Field Demonstration of Disaggregated Optical Network Consisting of ZR+ and Coherent Channels using Power Equalization by Switched Gain Equalization Controlled Amplifiers

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Abstract: We report a field trial of 400G-ZR+ QSFP-DD-DCO and ten coherent channels, interoperating with oFEC between two different vendors. We equalize the power by switched gain equalization controlled amplifers. Field trial is verified by simulations.

1. Introduction

With growing demand of high capacity and cost-effective data transmision, optical network operators are also aiming towards inter-operabilty of hardwares from different vendors [1, 2]. Thus, making disaggregated optical networking, as a popular choice among tier-1 operators, as it provides freedom from vendor lock-in, allows choosing desirable partners based on lead time of delivery, and facilitates strong negotiations. 400G ZR+ QSFP-DD-DCO and open line systems are making disaggregation a reality, however, low transmitted power and high back-to-back required OSNR of 400G ZR+ syetem, limits its reach to metro and access data center interconnect applications [2–5]. This situation becomes worse for deployments over high fiber cut prone terrains like in India. Further, interoperability between low power (~ -10 dBm) ZR+ and high power ($\sim$3 dBm) coherent transponders, limits the performance of latter, which makes disaggregation more complex. This can be avoided by equalizing the power at various intermittent stations. However, power equalization can lead to lower link optical signal to noise ratio (OSNR), orginating from insertion loss and penalty caused by cascaded wavelength selective switches [5].

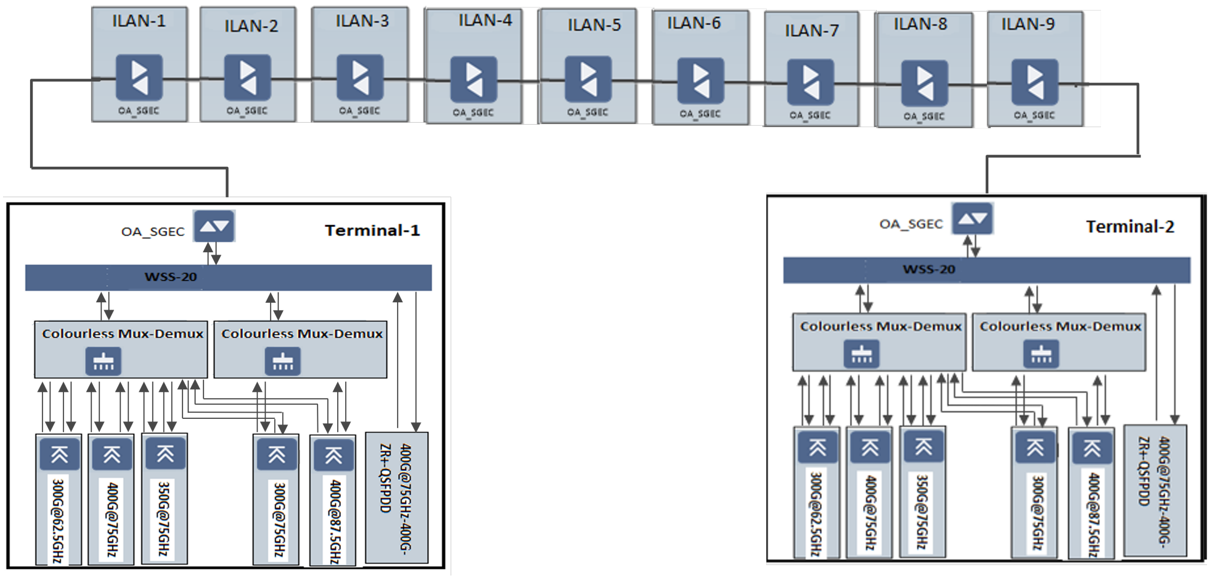

Fig. 1. A schematic presentation of the field-trial. OA_SGEC: Optical amplifier with switched gain equalization control, ILAN: In-line amplifier

In this paper, we report to increase low power ZR+ QSFP-DD-DCO reach to long haul distances, while simultaneously operating with ten high power coherent transponders, based on a field trial over 750 km dense wavelength division multiplexing (DWDM) link in India. We equalize the power by digital gain equalizer (DGE) of switched gain equalization controlled (SGEC) amplifier at each in-line amplifier (ILAN) site, without introducing inseration loss or filter penalty. Thus, improving OSNR by ∼4.5 dB, making it feasible to operate ZR+ and coherent transponders, simultaneously.

Table 1. The various channels transmitted over the field-trial network. SR: Symbol-rate. TC: Total capacity, Q1 and Q2: Q-margin without and with 400G ZR+ QSFP-DD-DCO, respectively.

Line-rate, Gb/s	BW, GHz	SR, G-Baud	TC, Tb/s	Q1, dB	Q2, dB
300	62.5	46.3	46.08	5.1	4.9
300	75	61.2	38.40	6.2	6
350	75	60.7	44.8	4.9	4.9
400	75	63.0	51.2	3	3
400	87.5	69.4	43.89	4.7	4.6

2. Field Trial and Results

Fig. 1 shows the schematic of 750 km DWDM optical transmission link used in field trial. The link consists of ten spans of G.652 fiber, with span length varries from 60 km to 90 km. The corresponding loss varries from 18 dB to 24 dB. We employed flex-grid and hybrid-modulation techniques, and transmitted ten coherent channels at various line-rates (LRs), bandwidths (BWs), and symbol rates (SRs), as summarized in Table 1. In addition to coherent channels, we also transmitted a low power (-10 dBm) alien channel at LR and BW of 400 Gb/s and 75 GHz, respectively, orginated from ZR+ QSFP-DD-DCO. Q-margin of the transmission system without (Q1) and with (Q2) 400G ZR+ QSFP-DD-DCO, for each LRs are tabulated in Table 1.

We equalize the power of coherent channels and 400G channel orginated from ZR+ QSFP-DD-DCO, using high power SGEC amplifiers. This is to ensure that, the two low and high power channels, will have similar power and OSNR evolution throughout the link, and thus making interoperability possible. The SGEC amplifier is a dual C-band module, which provide automatic gain control. The configurable gain ranges from 15 dB to 28 dB and 23 dB to 37 dB, for each modules, respectively. SGEC also supports optical channel monitoring (OCM) along with dynamic gain equalization (DGE) functionality. The SGEC amplifiers are used at ILAN and terminal sites, to provide equalization, without introducting additional insertion loss and filter penalty at relatively lower cost. This serves as alternative of using DGE from WSS with high loss and filter penalty, at higher cost.

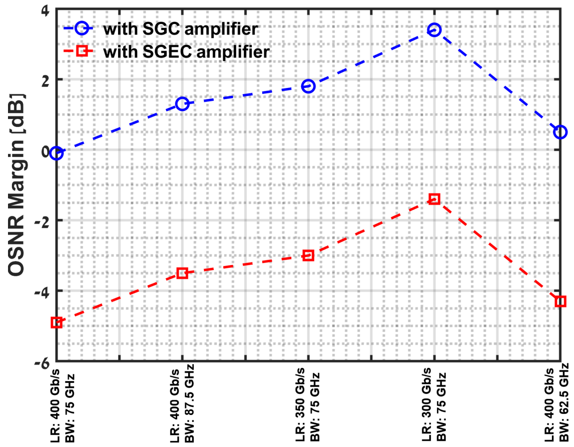

Fig. 2. Worst OSNR margin with SGC and with SGEC amplifiers. LR: Line-rate, BW: Bandwidth

We terminate the 400G ZR+ channel with Open forward error correction (oFEC) on client side of 20-port twin WSS at each terminal location (of DWDM transmission system). This shows interoperability between oFEC of two different original equipment manufacturers (OEMs), *i.e.*, between an alien channel and ten coherent channels, from ZR+ QSFP-DD-DCO and standard transponder, respectively. The standard coherent channels are transmitted with 3 dBm power and terminated on a colorless multiplexer/demultiplexer, with 11 dB insertion loss. Thus, resulting in -8 dBm effective transmitted power and -10 dBm power for coherent and ZR+ channels. Optical power of channels are further equalized by DGE in SGEC amplifiers, as explained in previous paragraph and noticed by similar Q-margin with and without Zr+ channel transmission, in Table 1. Finally, we achieved transmission of low power (-10 dBm), 400 Gb/s-LR and 75 GHz-BW channel orginated from ZR+ QSFP-DD-DCO with oFEC, running as alien wavelengths over ten coherent channels on 750 km DWDM link.

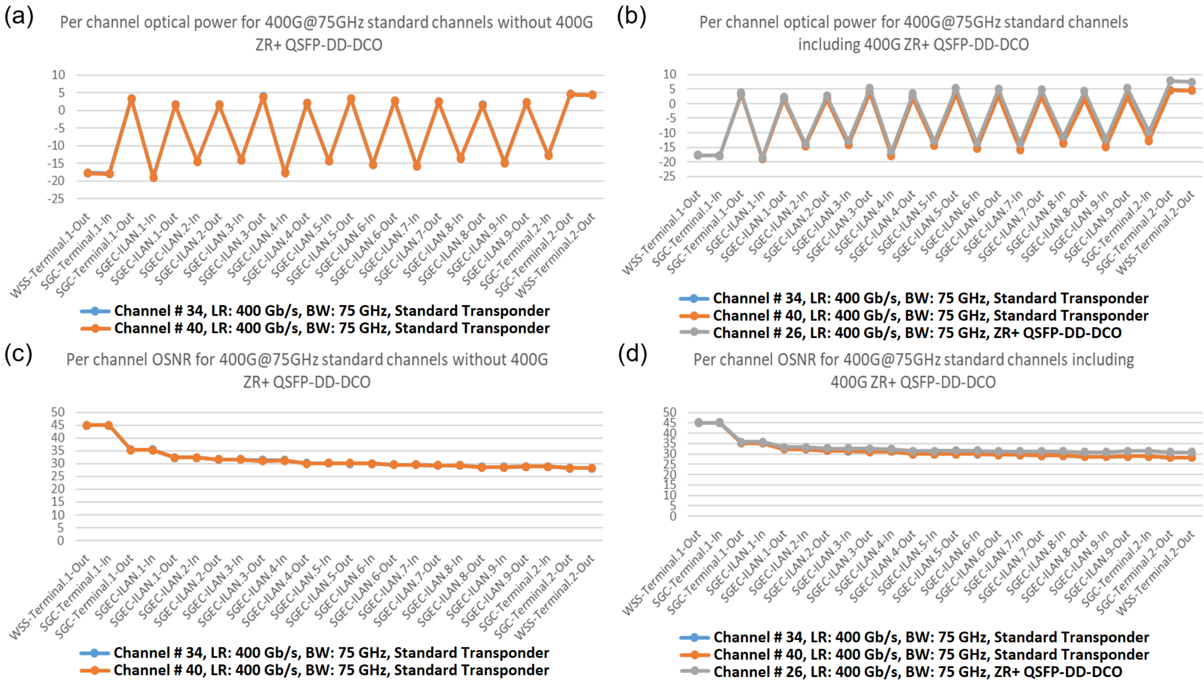

Fig. 3. Optical power at each ILAN site (a) without and (b) with 400G ZR+ QSFP-DD-DCO. OSNR per channel at each ILAN site (c) without and (d) with 400G ZR+ QSFD-DD-DC)

3. Simulation Results and Discussion

We simulated the field trial link for the channel with worst OSNR performance (among ten coherent channels), of each symbol-rate, with and without equalization by amplifiers. The amplifiers without equalization (also known as switched gain controlled (SGC) amplifiers) are considered with same noise figure and gain, as that of SGEC amplifiers. Fig. 2 compares the worst case OSNR margin with SGC and SGEC amplifiers. This shows $\sim$4.5 dB OSNR gain can be achieved with SGEC as compared to SGC, for each symbol-rate. Thus, empashising the use SGEC over SGC amplifier to achieve better OSNR.

Further, we also simulated the optical power and OSNR evolution at each ILAN sites (with SGEC amplifiers), with and without 400 Gb/s ZR+ channel, to visualize the power equalization by SGEC. Fig. 2a-c and Fig. 2b-d shows optical power and OSNR of two coherent channels, without and with ZR+ transmission. Blue, orange, and grey line, represents the channel number 34 and 40 of coherent signals, and channel number 26 of ZR+ signal, respectively. For simplicity, we plotted only two out of ten coherent channels. The two coherent channels have equal power and OSNR evolution throughout the link, as apparent from overlapping blue and orange curve (only orange curve is visible) in Fig. 2a-c. When ZR+ signal is added as alien channel with coherent channels, DGE in SGEC (at ILAN sites) tries to equalize the power and OSNR, as evident from Fig. 2b-d. This makes sucessful transmission of low power (-10dBm) 400G ZR+ QSFP-DD-DCO with high power (+3dBm) coherent channels from standard transponder over a 750km DWDM link, as supported by field trial result in Section 2.

4. Conclusion

We reported, to the best of our knowledge, a first time field trial of disaggregated optical network, consists of low power (-10 dBm) 400G ZR+ QSFP-DD-DCO and high power (3 dBm) coherent channel from standard transponder with interoperation of oFEC between two different vendors. The 400G ZR+ QSFP-DD-DCO channel transmitted as an alien wavelength a on 3rd party, ten high-capacity coherent channel, over 750km of DWDM link in India. We have achieved power equalization at each ILAN site using SGEC-amplifiers supporting DGE functionality, with very minimal insertion loss and filter penalty, as compared to conventional WSS components. The field trial result is further explained by simulation.

References

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