Multi-Vendor 100G DP-QPSK Line-Side Interoperability Field Trial over 1030 km

Nestor Garrafa(1), Omar Salome(1), Thomas Mueller(2), Oscar Pache Carcelen(2), Gianluca Calabretta(3), Nacho Carretero(3), Gabriele Galimberti(3), Steven Keck(2), Víctor López(4), Dirk van den Borne(2)

(1) Telxius, 1111 Brickell Ave, Miami, Florida 33131, USA (nestor.garrafa@telxius.com)
(2) Juniper Networks, 1133 Innovation Way, Sunnyvale, CA 94089, USA (dvandenborne@juniper.net)
(3) Cisco Systems Inc., Via S. Maria Molgora, 48 C, Vimercate, MB 20871, Italy (gcalabre@cisco.com, ggalimbe@cisco.com)
(4) Telefónica Global CTO, Ronda de la Comunicación 2, 28050 Madrid, Spain (victor.lopezalvarez@telefonica.com)

Abstract: We discuss a multi-vendor line-side interoperability field trial using Juniper and Cisco 100G coherent DWDM routers interfaces. The field trial demonstrates 100G DP-QPSK transmission over a 1030-km link from Boca Raton to Jacksonville uses the HG-FEC line-side interoperability mode for 100G coherent DWDM transceivers.

OCIS codes: (060.2330) Fiber optics communications; (060.4080) Modulation

1. Introduction

The use of coherent detection and digital signal processing (DSP) in 100G DWDM transceivers has revolutionized optical transport by vastly simplifying the design, deployment and performance monitoring of transport networks. This has quickly established 100G coherent DWDM transceivers as the technology-of-choice across metro, regional, long-haul and submarine transport networks. As a result, 100G coherent DWDM transceivers have evolved from initial deployments [1] in 2009/2010 into a mature technology with worldwide more than 200,000 ports deployed during 2015 [2].

Traditionally, data communication networks rely on a large number of standards and implementation agreements to ensure multi-vendor interoperability at the ODU, Ethernet and IP/MPLS network layers. However, at the optical transport layer proprietary implementations have so far dominated for 100G coherent DWDM transceivers. With 100G DP-QPSK now a mature technology it is also highly preferable that 100G coherent DWDM transceivers from different system vendors are interoperable at the optical transport layer. Multi-vendor line-side interoperability between 100G coherent DWDM transceivers has been demonstrated between transceivers used the same digital signal processing (DSP) ASIC [3]. However, in order to realize general line-side interoperability between independent DSP ASIC designs, a standardized forward error correction (FEC) code as well as a standardized OTN framing and common DP-QPSK symbol mapping are required.

In this paper we describe a multi-vendor line-side interoperability trial based on a common interoperability mode for the FEC code, framing and symbol mapping implemented in 100G DWDM transceivers utilizing independent DSP ASIC designs. Successful line-side interoperability is demonstrated in a field trial in the Telefonica International network between Boca Raton and Jacksonville, Florida. The DWDM interfaces are integrated on Juniper and Cisco routers with the aim to demonstrate router-to-router 100G coherent DWDM line-side interoperability over a long-haul distance of 1030 km.

2. 100G Line-side Interoperability

In most transport networks DWDM transceivers from different systems vendors are deployed, either as a result of legacy deployments, for technology redundancy, due to different optical performance requirements (metro vs. long-haul), or simply for commercial reasons. Without line-side interoperability each of the different 100G coherent DWDM transceivers needs to be book-ended by an identical DWDM transceiver, which significantly reduces flexibility in network deployments. Line-side interoperability is particularly relevant when the 100G coherent DWDM transceivers are integrated directly onto router line cards. Since multi-vendor interoperability is widely established for both IP/MPLS network protocols as well as Ethernet client interfaces, the same expectation is set for DWDM router interfaces.

The Juniper MX2020 and Cisco ASR9900 DWDM line cards both support an interoperable FEC mode for multi-vendor deployments based on the High-Gain FEC (HG-FEC) code. The HG-FEC code is specifically designed to align with the ITU-T standardized G.709 framing [4], preserving the standardized OTU4 frame for 100GbE client signals with a bit rate of 111.81 Gbps. G.709 includes GFEC as the standard FEC code, but the fairly low net coding gain (NCG) of 6.2 dB makes this code only suitable for metro distances at 100G bit rates. The HG-FEC code is based on a Bose-Chaudhuri-Hocquenghem (BCH) code with a code rate R = 239/255 (6.7% overhead). The iterative hard-decision decoding algorithm results in a pre-FEC BER threshold of 4.6e-3 for a post-FEC BER of 1e-15, translating into a 9.4 dB NCG [5]. The HG-FEC code therefore provides a significantly higher NCG compared to GFEC, which enables 100G line-side interoperability over regional or even long-haul transmission distances. Since the HG-FEC mode uses a hard-decision decoder it has only a moderate implementation complexity and can either be integrated into the DSP ASIC, a separate OTN famer ASIC, or implemented in an FPGA. This implementation flexibility makes the HG-FEC code ideally suited for line-side interoperability across different 100G transport platforms. In addition to the HG-FEC code for line-side interop, both cards support as well a proprietary FEC mode with soft-decision de-coding for maximum optical performance, enabling (ultra) long-haul transmission.

The 100G DWDM line cards used in this field trial are in addition equipped with CFP2-ACO pluggable DWDM coherent optics, following the OIF implementation agreement [6]. The Analog Coherent Optics (ACO) architecture decouples the optical and electronic functionality of a 100G coherent DWDM interface, with the complete 100G coherent front-end in the optical pluggable interface while the DSP ASIC is still located on the line card. This disaggregated architecture further improves interoperability as the same pluggable coherent optics implementation can be used across different transport platforms.

3. Field trial configuration

The field trial used two deployed Juniper MX2020 routers in Boca Raton, Florida and Jacksonville, Florida. The MX2020 is Juniper's flagship router for provider edge networks and is widely used in edge, peering and core network deployments. On the other end, a Cisco ASR 9904 router is used during the field trial, as well located in Boca Raton. ASR 9904 is part of the ASR 9900 series, representing Cisco's paradigm in edge and core routing.

The DWDM transport link used during the field trial is part of Telefonica's Network in Florida, running between Boca Raton and Jacksonville, with a one-way distance of approximately 515 km. The link consists of 6 fiber spans, with five in-line EDFAs, one intermediate ROADM and two ROADMs with DWDM multiplexers at the end-points. The transmission link consists of 470 km of LEAF as well as a single 45 km fiber span of SSMF, and is dispersion un-compensated. The 100G DWDM channel is transported as alien wavelength over a 3rd-party transport system, simultaneously carrying production traffic during the field trial. The 100G DWDM channel-under test is located at 1561.42 nm, where an appropriate guard-band between channel-under-test and co-propagating channels ensured that there was no interference between the DWDM channels.

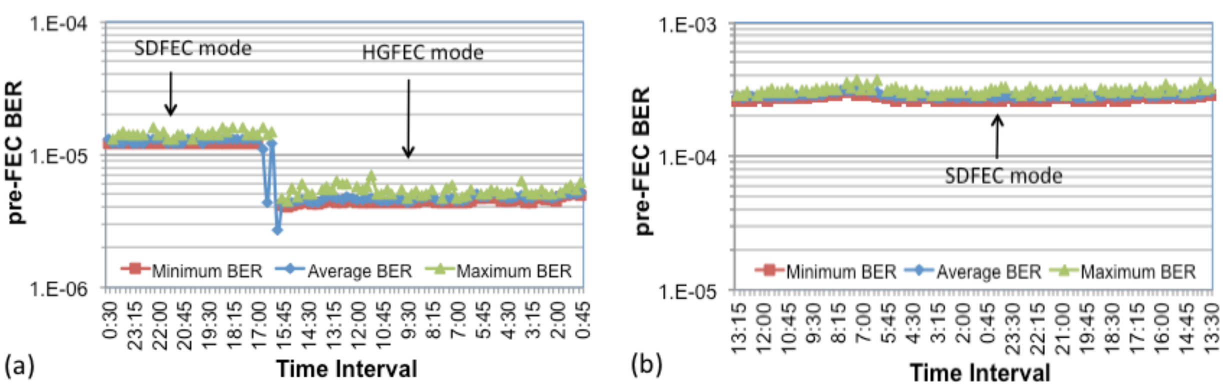

Fig. 1: (a) Uni-directional 100G DP-QPSK transmission results over 515 km in either HG-FEC or SD-FEC mode and (b) Bi-directional 100G DP-QPSK transmission over 1030 km in SD-FEC mode

4. Field trial results

The initial test consists of uni-directional transmission between the two MX2020 routers in Boca Raton and Jacksonville. Each of the MX2020 uses one 100G DWDM line card. In the first test scenario both the optical performance in SD-FEC and HG-FEC modes are tested during an overnight soak test to ensure long-term stability and obtain statistical information on the optical transmission performance. The pre-FEC BER is reported in 15-minute time intervals. Both the minimum, average and maximum pre-FEC BER values are reported, where minimum and maximum values represent the 1-second lowest, respectively highest pre-FEC BER interval during each 15-minute period.

In HG-FEC mode an average pre-FEC BER of 4.7e-6 (12.9 dBQ) is measured, whereas the average pre-FEC BER in SD-FEC mode is equal to 1.3e-5 (12.5 dBQ), as shown in Fig.1a. The difference of 0.4 dB in the measured Q-factor is a result of the higher bit rate in SD-FEC mode. The SD-FEC is based on a Turbo Product Code (TPC) with 15% overhead, resulting in a 120.58 Gbps bit rate and 10.8 dB NCG. The change from a 111.81 Gbps bit rate to a 120.58 Gbps bit rate would theoretically result in a 0.33 dB difference, which is close to the actually measured performance difference. Based on the maximum pre-FEC BER the system margin is equal to 5.8 dB and 4.5 dB for SD-FEC and HG-FEC, respectively. The SD-FEC mode therefore still has a higher system margin despite the somewhat higher pre-FEC BER measured. This aligns well with the difference in NCG between the HG-FEC and SD-FEC modes of 1.4 dB. The small difference between average and maximum pre-FEC BER indicates that the transport link is very stable during the entire 24-hour soak test.

The total transmission distance is subsequently doubled to 1030 km by switching to optical loop-back on the ROADM in Boca Raton and terminating the wavelength on the same DWDM line card in Jacksonville. The soak test in this configuration shows stable optical performance over a 24-hour period with an average measured pre-FEC BER of 2.8e-4 and a worse-case pre-FEC BER of 3.7e-4 in SD-FEC mode, as depicted in Fig. 1b. The worst-case system margin with respect to the SD-FEC threshold is equal to 4.0 dB.

The test setup is then switched from Juniper MX2020 routers on both end-points to a line side interoperability test scenario between the Juniper MX2020 and Cisco ASR 9904 routers. Both routers are located in Boca Raton and the same 1030 km transport link from Boca Raton to Jacksonville with loop-back in Jacksonville is used. In the first test, the transmitter of the ASR 9904 100G DWDM line card transmits the signal over the long-haul transport link. The signal received from the transmission link is fed into the receiver of the Juniper MX2020 100G DWDM line card, which is also used to collect the optical transmission performance. Optical performance measurements for the multi-vendor line-side interoperability scenario are collected during a soak test running over 8 hours, as shown in Fig. 2a. The worst-case measured pre-FEC BER during the measurement time frame was 7.6e-5 with an average pre-FEC BER of 6.7e-5. The measured pre-FEC BER translates into a worst-case system margin relative to the HG-FEC threshold of 3.2 dB. This confirms line-side interoperability between Juniper and Cisco DWDM router line cards using the HG-FEC mode with excellent optical performance over 1030 km.

Finally, in a second test the transmitter and receiver directions are exchanged between the Juniper MX2020 and the Cisco ASR9904 routers. The 100G coherent DWDM line card in the Juniper MX2020 router now transmits the signal over the long-haul link with the 100G DWDM line card in the Cisco ASR9904 as the receiver. The optical performance statistics are now collected on the Cisco ASR9904 DWDM line card during an 18-minute interval, as shown in Fig. 2b. The average pre-FEC BER (over 2-minute time slots) is 4.1e-5, with an average pre-FEC BER over the 18-minute measurement window of 2.3e-5.

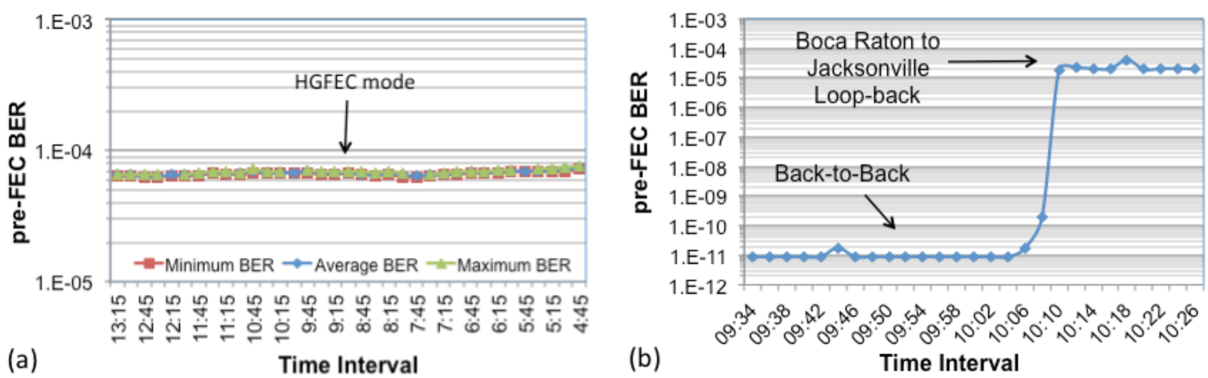

Fig. 2: Line-side interoperability transmission results over 1030 km measured on (a) Juniper MX2020 and (b) Cisco ASR9004

4. Conclusions

We demonstrated 100G coherent DWDM multi-vendor line-side interoperability between Juniper MX2020 and Cisco ASR9904 routers over a 1030-km DWDM link in the Telefonica network. The DWDM line cards use 100G CFP2-ACO pluggable coherent DWDM optics and supports the HG-FEC line-side interworking code. A 3.2 dB margin is measured after 1030 km for the multi-vendor line-side interoperability tests, whereas single-vendor measurements using a proprietary SD-FEC code showed a 4.0 dB system margin.

5. References

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