords: IP over DWDM, 40 Gbps transmission, duo-binary modulation

1 Introduction

The CESNET Association operates the national DWDM and IP/MPLS network (CESNET2) covering multiple regions in the Czech Republic. The current CESNET2 network is built around a DWDM core providing 10 Gbps channels. It is based on Cisco ONS15454 MSTP system with the multidegree ROADM technology. The main DWDM ring interconnects Praha – Brno – Olomouc – Hradec Králové – Praha PoPs with a transmission capacity of up to 32 optical channels in C-band at the speed up to 10 Gbps. The detailed CESNET2 backbone optical topology with the DWDM technology is shown in Figure 1.

Span length and optical amplification nodes deployment are also included in this picture. Optical fibers parameters between Praha and Brno are presented in the Tables 1 and 2.

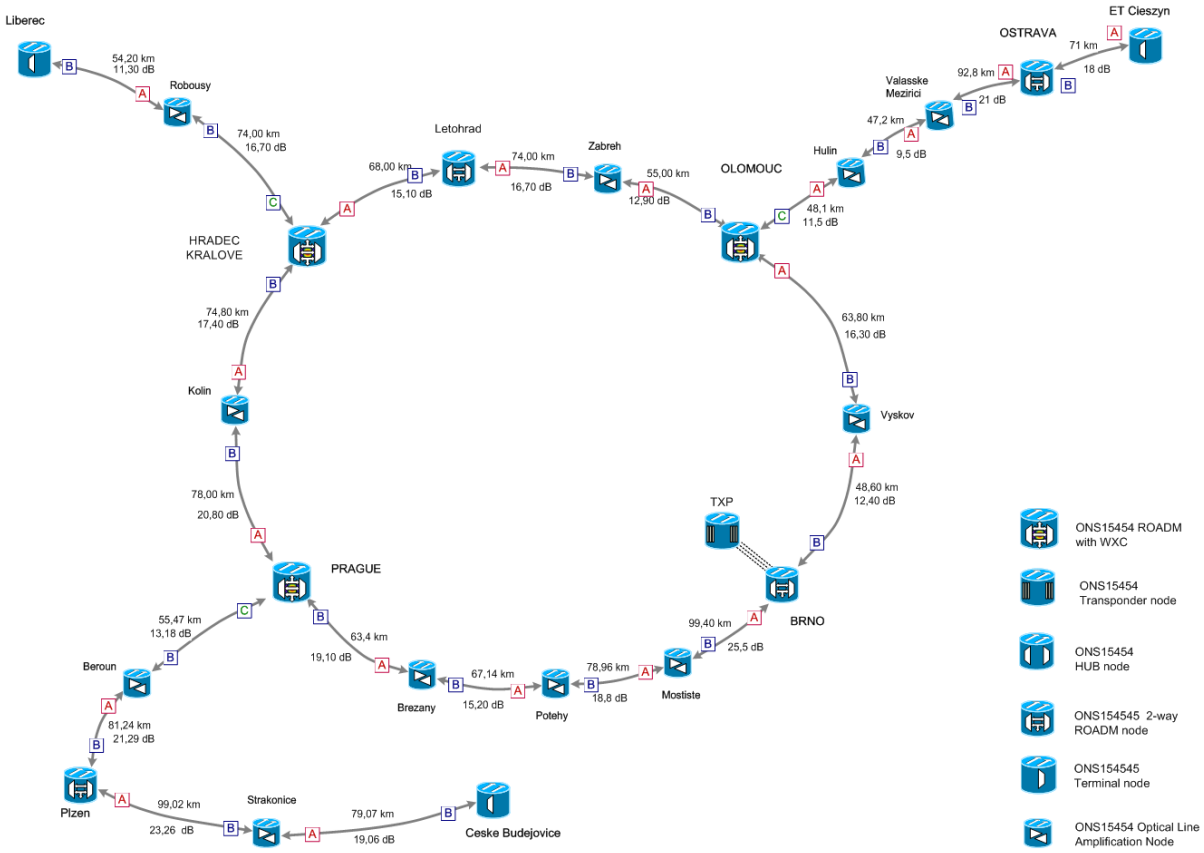

Figure 1. CESNET2 DWDM optical transport network topology

Table 1. Detailed parameters of optical fibers at Southern path Praha – Brno (total length 299 km).

Fiber type	G.652	G.655	G.655	G.655	G.655	G.652
Attenuation [dB@1550nm]	FO J1 -6.50 dB FO J2 -6.50 dB	-10.70 dB FO 69 -11.00 dB FO 70	FO 70 -15.20 dB FO 70 FO 70 -14.92 dB FO 70	FO 69 -21.82 dB FO 71 FO 70 -22.10 dB FO 72	FO 68 -20.73 dB FO 69 -20.56 dB FO 70	-1.50 dB FO 69 -1.50 dB FO 70
Average Chr. Disp., C-band	504 ps/nm (1)	-10 ps/nm (2)	12 ps/nm (3)	230 ps/nm (4)		
Chr. Disp. @1550nm	571/458 ps/nm (1)	-2/5 ps/nm (2)	23/32 ps/nm (3)	242/249 ps/nm (4)		
Length	23.79 km	39.67 km	57.14 km	78.95 km	94.95 km	4.45 km

The CESNET2 IP/MPLS network layer is based on Cisco OSR 7600 routers in the PoPs and operates at 10 Gbps. In 2008, first CRS-1/16 terabit router was installed in the main Praha PoP to enable 40 Gbps production deployment and possible migration to 100 Gbps in future. For the experiment Cisco Systems loaned not only 40-Gbps cards, but all other necessary HW needed for the tests. It included another CRS-1/4 chassis for the Brno PoP and 10GE interfaces to connect the IP testers as well. Detailed technical parameters of the tested 40-Gbps cards are available on the Cisco web pages, the main are shown in Table 3.

Table 2. Detailed parameters of optical fibers at Northern path Praha – Brno

Attenuation [dB@1550 nm]	PMD [ps/$\sqrt{\text{km}}$]	Chr. dispersion [ps/nm@1550 nm]	Length [km]
-17.8	0.04	1285/1288	78.0
-16.1	0.01	1252/1247	74.8
-14.1	0.01	1132/1133	67.7
-15.6	N/A	1218/1212	72.8
-11.5	0.03	930/917	55.0
-15.2	0.03	1047/1043	63.8
-11.4	0.05	804/790	48.6

Table 3. Basic optical parameters of 40-Gbps cards

Type of cards [PN]	**1OC768-ITU/C**	**1OC768-DPSK/C**
Modulation type	ODB	DPSK+
Framing	WDMPOS	WDMPOS
CD tolerance [ps/nm]	± 150	± 700
PMD tolerance [ps]	2.5	2.5
Target distance [km]	~ 1000	~ 2000 km
Filtering	50 & 100 GHz	50 & 100 GHz
Transmitter Power Range [dBm]	-19.0 to 1.0	-19.0 to 1.0
Receiver Sensitivity [dBm]	-18.0	-18.0

2 Test Setup and Performed Tests

The 40-Gbps test topology is shown in Figure 2. In the Praha PoP 40-Gbps cards were installed in the production CRS-1/16 router, P-section of R119 (IOS-XR 3.7.0). In the Brno PoP, CRS-1/4 router (IOS-XR 3.8.0) was used. Two Linux workstations with the 10 Gbps interfaces and two testers EXFO FTB-200 with the 10GE test modules FTB-8510G were used as the traffic generators. 10 Gbps traffic generated by testers was multiplied by the concatenated EoMPLS tunnels between CRS-1 routers on the 40 Gbps line. With the limited number of available 10 Gbps interfaces it was possible to load line up to 30 Gbps only.

We performed the following tests:

1. ODB interfaces in Praha and Brno and optical channels on both south and north paths.
2. DPSK+ interfaces in Praha and Brno and optical channels on both paths.
3. ODB interface in Praha and DPSK+ in Brno on both paths.

We also detected DPSK+ signal by an optical spectral analyzer in Praha PoP and tried to display eye diagram by the optical sampling oscilloscope EXFO PSO-100 series with the external demodulator.

We used following interface settings on both sides:

— DWDM – MSA ITU Channel=47, Frequency=193.80 THz, Wavelength=1546.917 nm, Enhanced FEC Mode (default),
— SONET – all parameters default,
— IP – MTU=9216.

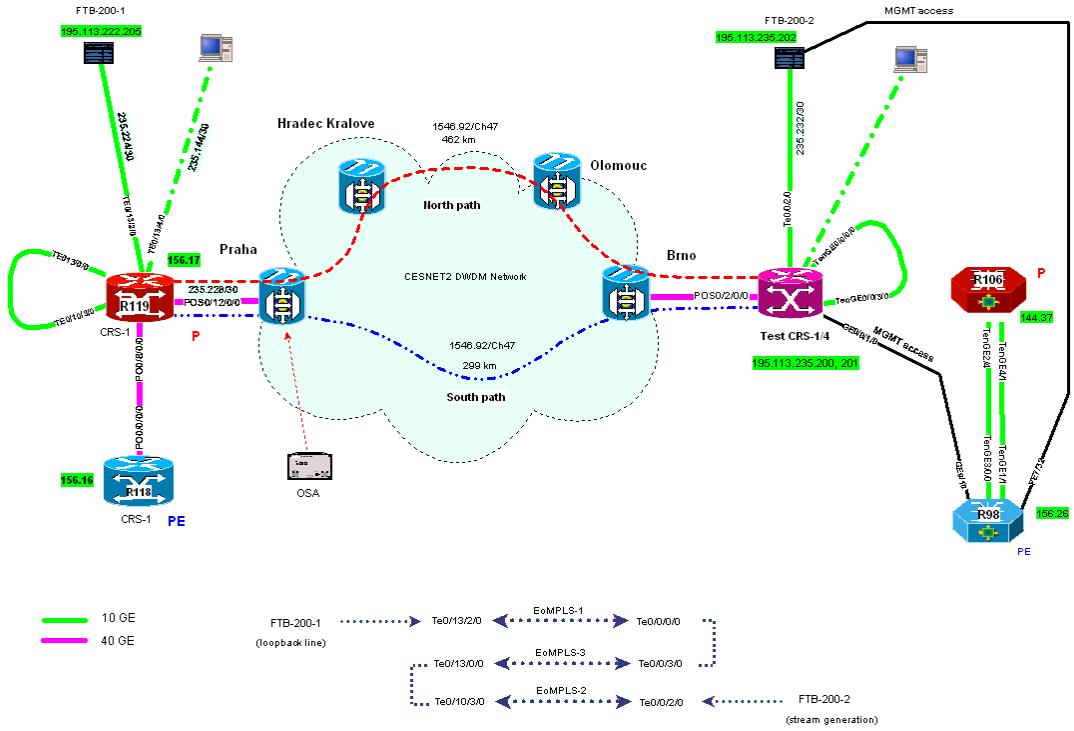

Figure 2. 40-Gbps test setup topology Praha – Brno

The tests 1 and 2 were successfully finished and no errors encountered on any level (FEC EC=0).

Figure 3 shows the spectral analyzer form of DPSK+ signal. The RX represents output from the DWDM system and is filtered by DMX while TX is direct output signal from the DPSK+ card.

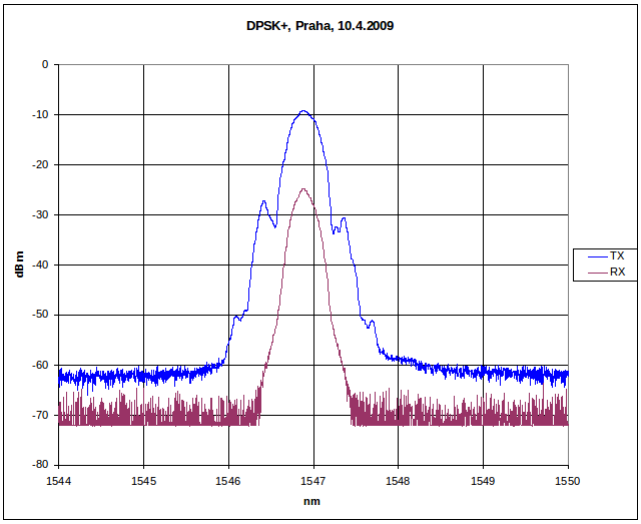

Figure 3. RX and TX signals of DPSK+ interface in Praha PoP

The detection of the eye diagram was unsuccessful for the technical problems

with the 40 Gbps optical sampling oscilloscope.

Table 4 shows the result from test 3, i.e. between the Godzilla and Godzilla+ cards. These practical results demonstrate that ODB (used duobinary transmitter is also called Phase Shaped Binary Transmitter – PSBT) and DPSK are closely related modulation forms and can theoretically and practically interoperate [1]. The ODB modulations achieves correlation between adjacent bits via the TX while the Delay interferometer (DI) in the DPSK RX creates the same correlation. DPSK demodulator could'nt take advantage of balanced detection for ODB input signal, which cause reduced performance.

With the same types of ODB or DPSK+ cards on both sides we observed Pre-FEC BER<9.00E-11. With the mix ODB and DPSK+ plus cards we observed the Pre-FEC BER much worse (see Table 4) and FEC corrected huge amount of words. With the possible maximum load about 30 Gbps (see Figures 4 and 5) all the words were successfully corrected and no performance impact happened.

Table 4. OCHNC via both paths.

Path	Southern (299 km)		Northern (462 km)	
Location	Praha	Brno	Praha	Brno
Modulation	ODB	DPSK+	ODB	DPSK+
RX power [dBm]	-16.87	-18.35	-15.77	-15.94
TX power [dBm]	1.05	1.06	1.05	1.06
TDC setting [ps/nm]	N/A	-141	N/A	-60
Pre-FEC BER	2.37E-7	3.59E-9	9.48E-6	1.42E-9
EC	164429375	1226603	36437247869	62975444
UC	0	0	0	0
Q	5.9	5.85	4.30	6.01
Q Margin	5.19	6.41	3.74	6.64
Input bytes	62.79E12	41.86E12	82.27E12	
Output bytes	41.86E12	62.79E12	54.85E12	82.27E12

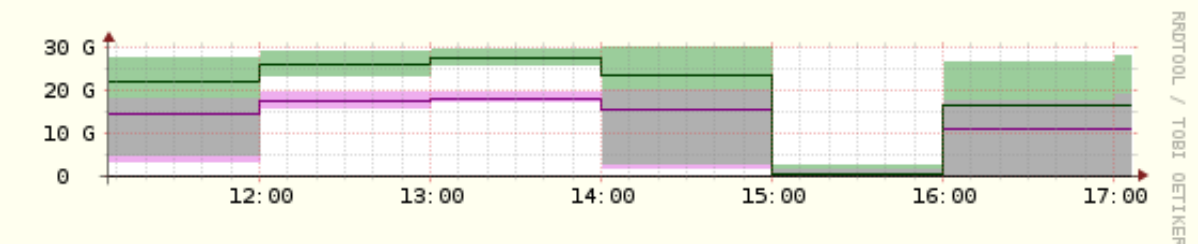

Figure 4. Traffic load on 40-Gbps card in Praha (R119).
Input bitrate min=8.448 kbps, max=19.871 Gbps, average=12.553 Gbps; output bitrate min=8.431 kbps, max=29.806 Gbps, average=18.830 Gbps.

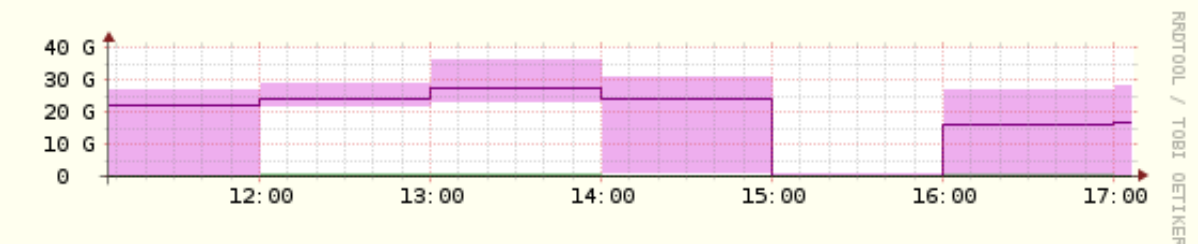

Figure 5. Traffic load on 40-Gbps card in Brno (CRS-1/4).
Input bitrate min=6.566 kbps, max=35.686 Gbps, average=18.616 Gbps; output bitrate min=6.593 kbps, max=333.184 Mbps, average=23.336 Mbps.

3 Conclusion

We verified that the CESNET2 optical transport DWDM network is ready for real deployment of 40-Gbps across the current 10 Gbps network design. Because the expected 40 Gbps optical channels length is less than 1000 km, the 1OC768-ITU/C line card with the ODB modulation will be sufficient for future deployment.

We compared both ODB and DPSK+ 40 Gbps cards in CRS-1 routers. During the tests we demonstrated functionality between ODB and DPSK+ cards across our DWDM system. There was error-free data transmission, because E-FEC corrected all errors. There were a many of corrected errors (EC) on the optical layer, but no uncorrected words (UC). This unexpected experiment result confirmed the theoretical possibility that DPSK+ can be seen as ODB transmission for which the precoding occurs at the transmitter side and the coding/decoding at the receiver side.

References

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