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Wire Speed. Why wait?

IP over DWDM
GMPLS

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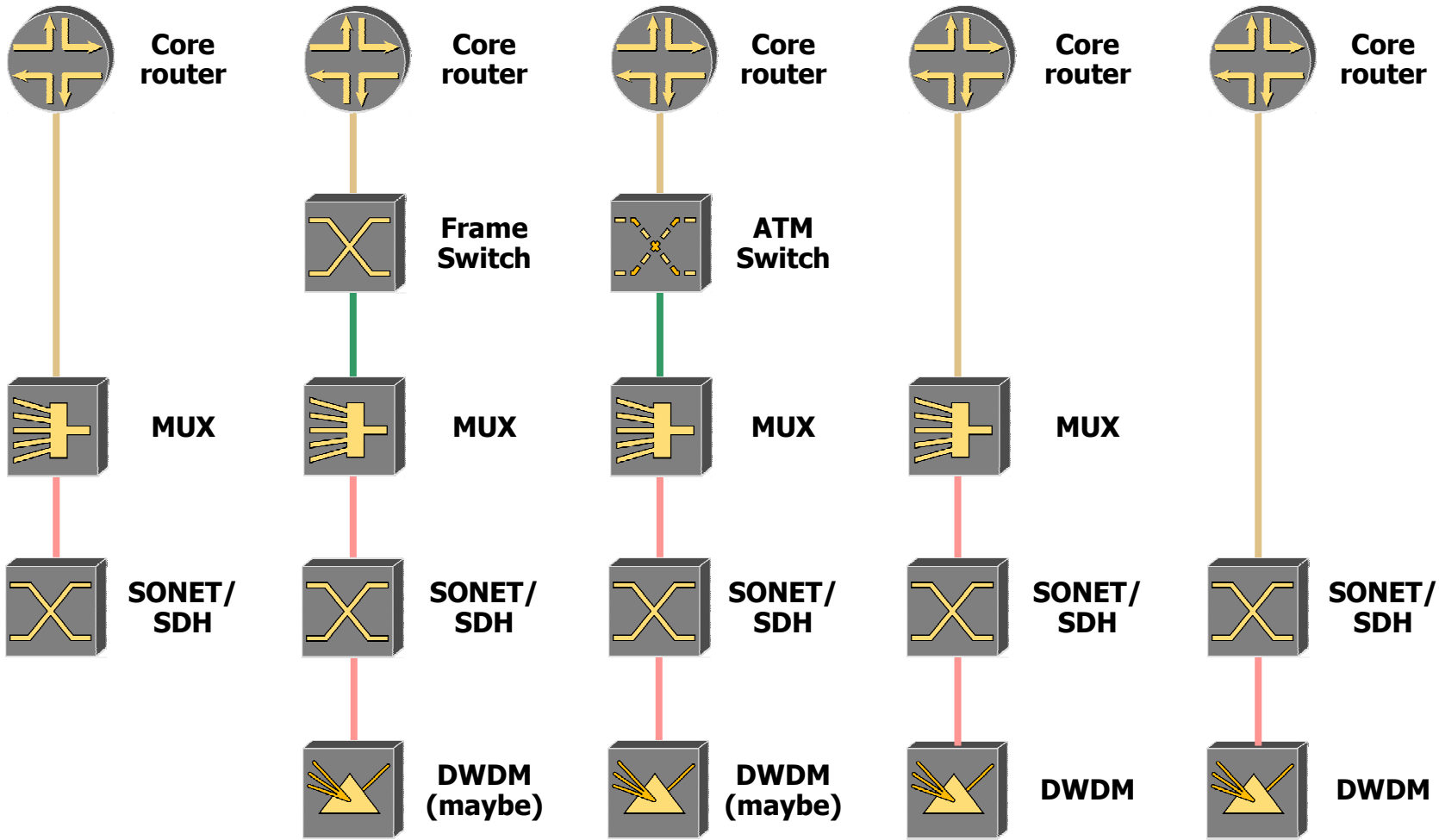
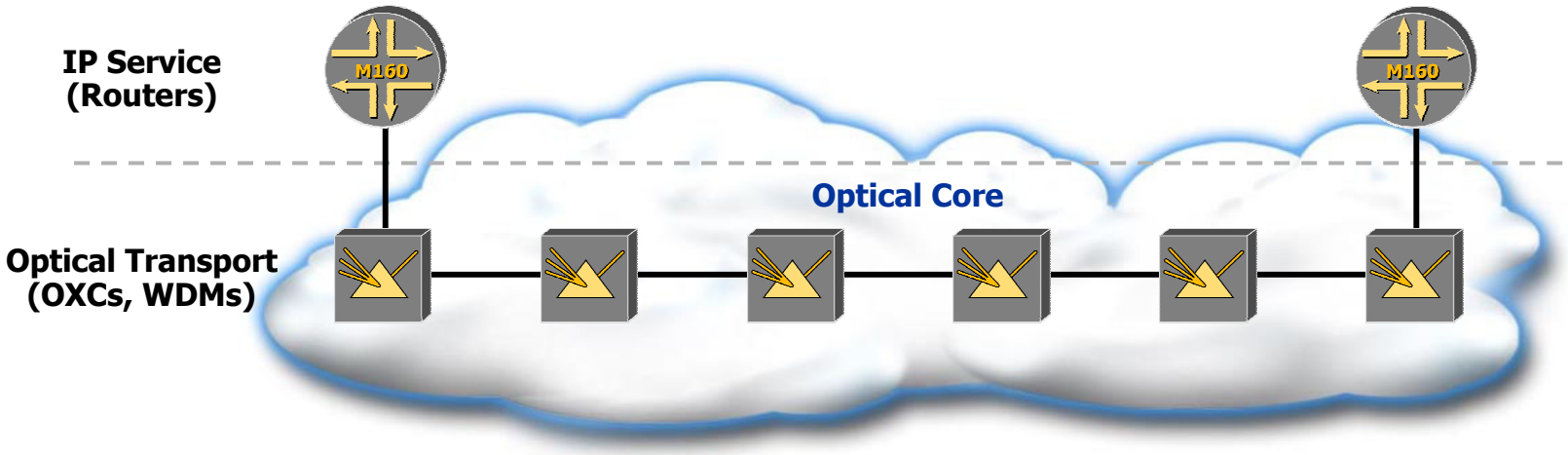
A History of Equipment Layers

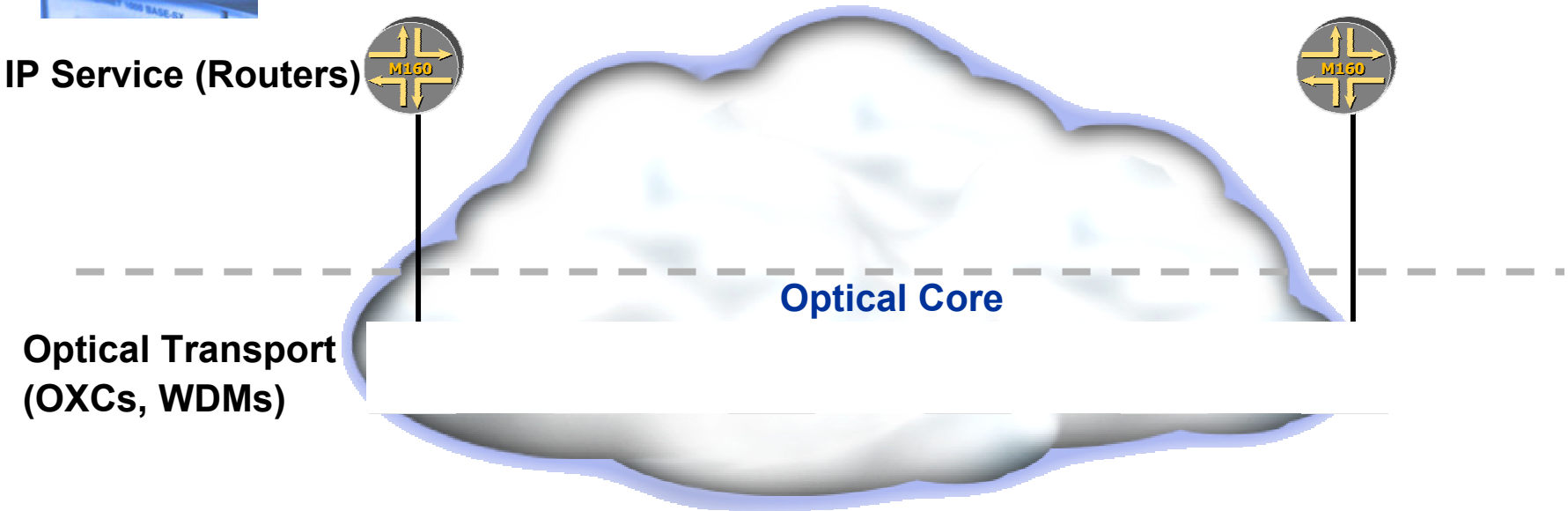


The Emerging Two-Layer Network



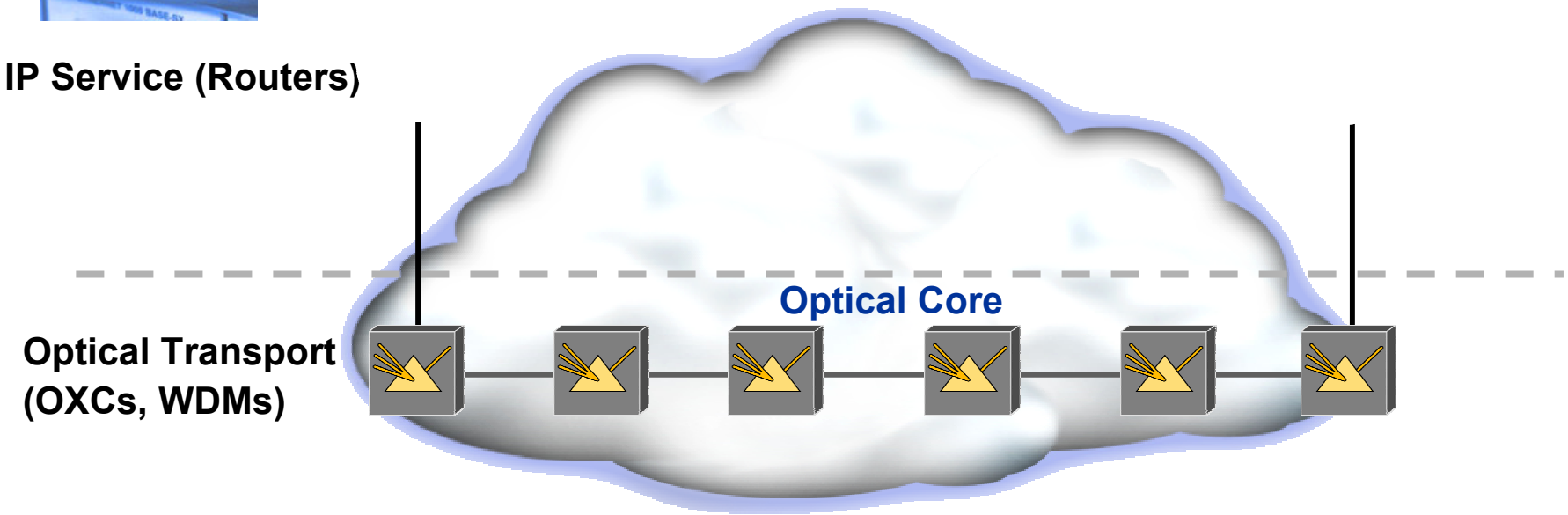
- Reduce complexity
- Reduce cost
- Router subsumes functions performed by other layers
  - Fast router interfaces eliminate the need for MUXs
  - MPLS replaces ATM/FR for traffic engineering
  - MPLS fast reroute obviates SONET APS restoration
- Dynamic provisioning of optical bandwidth is required for growth and innovative service creation

Collapsing Into Two Layers



- IP router layer functions
  - Service creation
  - Multiplexing and statistical gain
  - Any-to-any connections
  - Traffic engineering
  - Restoration (10s ms)
  - Subscriber to transport speed matching
  - Delay bandwidth buffering and congestion control
  - Internet scalability

Collapsing Into Two Layers

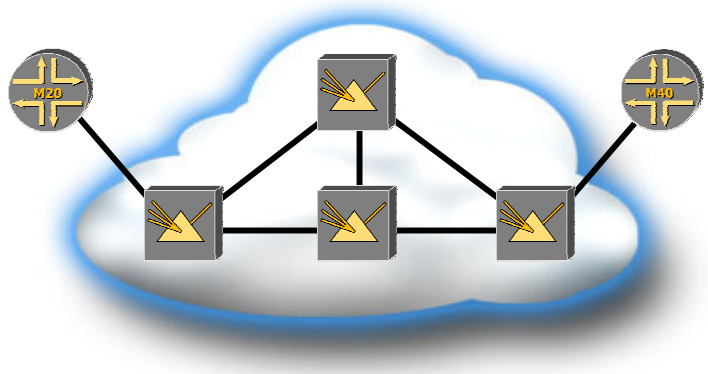


- **Optical transport layer functions**
  - **TDM and standard framing format**
  - **Fault isolation and sectioning**
  - **Restoration (10's ms)**
  - **Survivability**
  - **Cost efficient transport of massive bandwidth (DWDM)**
  - **Long haul transmission distances**
  - **Metro transmission distances ????**

Operational Approaches: Overlay and Peer Models

- **Overlay Model**
  - Two independent control planes
    - IP/MPLS routing
    - Optical domain routing
  - Router is client of optical domain
  - Optical topology invisible to routers
  - Does this look familiar?

- **Peer Model**
  - Single integrated control plane
  - Router & optical switches are peers
  - Optical topology is visible to routers
  - Similar to IP/MPLS model



Routers vs Optical XCs

- Optical cross-connects
  - High bandwidth, ease of provisioning
  - No statistical gain, no multiplexing
  - Limited, but great for connecting large routers
- Routers
  - Massive multiplexing
  - Huge statistical gain (buffering)
  - Supports IP Services (CoS, VPNs)
- MPLS signaling, constraint-based routing
  - Allows common control
  - Simplifies management of combined network

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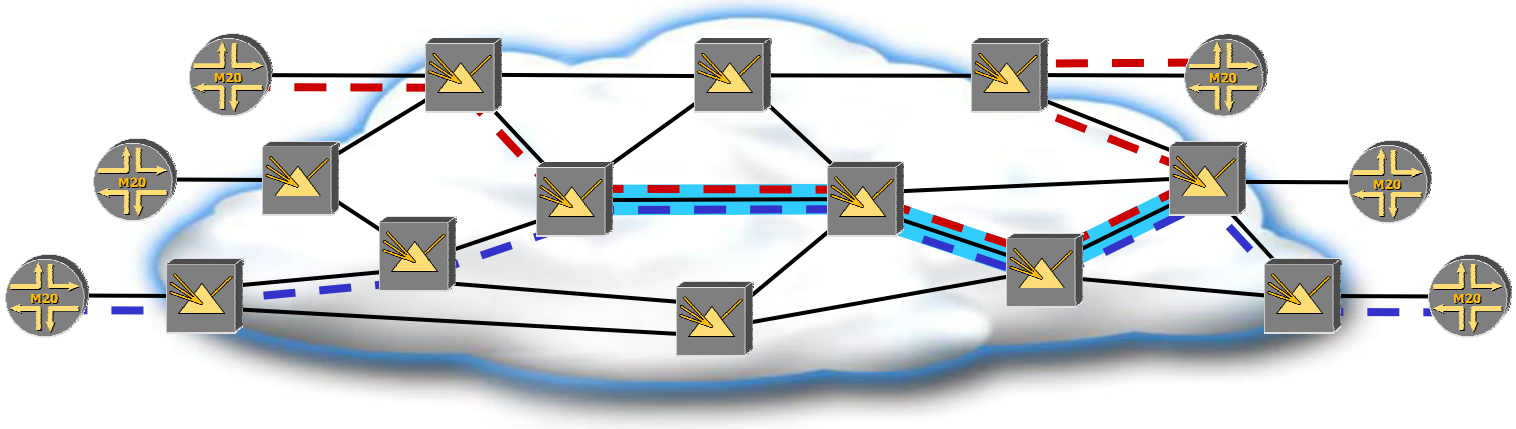
Generalized MPLS (GMPLS)

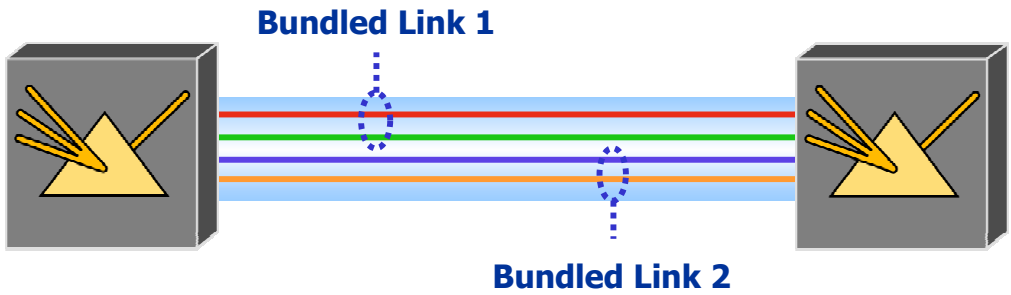
- Extends MPLS to support multiple switching types
  - TDM switching (SONET)
  - Wavelength switching (Lambda)
  - Physical port switching (Fiber)
- Peer model
- Uses existing and evolving technology
- Facilitates parallel evolution in the IP and optical transmission domains

GMPLS: Mechanisms



- IGP extensions
- Forwarding adjacency
- LSP hierarchy
- Constraint-based routing
- Signaling extensions
- Link Management Protocol (LMP)
- Link bundling
- OIF Optical UNI Signaling

GMPLS: Link Bundling



- Allows multiple parallel links between nodes to be advertised as a single link into the IGP
- Enhances IGP and traffic engineering scalability
- Component links must have the same type / metric
- (Max bandwidth request) ≤ (bandwidth of a component link)
- Link granularity can be as small as a λ

GMPLS Benefits

- Open standards allow use of best-of-breed equipment
  - Promotes parallel evolution of UNI and NNI standards
- Routers have visibility into full topology
  - Better scaling, Better routes
- Leverages operational experience with MPLS
- Facilitates growth of bandwidth, services
  - 21st Century, IP is the dominant application
  - Enables rapid development & deployment of OXCs

Questions - Panel

- **Q-1: Which e-Science projects do you consider most important for North and South American competitiveness?**
- **Q-2: For our Latin American participants on the panel, what have your North American colleagues done in the past that's been helpful and what do you believe they should do in the future?**

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Thank You

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