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Next-Generation Metro WDM Networks

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Outline

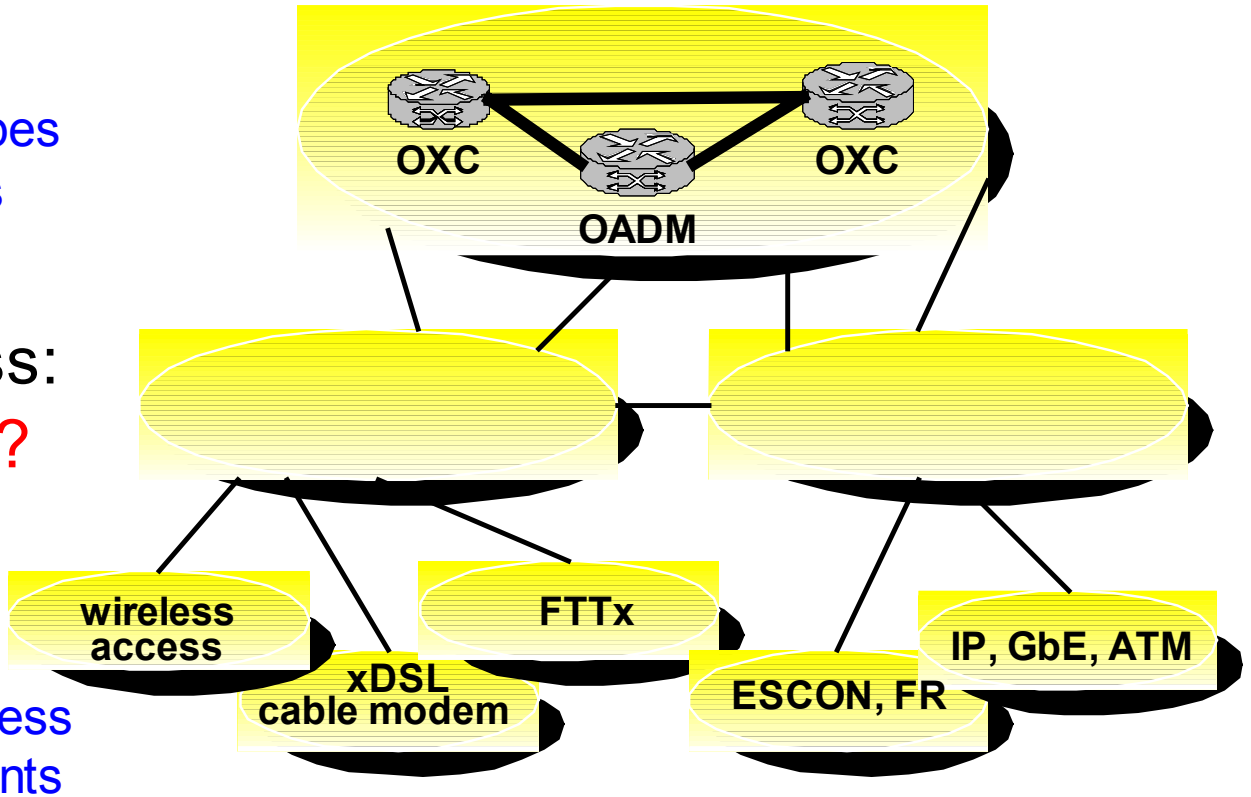
- Motivation
- Metro gap
- Requirements of future metro WDM networks
- Research & standardization activities
- Architecture & MAC protocol
- Results
- Conclusions

Motivation

Backbone:
- Huge WDM pipes
- Optical bypass

Metro/Access:
Bottleneck ?

Local:
- Broadband access
- High-speed clients



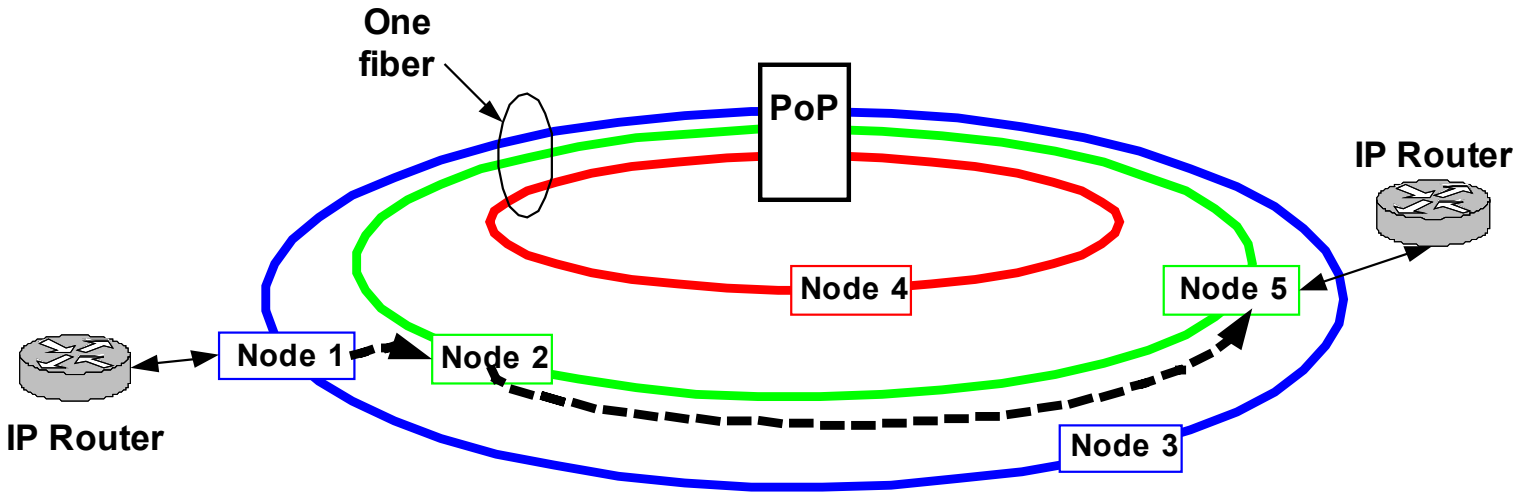
Metro Gap

- Current metro networks mostly based on SONET/SDH rings
- Inefficiencies due to TDM and mapping
- Bandwidth abyss between backbone and clients causes so-called metro gap
- Solutions required to bridge this gap
- RHK: „... *Metro and access optical markets are currently the fastest growing segments* ...“

Metro WDM Networks: Requirements

- Flexibility: Support of a wide range of legacy protocols and also new services
  - TDM voice and leased lines, VPN
  - IP, ATM, FR, GbE, ESCON, Fibre Channel
  - Peer-to-peer applications (e.g., Napster)
- Cost-sensitivity: Simple architecture and operation
- Scalability/Upgradability
- Reliability: 50 ms restoration
- Compatibility with access and backbone infrastructure (OAM/P)

Metro WDM Ring Networks: HORNET



- Hybrid Optoelectronic Ring NETwork (Stanford & Sprint) [1]
- Packets directly over WDM ring w/o SONET transport
- Nodes equipped with fast tunable Tx and fixed tuned Rx
- CSMA/CA MAC protocol

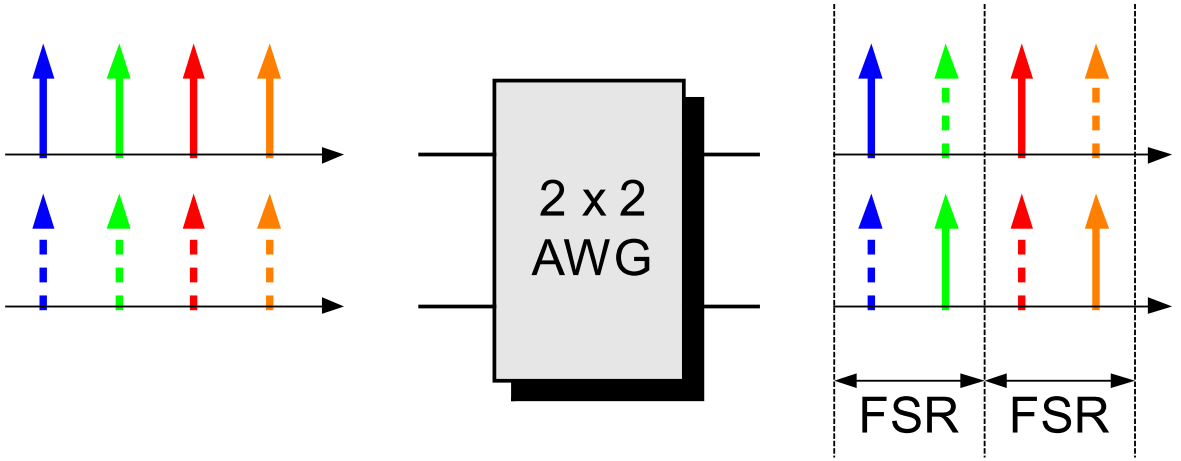
Metro WDM Ring Networks: RPR

- Resilient Packet Ring (standard to be completed in 2003)
  - IEEE 802.17 WG
  - IETF WG IPoRPR
  - Dual ring comprising price & performance of Ethernet and resilience of SONET/SDH
- Vendors with proprietary pre-standard solutions (e.g., CISCO‘s DPT/SRP: RFC 2892)
- Fredrik Hanell, DYNARC:

  „... *RPR uses ... two performance-enhancing schemes: Spatial reuse ... [and] Shortest path steering...*“

Arrayed-Waveguide Grating

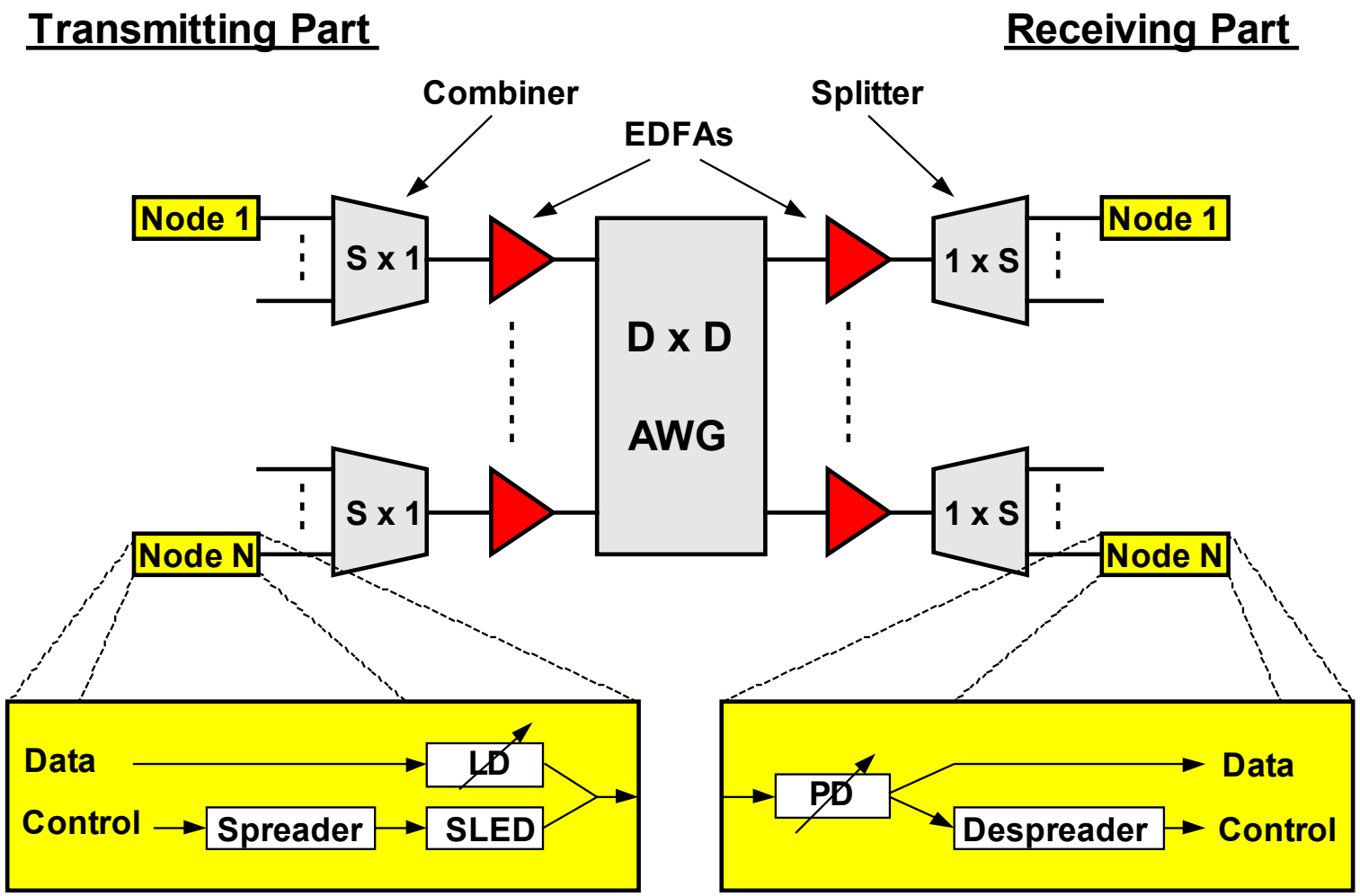
- Arrayed-Waveguide Grating (AWG):
  - Passive wavelength router
  - Allows for extensive spatial wavelength reuse
  - Used for single-hop WDM networks



AWG-based Metro WDM Star Networks

- Telstra:
  - AWGs for cost-effective metro WDM network architectures [2]
- NTT:
  - Multiple fixed-tuned transceivers per node [3]
  - Centralized resource management with λ-conversion [4]
- ACTS programme SONATA (national-scale network):
  - Reservation based access
  - Each node with one tunable transceiver
  - Centralized slot/wavelength assignment [5]

Network and Node Architecture



Architecture: Characteristics [6]

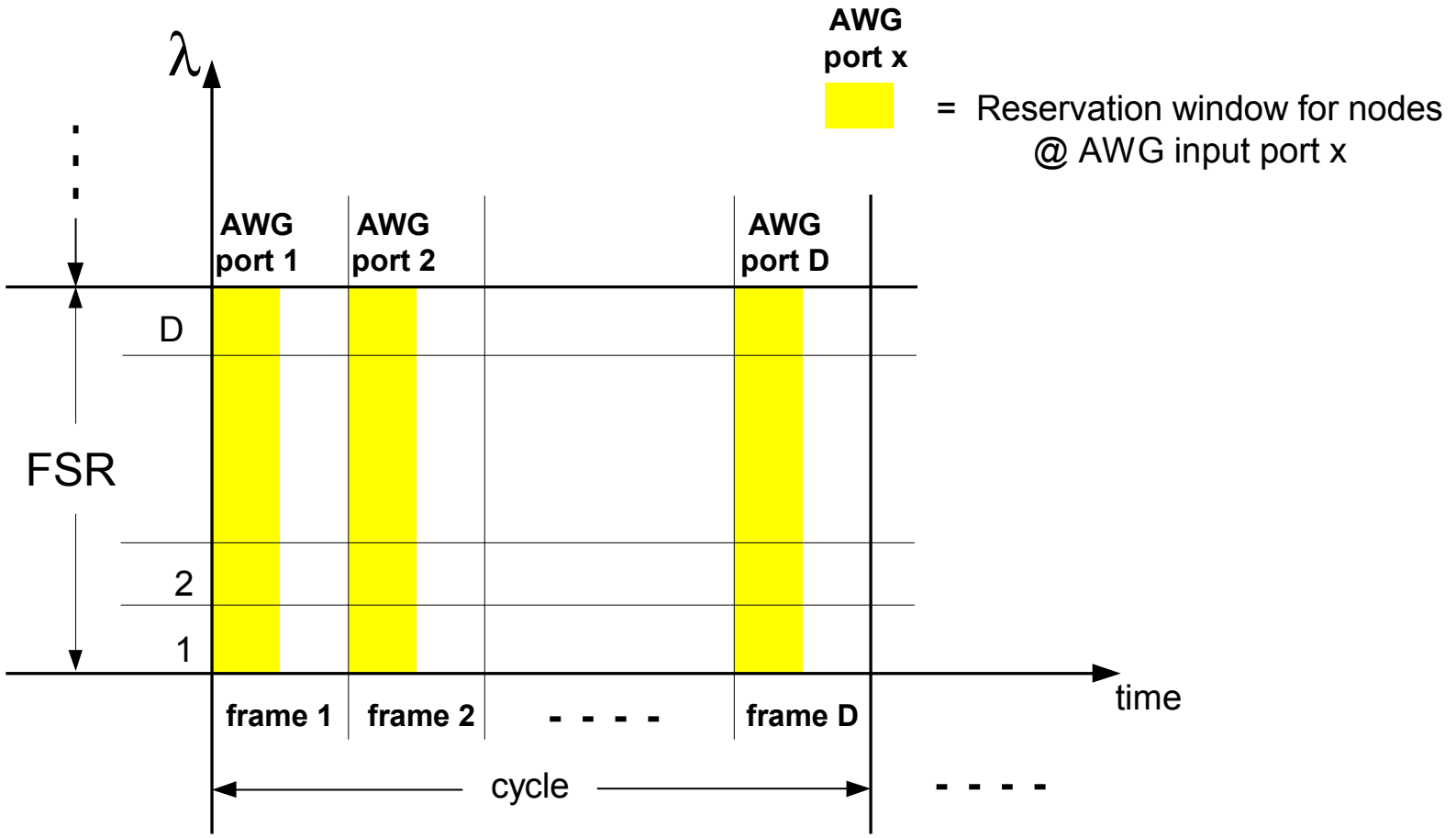
- No central controller with λ-conversion
- Resources are allocated in a distributed fashion
- Increased concurrency by using multiple FSRs
- Novel node architecture:

  Simultaneous transmission of control and data without requiring additional control channel(s) and receiver(s)
- Control broadcast by means of spectral slicing
- Extendable to CDMA

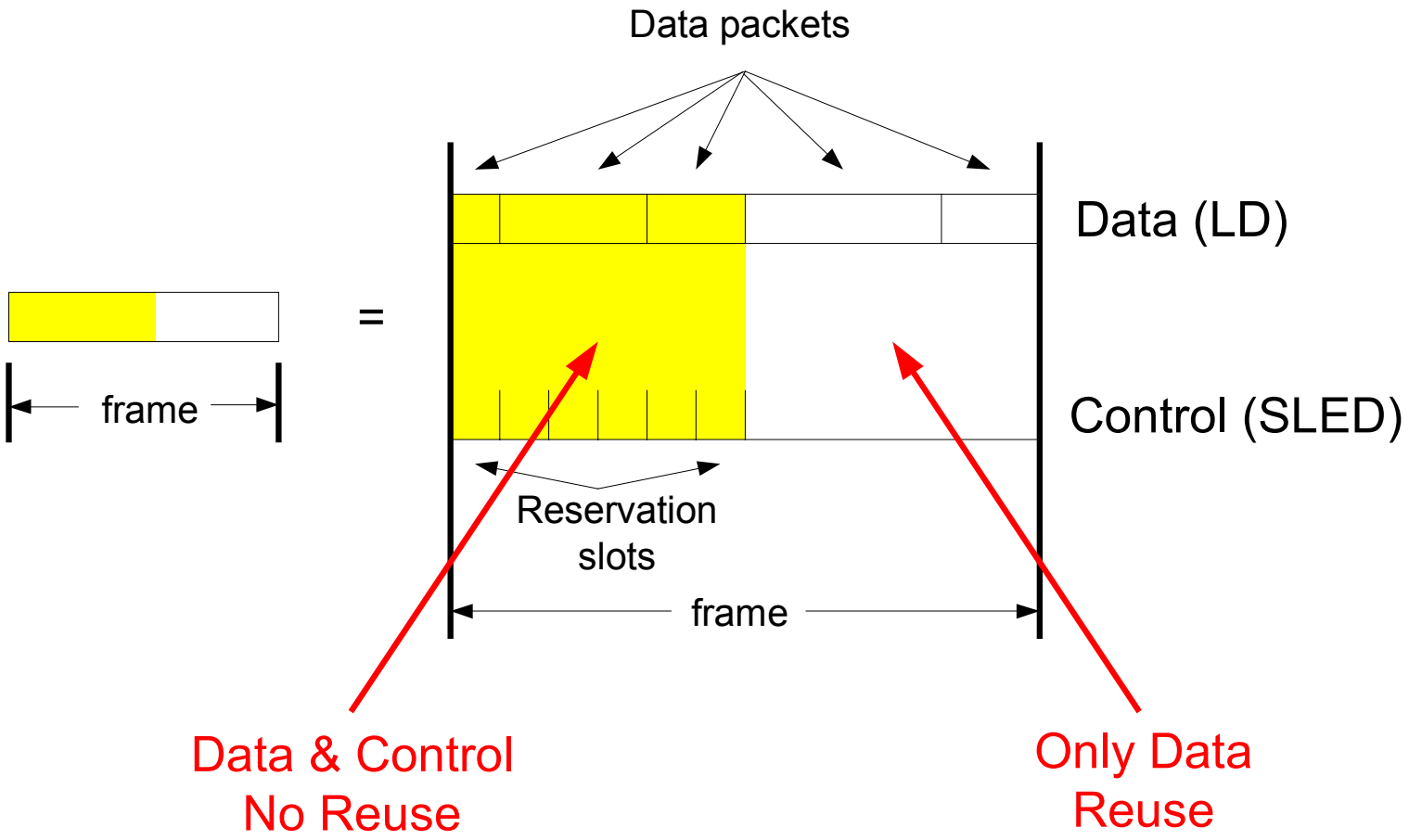
MAC Protocol: Basic Principles [7]

- WDM/SDM/TDM/CDM
- Reservation based $\Rightarrow$ Pretransmission coordination
  $\Rightarrow$ control packet (via modified slotted ALOHA)
- Control packet:
  - **Destination address** (unicast and/or multicast)
  - **Length** of corresponding data packet
  - **Type**: Packet or circuit switching
- Global knowledge at each node
- Distributed scheduling $\Rightarrow$ no explicit ACKs
- In case of failure: Retransmit control packet

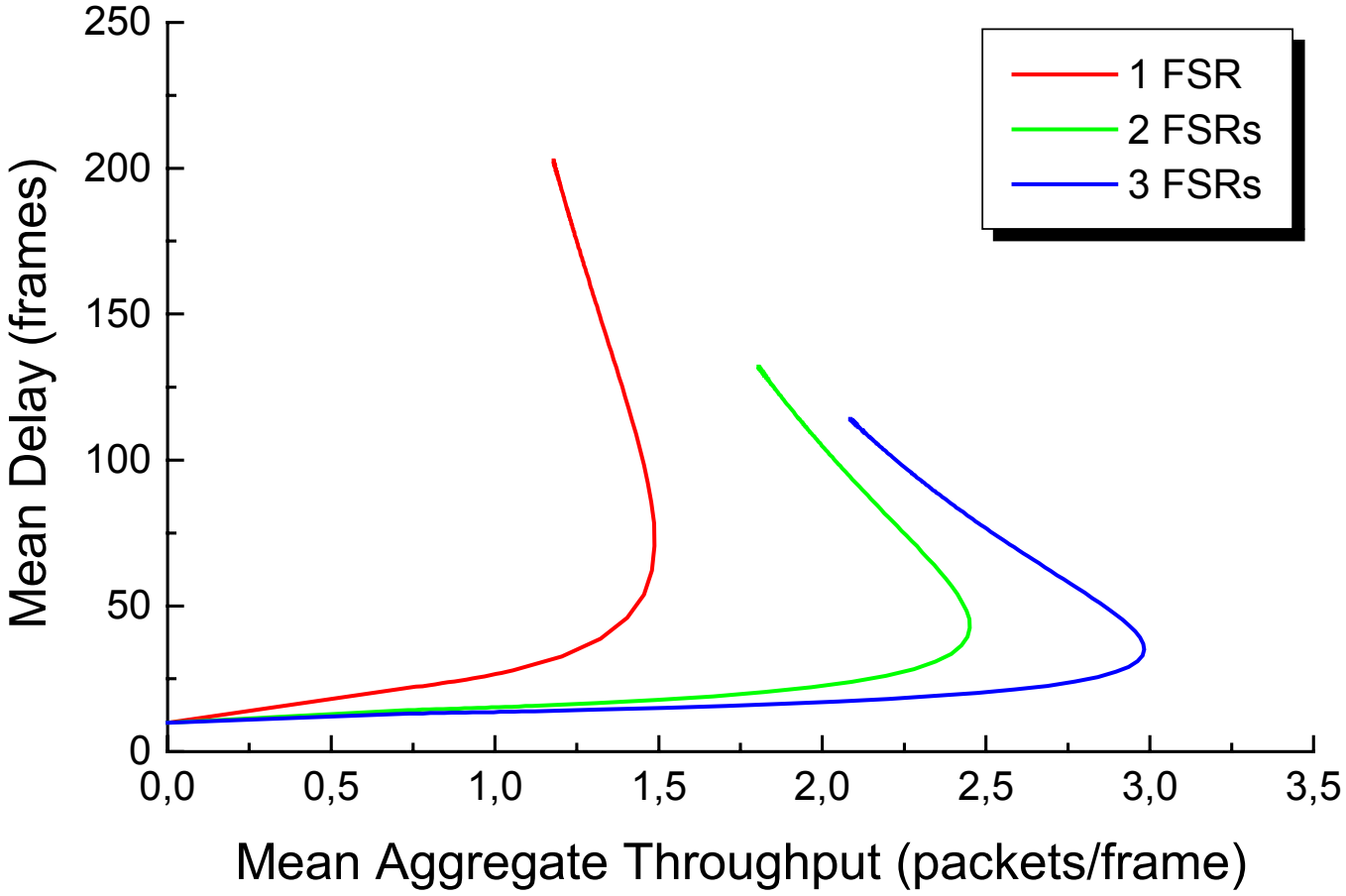
MAC Protocol: Wavelength Assignment



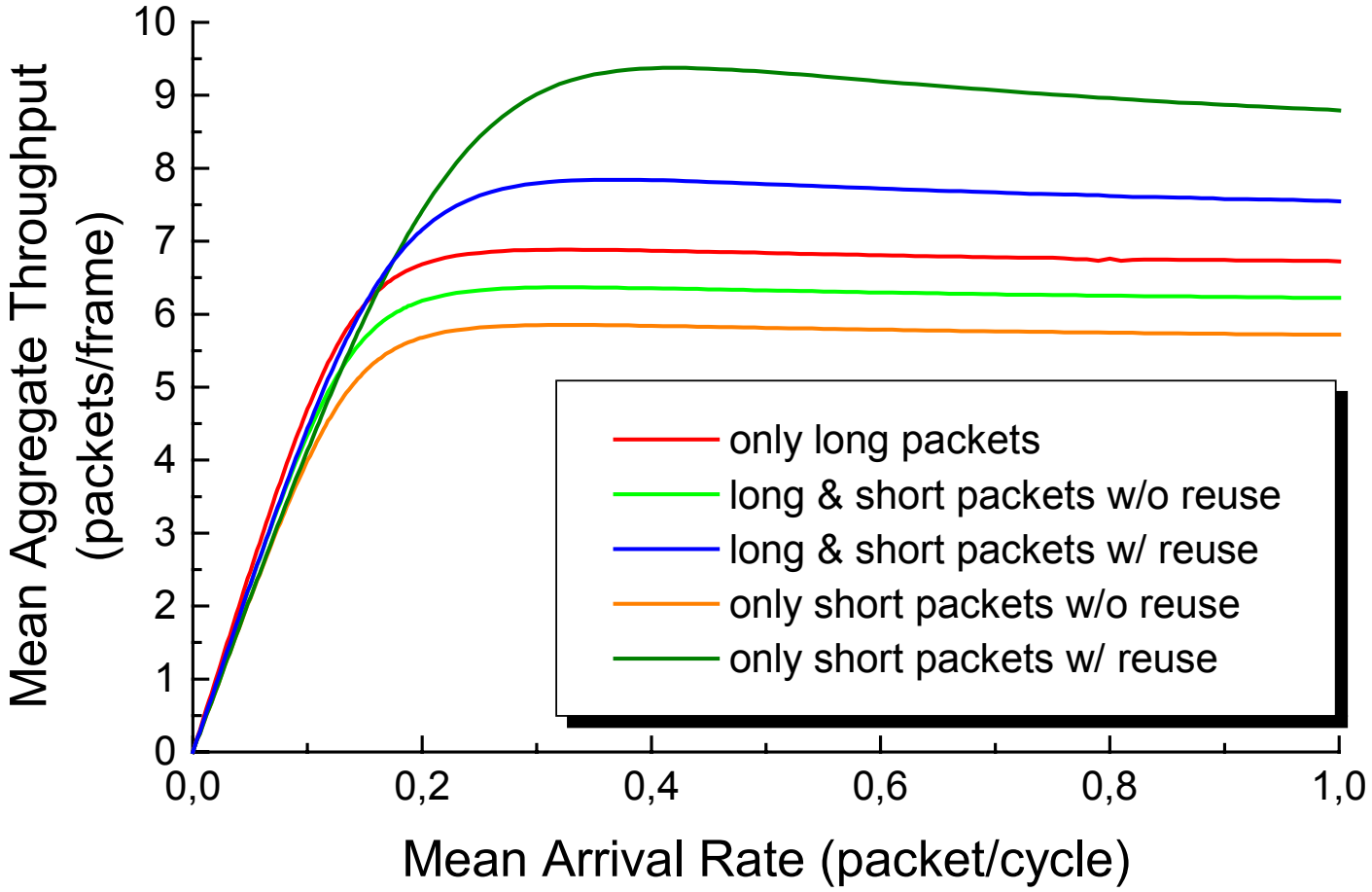
MAC Protocol: Frame Format



Fixed-Size Packets: Multiple FSRs



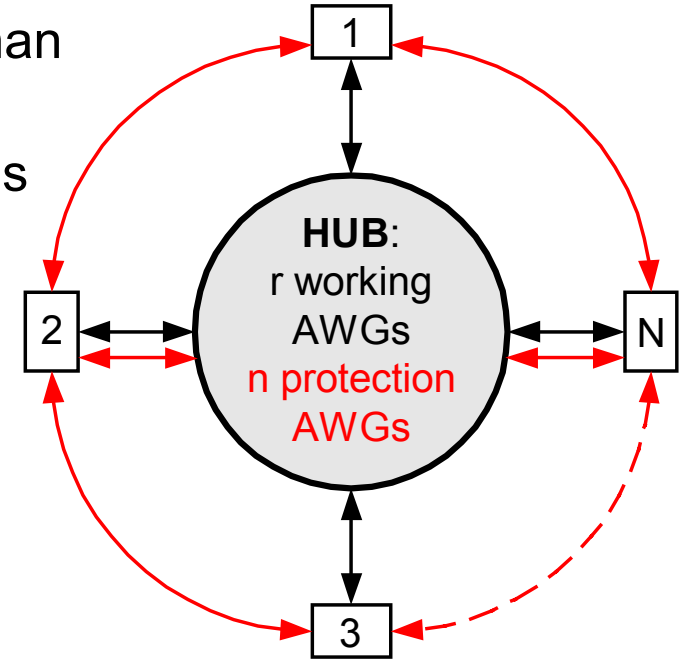
Variable-Size Packets: Multiple FSRs + Reuse



Protection

- Reliability challenges in star (and bus) topologies
- 1+1 redundancy
- Alternative strategy: n:r router & m:N path protection [8]:

- greater resilience than ring structures
- restoration <= 50 ms



= working

= protection

Conclusions

- Metro gap
- IP & WDM w/o SONET/SDH transport
- RPR: Ethernet price and performance & SONET/SDH survivability
- AWG:
  - Efficient star networks
  - Alternative protection schemes

References

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[3] K. Kato *et al.,* „10-Tbps Full-Mesh WDM Network Based On Cyclic-Frequency Arrayed-Waveguide Grating Router“, in *Proc., ECOC 2000,* vol. 1, pp. 105-107, Munich, Germany, Sept. 2000

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[6] M. Maier *et al.*, „High-performance switchless WDM network using multiple free spectral ranges of an arrayed-waveguide grating“, in *Proc., Terabit Optical Networking: Architecture, Control and Management Issues, Part of SPIE Photonics East 2000,* vol. 4213, pp. 101-112, Boston, MA, Nov. 2000

[7] M. Maier *et al.*, „Towards Efficient Packet Switching Metro WDM Networks“, *SPIE Optical Networks Magazine, Special Issue: Optical Packet Switching Networks, 2002*

[8] A. M. Hill *et al.*, „Multiple-Star Wavelength-Router Network and Its Protection Strategy“, *IEEE JSAC*, vol. 16, no. 7, pp. 1134-1145, Sept. 1998