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Network Traffic Analysis of Modular Multiband Integrated WSS based ROADMs

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Abstract

We present a novel photonic integrated multiband wavelength selective switch with a wide spectral operating range. We investigated the network performance of the device for SDM and BDM scenarios. The results show that BDM is a cost-effective solution to extend the network capacity.

Keywords

Multiband, Wavelength Selective Switch , Photonics Integrated circuits, High-capacity Systems, Network Traffic Analysis.

I. Introduction

The increasing Internet IP traffic requires the adoption of cost-effective, scalable, and adaptable solutions by service providers to expand the capacity of existing infrastructure. Modern optical transport is typically based on transparent propagation of Wavelength Division Multiplexing (WDM) channels over the entire C-band in a spectral window of 4.8THz using coherent dual-polarization optical technologies, enabling a maximum transmission capacity of about 38.4Tbps per fiber. The WSS, which provides independent control and routing of each input channel to a fiber output, is a critical component of the WDM switching architecture. In this paper, a multiband Wavelength Selective Switch (WSS) implementation based on Photonic Integrated Circuit (PIC) technology is proposed as a low-cost solution with small footprint and high production capacity. The proposed WSS has a modular architecture that allows it to utilize the entire optical spectrum, including the S+C+L bands. To further increase the network capacity, methods are needed to scale the capacity of existing technology or implement new technologies. The most viable options for improving the available capacity of optical networks are Spatial Division Multiplexing (SDM) which uses multiple fibers or Band Division Multiplexing (BDM), which uses a wider spectral range of the fiber to enable transmission over the entire low-loss spectrum of optical fibers (e.g., 54THz in ITU G.652.D fibers).

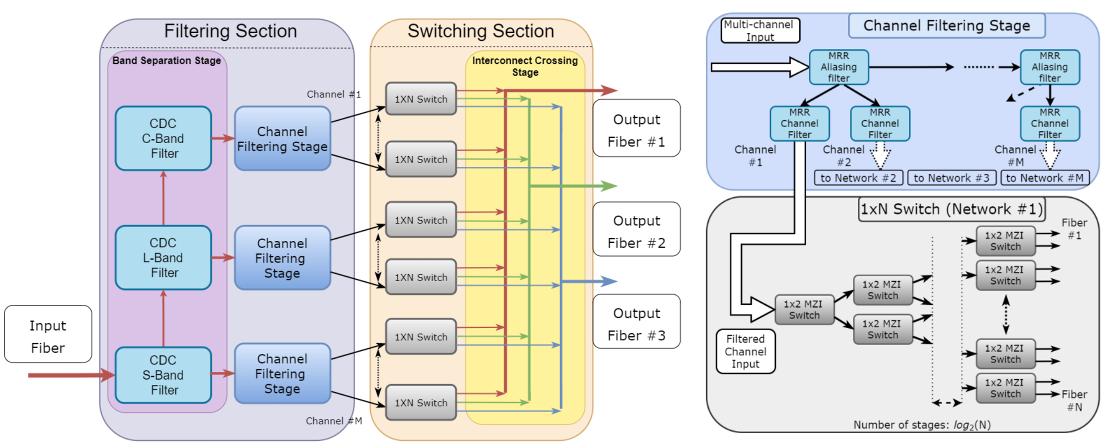

Fig. 1: Architecture of the proposed switch

II. WSS Architecture

The proposed WSS architecture can route M independent channels towards the target N output ports, allowing any desired output configuration with respect to the input WDM comb. The design has been carried out by separating the channel separation and routing into multiple layers, allowing parallelization of the routing process, which ensures no conflict for any possible required configuration. The general structure, depicted in Fig. 1, highlights the main operational stages: firstly a filtering section is tasked with separating each channel into a separate line, which is then switched to the appropriate output through a set of M $1 \times N$ switching sub-networks. The filtering structure is furthermore made of multiple layers, as to reduce cross-talk and avoid channel aliasing, allowing the device to handle a larger bandwidth of operation and number of channels.

The initial filtering of the three bands of interest (S+C+L) is carried out through Contra-Directional Coupler (CDC) [1], which feed into three independent channel filtering stages: the channel separation is then achieved by Micro-Ring Resonator (MRR) filters, which have been modelled as two-stage ladder structures [2]. Each channel is then routed by a binary tree switching network made from wide-band tunable Mach-Zehnder Interferometers (MZI), [3], which allow frequency independent operation over the required bandwidth, minimizing the loss and cross-talk. The QoT of the device has been evaluated in the Optsim Simulation Suite, using the OSNR added penalty as the metric. The DSP-based simulation has been done considering dual-polarization 16QAM with symbol rate R_s=60GBaud and channel spacing FSR=100 GHz.

III. Network performance assessment

We used the Statistical Network Assessment Process (SNAP) [4] to investigate the impact of the new WSS architecture on various optical transport technologies. We assume that a multiband optical system consists of a set of bands, each having its own set of components, particularly optical amplifiers. We assume that each fiber in the amplified lines has the same length of 75 kilometers and that the fiber types deployed are standard single-mode fibers (ITU-T G.652D). We assumed commercially available erbium-doped fiber amplifiers (EDFAs) for the C- and L-band channels and thulium-doped fiber amplifiers for the S-band. Transceivers tuned to a symbol rate of 60Gbaud operate on the ITU-T 100GHz WDM grid in each band. Lightpaths are assigned based on the ZR+ transceiver's characteristics and the specified Routing and Wavelength Assignment (RWA) method (k-shortest routes with $k_{max} = 5$ for routing and first-fit for spectrum allocation).

IV. Results & Conclusion

For both the SDM and BDM cases, the simulations are performed on the German network topology. Fig. 2 (a) shows the links allocation in terms of traffic in the SDM scenario for both the uniform traffic profile and the population traffic profile (based on node-city population), with the blocking probability threshold set at 1%. For a traffic profile based on the population of each node, 9 links have congestion greater than 60%. For the uniform traffic profile, on the other hand, only 5 connections have congestion of more than 60%. To solve this mismatch of allocaiton, the use of BDM on a few selected links (with more traffic) or overall network could be extremely beneficial in utilizing the capacity. In this scenario, Fig. 2 (b) and (c) shows a comparison between SDM and BDM for both the uniform and population based traffic scenario. The results are nearly identical in both cases, with SDM slightly outperforming BDM. However, to make the best use of the existing network infrastructure, BDM proves to be the most cost-effective option.

(a) SDM (C-band 1x fiber)

(b) Population based traffic (SDM-C-band 3x-fiber vs BDM-C+L+S band 1x-fiber)

(c) Uniform based traffic (SDM-C-band 3x-fiber vs BDM-C+L+S band 1x-fiber)

Fig. 2: Link allocation for SDM vs BDM

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