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On the Design of High-Efficiency WDM Networks

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Outline

- Motivation
- Means to increase network efficiency
- Arrayed-waveguide grating (AWG)
- Architecture
- MAC protocol
- Results

Motivation (1)

- Optical fiber
  - Huge bandwidth (35,000 GHz)
  - Low loss (0.25 dB/km)
  - Low costs (2 cents/m)
  - Small diameter (125 μm)
  - Immunity from EMI

Motivation (2)

- Ever increasing number of users and applications
  - ➨ Call for more bandwidth
- Economic solution:

  Wavelength Division Multiplexing (WDM)
- Current situation: IP/ATM/SONET/WDM

Efficiency: Slim Protocol Stack

IP/ATM/SONET/WDM

self-similar, asymmetric	cell tax 25%, complex mapping & signaling, expensive	designed for synchronous & symmetric traffic, expensive	?

- Plus: Redundant resilience functions in ATM and SONET with complex layer interworking schemes
- IP/ATM/SONET/WDM ➨ IP/WDM

WDM Networks

Single-hop networks:

- Minimum mean hop distance
- High channel utilization
- Inherent transparency
- Low nodal processing requirements

Multihop networks:

Electro-optic bottleneck

➨ Optical switching techniques: OLS, OBS, OPS, or PSR

Single-Hop WDM Networks

Efficiency = Concurrency + Utilization

Architecture

Wavelength-sensitive devices

➨ Spatial wavelength reuse

Protocol

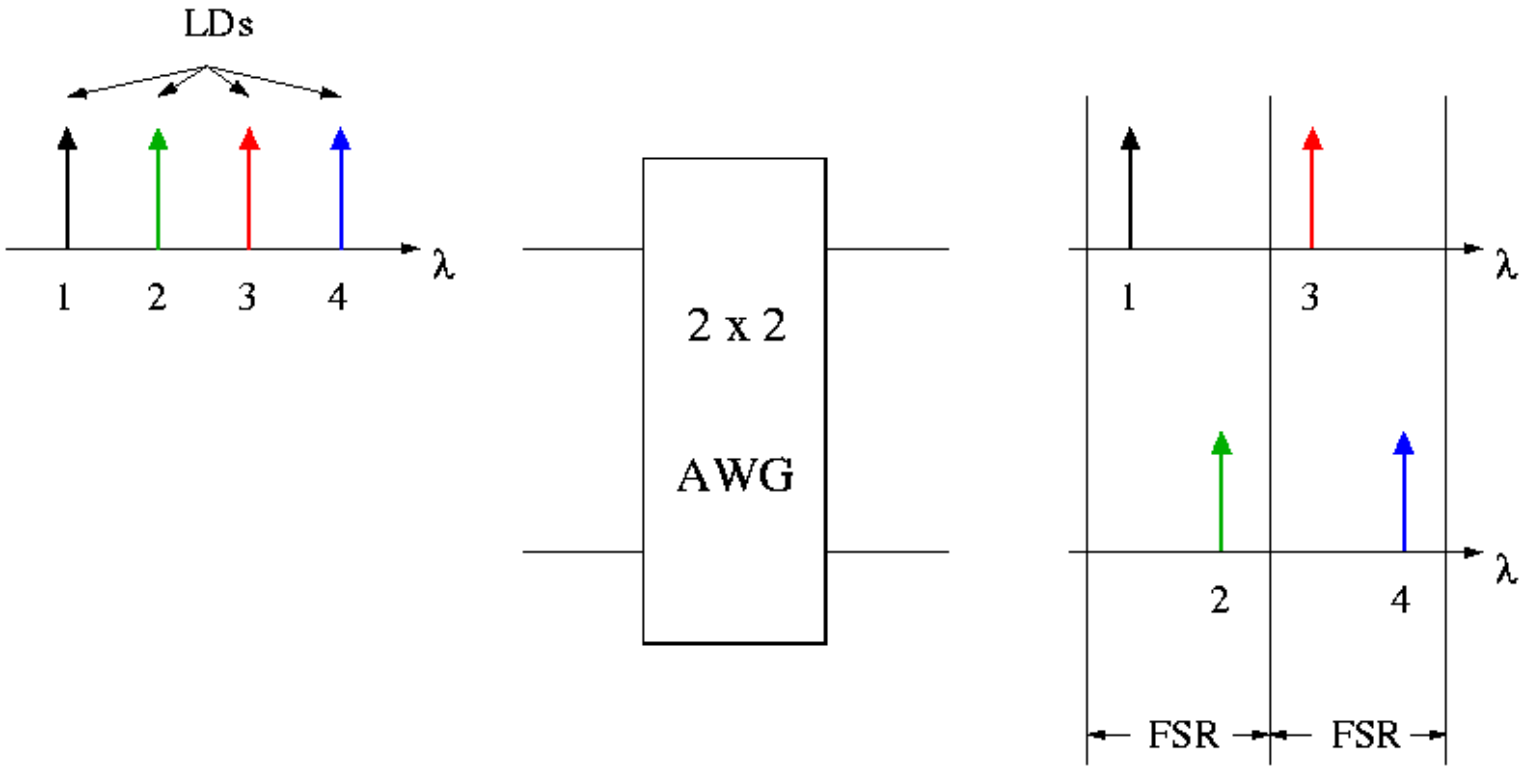
Reduce overhead & avoid collisions

Arrayed-Waveguide Grating (AWG)

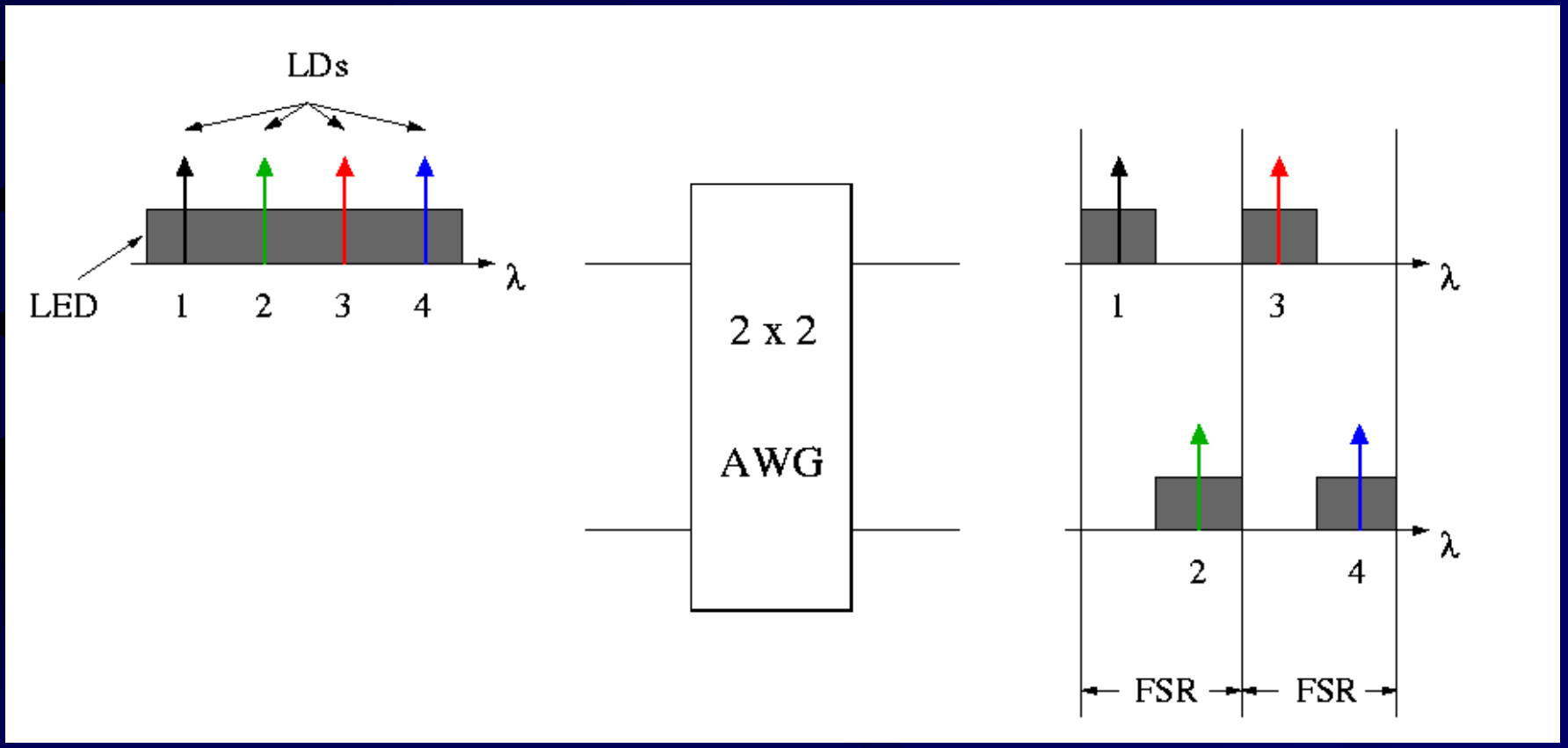
Salient features of AWG:

- Periodic wavelength routing
- Spectral slicing of broadband light sources
- Spatial wavelength reuse

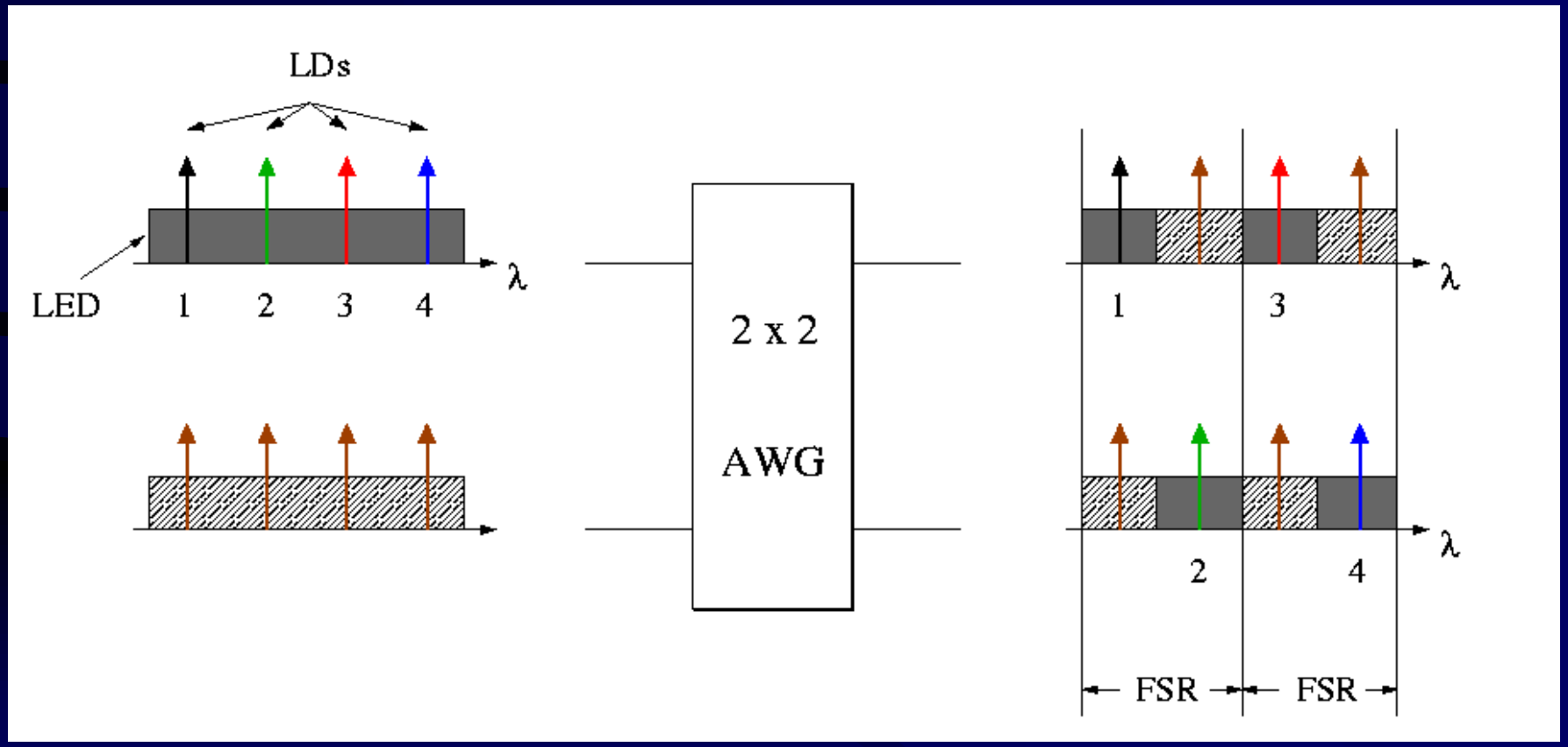
AWG: Periodic Wavelength Routing



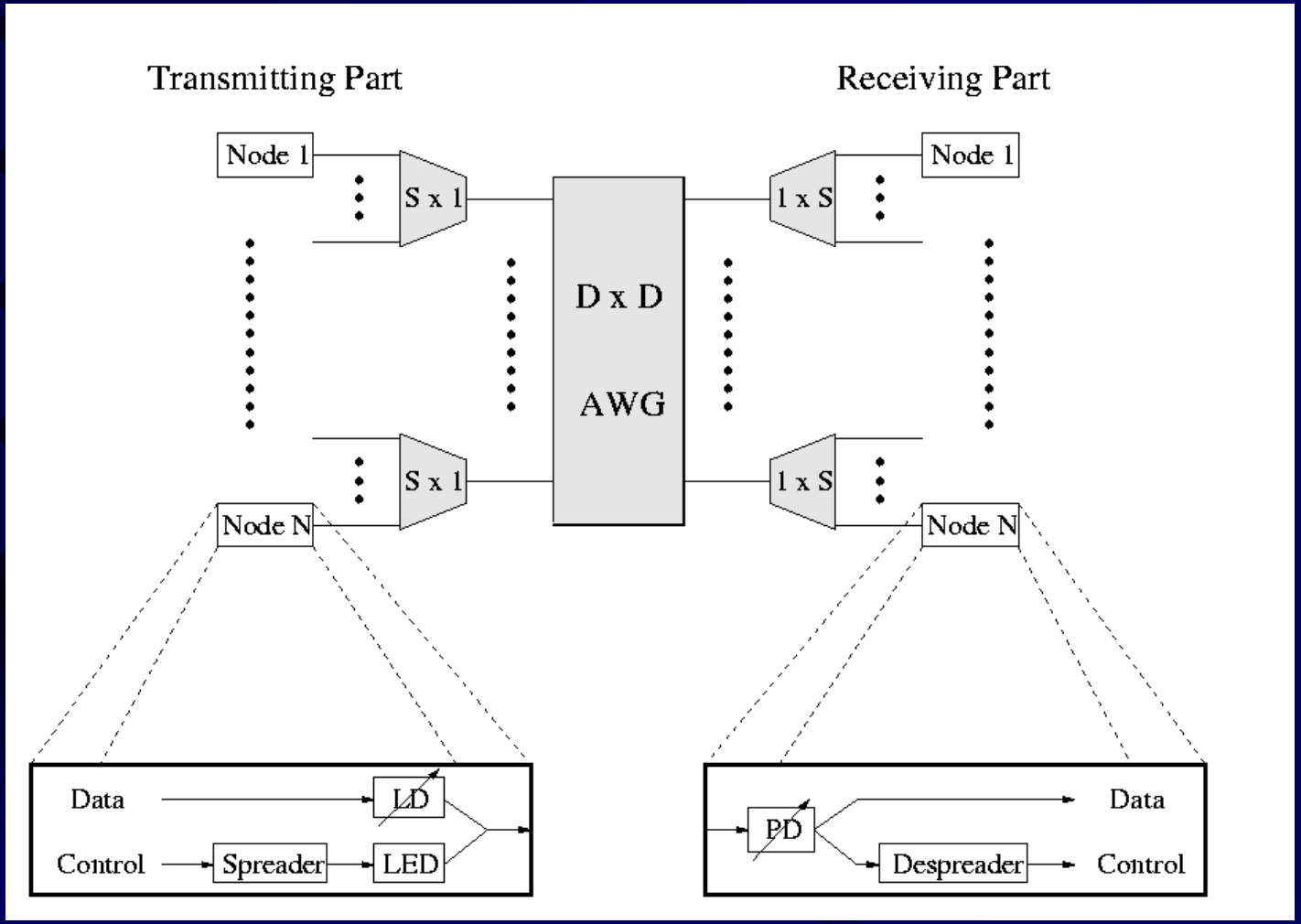
AWG: Spectral slicing



AWG: Spatial Wavelength Reuse



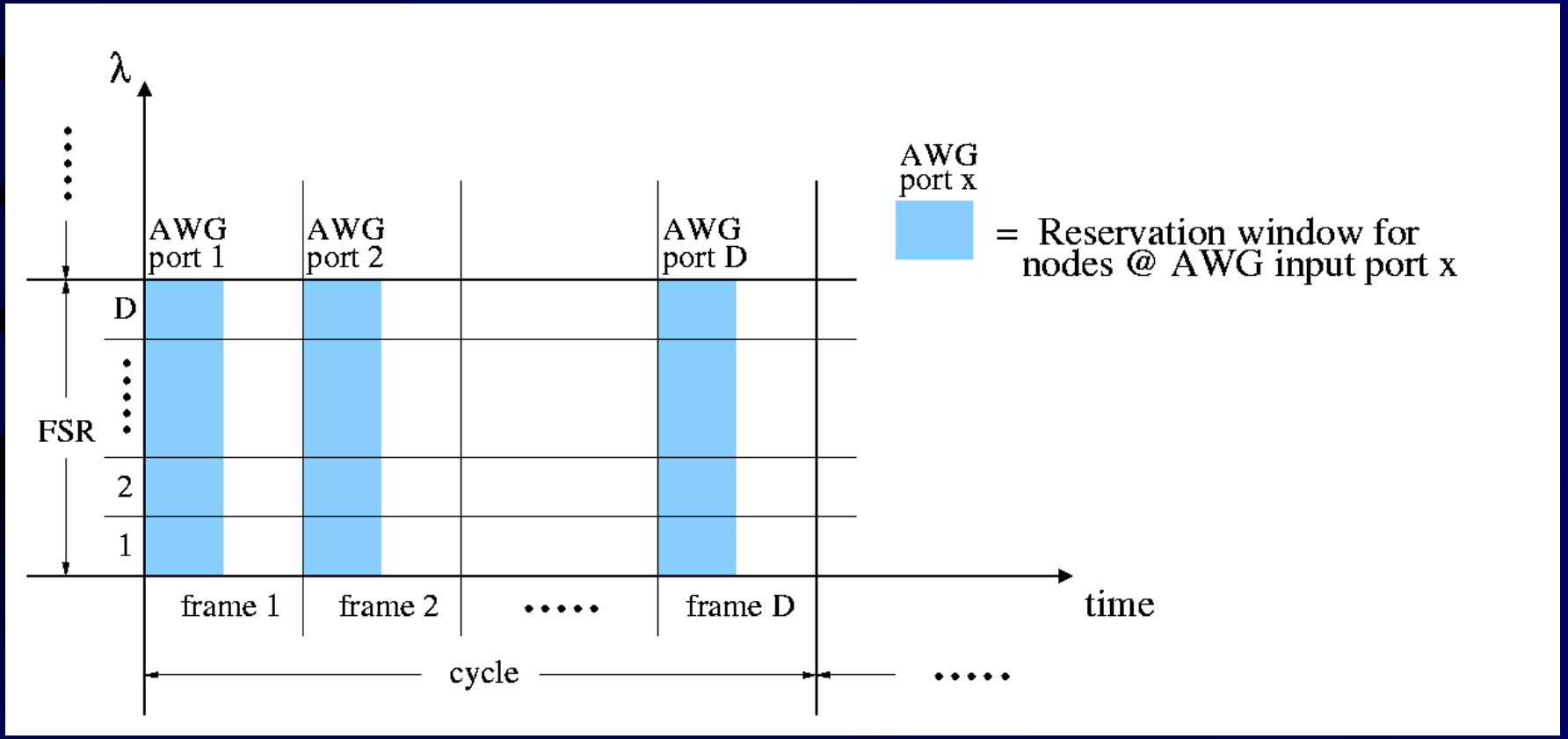
Architecture



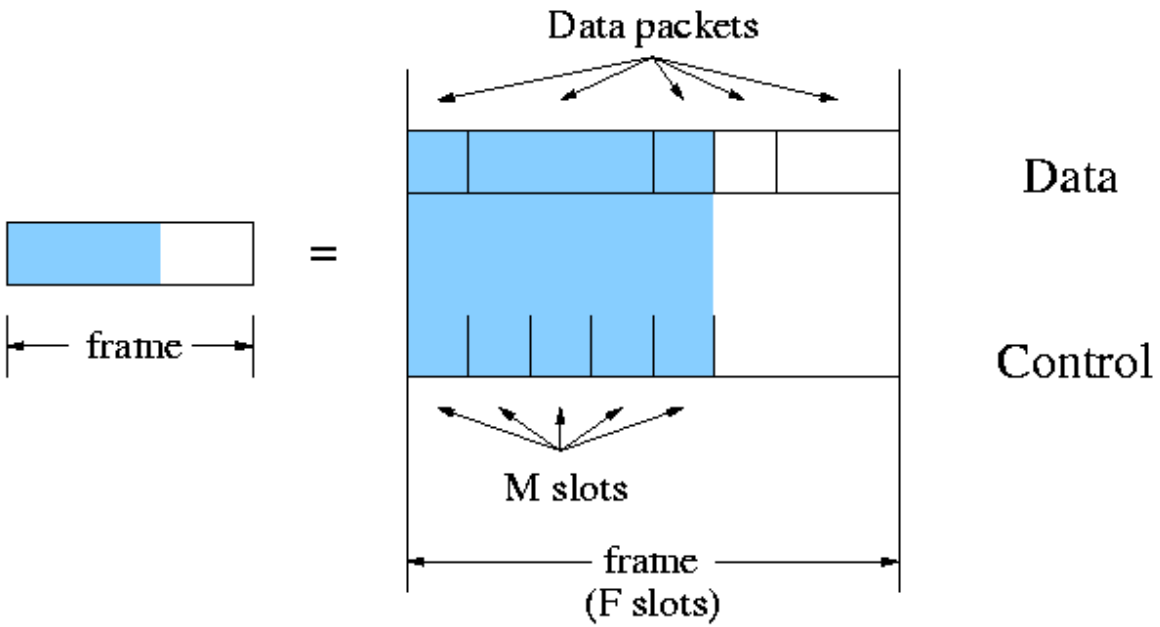
MAC Protocol

- Pretransmission coordination ➨ control packet
- Control packet:
  - Destination address
  - Length of corresponding data packet
  - Type: Packet or circuit switching
- No receiver collisions of control packets ➨ Global knowledge at each node
- Distributed scheduling using identical first-come-first-served and first-fit arbitration algorithm ➨ No channel and receiver collisions of data packets
- In case of failure: Retransmit control packet

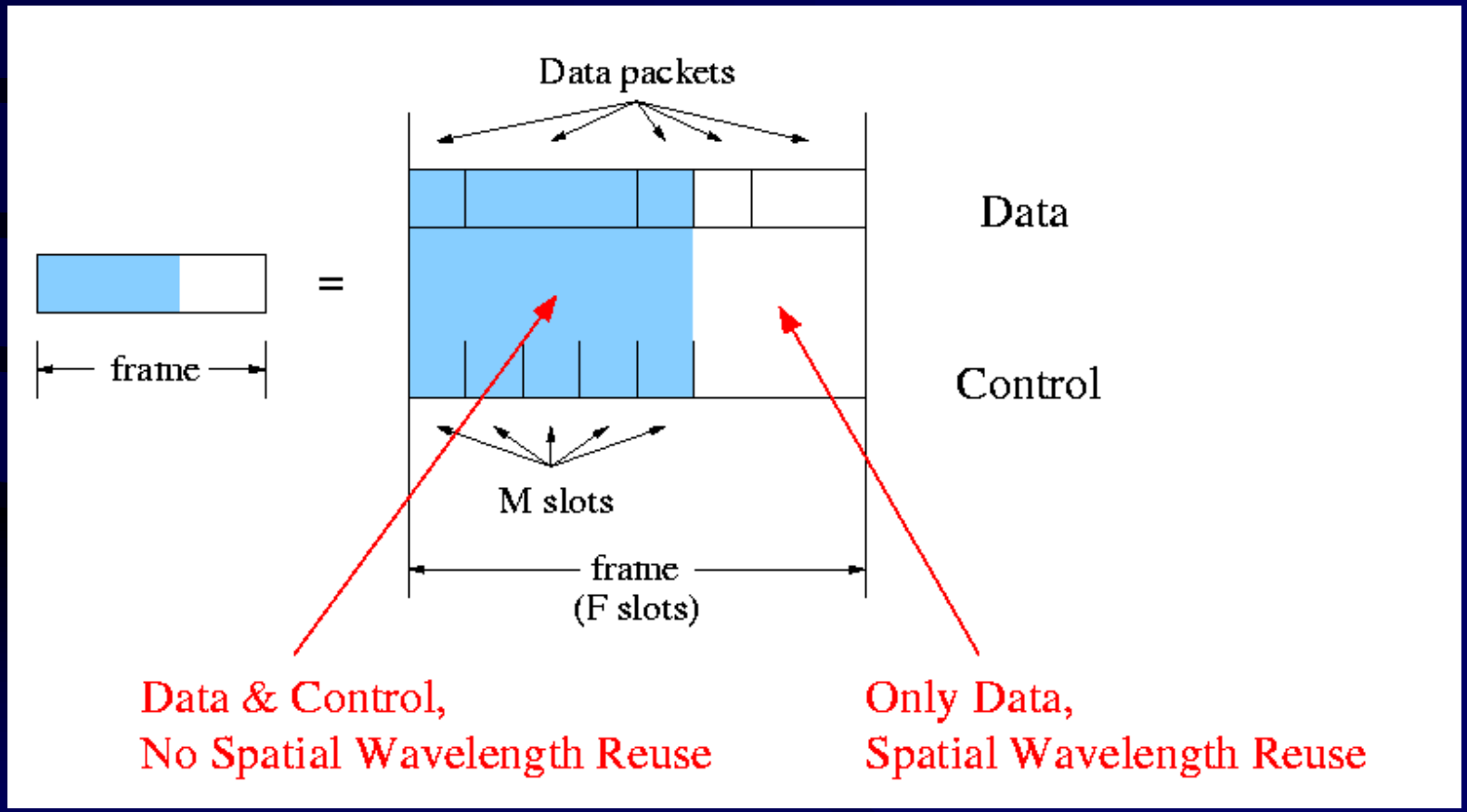
MAC Protocol: Channel Assignment



MAC Protocol: Frame Format



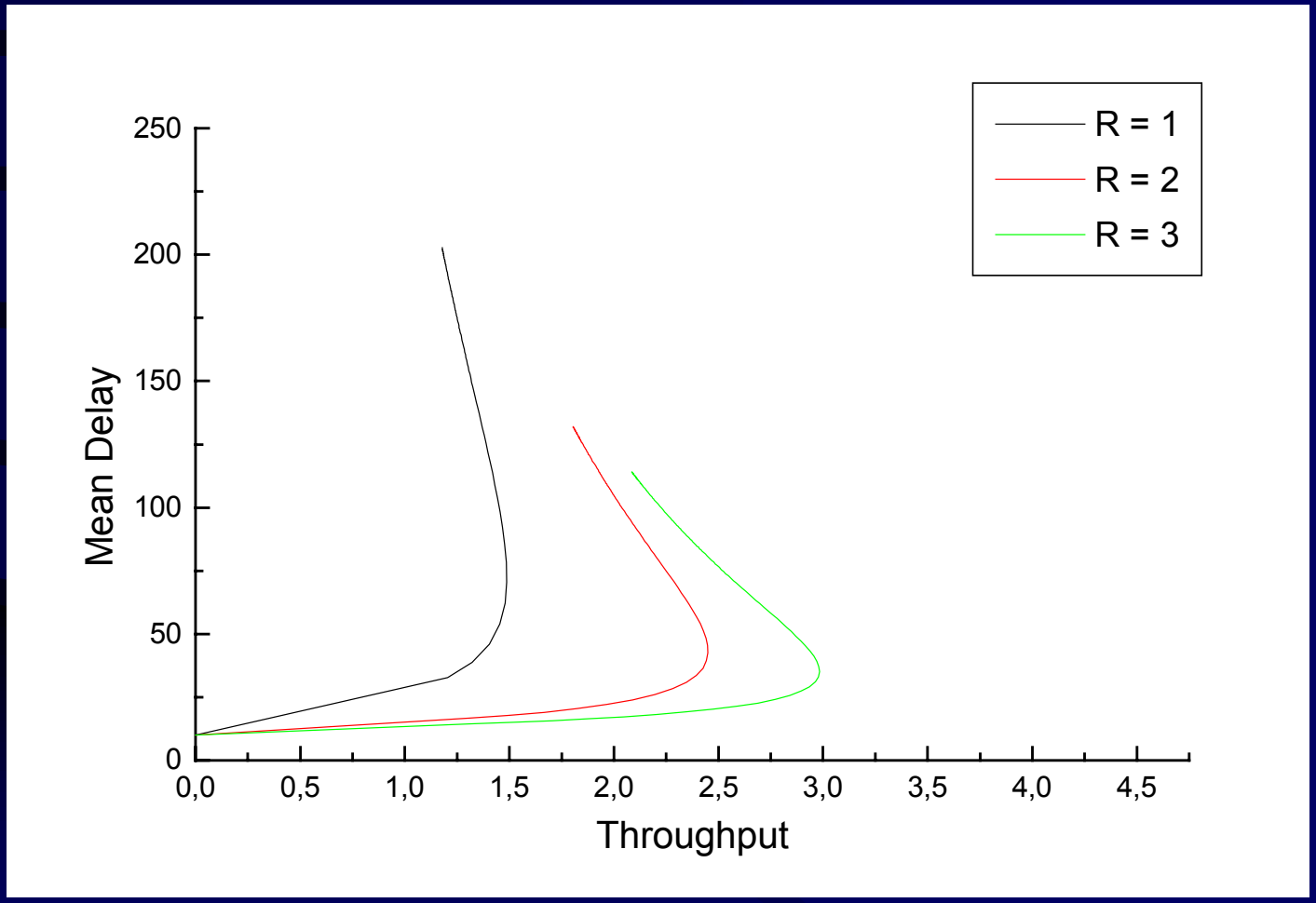
MAC Protocol: Frame Format



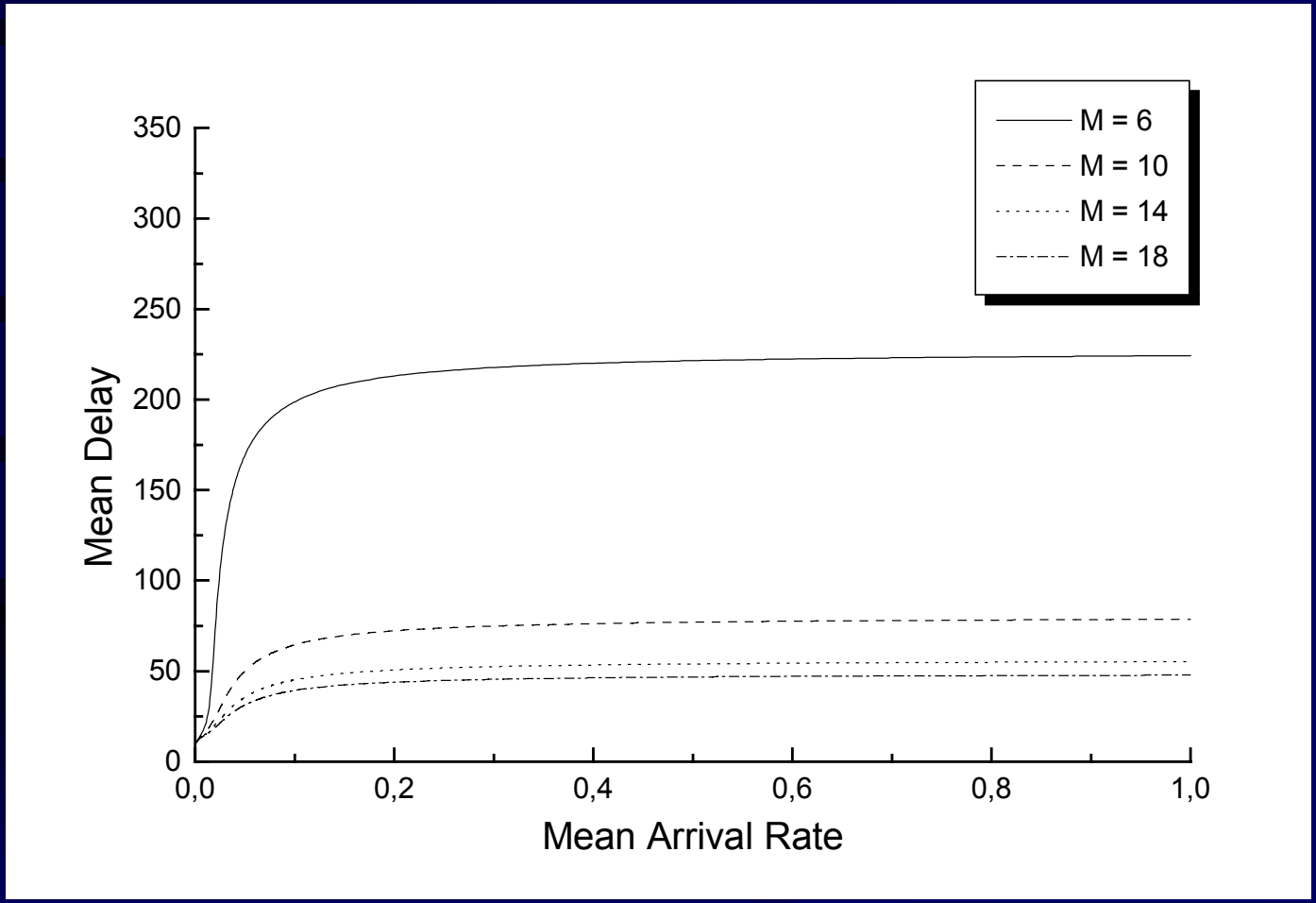
MAC Protocol: Features

- Slotted ALOHA for control packets ➨ scalable
- No collisions of data packets
- Variable-size data packets
- Packet and circuit switching ➨ QoS
- Multicasting
- Global knowledge ➨ No explicit ACKs required
- Scheduling ➨ Improved throughput-delay performance at higher loads

Results: Number of FSRs



Results: Number of Reservation Slots



Conclusions

- Single-hop WDM network with high degree of concurrency
  - Multiple FSRs of AWG
  - Spatial wavelength reuse
  - CDMA
- Simple node structure
- MAC protocol
  - Reservation & scheduling
  - No collisions of data packets
  - Packet and circuit switching
- Using multiple FSRs significantly improves throughput-delay performance

Future Work

- Multicasting
  - Tradeoff: Receiver throughput $\Leftrightarrow$ Spatial wavelength reuse
- Variable-size data packets
- Optimization