# Workshop - New Paradigms for Routing in Optical Networks

Efficient routing for high capacity, flexible optical networks with different classes of service

**Douglas Aguiar**

*July 2015*

# Summary

1. Photonic Networks
2. Classes of Service in Optical Networks
3. Routing for Optical Restoration
4. The Future and its Challenges

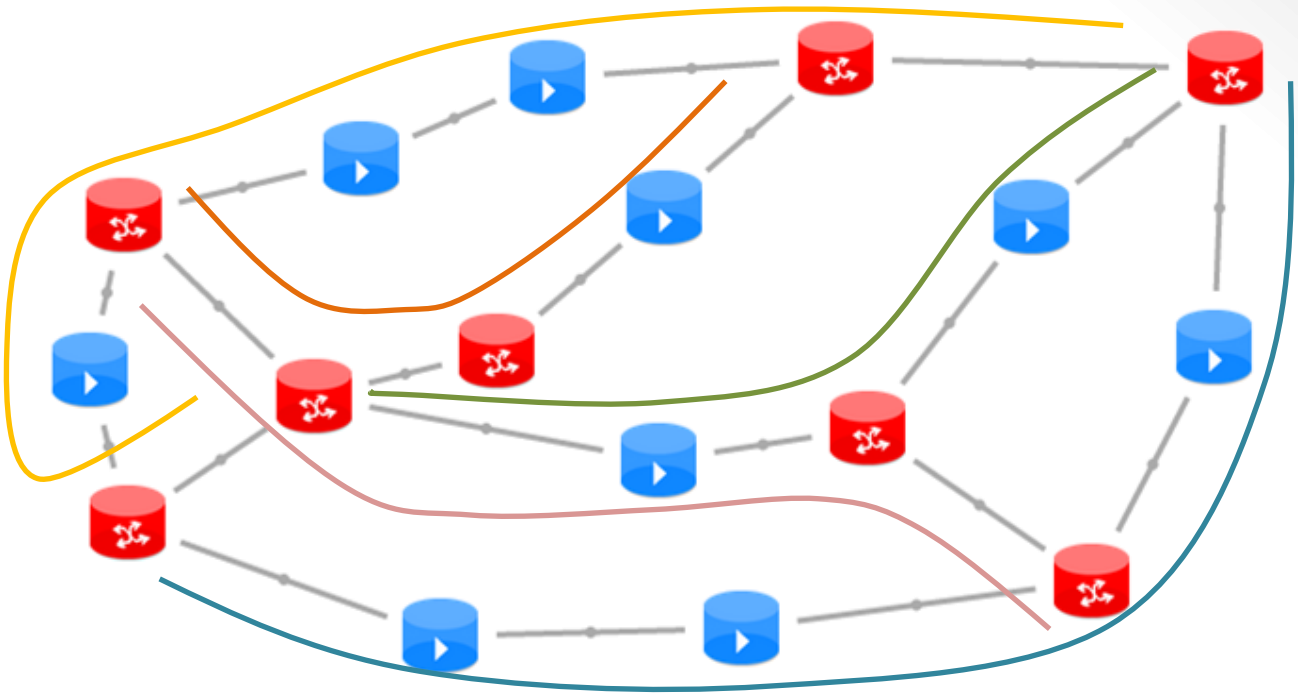
# Summary

1. **Photonic Networks**
2. Classes of Service in Optical Networks
3. Routing for Optical Restoration
4. The Future and its Challenges

# Photonic Networks

**Photonic network** Optical network able to route lightpaths

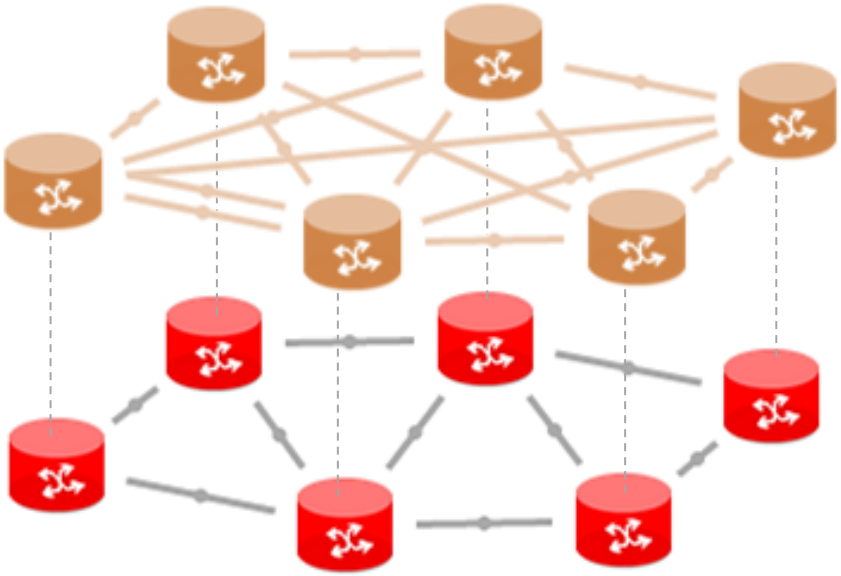
**Lightpath** Optical path inside a photonic nework



Even in today's quasi-static networks ROADMs provide the efficient use of the network capacity

# Topology virtualization

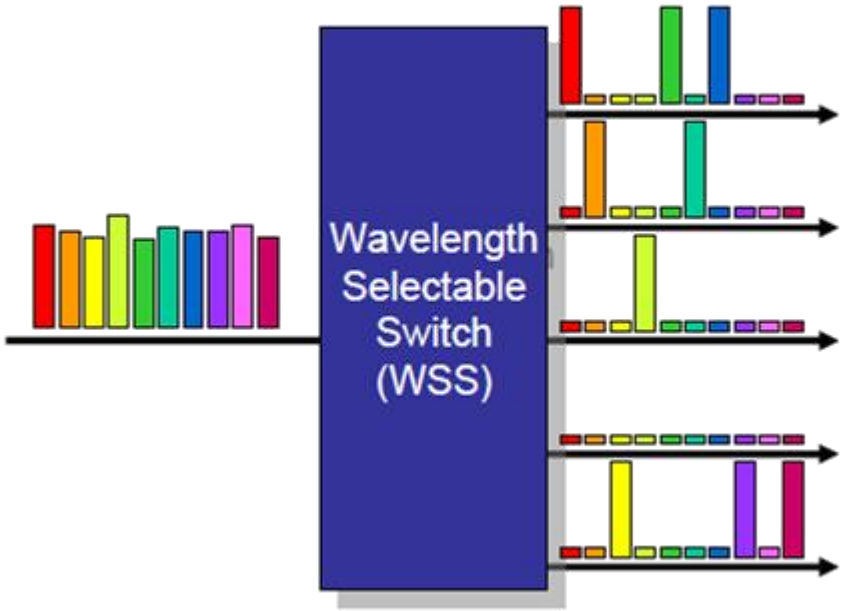
With proper planning complex topologies with virtual point to point links can be established

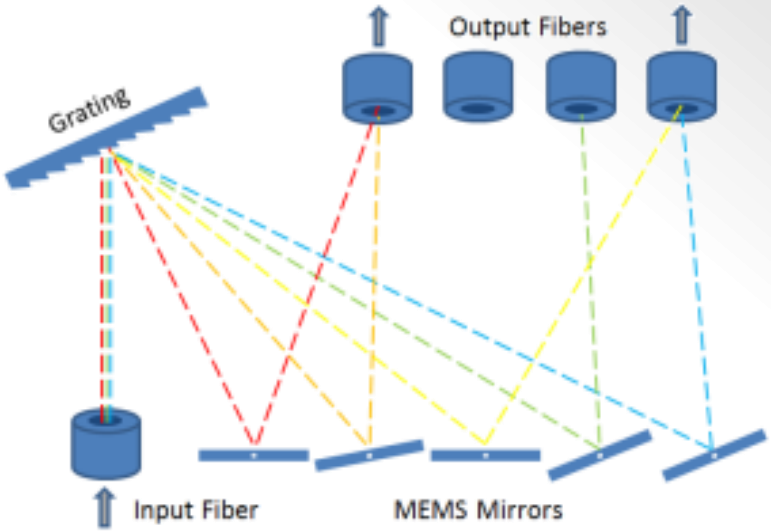



- Traffic growth uncertainty can be more effectively addressed (Traffic Engineering)
- Imposes greater complexity during network planning.
- Allow the planning of complex protection architectures

# ROADM site building block

Wavelength Selective Switches (WSS) are key elements for current ROADM architectures.

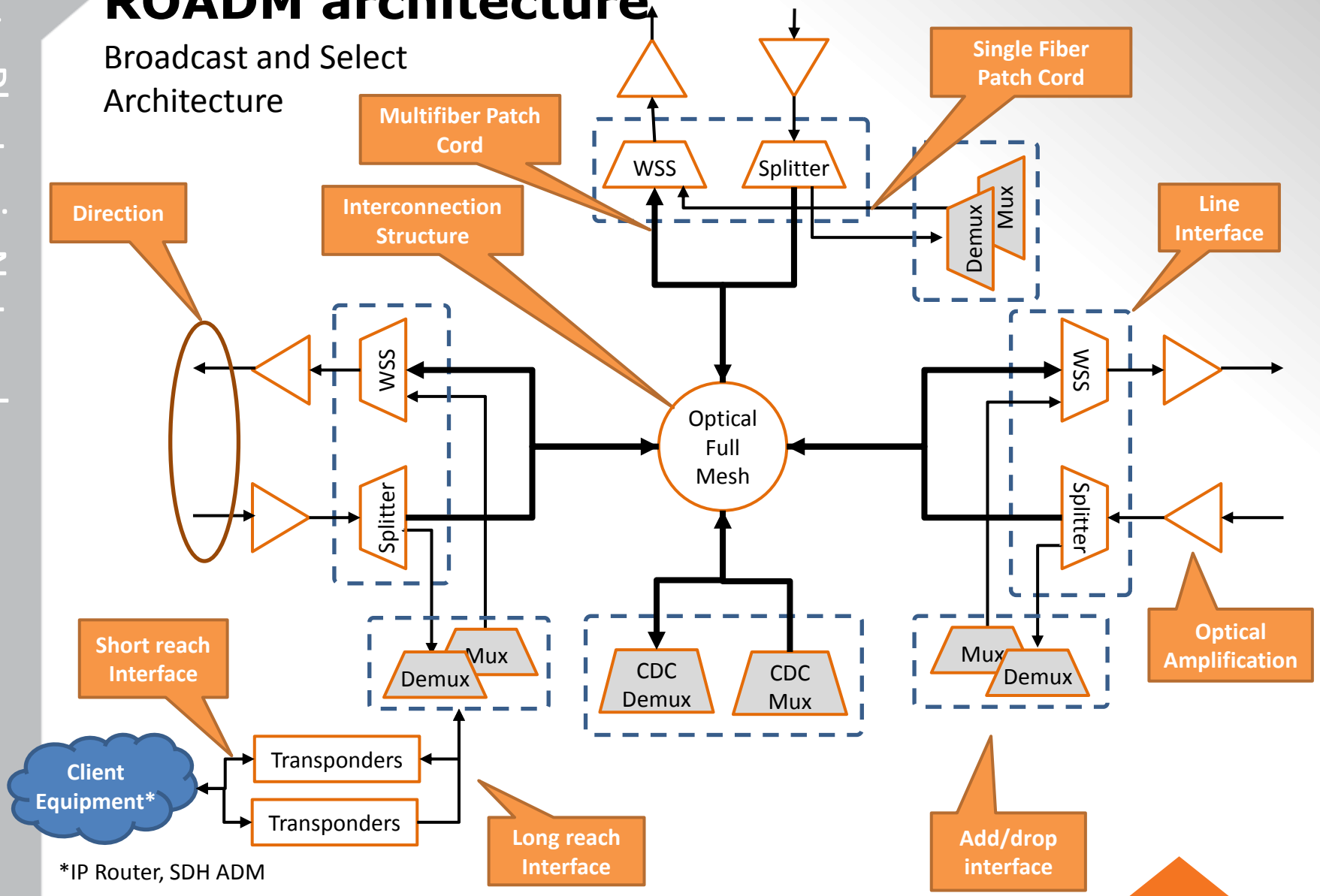



- Flexgrid capability (ITU-T G.694.1)
- Switching time
- Port to port isolation

# ROADM architecture

## Broadcast and Select Architecture




*IP Router, SDH ADM

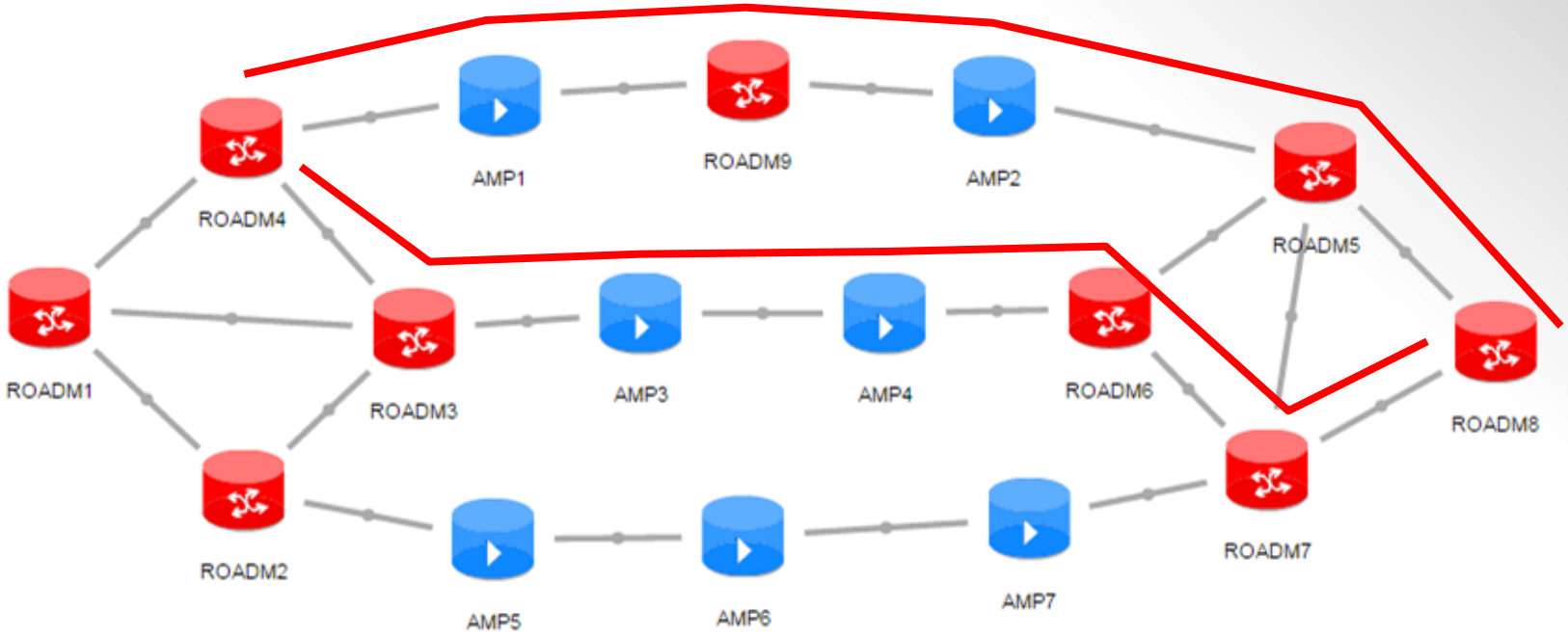
# Summary

1. Photonic Networks
2. **Classes of Service in Optical Networks**
3. Routing for Optical Restoration
4. The Future and its Challenges

# Typical classes of service

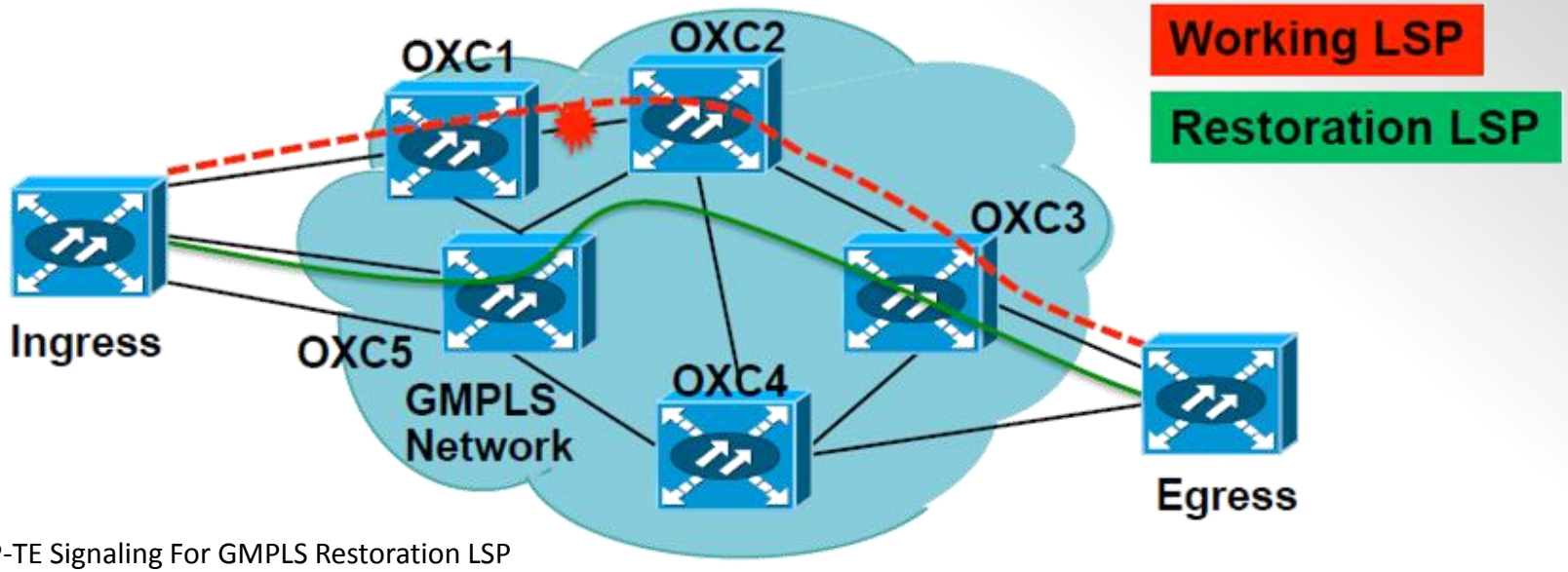
- Unprotected service (1+0)
- Restorable service (1+R)
- Protected service (1+1)
- Protected and restorable service (1+1+R)

# Unprotected service (1+0)




1. Two unprotected services with **possible** protection provided by client layer;
2. Possible to allocate a 1+0 service disjoint to an already provisioned service.

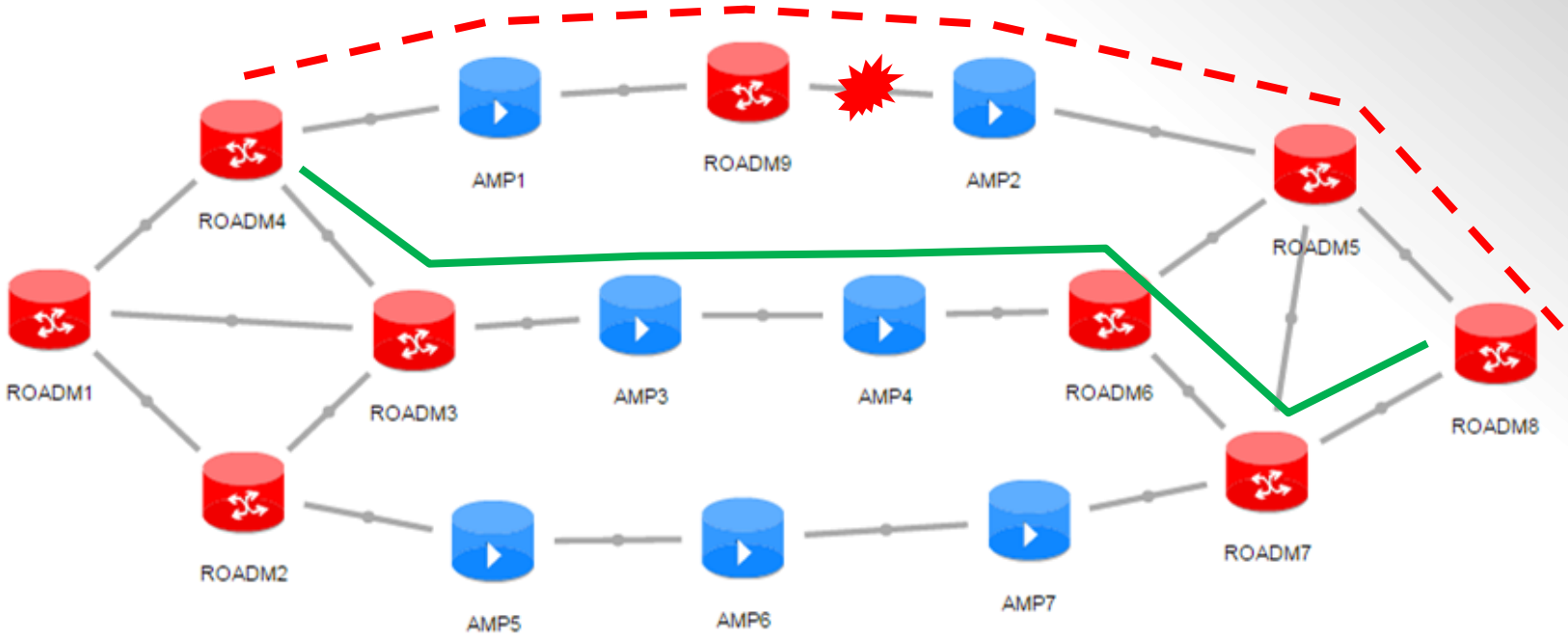
# Restorable service (1+R)




RSVP-TE Signaling For GMPLS Restoration LSP
draft-gandhi-ccamp-gmpls-restoration-lsp-03

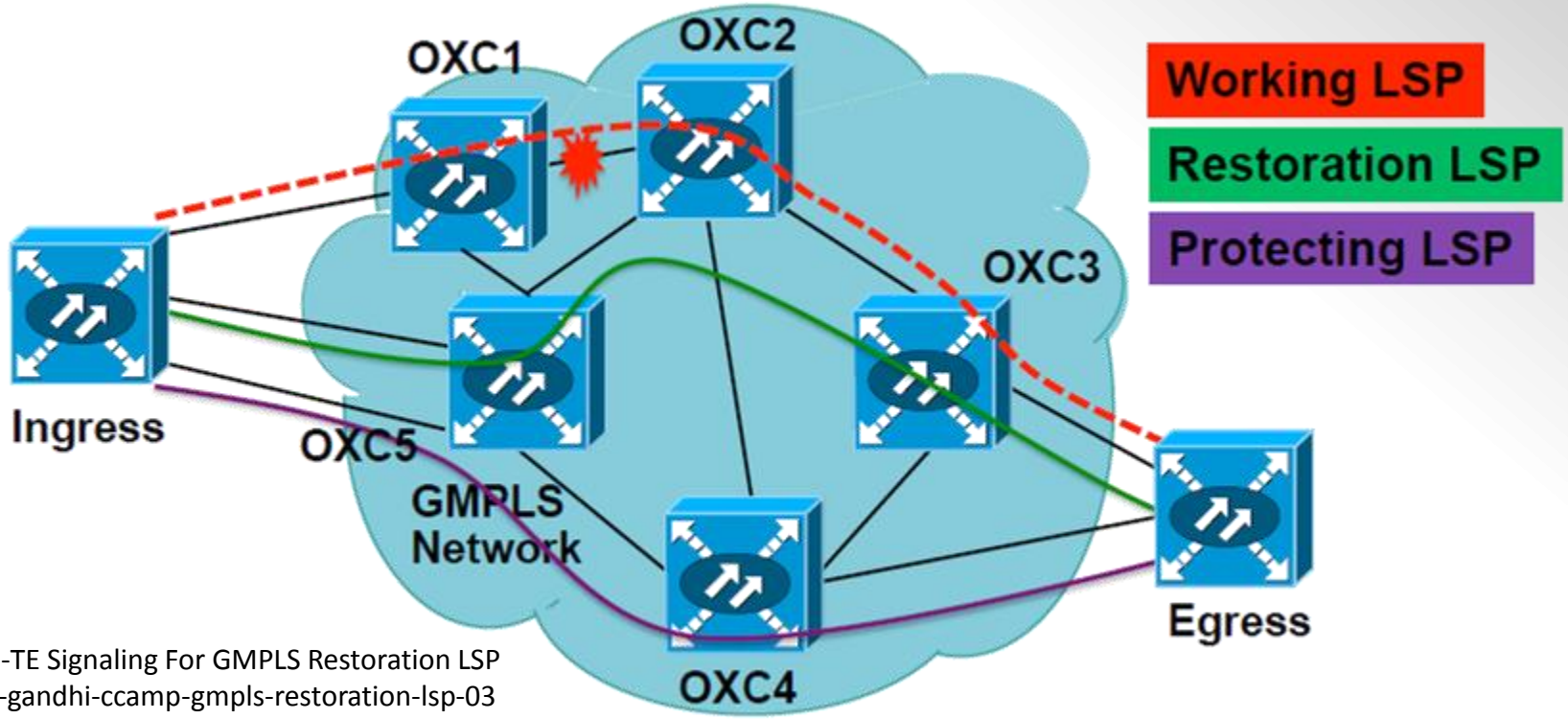
1. Restoration LSP is signaled **after** the failure of the working LSP is detected.
2. Restoration LSP **may share** resources with the failed working LSP.

# Protected service (1+1)




1. Two disjoint LSPs are established
2. Traffic is transmitted through both paths
3. In case of failure both receivers switch to the protection LSP

# Protected and restorable service (1+1+R)




RSVP-TE Signaling For GMPLS Restoration LSP
draft-gandhi-ccamp-gmpls-restoration-lsp-03

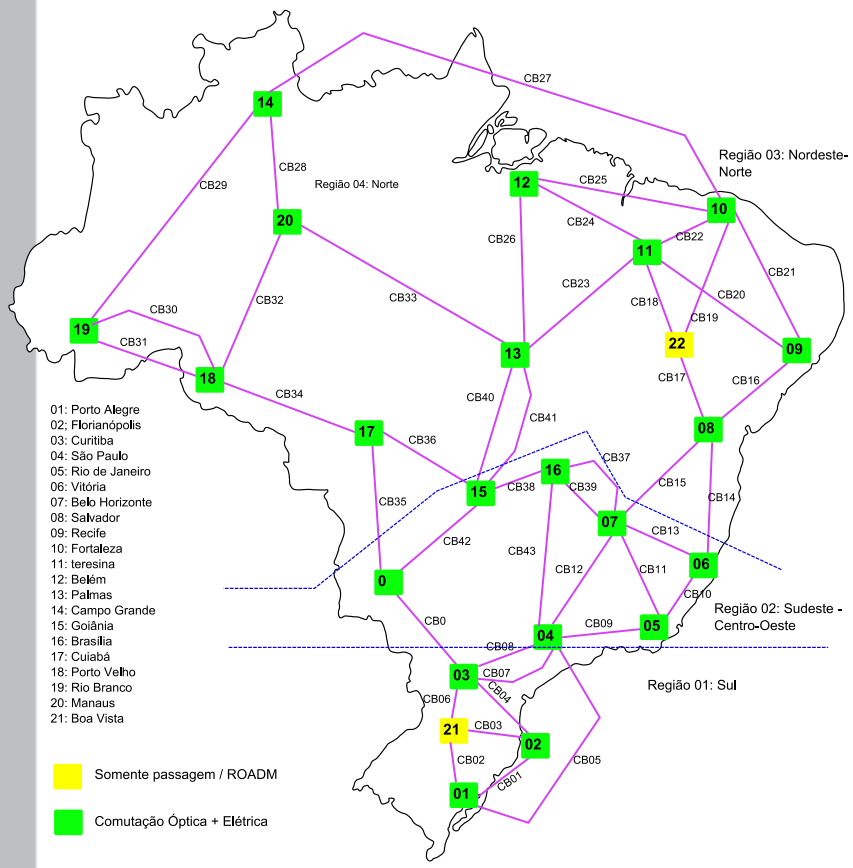
1. Restoration LSP is signaled **after** the failure of the working LSP **and/or** protecting LSP;
2. Restoration LSP **may share** resources with the failed working/protecting LSP;
3. Restoration LSP provides protection against a second order failure for 1+1+R.

# Summary

1. Photonic Networks
2. Classes of Service in Optical Networks
3. **Routing for Optical Restoration**
4. The Future and its Challenges

# Planning for the DWDM layer

## Physical Layer



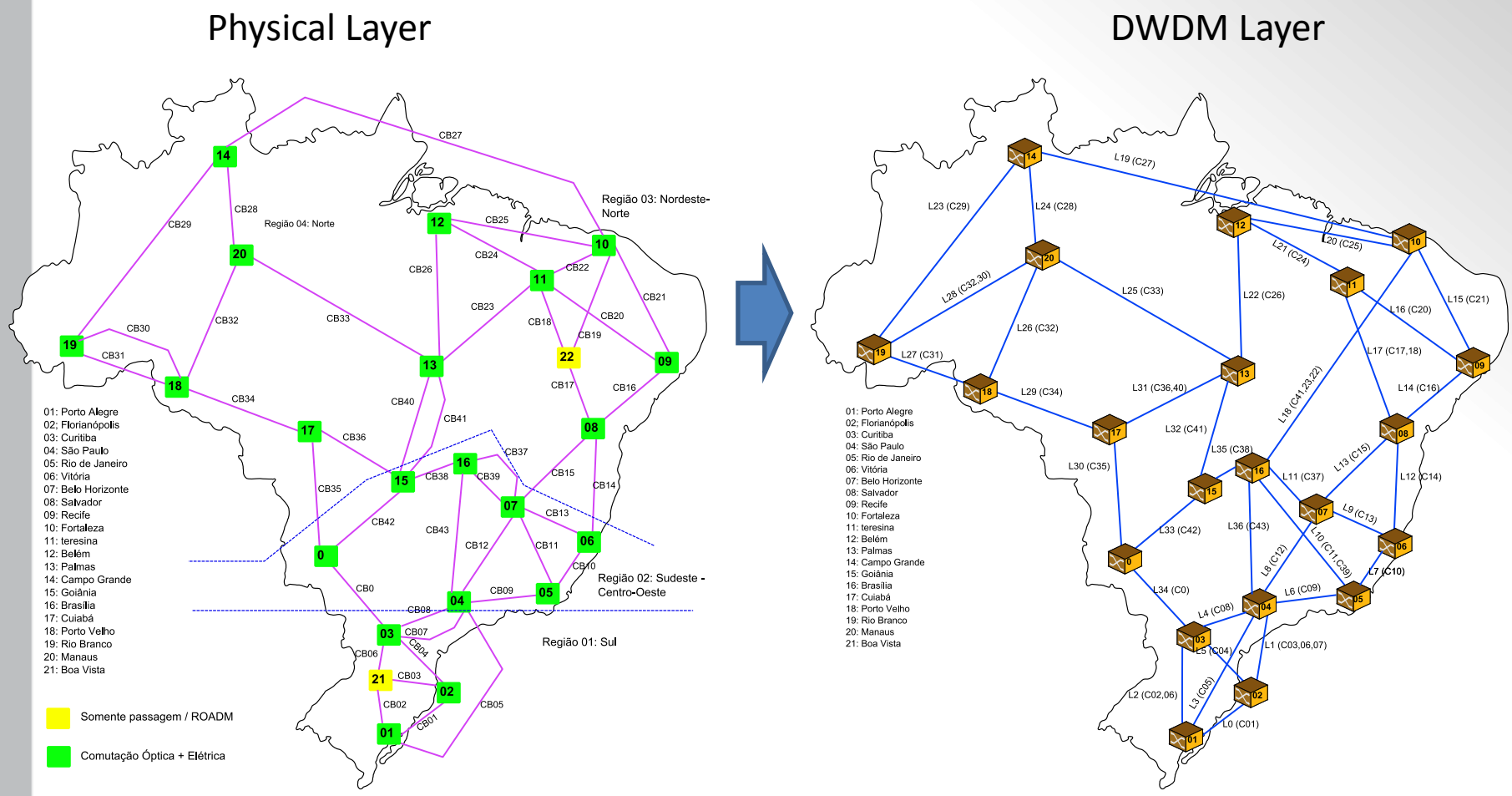

*1+R 100G Services*

| | BSA (16) | FTL (10) | SPO (06) | RJO (05) | PAE (01) | BHZ (07) | CCR (14) |
|---|---|---|---|---|---|---|---|
| BSA (16) | | | | | | | |
| FTL (10) | 10 | | | | | | |
| SPO (06) | 10 | 10 | | | | | |
| RJO (05) | 10 | 10 | 10 | | | | |
| PAE (01) | | | 4 | | | | |
| BHZ (07) | | | | 4 | 4 | | |
| CCR (14) | 4 | | | | 4 | | |
| MNS (20) | | 4 | | | | 4 | 4 |

*1+1+R 100G Services*

| | BSA (16) | FTL (10) | SPO (06) | RJO (05) | PAE (01) | BHZ (07) | CCR (14) |
|---|---|---|---|---|---|---|---|
| BSA (16) | | | | | | | |
| FTL (10) | 1 | | | | | | |
| SPO (06) | 1 | 5 | | | | | |
| RJO (05) | 5 | 5 | 5 | | | | |
| PAE (01) | | | 1 | | | | |
| BHZ (07) | | | | 5 | 1 | | |
| CCR (14) | 1 | | | | 1 | | |
| MNS (20) | | 5 | | | | 1 | 1 |

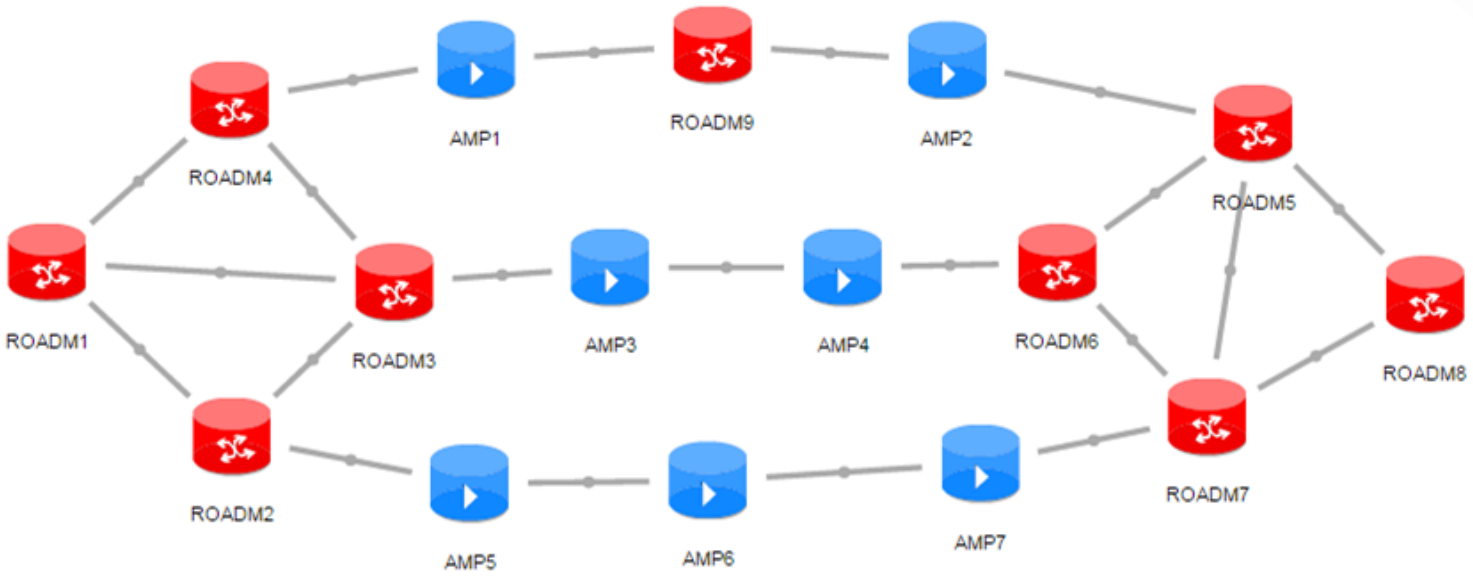
# Planning for the DWDM layer



# Efficient Network Planning

In order to maximize restoration availability and minimize cost, one can make use of:

- Efficient Routing and Wavelength Assignment algorithms
- Regeneration pools



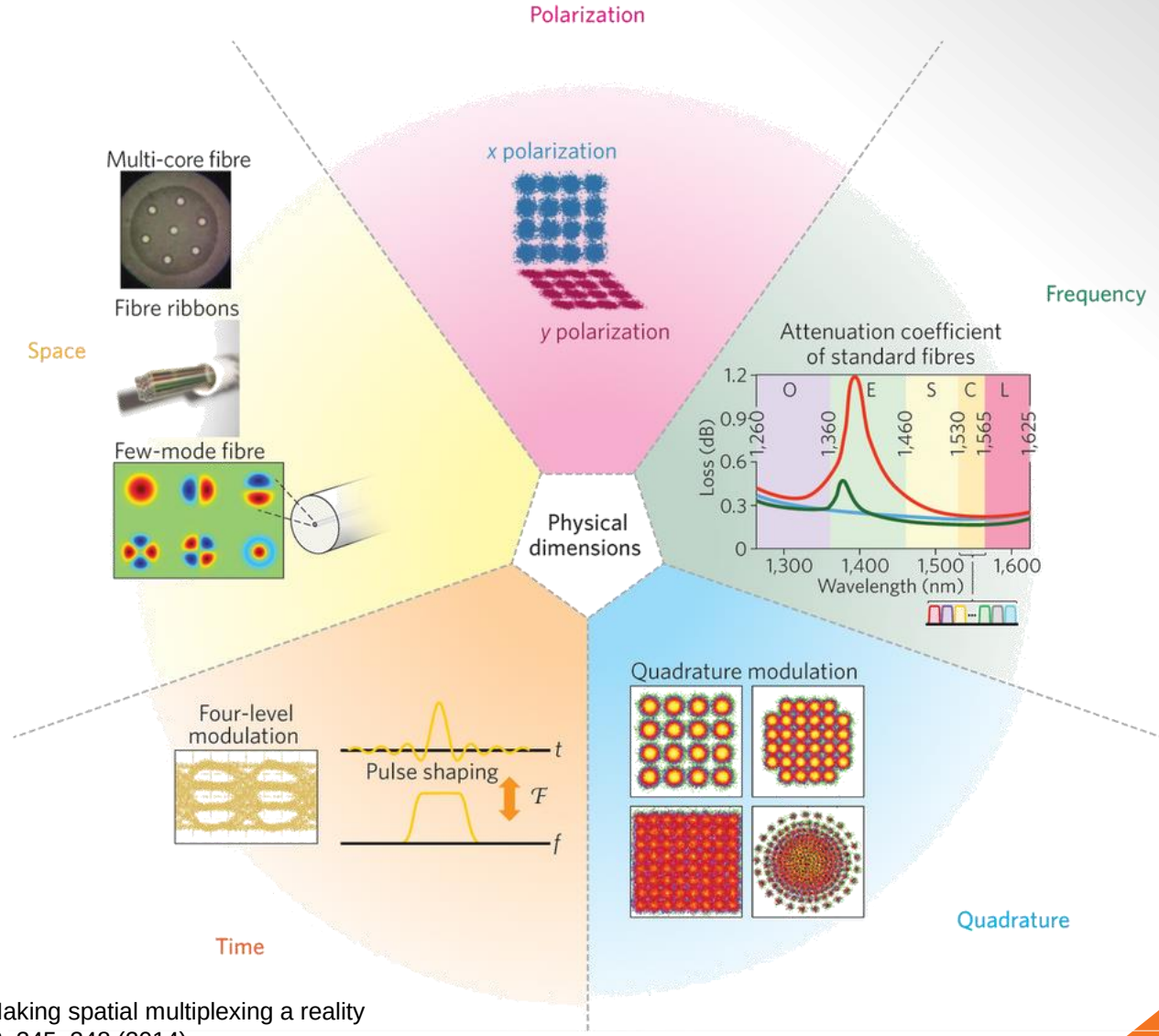
# Summary

1. Photonic Networks
2. Classes of Service in Optical Networks
3. Routing for Optical Restoration
4. **The Future and its Challenges**

# Technologies

- Flexible transponders
- Software Defined Networks
- Spatial Division Multiplexing

# Physical dimensions

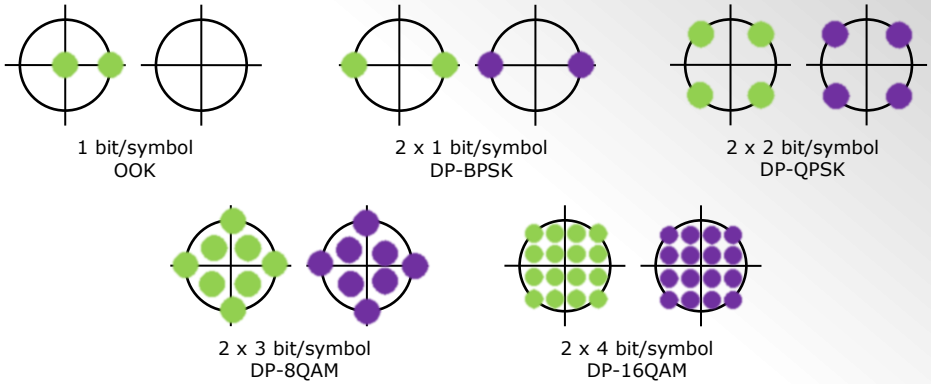



Peter J. Winzer , Making spatial multiplexing a reality
*Nature Photonics* 8, 345–348 (2014)

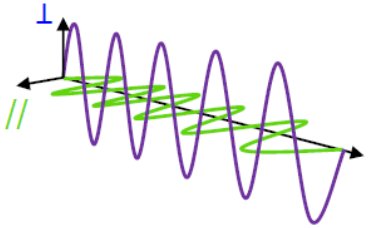
# Flexible transponders

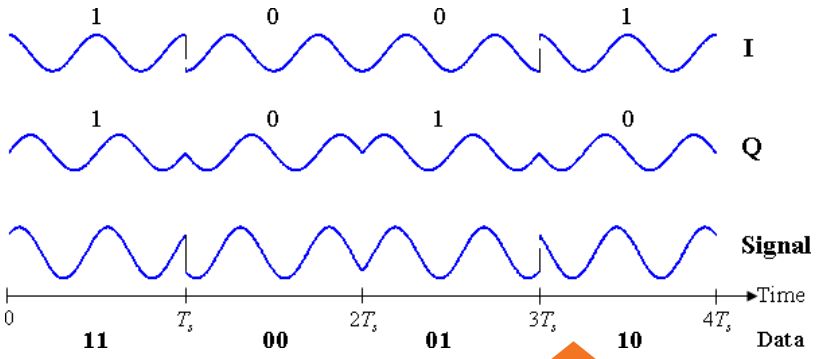
Advanced and flexible modulation formats allow to balance between

- Reach
- Performance
- Spectral occupation




| Modulation Format | Spectral efficiency [bit/s/Hz] | Bits per symbol |
|---|---|---|
| OOK | 0,5 | 1 |
| BPSK | 0,5 | 1 |
| QPSK | 1 | 2 |
| 16-QAM | 2 | 4 |
| DP-QPSK | 2 | 4 |
| DP-16QAM | 4 | 8 |



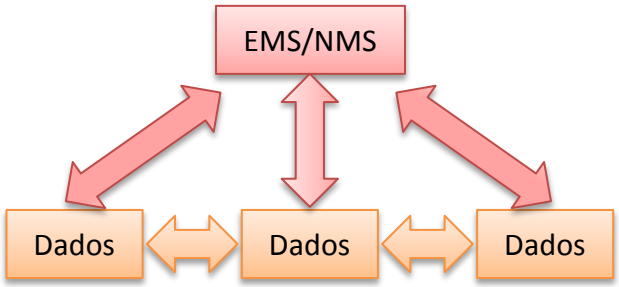



# Software Defined Networks

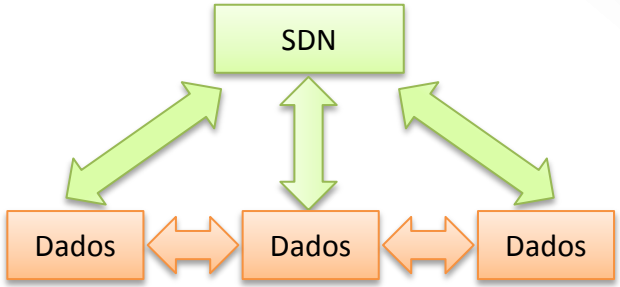
Centralized control benefits
- Simpler HW
- Open to third party development

But transport networks has always been centralized (!)

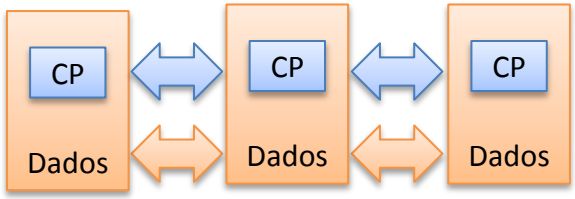
Differences are:
- Standards (??)
- Open to third party




*Centralized control via EMS/NMS in transport networks*



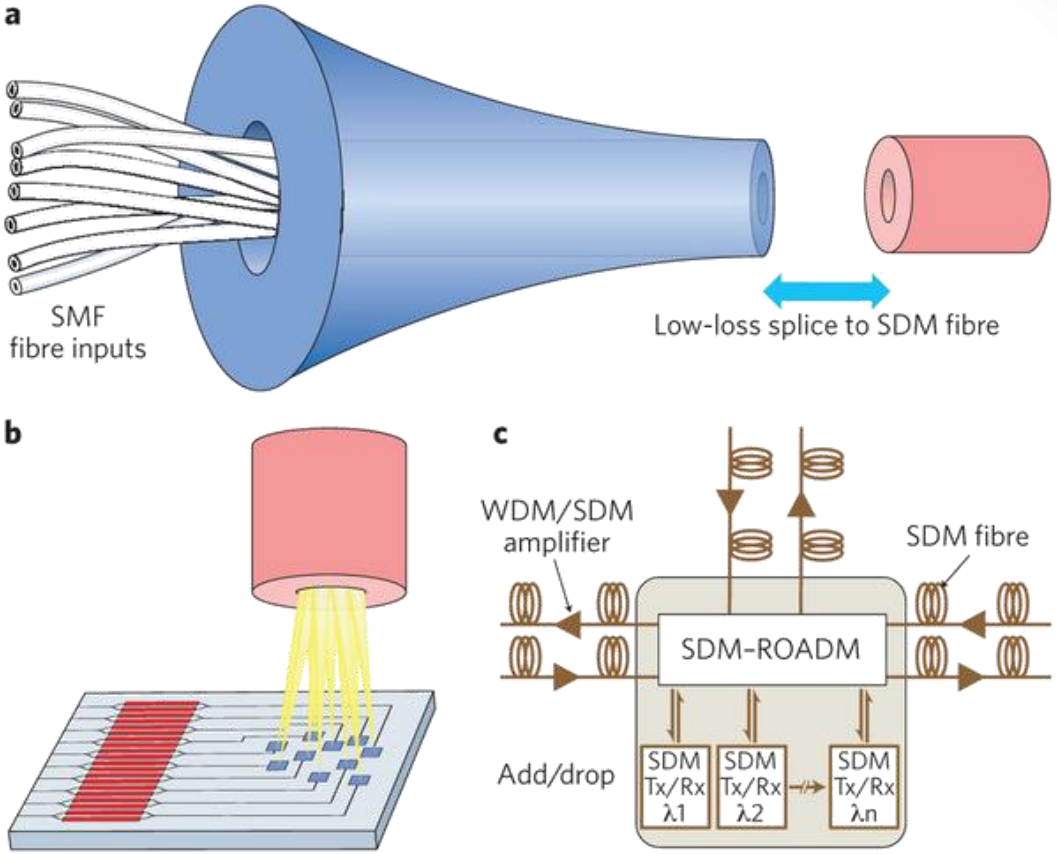

*Centralized control via SDN in transport networks*




*Distributed control in packet networks*

# Spatial Division Multiplexing

- Bandwidth growth need is a fact
- To achieve Tbps channels SDM might be useful.



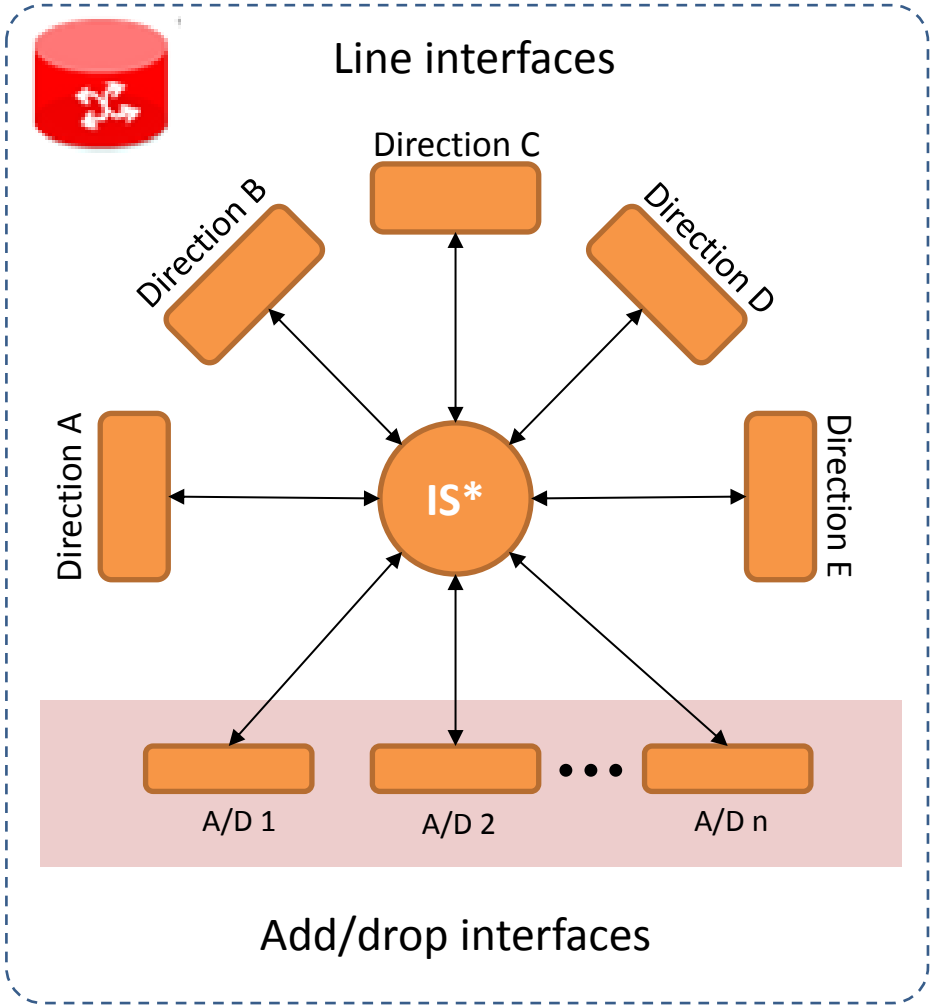

D. J. Richardson, J. M. Fini & L. E. Nelson, Space-division multiplexing in optical fibres, Nature Photonics 7, 354–362 (2013)

Thanks!

padtec.com

Padtec

# ROADM interfaces

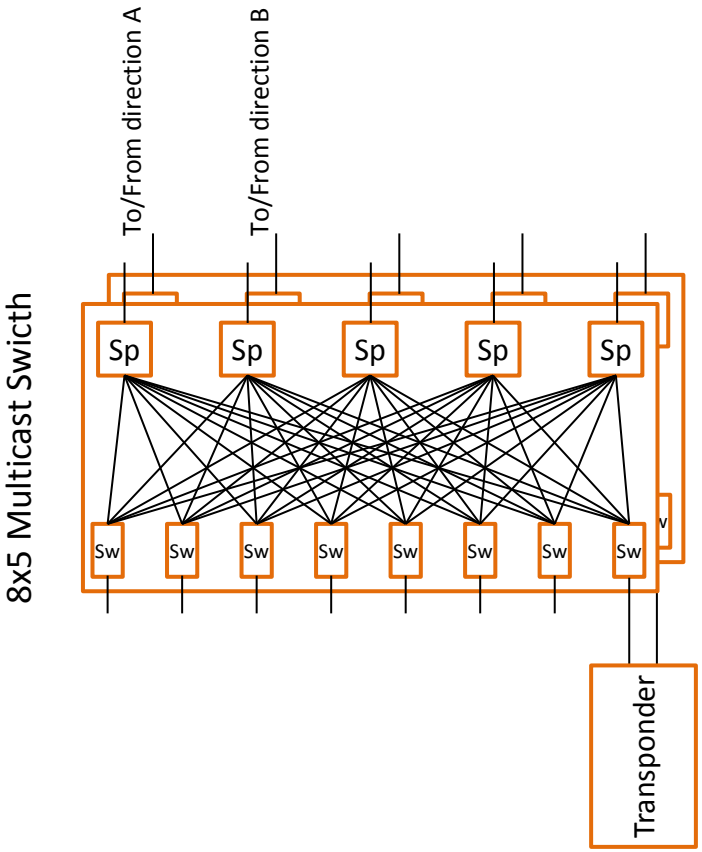



- Colorless (C)
  Any port in any unrepeatered wavelength
- Directionless (D)
  Any port to any direction
- Contentionless (C)
  Any port in any wavelength

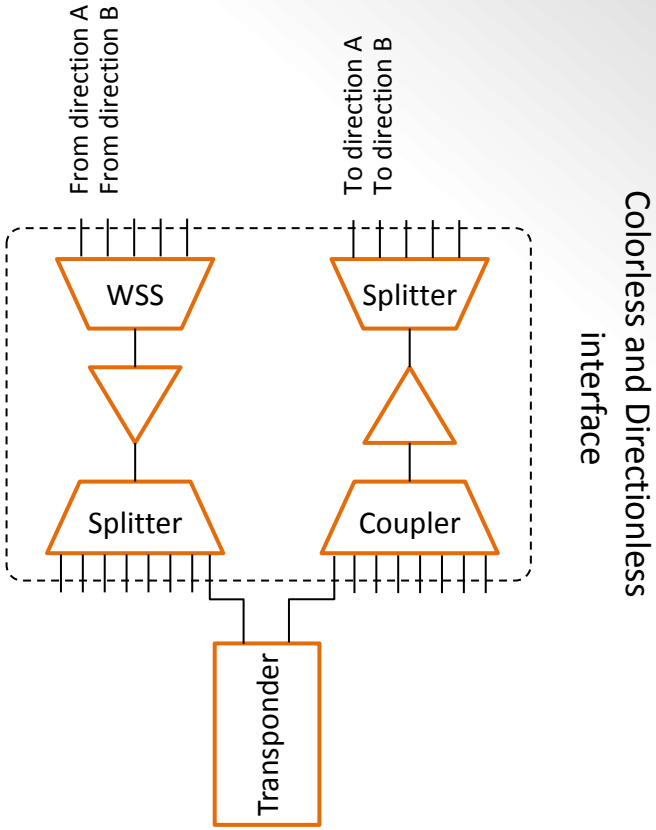
*Interconnection Structure

# ROADM Add/Drop interfaces

Colorless, Directionless and Contentionless interfaces

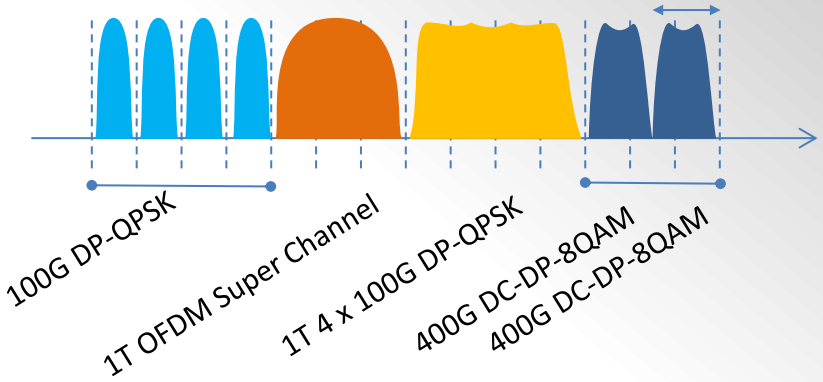

CDC interface for 8 channels
in a 5 degree ROADM Node

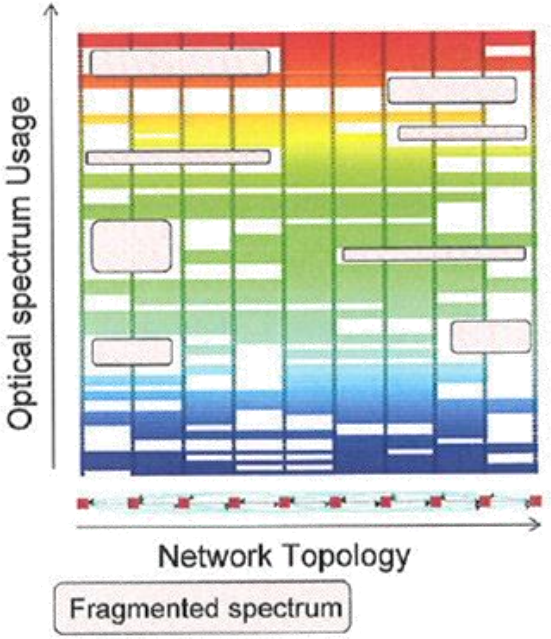


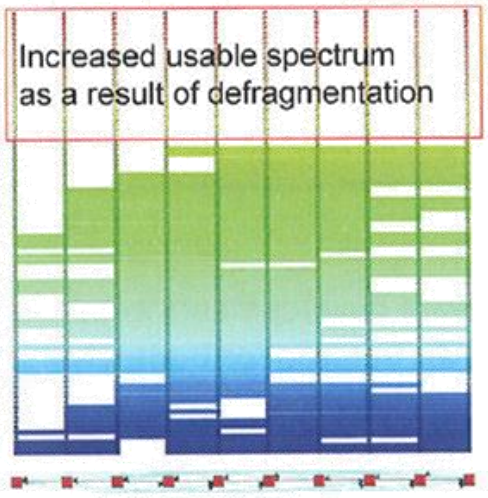

CD interface for 8 channels
in a 5 degree ROADM Node

# Flexible transponders and networks

- Flexible grid
- Superchannels
- Network defragmentation
- Interference in Colorless interfaces




X. Wang et al., ECOC2012, paper P.5.04