Research context and motivation

- The reliance of our modern society on the Internet has only grown stronger over the years. Wavelength division multiplexing (WDM) that exploits only the C-band with a bandwidth of ≈ 4.8 THz is currently the most commonly deployed and cost-effective solution for transmitting the required data in optical networks, ranging from very long-haul/submarine to metro networks.

- Multi-band optical fiber transmission (MBT) is a natural solution to cope with the increasing request of capacity, as it requires fewer changes to existing optical fiber infrastructures. This solution implements transmission over a wider spectral range within the low-loss region of the widely deployed single-mode optical fibers, namely the ITU-T G.652.D type, exceeding a total transmission bandwidth of ≈ 50 THz.

Addressed research questions/problems

- Two main solutions for increasing the network capacity proposed and compared in terms of capacity expansion, transportation, costs, and link congestions: (i) using MBT systems in the C-, C+L-, C+L+S, and C+L+S+U bands, (ii) using signal regeneration in the intermediate nodes (translucent network design).

- The accurate modeling of signal propagation along an optical fiber, especially in MBT scenarios the QoT at the end of each fiber span for the i\_th channel is computed using the generalized signal-to-noise ratio (GSNR):

\[
\text{GSNR}_i = \frac{1}{\text{SNR}_i} = \frac{P_{\text{in}}}{N_0} \left( 1 + \frac{\text{SNR}_i}{1 + \text{SNR}_i} \right)
\]

- Above figure depicts the GSNR profile after transmission of 64 channels with symbol rate of 64 Gbaud in the 75 GHz WDM grid along a single 75 km ITU-T G.652D optical fiber span. The network evaluation is performed using the statistical network assessment process (SNAP) framework, which uses the GSNR as the QoT metric. The SNAP framework has been customized to cover both transparent and translucent network design scenarios. Also, 3R assignment algorithm proposed in the below (General Algorithm).

Novel contributions

- Three different 3R regenerator placement algorithms are considered. Two of them can be used to assign 3R regenerators in any band whereas the last one focuses on placing 3R regenerators in the S-band only; since this band presents the lowest QoT in comparison to the other bands. The efficiency of the three different algorithms is compared in terms of total allocated traffic, consumed energy per Terabit, interface count as a cost, and allocated LPs.

Adopted methodologies

- It can be observed that increasing the network capacity by exploiting more bands is more effective than deploying 3R regenerators in the C-band only scenario. Indeed, enabling the L-band in a transparent network design leads to more than twice the capacity, but performing signal regeneration only increases the network capacity by \( \times 1.09 \) and \( \times 1.07 \) times with the General and Pow. Opt. algorithms, respectively.

Future work

- Another possibility to augment fiber capacity is to extend the used bandwidth of traditional bands (C and L) from 4.8 to approximately 6 THz in each band, without needing new amplifiers.

- We compared the network capacity as well as the number of interfaces between regular and extended bandwidth bands in transparent and translucent network designs. We showed that super bands lead to an increase in network capacity in comparison to the regular bands for the same number of bands. Importantly, super bands transparent network design provides the same delivered traffic compared with regular C+L+S+U transparent network design, with both solutions featuring a trade-off between extra interfaces and extra amplifiers.

- Additionally, using machine learning (ML) / Reinforcement Learning (RL) would help to increase the network capacity. This topic currently is the topic that I am working on it. And good results have been achieved by PLANET team.

Submitted and published works

- R. Sadeghi, B. Correia, A. Napolli, J. Pedro, V. Curti, “Capacity and Energy Consumption Comparison in Translucent Versus Transparent Multi-Band Design”, International Conference on Optical Network Design and

List of attended classes

- 01REKRV – Coherent detection: a revolution in optical communication (2021, credits)
- 01GSAIU – Heuristics and metaheuristics for problem solving new trends and software tools (2021, credits)
- 01TRLRVR – Optical Transport Networks (2021, credits)
- 01RGBVR – Optimization methods for engineering problems(2021, credits)
- 01SFURV – Advanced scientific programming in matlab (2021, credits)
- 02LHVR – Communication (2021, credits)
- 01SYBVR – Research integrity (2021, credits)
- 08IXTRV – Project management (2021, credits)