# Multi-band Photonic Integrated WSS for 800G Optical Data Center Interconnect Systems


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***Abstract*—This study presents a networking performance analysis of a modular photonic integrated multi-band Wavelength-Selective-Switch (WSS), which can operate on multi-bands covering (S+C+L) bands. The WSS is designed for inter-data center applications, and its networking performance is analyzed for 800G transmission systems.**



***Index Terms*—Multi-band, Photonic Integrated Circuits, Wavelength-Selective-Switch, Data Center Interconnects.**


## I. Introduction

Due to the rapidly increasing demand for bandwidth, Data Center Interconnect (DCI) must scale up to higher rates. The 400ZR deployment empowers 400G operations based on dual-polarization coherent detection technology [1]. The commercial implementation demonstrates that coherent optical communication technologies are a promising solution for 400G DCI and beyond [2]. Moving in this direction, coherent technologies for higher rates, such as 800G and beyond, are being discussed in several standardization proposals, and they may be implemented in different schemes such as LR, ER, and ZR [3]. Focusing on the 800G systems, they utilize a higher baud rate and traditional modulation formats, such as 80Gbaud 64QAM (for short-range communication) and 96 GBaud 32QAM, and 120 GBaud 16QAM (for medium to long-range communication), due to cost and implementation complexity [4].

The present state-of-the-art optical infrastructure exploits Wavelength Division Multiplexing (WDM) using the standard C-band, which has a bandwidth of 4.8 THz. A new fiber deployment must be a possible solution to increase further the capacity to support the DCI requirements. Installing a new fiber to increase capacity can be expensive, especially when fiber resources are scarce [5]. In this context, multi-band transmission is defined as the transmission of data over a broader range of low-loss optical fiber spectral bandwidths (e.g., 54 THz in ITU G.652.D fibers), offers a good solution for enhancing network capacity and reusing existing fiber infrastructure. The initial step in implementing multi-band transmission systems is the development of filtering and switching components. In this regard, WSS is an essential component of transmission systems that provides independent control and routing of each input channel of the WDM comb to the fiber output. Typically, WSS systems are built using complicated and cumbersome technologies like Liquid Crystal on Silicon (LCoS) and Microelectromechanical Systems (MEMS) [6].

The present work assessed the performance analysis of modular photonic integrated multi-band WSS implementation for DCI operation. The WSS considered in this analysis features a modular architecture that allows it to operate across a large optical spectrum, including the S+C+L bands [7]. The considered WSS solely contemplates the switching capabilities of the WSS module and disregards the local add/drop module of the Reconfigurable Optical Add-drop Multiplexer (ROADM). Initially, the network performance analysis of this multi-band modular WSS is performed by operating it on 16QAM modulation format with a symbol rate of $R_s = 60$ GBaud and Free Spectral Range (FSR) $= 100\,\mathrm{GHz}$ WDM comb to enable 400G transmission for long-range transmission [8]. This study begins by proposing the redesign of the WSS to support 800G transmission for DCI applications with FSR $= 100\,\mathrm{GHz}$ (with 40 channels per band) and 64QAM modulation format with $R_s = 80$ GBaud and then evaluate the WSS performance on the network layer. For DCI operation, the performance of the WSS is observed on the random metro network for inter-data center transmission.

## II. Performance Analysis of WSS for DCI Systems

The overall network performance is evaluated to assess the impact of the 800G transmission system for DCI. For this purpose, the Statistical Network Assessment Process (SNAP) [9] is utilized, which operates at the physical layer of the network being tested and evaluates the Quality-of-service (QoS) degradation caused by each network element. Lightpaths (LPs) are designated using the Routing and Wavelength Assignment (RWA) algorithm; the $k$-shortest routes with $k = 5$ are used for routing, and the first-fit technique is used to assign spectrum. Traffic grooming attempts to reduce the need for new LPs by validating the availability of unused capacity in existing LPs. If a new LP must be established, the optical controller chooses the proper modulation format based on the estimated Quality-of-transmission (QoT) and the Required Generalized

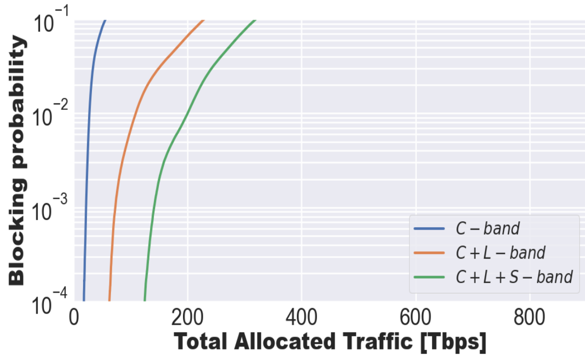


Fig. 1: BP evaluated considering 800G transceivers.

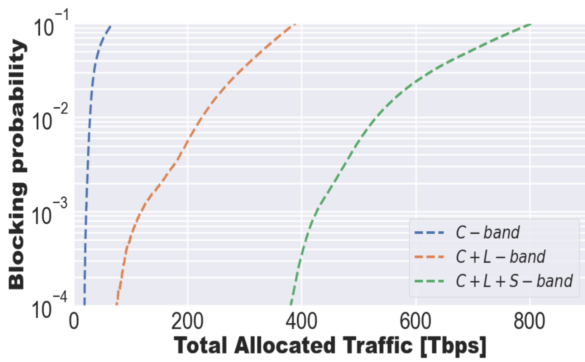


Fig. 2: BP evaluated considering ideal transceivers.

Signal to Noise Ratio (RGSNR) for the performance. Our study presumes that the optical amplifiers in a multi-band optical system, including the C- and L-band channels amplified by commercial Erbium-Doped Fiber Amplifiers (EDFAs) and the S-band channels amplified by Thulium-Doped Fiber Amplifiers (TDFAs), are tuned separately for each band. In addition, the network evaluation is conducted with a uniform distribution of traffic across all network nodes. This study uses a random metro area network with an average link length of 64 kilometers and a maximum link length of 90 kilometers. The total number of nodes in the network is 20. The average node degree for the considered network is 3.2, with a maximum node degree of 4.

Now, to evaluate the performance of the considered WSS, **Fig. 1** shows the traffic allocation versus the range of Blocking Probabilities (BP) for the 800G Transceiver (TRx). Whereas **Fig. 2** depicts the traffic allocation versus the degree of blocking possibilities for the ideal transceiver case where the maximum achievable traffic capacity over the links can be reached. The comparison of traffic allocation in both cases is shown in **Fig. 3**, where the blue bars represent 800G and the green bars show the ideal case. For the C-band only, the 800G TRx performs close to the ideal transceiver case with 43 Tbps and 51 Tbps for BP = $10^{-2}$ and $10^{-1}$, respectively. However, for the ideal case, the total possible traffic allocation for the C-band is 50 and 70 Tbps for the same BP. For the C+L- band case, the difference between the ideal and 800G TRx case increases by 210 Tbps (68%) and 250 Tbps(55%)

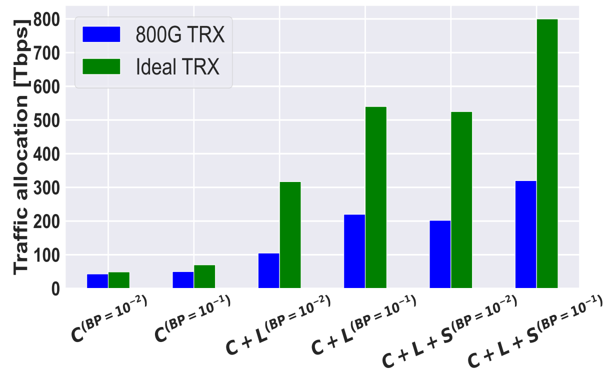


Fig. 3: Comparison of 800G TRx and Ideal TRx case with $BP = 10^{-2}$ and $BP = 10^{-1}$

for $BP = 10^{-2}$ and $10^{-1}$, respectively. Likewise, for the C+L+S- bands, the difference between the ideal and 800G TRx case is almost 315 Tbps (62%) and 480 Tbps (60%) for $BP = 10^{-2}$ and $10^{-1}$, respectively. In the case of multi-band scenarios such as the C+L- and C+L+S- bands, traffic allocation is improved mainly by the WDM technique, which enables more channel allocation and provides better traffic grooming capabilities.

## III. Conclusion

In conclusion, the study presented a performance analysis of a modular photonic integrated multi-band WSS implementation for DCI operation. The WSS is designed to support 800G transmission for DCI applications, and its performance is evaluated on a random metro network for inter-data center transmission. The results show that the multi-band WSS can enhance network capacity, and multi-band transmission is a promising solution to reuse existing fiber infrastructure.

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