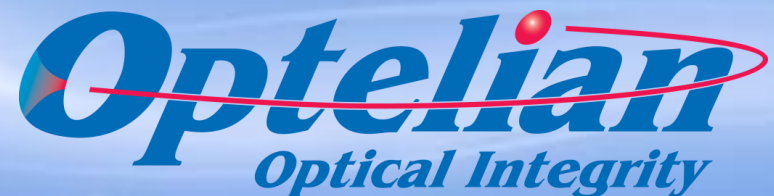


Next-Generation ROADMs

October 1, 2012

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CTO, Optelian

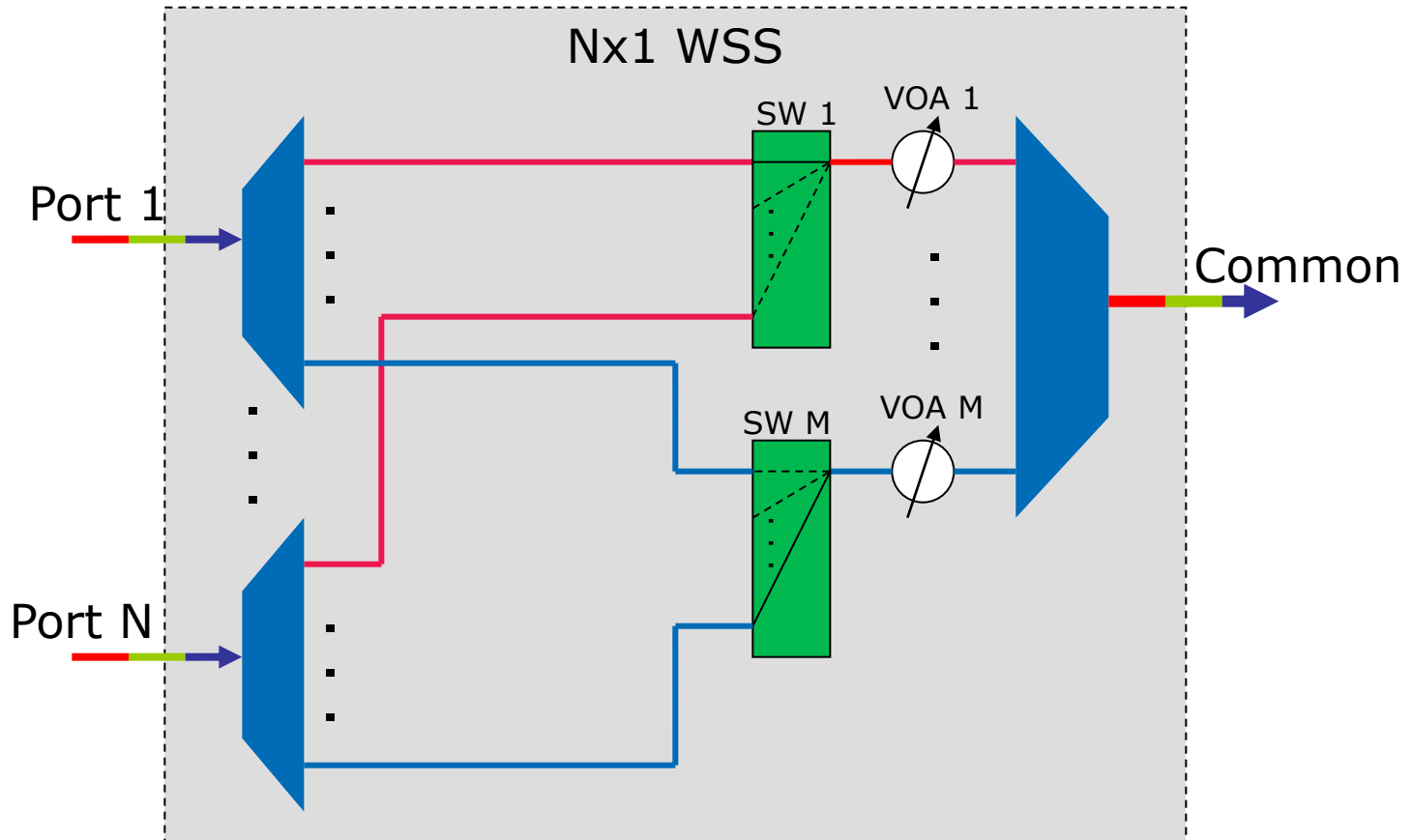


Contents



- Introduction
- Wavelength Selective Switch
- Colorless, Directionless and Contentionless
- Flexible Bandwidth ROADMs and Transmission Beyond 100 Gb/s
- ROADM Control, OpenFlow and SDN
- Conclusion

Wavelength Selective Switch Functionality



Colorless, Directionless and Contentionless (CDC)



Colorless

Any wavelength can be dynamically added/dropped without having to re-fiber a transceiver.

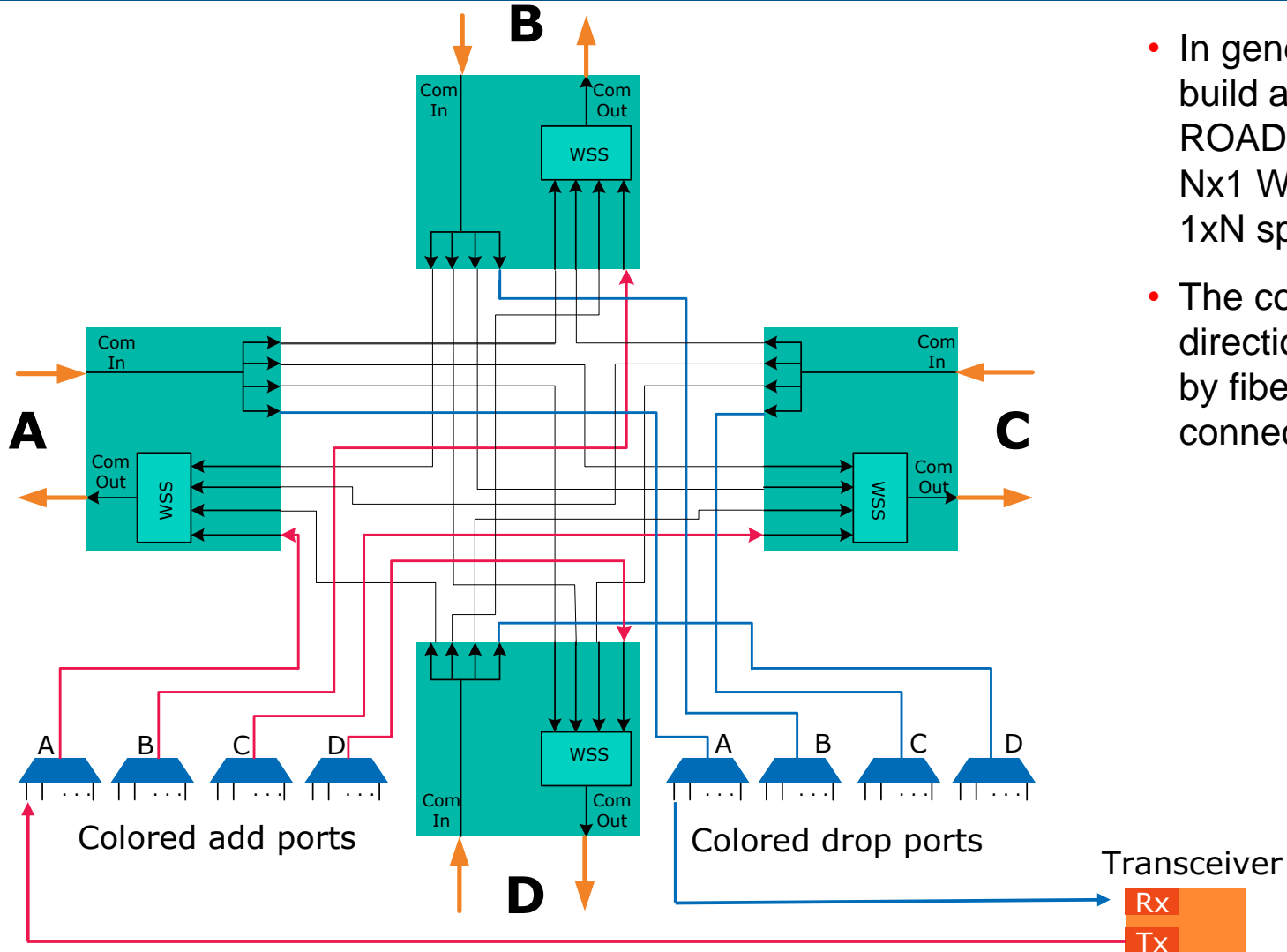
Directionless

A wavelength can be dynamically added/dropped from any direction without having to re-fiber a transceiver.

Contentionless

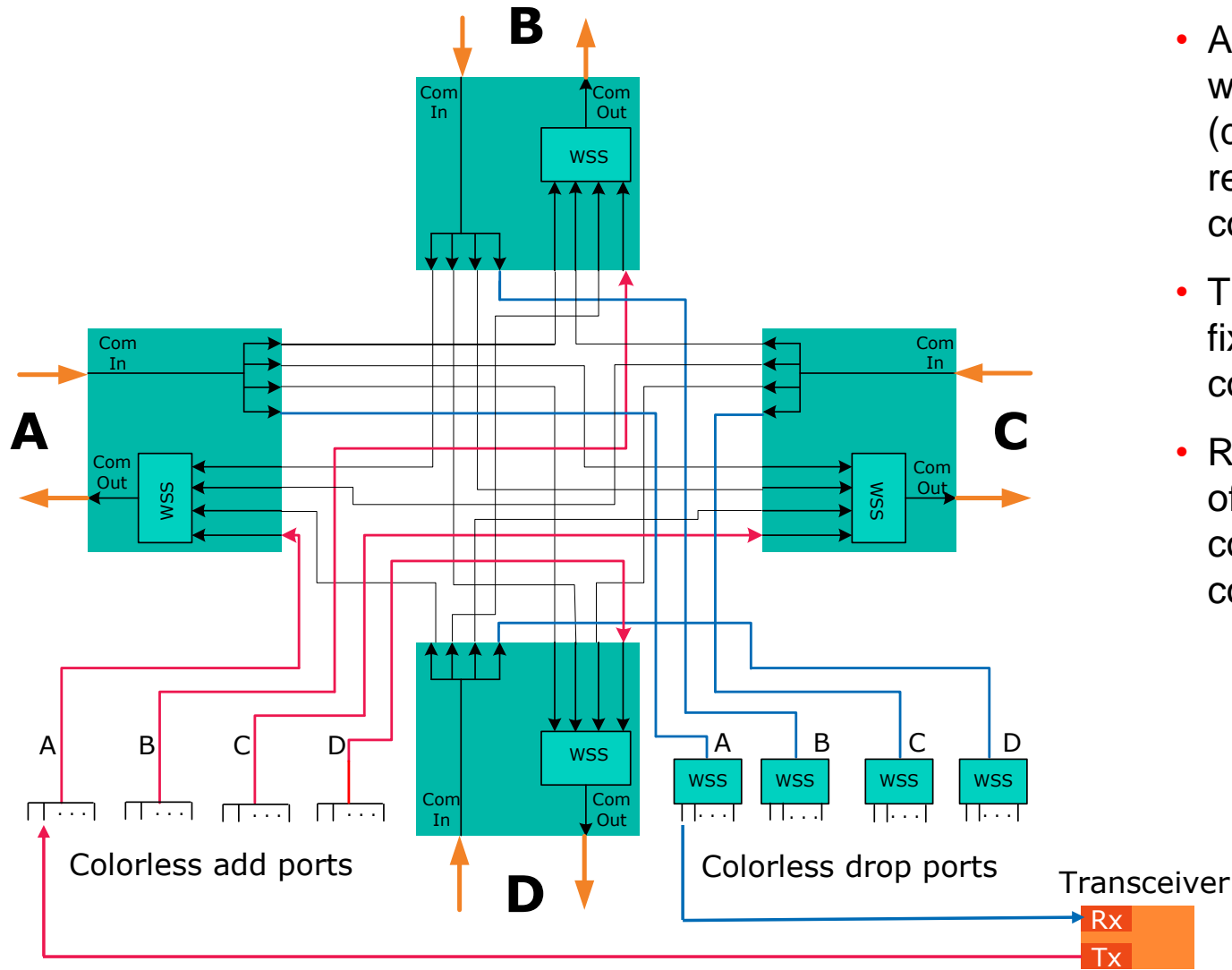
A wavelength can be re-used on all directions without any restrictions.

4-Degree ROADM (Colored)



- In general, can build an N-degree ROADM using $N \times 1$ WSSs and $1 \times N$ splitters.
- The color and direction are fixed by fiber connections.

4-Degree ROADM (Colorless)

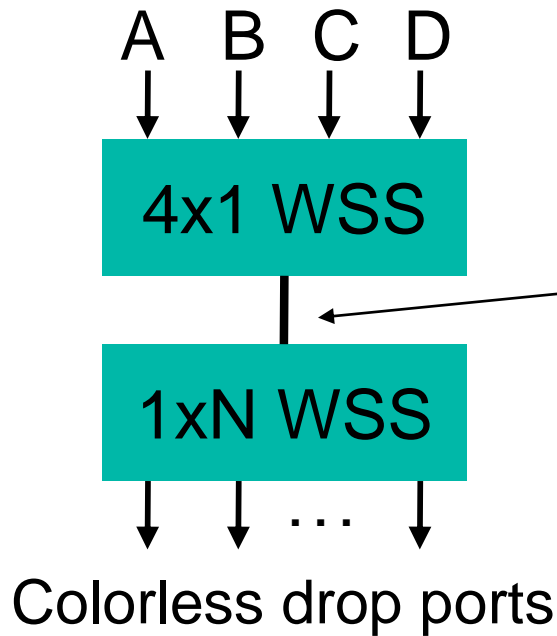


- Any transceiver wavelength (color) can be remotely configured
- The direction is fixed by fiber connections.
- Reduced number of access ports compared to colored.

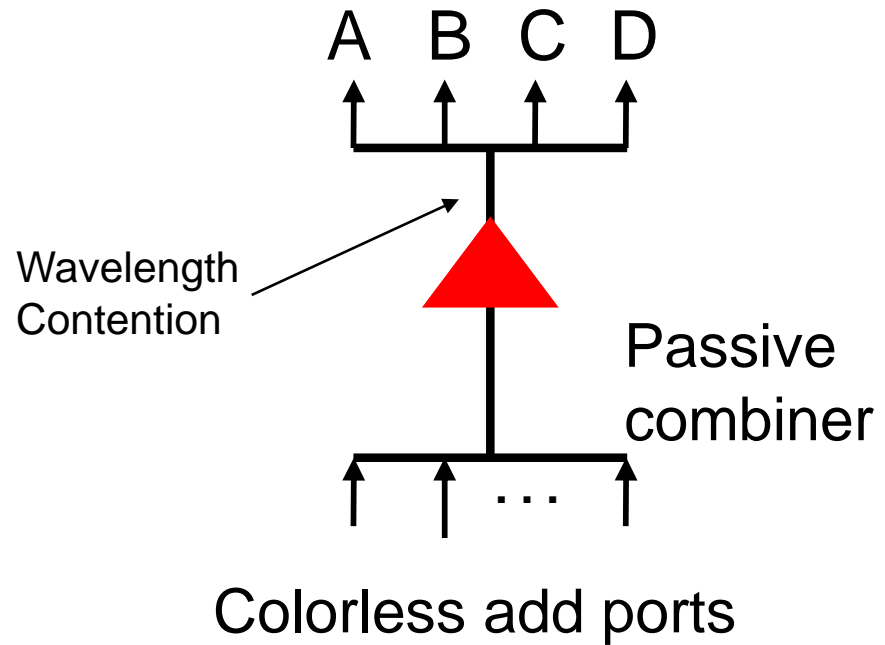
Colorless and Directionless



Drop directions



Add directions

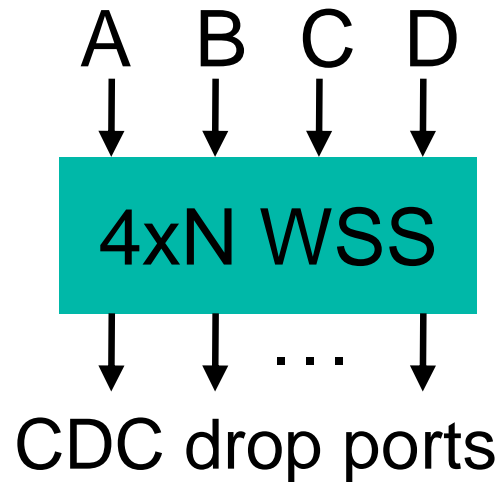


- Structure for cross connecting between degrees remains the same as shown for the 4-degree ROADM on earlier slide.

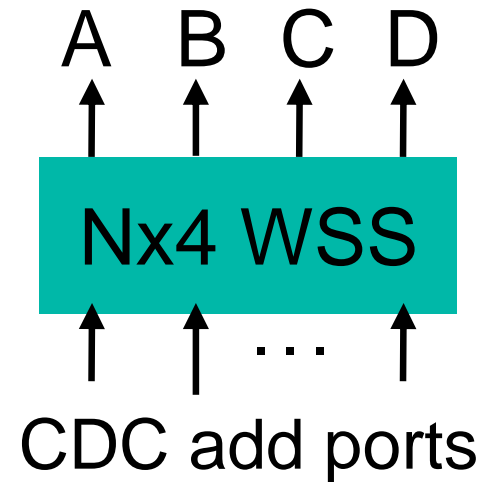
Colorless, Directionless and Contentionless (using $N \times M$ WSSs)



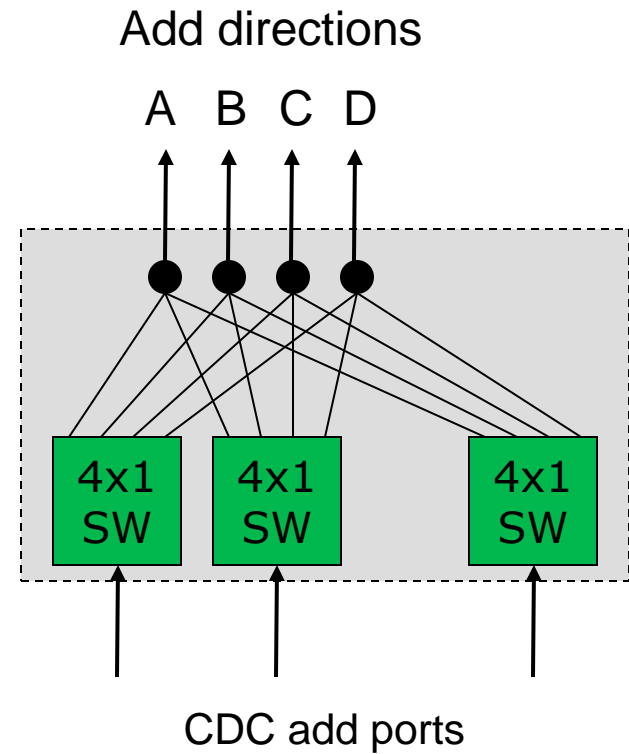
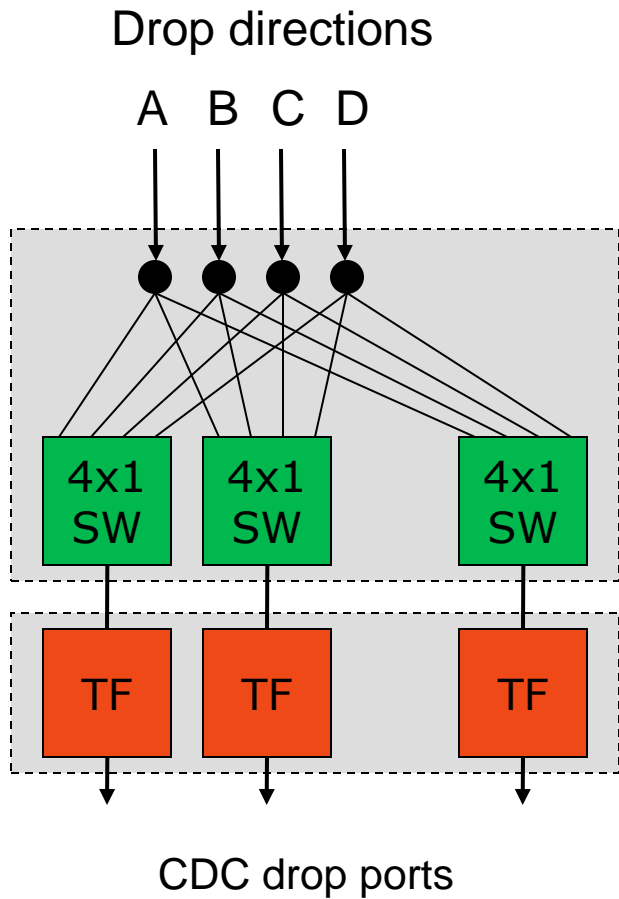
drop directions



add directions

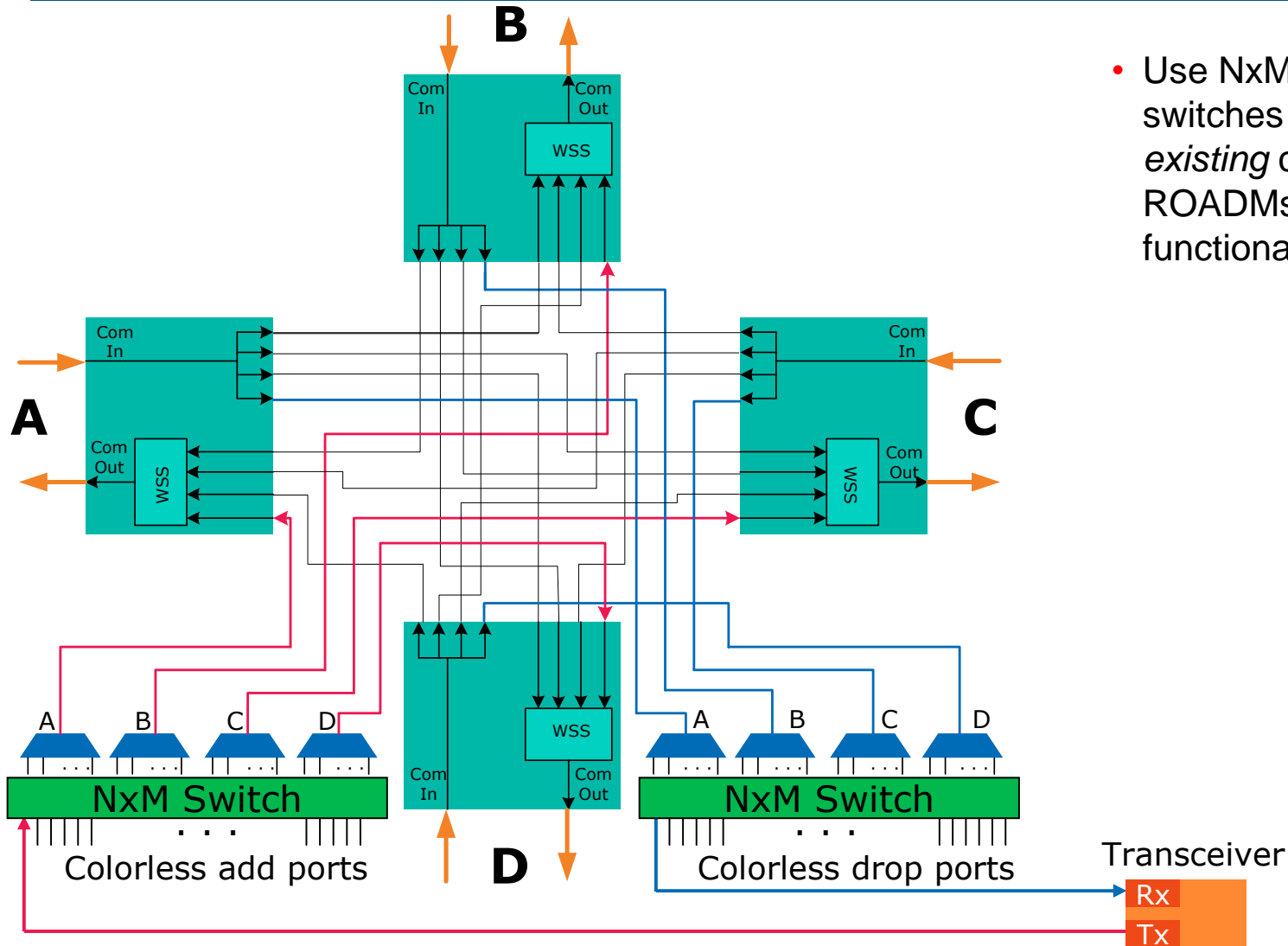


Colorless, Directionless and Contentionless (using Broadcast-and-Select with Tunable Filters)



Colorless, Directionless and Contentionless (using Adjunct NxM Photonic Switches)

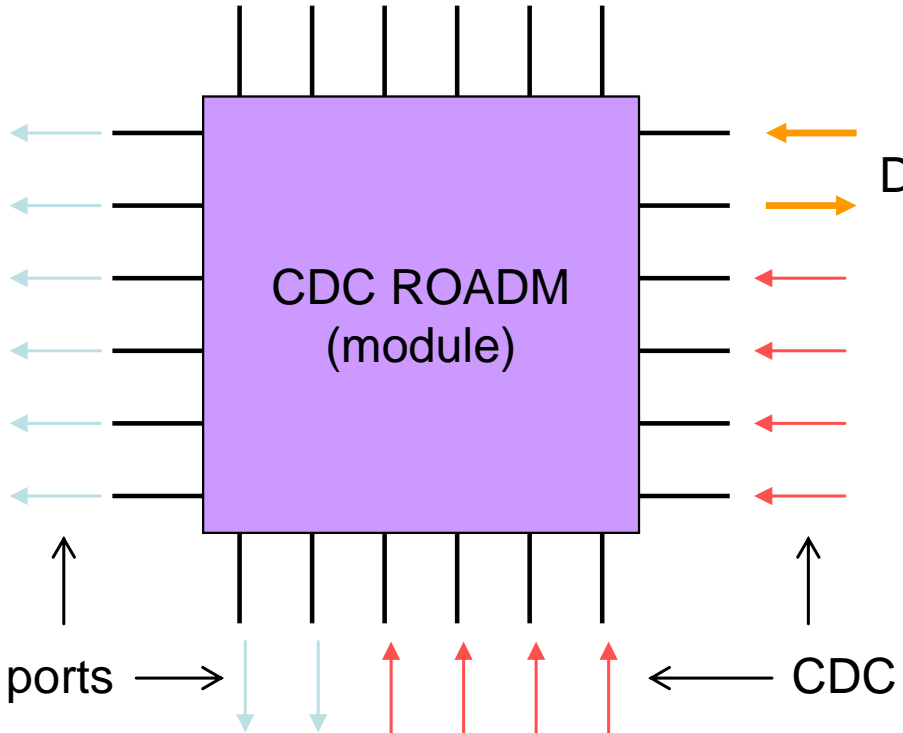
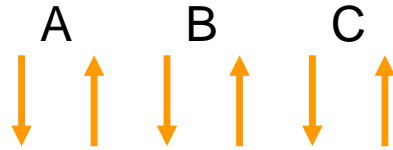
- Use NxM photonic switches to upgrade *existing* colored ROADMs to full CDC functionality



Ideal CDC WSS



Directions

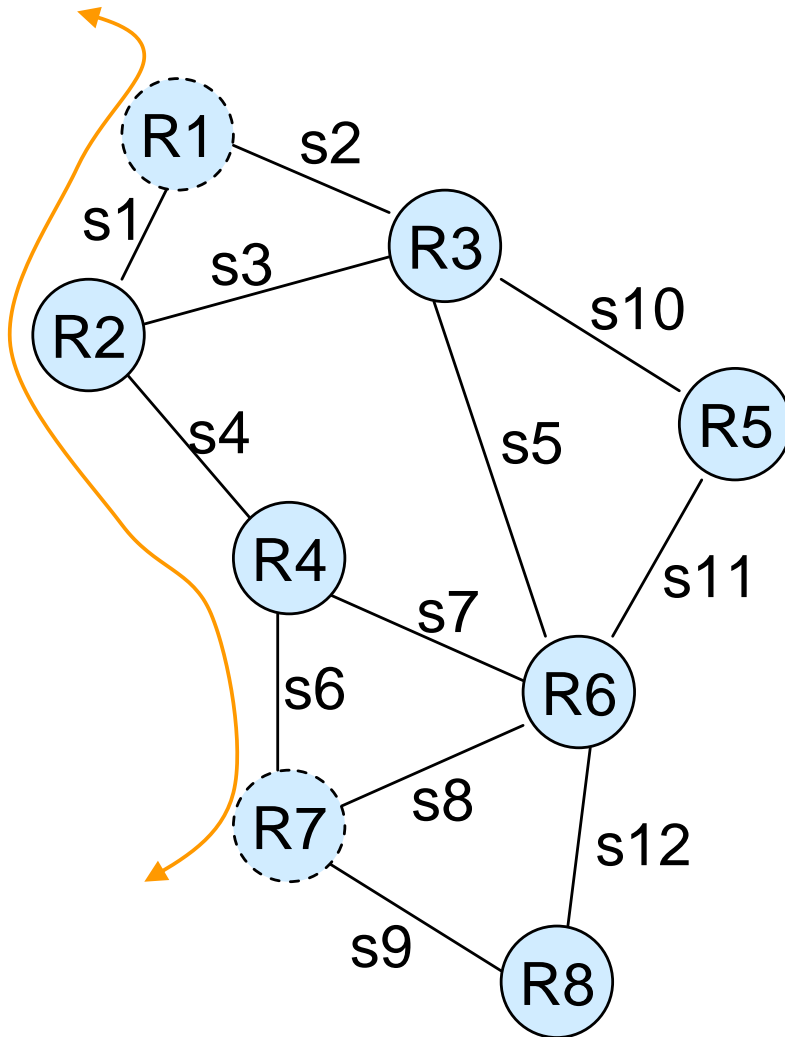


- Concept module
- Non-blocking wavelength switching between any set of ports.
- Per wavelength attenuation control at line egress ports.
- Low insertion loss (up to a few dB)
- Very high reliability.

CDC drop ports

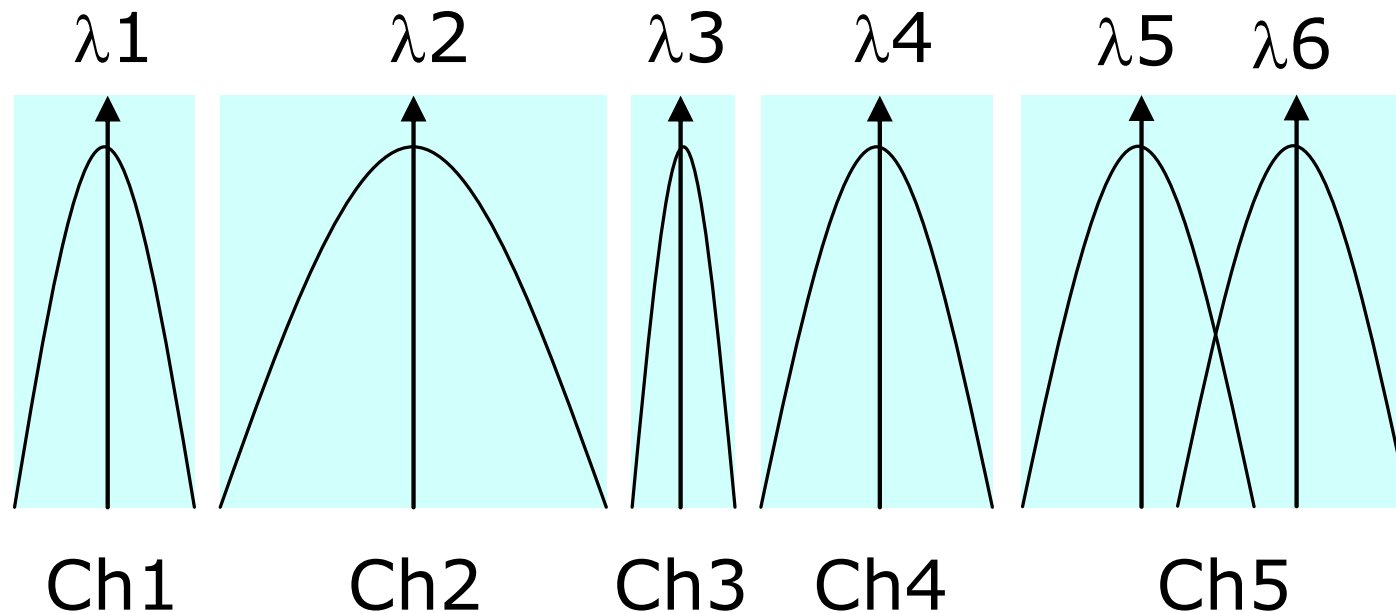
CDC add ports

The Benefit of CDC Functionality



- Without CDC, cannot automatically restore optical circuit for failure on Span S1 or S6, or power failure at Node R2 or R4.
- CDC allows more flexibility to remotely reroute optical circuit when optimizing network utilization.
- Consideration: OTN and/or Layer 2+ protection and switching capabilities may reduce need for optical circuit dynamic routing.

Flexible Bandwidth ROADMs



- Flexible bandwidth (FB) ROADMs (aka gridless ROADMs) allow the passband center and/or width to be dynamically adjusted.
- Many people advocate that FB ROADMs will be required to support bit rates beyond 100G.

Considerations for Transmission Beyond 100 Gb/s



- For 40G and 100G transmission, the client interface has transitioned to parallel optics, while the line interface has retained single-carrier optics for improved transmission capacity. Parallel optics will likely be required on the line interface for bit rates approaching 1 Tb/s and beyond.
- Multi-carrier channels or superchannels are likely to be used for long-haul transmission beyond 100 Gb/s, with PDM-QPSK used for each constituent carrier. PDM-xQAM may be used in Metro (shorter distance) applications.
- Although FB ROADMs may provide improved spectral efficiency, they are not required for transmission beyond 100 Gb/s.



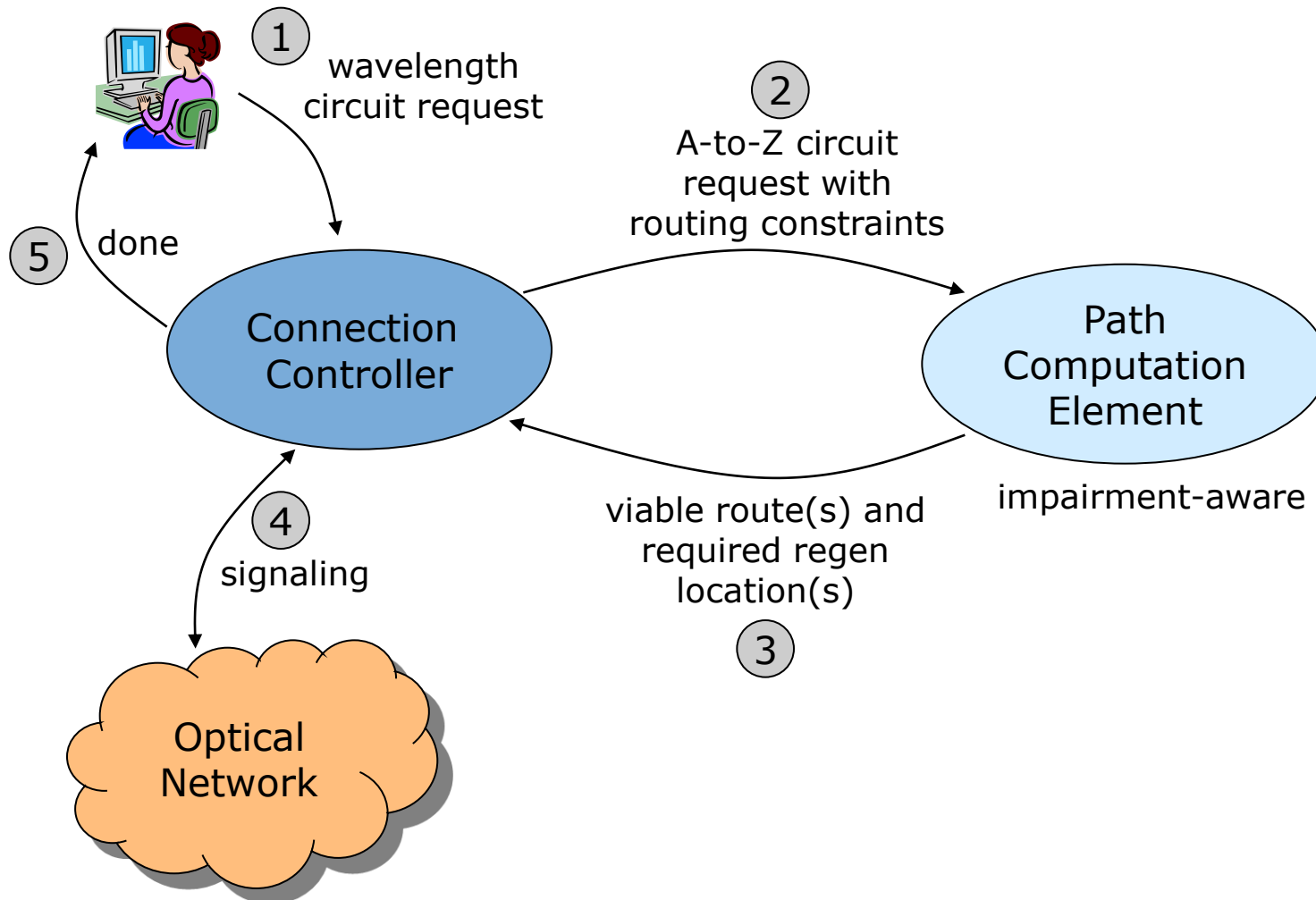
Automated Optical Layer

- Controls the power level of each wavelength at ROADM ports to a set target (Automatic Power Balancing)
- Span or link gain control

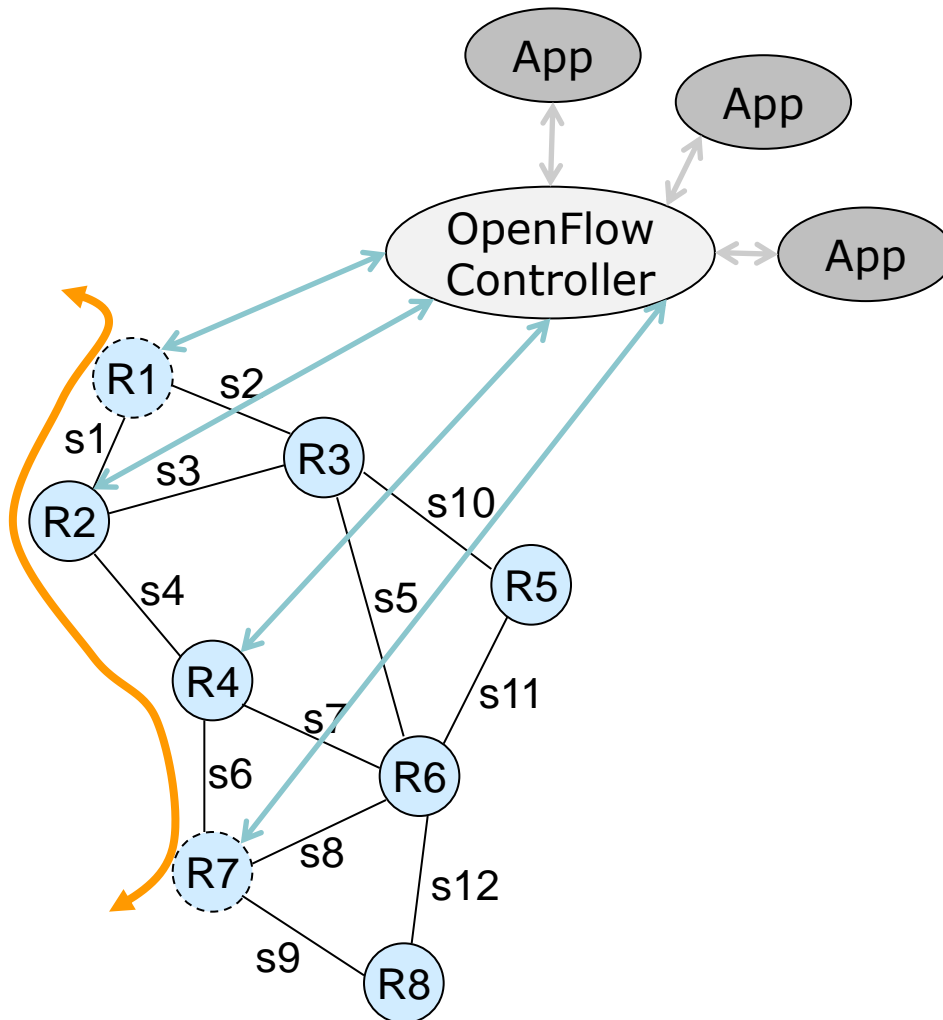
Automated Wavelength Circuit Provisioning

- Impairment-aware path computation (wavelength routing)
- ROADM switch configuration

Automated Wavelength Circuit Provisioning



OpenFlow and SDN



- Centralized dynamic control
- Simple flow table entry at each ROADM for wavelength connection
- Smart Apps – must be aware of topology, resource availability and state, fiber properties, impairment modeling, etc.
- Opportunity for OpenFlow applications to have multi-layer control and visibility
- Apps can evolve independently of physical network

Conclusion



- Current generation ROADMs use WSS modules and have colored or colorless access ports.
- CDC functionality generally has a higher capital cost and lower access port density, but may provide lower operational costs.
- FB ROADMs may provide improved spectral efficiency, but are not required to achieve transmission beyond 100 Gb/s
- Multi-carrier channels or superchannels will likely be used for long-haul transmission beyond 100 Gb/s, with PDM-QPSK used for each constituent carrier. PDM-xQAM may see application in the Metro
- Automated ROADM networks are well-suited to centralized control, making OpenFlow a good match. This could also facilitate multi-layer control.

Thank You

