Multi Bands Network Performance Assessment for Different System Upgrades

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Abstract: We investigate the capacity of a reference German network when employing band-division multiplexing (BDM) using C+L+S-bands and spatial-division multiplexing (SDM) in case of different nodes distribution scenarios. We show that BDM enables increasing the network capacity by up to almost 3× with respect to C-band transmission only.
Keywords- *Multi-band, Transmission Modeling, High-capacity Optical Systems*

1. Introduction

Optical networks with increased capacity are essential to support the imminent 5G implementation [1]. Two solutions, spatial- and band-division multiplexing (SDM/BDM) [3], have been proposed aiming at extending the capacity of current wavelength division multiplexing (WDM) networks, using up to 96 channels over 4.8 THz in the C-band ITU-T 50 GHz grid. BDM solutions are currently commercially available using C- and L-bands which extend the line systems transmission spectrum from 4.8 THz to near 10 THz [2,3], while the alternative approach – SDM – consists in lighting up additional dark fibers in network links. When moving toward wideband systems, it is essential to perform an accurate launch power optimization to avoid a variation of the generalized signal to noise ratio (GSNR) [4], which is assumed as the Quality of Transmission (QoT) [5] metric, between the different channels. Namely, the non-linear Stimulated Raman Scattering (SRS) must be carefully taken into account has it is a quite relevant nonlinear transmission effect in wideband systems. In [7], the authors investigated the launch power optimization and network performance for upgrades enabling L-band in addition to C-band and compared it with doubling the number of optical fibers in each link of the network. This work extends [7] by adding the S-band (to C+L systems) and comparing the network capacity with the SDM approach (using three fibers) for a reference German topology and for two types of traffic distribution: uniform and non-uniform.

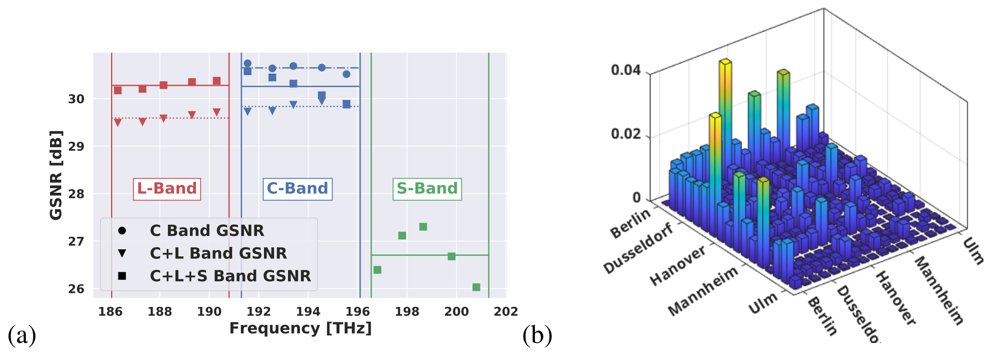
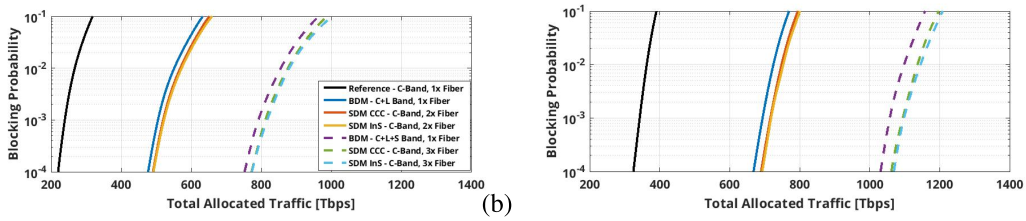


Fig. 1. a) GSNR for C, C+L and C+L+S-bands, b) non-uniform joint PDF.

2. Methodology and Results

The procedure consists of two parts. First, the launch power profile over the three scenarios: C, C+L and C+L+S-bands is optimized in order to maximize and flatten the GSNR, using the strategy of tilts and offset to define the power over the spectrum bands as in [7]. An optimum tilt range for C+L+S case from -1 to 1 dB/THz is analyzed for all bands, while an optimum offset ranging from -1 dB to 2 dB for C-band and from 0 dB to 3 dB for L- and S-bands is investigated. The GSNR for the 5 channels under test in each band are shown in Fig. 1. The tilt and offset for each band leading to the best QoT are selected in this case. The GSNR averages are: 30.6 dB for C-band only, 29.8 dB and 29.6 dB for C-and L-bands, respectively, in C+L case and 30.2, 30.3 and 26.7 dB for C, L and S-bands in C+L+S scenario. It is worth to mention that the lower performance of the S-band are due to the higher noise figure of the considered amplifier, which is a non-optimized benchtop amplifier. On the other hand, we considered high performing amplifier for C and L-band, with low and almost constant noise figure over the transmittable spectrum.

The second part of the proposed procedure consists in the network performance analysis using the Statistical Network Assessment Process (SNAP) with the QoT estimation found previously [8,9]. In the SDM case, independent switching (InS) and core continuity constraint (CCC) re configurable optical add-drop multiplexer (ROADM) switching techniques are used following the same approach investigated in [6]. We also investigate two different Joint Probability Density Functions (JPDFs), uniform and non-uniform, based on population. The Non-uniform JPDF is shown in Fig. 1b for a reference German topology. Blocking probability (BP) is measured by merging the JPDF and QoT with SNAP [8] results. The transmission of 96 channels with a symbol rate of 32Gbd has been considered for reference case (only C-band/single fiber). Additional 96 channels are considered per band. The k-shortest path algorithm is used for finding k alternative shortest paths between requests, with $k_{max} = 15$.



(a) (b)

Fig. 2. Blocking probability versus total allocated traffic in a reference German network for: a) Uniform b) Non-uniform JPDF.

Figs. 2a,b) report the BP for all considered scenarios: C+L and C+L+S upgrades in case of uniform and non-uniform JPDFs, respectively. In the reference case, which consists in C-band only transmission and using only a single optical fiber in each fiber link, the allocated traffic at BP = 1% is $\sim$267.5 Tbps. However, by enabling L and S-bands in BDM, the capacity of network increases by $2\times$ and $3\times$ respectively. Also, instead of activating more bands, we could also light up 2 and 3 dark fibers (SDM upgrade). The results show that the capacity would also increase 2 and 3 times, respectively, in this case. For instance, at BP = 1% with 2 and 3 fibers, the total allocated traffic is 573 and 880 Tbps for SDM-CCC, and 570 and 876 Tbps for SDM-InS, respectively. The penalty between BDM and SDM results can be explained by the lower QoT in case of BDM systems, which is mainly caused by SRS. This penalty increases for the C+L+S scenario in comparison with C+L case, with an additional penalty of 1 dB QoT in C+L and 1.5 dB in the C+L+S case. Furthermore, the behavior of the different considered ROADM switching techniques – SDM-CCC and SDM-InS – is similar. Changing to non-uniform JPDF, it is observable that BDM and SDM preserved also comparable performance. However, non-uniform JPDF leads to increased capacity; and this might be explained by the specific structure of the reference German network. This results into more than 95 Tbps allocated traffic difference when comparing the uniform and non-uniform traffic JPDFs at BP = 1%.

3. Conclusion

BDM and SDM upgrades enable increasing the capacity of optical networks. Although BDM has a smaller traffic allocation in comparison with SDM/InS and CCC, it might result in a valuable choice when dark fibers are unavailable between nodes. Non-uniform JPDF of traffic distribution showed that node arrangement is important in a network. Finally, we showed that BDM with 3 bands (S+C+L) achieves almost comparable performance to SDM with three fibers.

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