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Experimental Validation of an Open Source Quality of Transmission Estimator for Open Optical Networks

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Abstract: We test the QoT-E of the GNPpy library fed by data from the network controller against experimental measurements on mixed-fiber, Raman-amplified, multi-vendor scenarios on the full C-band: an excellent accuracy within 1 dB is shown. © 2020 The Author(s)
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1. Introduction

Operators are always willing to improve their network efficiency given the ever-increasing traffic and resource-constrained long-haul fiber. Furthermore, optical infrastructures based on coherent transmission technologies are indeed available for optimizations [1] aimed at exploiting the maximum available capacity of the deployed network [2]. An accurate quality of transmission (QoT) estimator (QoT-E) is fundamental to achieve this goal. Thus, open optical networks are challenging the status-quo by enabling operators to perform vendor-neutral analysis and planning, relying on quick network performance estimation. This way, operators and vendors alike are able to predict optical network performance and scrutinize results, both off- and on-line, in a trusted and comparable manner. Leveraging such capabilities within a software-define network (SDN) environment is instrumental for optimizing and automating the infrastructures' usage. The reference implementation is provided within the Telecom Infra Project (TIP) by the Physical Simulation Environment (PSE) working group [3, 4] as an open source code library by the name "GNPpy" [5]. As depicted in Fig. 1, GNPpy requires a description of the network status at layer-0, of the route under analysis and of the related spectral load, then it computes physical impairments along the path: GNPpy acts as a QoT-E. The QoT-E delivers a quick evaluation of a commonly accepted, unique QoT parameter: the generalized signal-to-noise ratio (GSNR), which considers both the the accumulation of the Amplified Spontaneous Emission (ASE) noise and of the nonlinear interference (NLI) [6, 7].

This work documents the validation effort carried out over Microsoft's lab test-bed, evaluating the latest QoT-E version based on the generalized Gaussian noise model [8, 9] for the NLI calculation, and on accurate amplifier models for the analysis of the ASE noise. To this aim, the stimulated Raman scattering (SRS) is included by introducing a Raman solver [10] to accurately assess distributed Raman amplification. Furthermore, this is the first test based on data reported by the network controller or provided by the vendor without acquiring extra measurements from the field; contrary to what has been done in [6]. The presented results are obtained using GNPpy as depicted in Fig. 1: network data are requested from the photonic controller and used to feed the QoT-E which is able to predict the GSNR within a matter of seconds¹. To validate the GNPpy predictions, GSNRs are compared to experimental bit-error-rate (BER) measurements by deriving the GSNR from BER.

The test-bed at Microsoft included mixed fiber and hybrid EDFA/Raman amplification enabling measurements for propagation distances from 400 up to 4000 km. Experiments were performed on full C-band spectral load using multi-vendor transceivers and different modulation formats. Excellent results were obtained with a prediction accuracy of better than 1 dB for more than 90% of the investigated cases, including challenging shorter

¹One second per channel under test per fiber span, on a laptop with a dual core i7 CPU. Further reductions in computational time are already planned.

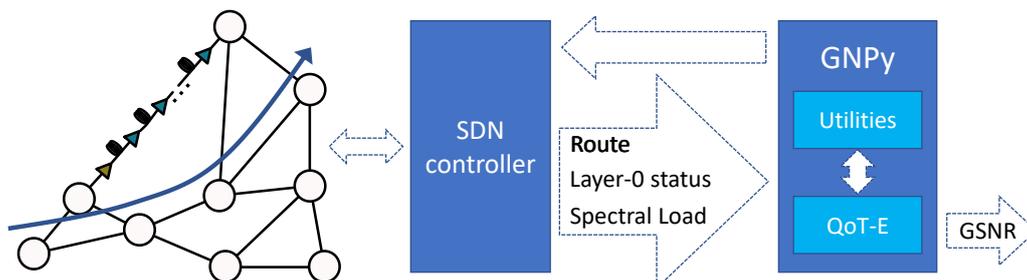


Fig. 1. Block diagram for the use of the GNPpy library within a SDN environment.

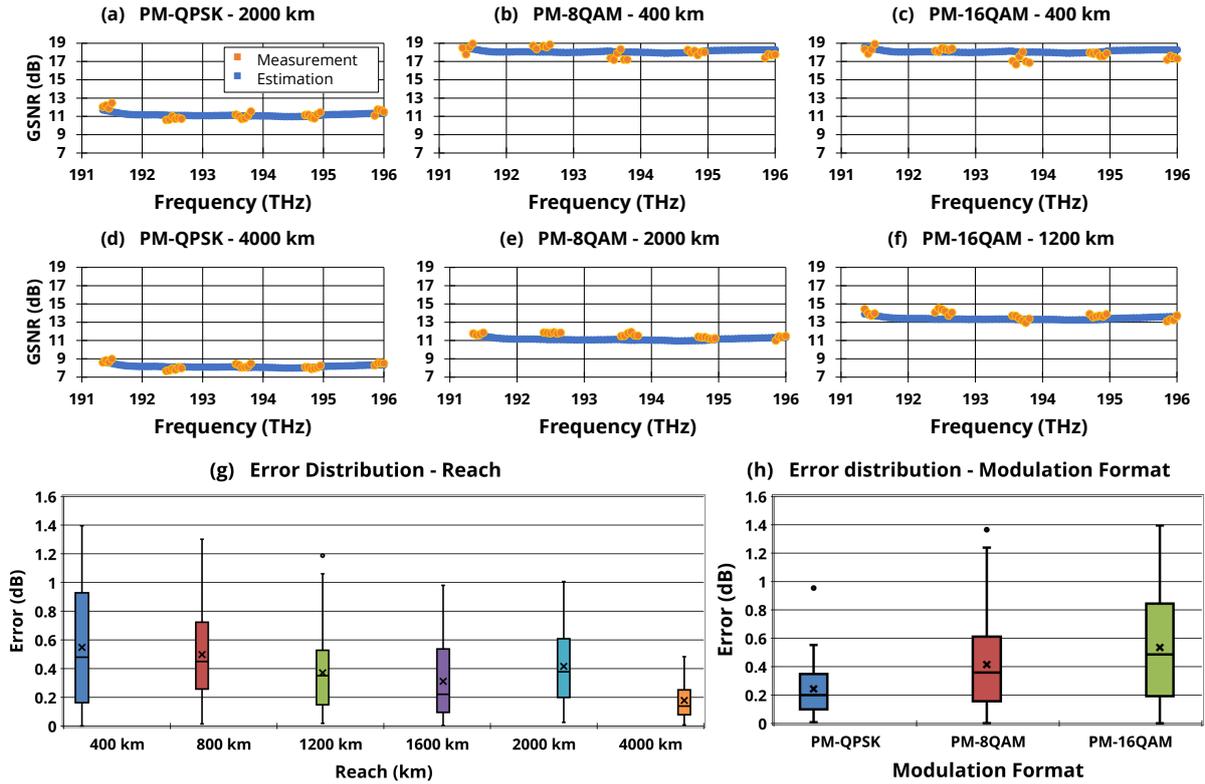


Fig. 3. GSNR estimated by GNPpy (blue lines) and the actual GSNR (yellow dots) for PM-QPSK (a and d), PM-8QAM (b and e) and PM-16QAM (c and f) and for different reaches. Error distribution for each reach (g) and for each modulation format (h).

reduces since the overall GSNR reduction mitigates the uncertainty on both ASE noise and NLI. Measuring the GSNR at shorter distances is, in fact, more difficult since i) the BER is lower, then, less stable and ii) the GSNR is higher and therefore, more sensitive to small inaccuracies.

Fig. 3(g),(h) report the error distribution for different distances (Fig. 3(g)) and different modulation formats (Fig. 3(h)) as box-plots. Such statistics are based on a total of ~ 500 samples of errors, in which, the largest value is at 400 km and it is 1.4 dB. Moreover, $\sim 80\%$ of the estimations are within 1 dB of error at 400 km. This percentage grows to $\sim 92\%$ at 800 km, then it reaches the 100% for larger distances. Furthermore, at 4000 km, all the errors are within 0.5 dB. Fig. 3(h) shows the error distribution per modulation format. The PM-QPSK is the modulation format presenting the lower error while PM-16QAM is the one affected by larger inaccuracy. This is related to the inaccuracies being larger at shorter distances and smaller at longer distances.

3. Conclusions

We show the accuracy of the QoT-E of the open source GNPpy library in predicting the GSNR for different modulation formats in a multi-vendor, full C-band, Raman amplified scenario. We used data programmatically obtained by the SDN controller and the accuracy of predictions against experimental measurements is within 1 dB for more than 90% of the cases, for distances from 400 km up to 4000 km.

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