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XXXIV cycle

Machine-learning Aided Quality of Transmission Estimation in Optical Line Systems

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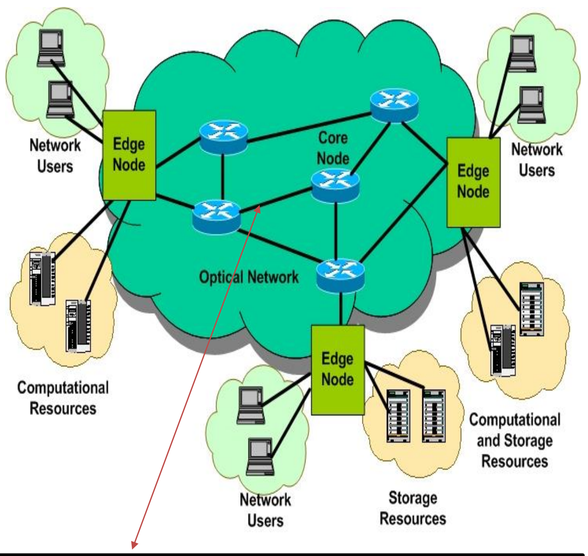
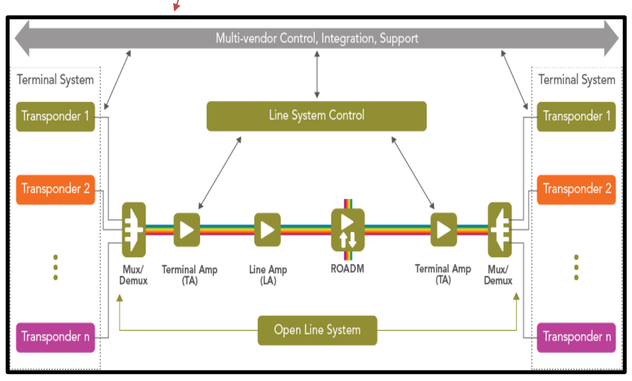
Research context and motivation

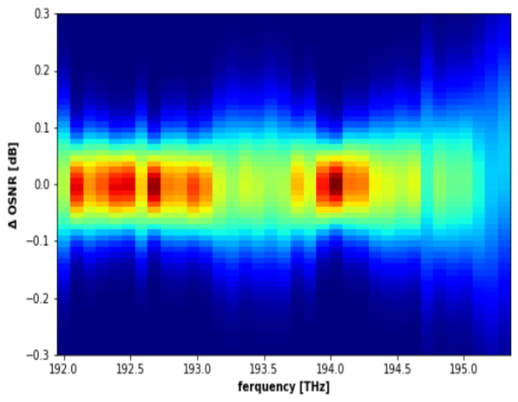
- Data traffic demand will experience a dramatic increase by the implementation of 5G and by the expansion of bandwidth hungry applications such as high definition video, virtual and augmented-reality contents
- Backbone optical networks will sustain such a growth, and a key operator's request is to exploit the existing infrastructure to maximize their returns over investments
- Operators interest is to exploit the capacity of existance fiber and infrastructure
- Such a need is directly related to the capability of orchestrating all the network layers to squeeze out all the available capacity from the existence infrastructure



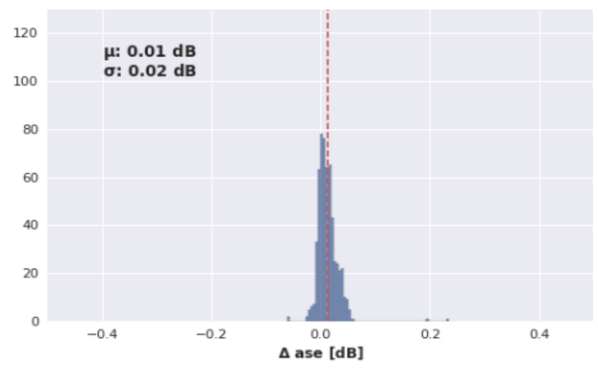


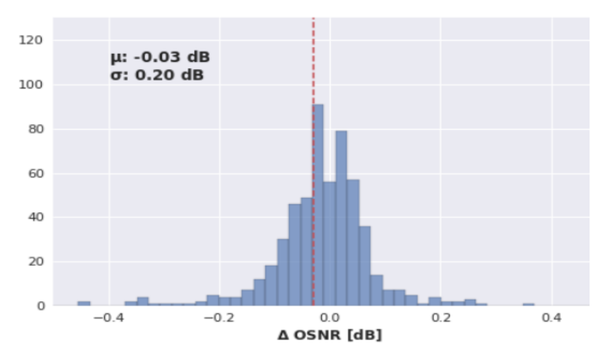
Novel contributions

- Our QoT-E using machine-learning techniques supposing the availability of a training data-set acquired before the deployment of real traffic, with the purpose of reducing the uncertainty on the estimated OSNR.
- We did not aim at developing specific machine learning methods, but only showing the effectiveness of ML for the objective purposes So, we relied on the available open source libraries, specifically on the TensorFlow platform .



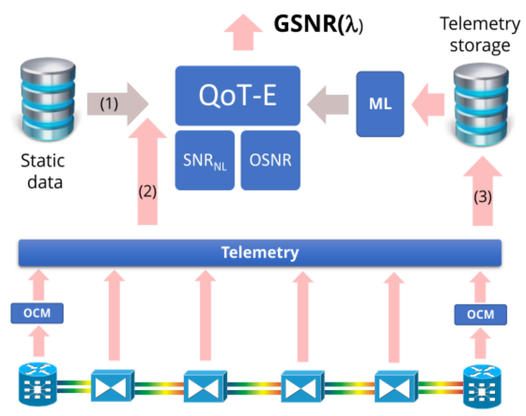
- We show that using deep neural network (DNN) algorithms, with some optimization, and properly exploiting the data-set, we reduced the uncertainty on the predicted OSNR down to 0.2 dB.



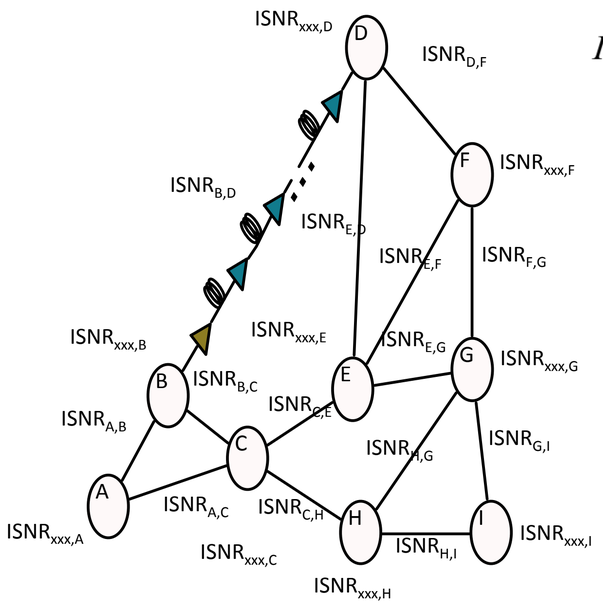


Addressed research questions/problems

- In optical networks, the enabler for the optimal exploitation of data transport – the dense wavelength division multiplexed (DWDM) transmission – is the control layer.
- In particular, software-defined network (SDN) controllers rely on a network abstraction where Quality-of-Transmission (QoT) degradation on Optical Line Systems (OLS) is given by the capability of OLS controllers to operate at the optimal working point



- The higher the accuracy in pursuing such a task, the lower the margin for traffic deployment and larger the deployed traffic rate.
- Moreover, network failures and recovery could be automatized and sped up. So, to reduce the margin it is mandatory to rely on a QoT estimator (QoT-E) that is able to reliably predict lightpath (LP) performance before its actual deployment, i.e., the generalized SNR
- (GSNR)=1/*ISNR* that includes both the effects of ASE noise and nonlinear interference.



$$ISNR_{ZY}(\lambda) = \frac{1}{OSNR_{ZY}(\lambda)} + \frac{1}{SNR_{NL,ZY}(\lambda)}$$

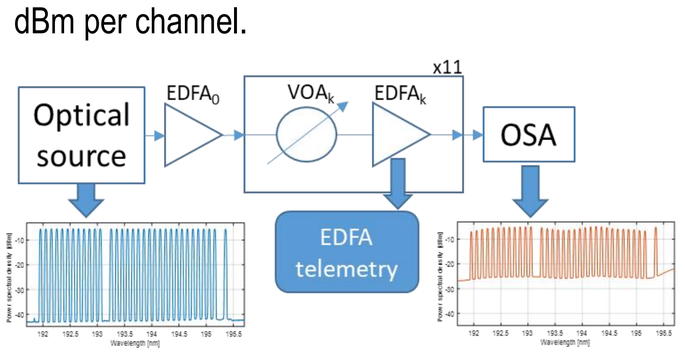
$$= \frac{P_{ASE,ZY}(\lambda)}{P_Y(\lambda)} + \frac{P_{NLI,ZY}(\lambda)}{P_Y(\lambda)}$$

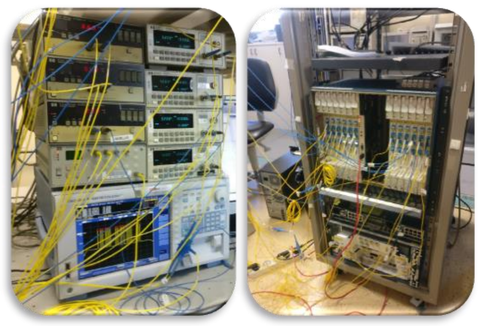
Exact evaluation if we know losses, gain(λ), NF(λ)

Excellent evaluation by propagation model. Open issue: connector losses

Adopted methodologies

- We suppose a completely agnostic scenario, by relying only on data coming from the optical channel monitor (OCM) available at the end of the line system.
- To emulate an OLS, we experimentally setup an 11-EDFA line and we changed spectral loading, collecting data from an optical spectrum analyzer (OSA) mimicking the OCM.
- The channel combs spectrally loading the OLS have been obtained by shaping ASE noise.
- The output of the ASE noise source is shaped by means of a programmable optical wave-shaper filter to generate a 100 GHz-spaced 35-channel WDM comb centered at 1550 nm and amplified by a booster amplifier
- The choice of the 100 GHz spacing was forced by the hardware availability as well as the limitation to 3.5 THz.
- The optical line is composed by 11 spans, each made of a VOA, setting the optical span attenuation to 10 dB, followed by an EDFA, operating at a constant output power of -1 dBm per channel.





Future work

- Future analyses performed by including also the available telemetry data from the EDFAs
  may yield to further reducing the residual uncertainty
- The effectiveness of machine learning in optical line systems will exploit the hidden capacity of already infrastructure to maximize the operator returns over investments

Submitted and published works

- Amico, A.; Straullu, S.; Nespola, A.; Khan, I., ; Abdelfattah, S.; Virgillito, E.; Piciaccia, S.; Tanzi, A.; Galimberti,G.; Abrate, S.; Curri, V., "Machine-learning aided osnr prediction in optical line systems",ECOC 2019, Dublin, Ireland, 2019

List of attended classes

- 01RONKG – Python in the Lab(25/06/2019, 20h)
- 01QTEIU – Data mining concepts and algorithms(11/01/2019, 20h)
- 01QFFRV – Tecniche innovative per l'ottimizzazione (06/03/2019, 20h)
- 01TEHRV – Data Science for Networks (09/04/2018, 30)
- 01QORRV – Writing Scientific Papers in English (28/03/2019, 15h)
- 01TCTRV – Photonext : Hands on course on Photonics for Fiber Transmission (18/07/2019, 30h)

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