



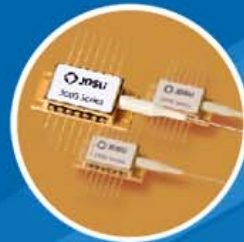
# Physical Layer Components, Architectures and Trends for Agile Photonic Layer Mesh Networking

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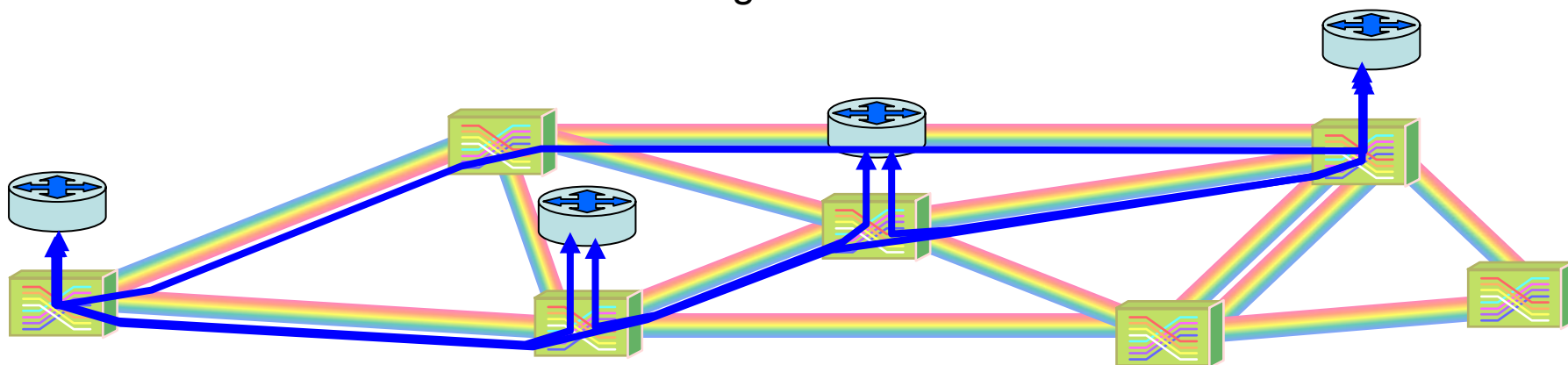


# Outline

- Advantages of “Static” ROADM Optical Mesh Networks
- The WSS and Current “Static” Mesh Node Architectures
- Applications of “Dynamic” Optical Mesh Networks
- Node Architectures for “Dynamic” Mesh Networks
  - Colorless ports
  - Directionless ports

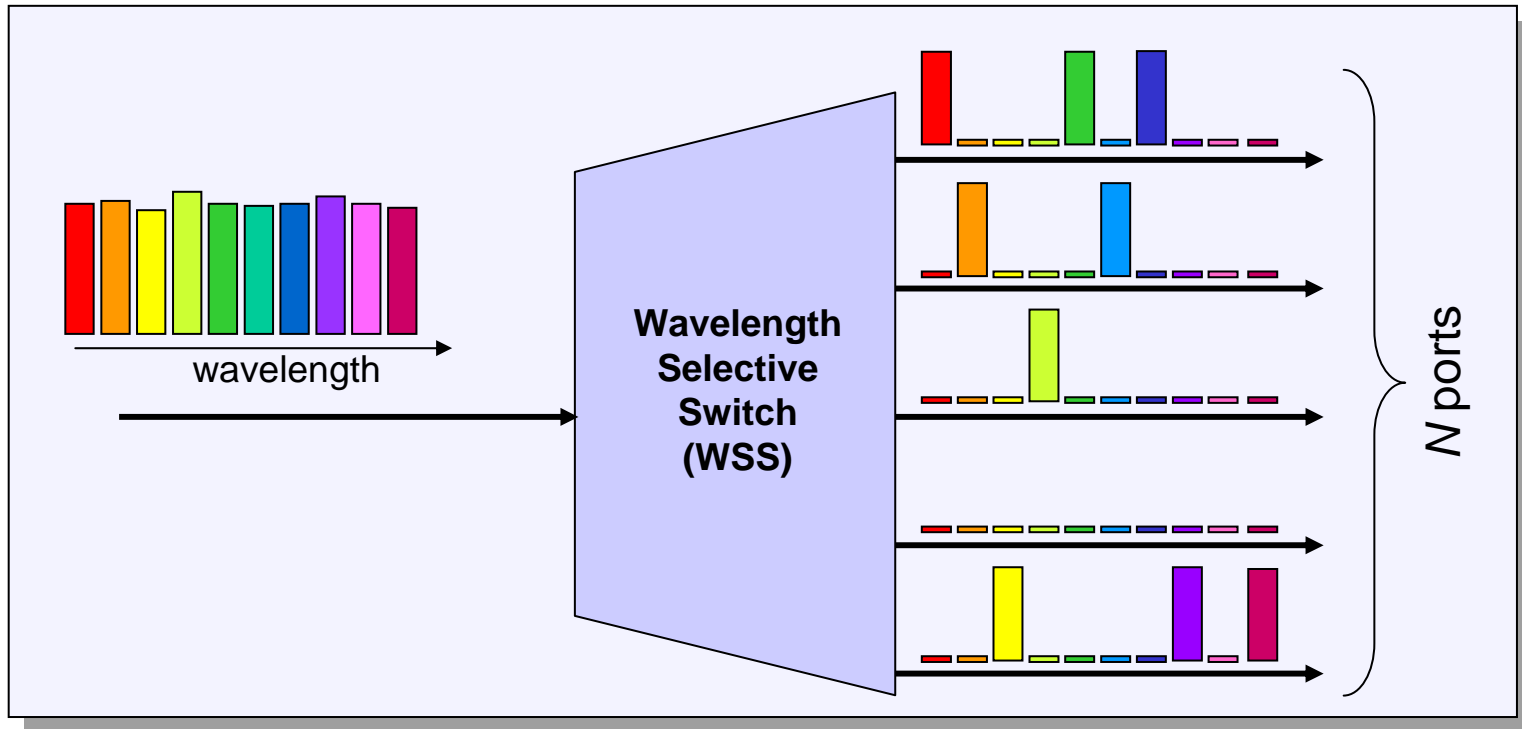
# Advantages of Static ROADM Optical Mesh Networks

- Eliminate OEO at network junctions
  - Considerable cost, complexity and maintenance savings
- Flexible wavelength topology enables efficient capacity growth
  - Most efficient routes can be selected
  - Extends lifetime of system
- Add new connectivity via unused degrees as needed
  - Parallel spans, spurs, extensions, ring interconnects
  - Maintains in-situ HW and management



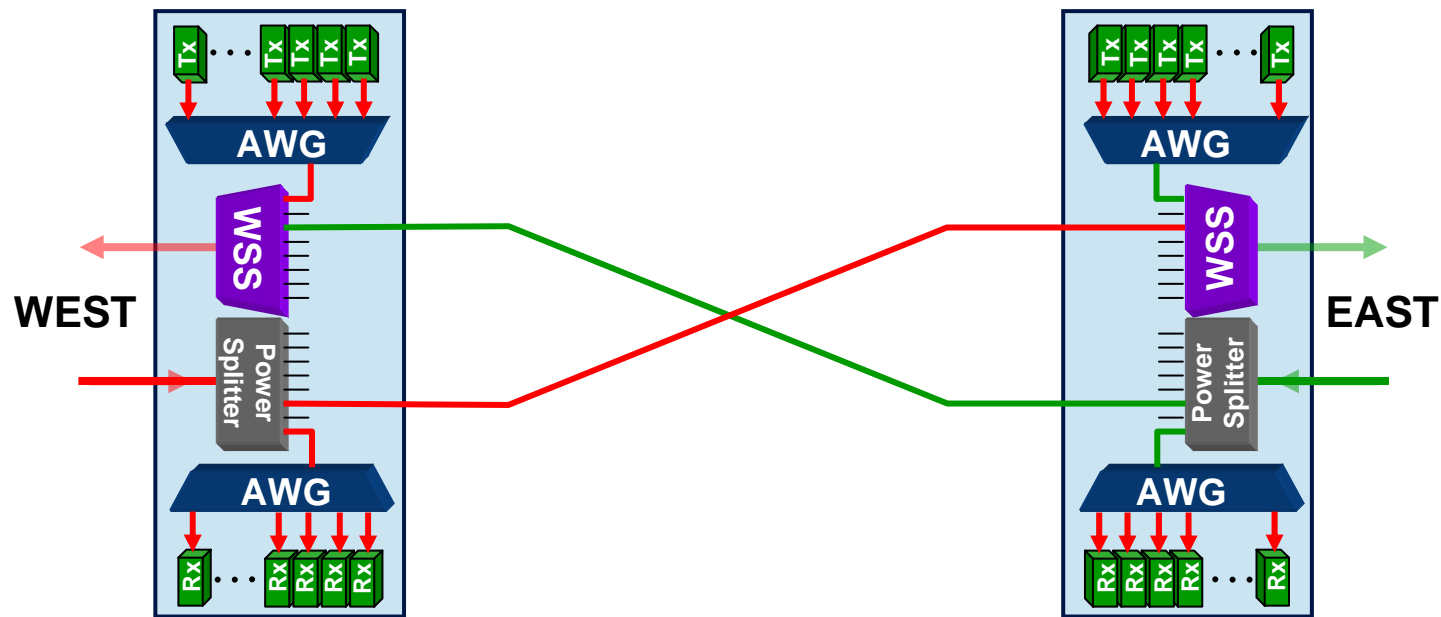
# The Wavelength Selective Switch (WSS)

- 1xN port device
- Independently routes each channel to one of N ports
- Attenuate and block channels independently
- Optically bi-directional

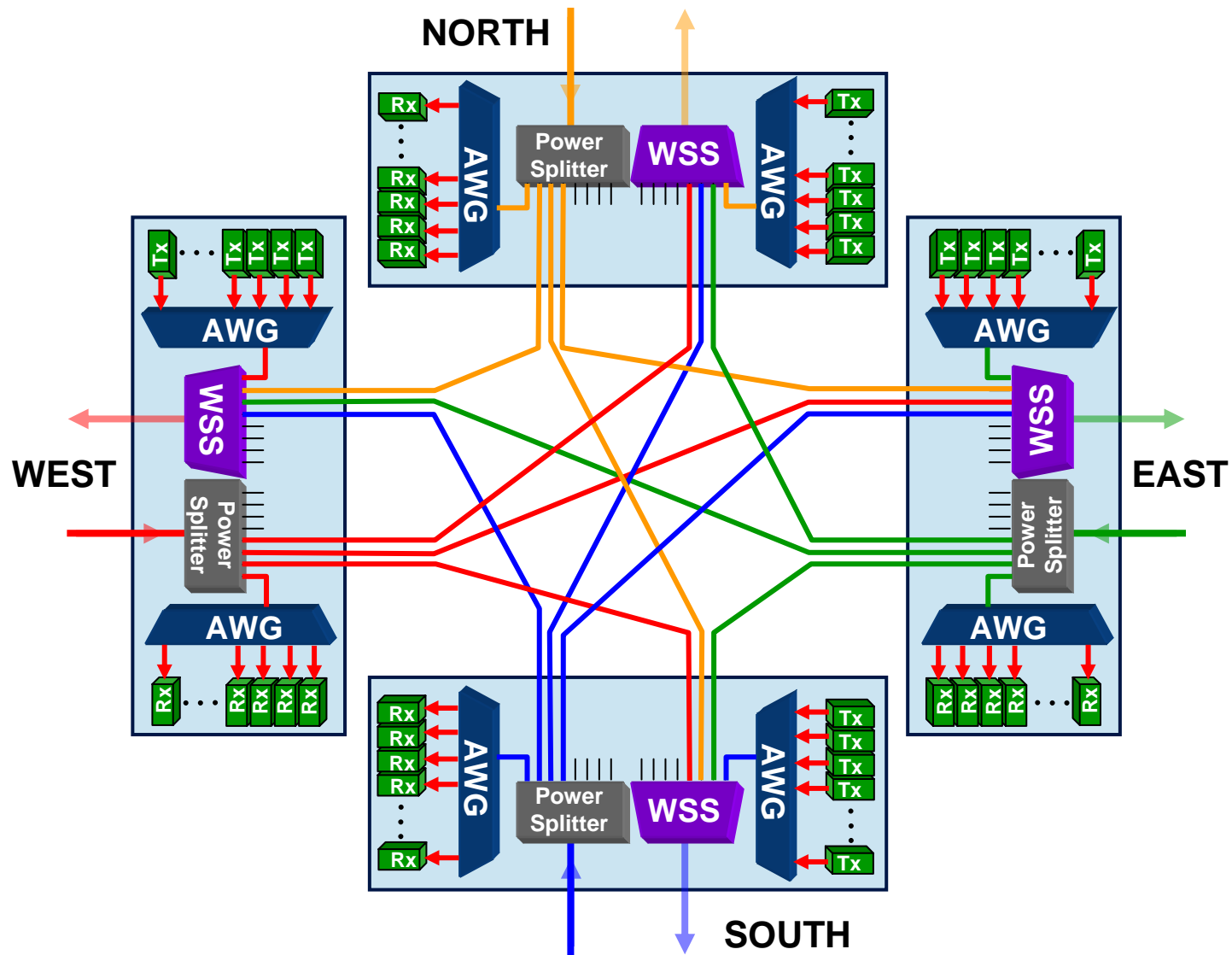


# Typical Reconfigurable Ring Node Architecture

- WSS selects outbound wavelength traffic
- AWG's used to multiplex and demultiplex locally added and dropped channels
  - “Colored” add/drop ports

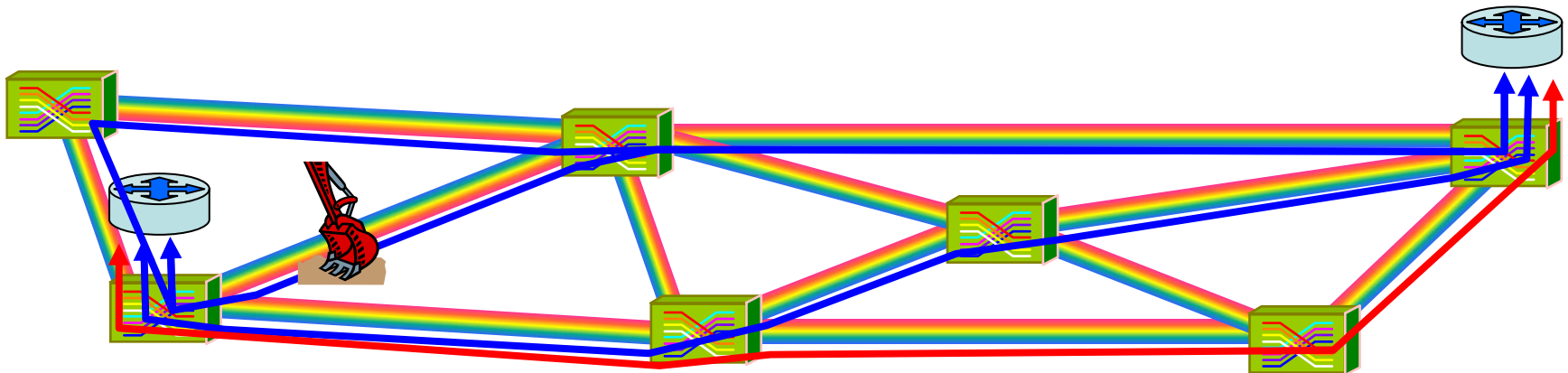


# Typical Reconfigurable Mesh Node Architecture



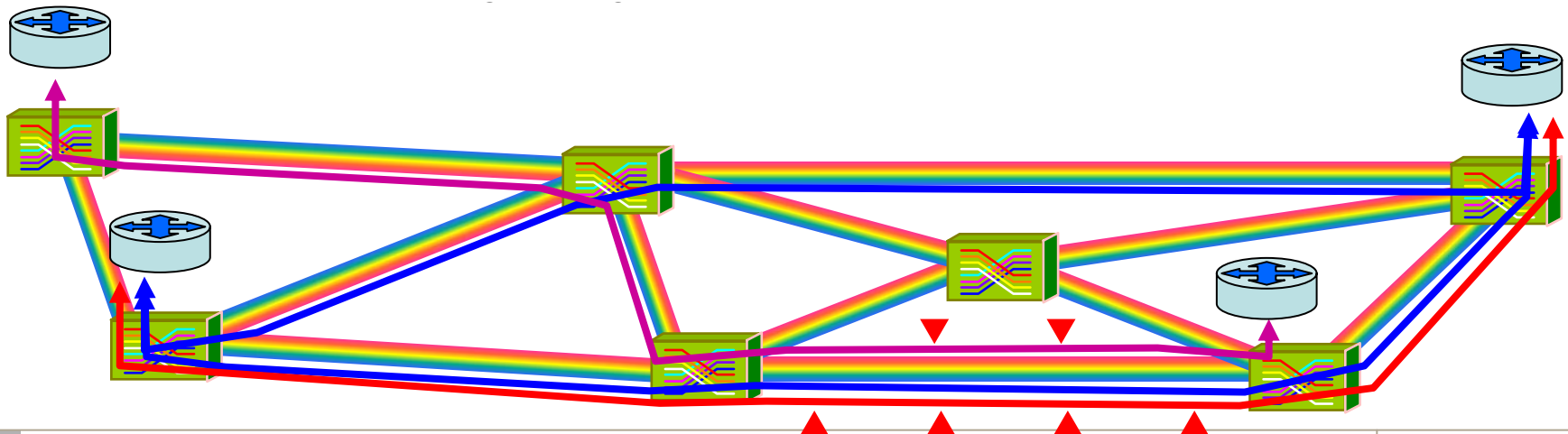
# Dynamic Optical Mesh Network Applications

- Photonic layer restoration
  - Restoration complements higher layer protection to increase overall availability
  - Relaxes urgency to repair fiber (OpEx argument and reliability increase)
    - Some locations have limited access (disaster zone, subways, remote locations, undersea festoons)
  - Reduces excess capacity allocated for protection contingencies (CapEx argument)



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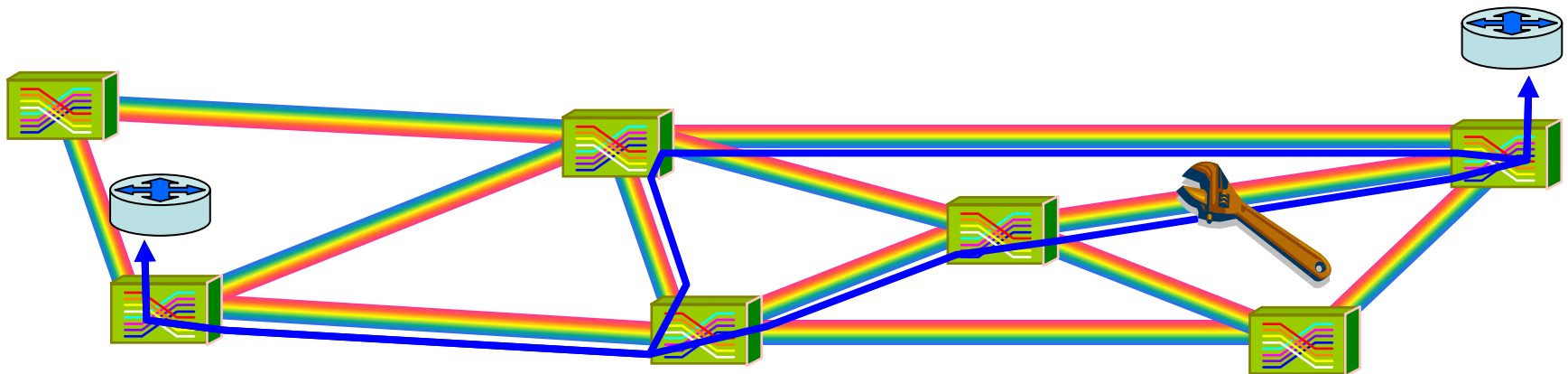
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- Load Balancing
  - Move existing traffic to relieve emerging bottlenecks





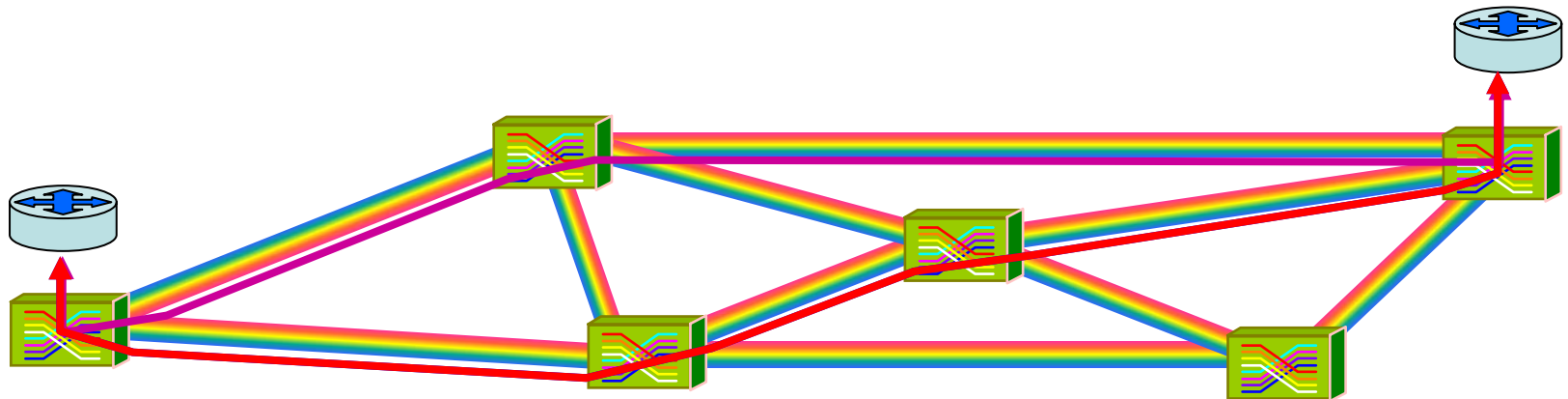
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- Load Balancing
  - Move existing traffic to relieve emerging bottlenecks
- Maintenance switching
  - Move traffic away from area of planned maintenance



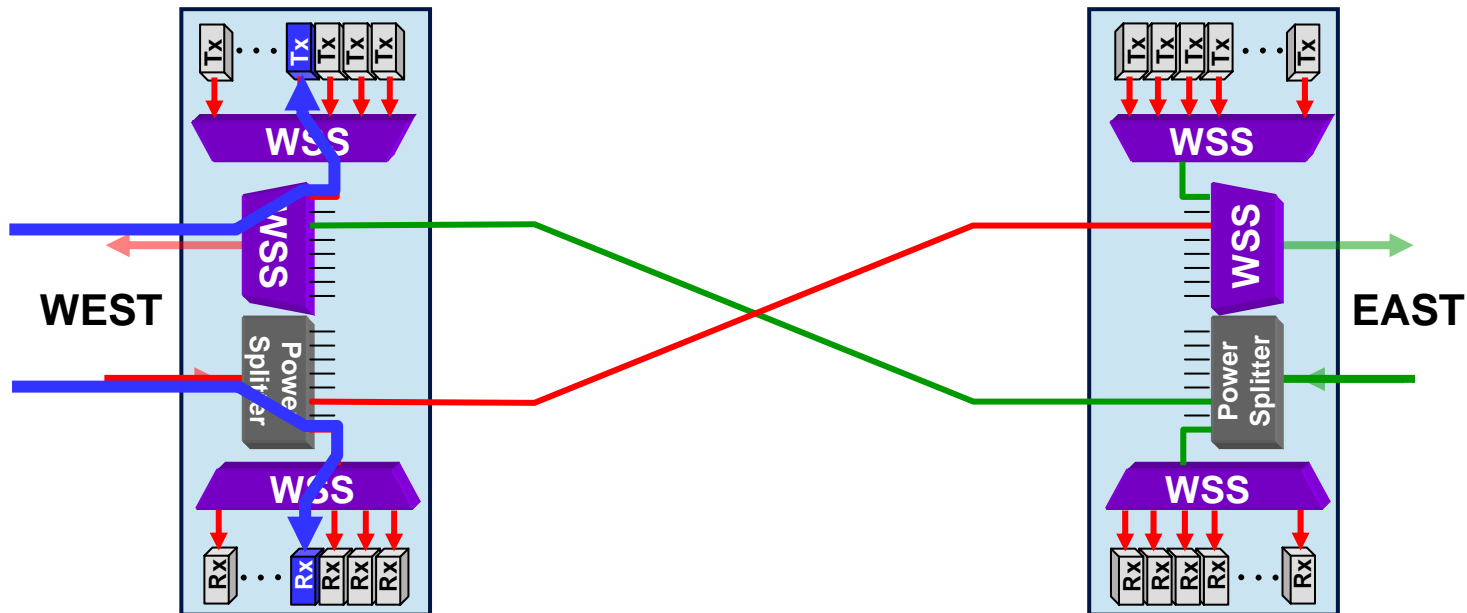
# Dynamic Optical Mesh Switching Requires...

- Optical network level features:
  - Colorless add/drop ports
  - Directionless add/drop ports

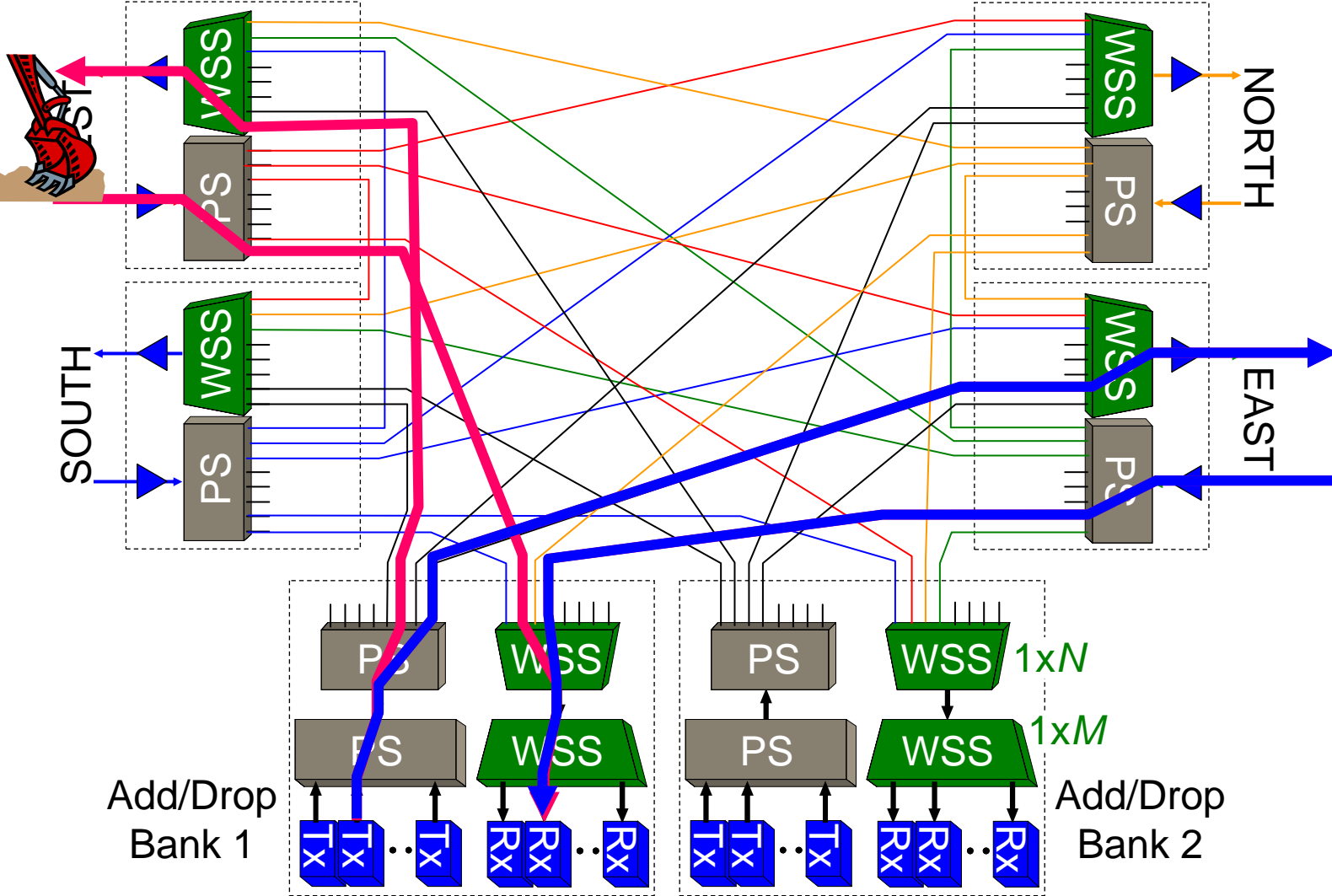


# Colorless Add/Drop Ports

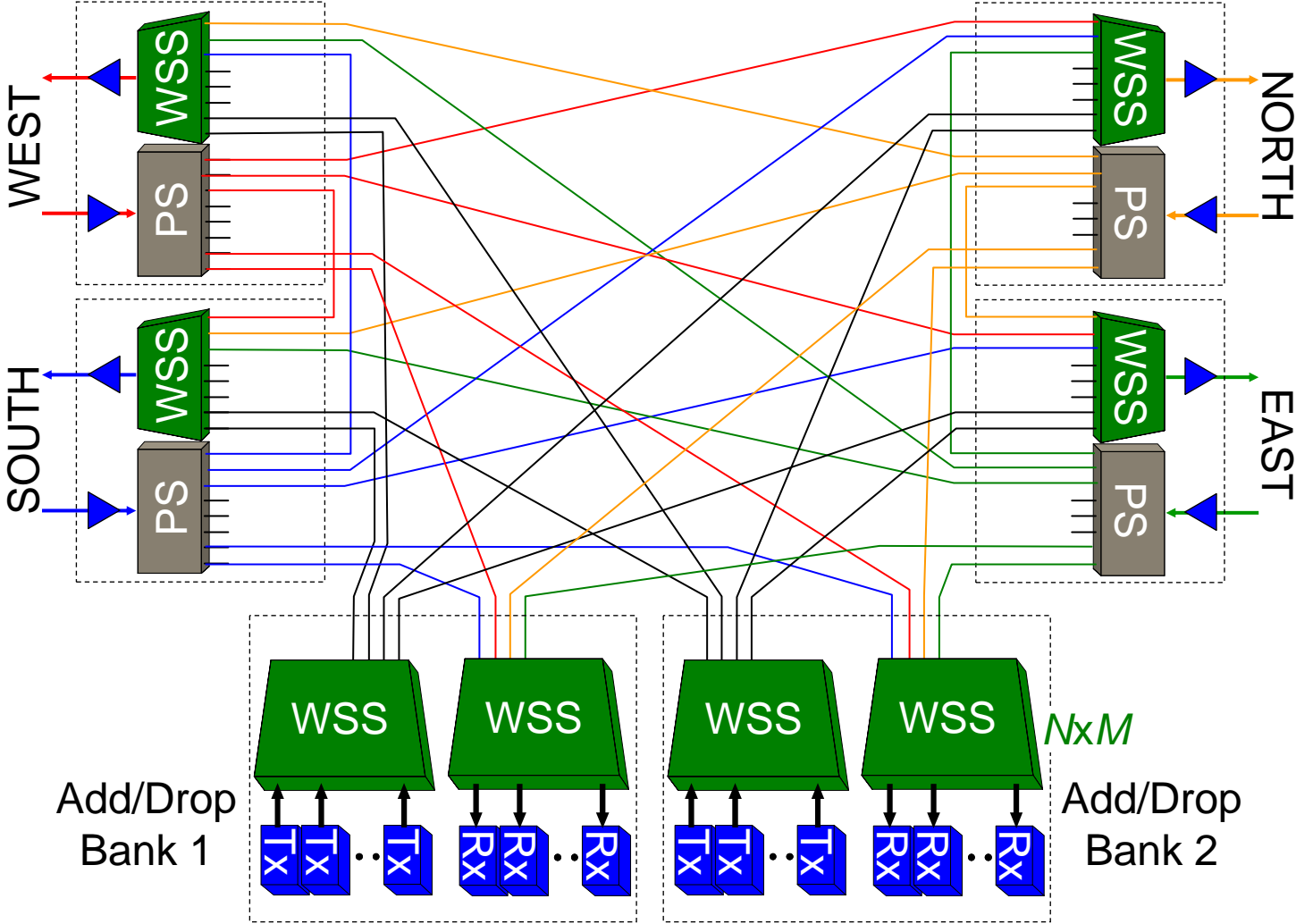
- Replace mux/demux AWGs with WSS's
  - Wavelength assigned to each port is provisionable
- Applications
  - Fewer physical ports present simplifying faceplate
  - Operating wavelength can be remotely modified



# Directionless Add/Drop Ports



# Directionless Add/Drop Ports: $N \times M$ WSS



# Summary

- Past and Present
  - Optical mesh networks currently being deployed for efficient operations and capacity growth
- Present
  - Applications leveraging the dynamic capabilities of the mesh network are emerging
- Future
  - Mesh networks with colorless and directionless add/drop ports
  - Network optimization must become multi-layer
    - Leveraging the strengths of each layer
  - Develop multi-layer management systems which can execute this optimization automatically and seamlessly



# Thank You!

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