# Spatial Channel Network (SCN): Introducing Spatial Bypass Toward the SDM Era

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## 1. Introduction

Based on the extrapolation of recent compound annual growth rates of high-end router blades and other technologies used to generate and process data, the need for commercial 10-Tb/s optical interfaces working in 1-P b/s optical transport systems by around 2024 was recently predicted. Since the optical-transport system capacity of 1-P b/s far exceeds the fundamental capacity limit of the conventional single mode fiber (SMF), there will be massive numbers of parallel SMFs and/or novel fibers with a new core structure, *e.g.,* uncoupled multi-core fibers (MCFs), between adjacent optical nodes. In addition, since optical channels having bit rates of 10-Tb/s and beyond will occupy almost the entire available spectrum in a conventional SMF, they will no longer require the wavelength switching layer. Considering the above-noted trend and recalling the introduction of an *optical bypass* when entering the wavelength abundant era in the early 2000s, we believe it would be natural to introduce a *spatial bypass* through a spatial channel cross-connect (SXC) rather than working on achieving larger-scale single-layer reconfigurable optical add drop multiplexers in the forthcoming massive space division multiplexing (SDM) era. According to these observations, our research group recently reevaluated traditional hierarchical optical networks and proposed a spatial channel network (SCN) that employs a *spatial bypass* through a potentially cost-effective and low-loss SXC [1].

## 2. SCN Architecture

Figure 1 shows an SCN architecture [1] where the SDM layer comprises SXCs and parallel spatial lanes (SLs), whose physical entities are single mode cores in SMFs and/or MCFs, and the wavelength division multiplexing (WDM) layer comprises wavelength cross-connects (WXCs) and frequency slots. An SXC and an overlying WXC form a hierarchical optical cross-connect (HOXC) (Fig. 2). The SXC performs SL level multiplexing and grooming and serves as the main switch in the HOXC. The WXC performs wavelength level multiplexing and grooming and serves as an edge switch in the HOXC. Following the definition of the optical multiplexing section (OMS) in a current optical transport network, which is defined between adjacent WXCs, a spatial multiplexing section (SMS) is defined between adjacent SXCs. In an SCN, a spatial channel (SCh) is defined as an ultra-high capacity optical data stream that is allowed to occupy the entire available spectrum of a core in an SMF or MCF. An SCh transports a single or multiple optical channels (OChs) that are spectrally aligned with the G.694.1 flexible grid paradigm. An SCh is spatially routed end to end as a single entity through SXCs bypassing the overlying WDM layer. If there is an insufficient amount of traffic between a source/destination pair, the corresponding OCh shares an SCh with other low-capacity OChs that have different source/destination pairs for better resource utilization.

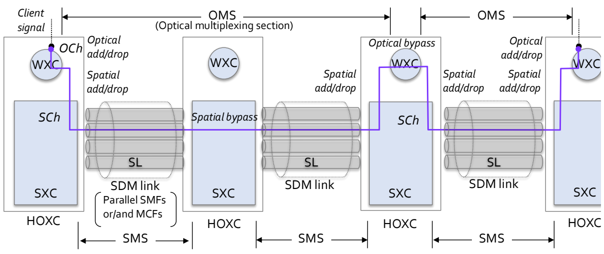


Fig. 1. Spatial channel network (SCN) architecture.

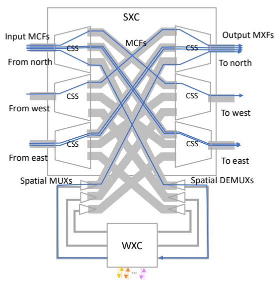


Fig. 2. SXC architectures.

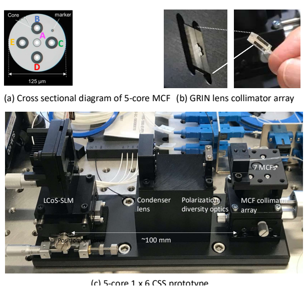


Fig. 3. Free-space based CSS

## 3. Free-Space-Based CSS prototype

We recently designed and prototyped a compact 5-core 1×6 CSS that incorporates an integrated input and output MCF array with spatial multiplexer/demultiplexers and a liquid crystal on silicon spatial light modulator (Fig. 3). The CSS comprises two-dimensionally arranged input and output MCFs with collimating lenses, a condenser lens, and two-dimensionally arranged switching mirrors. Five beams launched from each core of an input MCF converge to the same spot at the focus of the collimating lens at different angles. A condenser lens focuses each beam onto a different switching mirror according to its angle. By controlling the tilt of each mirror in two angular dimensions, a beam from any core of the input MCF can be connected to a core with the same index of any output MCF. Using the CSS prototype, we demonstrated spatial channel networking including spatial bypassing and spectral grooming of a 900-Gb/s spatial channel.

**Acknowledgement**

This work was supported in part by the JSPS KAKENHI Grant Number JP18H01443, and the National Institute of Information and Communication Technology (NICT) Grant Numbers 19302/2040.

**References**

[1] M. Jinno, "Spatial Channel Network (SCN): Opportunities and Challenges of Introducing Spatial Bypass Toward Massive SDM Era," J. Opt. Commun. Netw., Vol. 11 No. 3, 2019.