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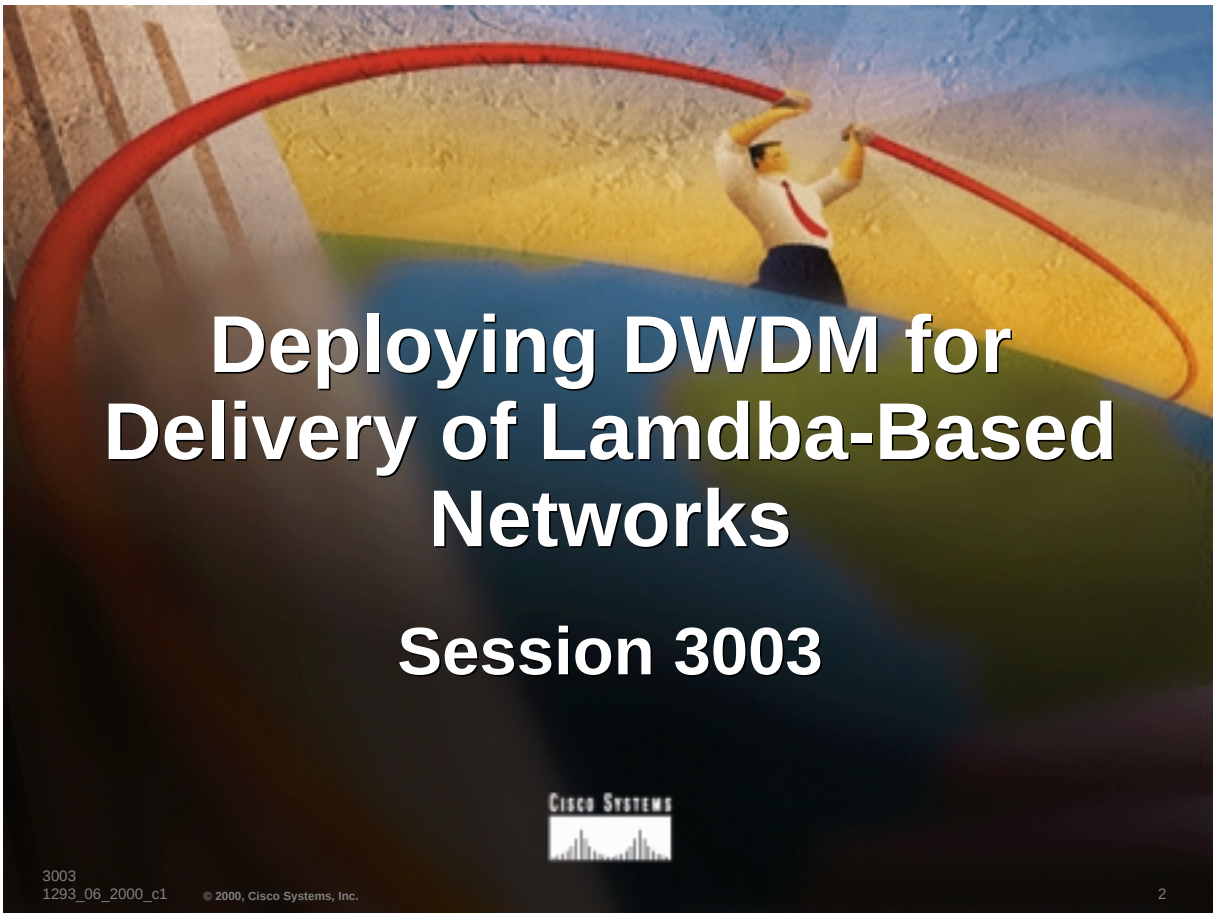

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Agenda

- What Is a Lambda Service?
- SONET Provisioning Bottleneck
- Impact of DWDM Deployments
- Intelligent Transport in the Core
- Intelligent Transport in the Metro
- What's Coming Next

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Lambda Services

- Provisioning bandwidth at Internet speed
  - Bandwidth on demand—not nailed down
  - Liquid pool of bandwidth—shared resource
- Enabled by capacity and intelligence in the optical transport layer
  - High-capacity DWDM systems
  - Intelligent optical cross connects

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Lambda Services (Cont.)

- **Bandwidth comes in several forms**
  - **DWDM wavelengths (lambdas)**
  - **OC-48c/192c and 10 GE**
  - **Lower capacity circuits**
- **Bandwidth comes in many flavors**
  - **Restoration and preemptability**
  - **Traffic engineering and diversity**

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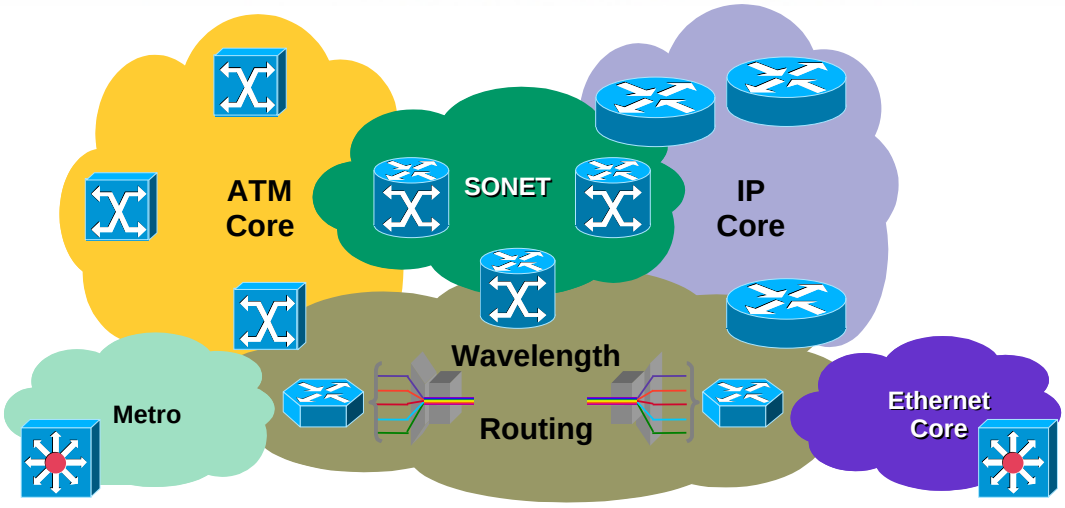
Lambda Services Benefit All



- **The network becomes more integrated, flexible and responsive for all services**

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A Tale of Two SONETs

- SONET is the standard for optical transport
  - Multiplexing hierarchy based on DS0
  - Fast protection switching for all traffic
- SONET has two parts
  - Protocol—framing structure, signaling
  - ➡ Architecture—self-healing rings

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SONET Ring Deployments

- **SONET rings are the most widely deployed transport architecture today**
  - **Originally designed for voice**
  - **Now used for voice and data**
- **There are two categories of SONET rings**
  - **Bidirectional Line-Switched Rings (BLSR)**
  - **Unidirectional Path-Switched Rings (UPSR)**

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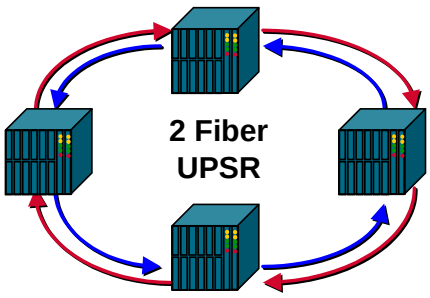
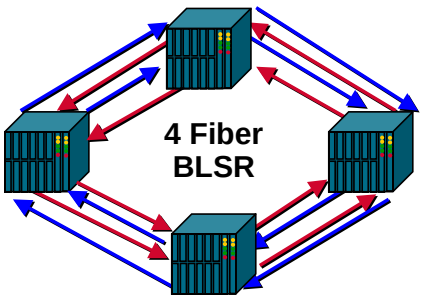
UPSR and BLSR Configurations





- **Deployed in MANs**
- **All traffic homing to central node**
- **Dedicated protection (1+1)**

- **Deployed in WANs**
- **Neighbor-to-neighbor traffic**
- **Shared protection (1:1)**

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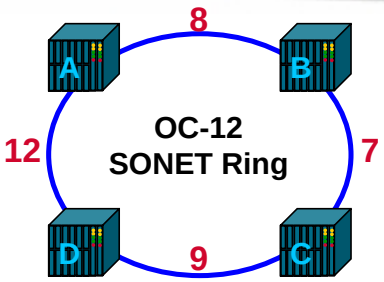
Inefficiencies of SONET Rings



	A	B	C	D
A	X	2	2	2
B	4	X	1	1
C	5	2	X	1
D	5	1	1	X

Traffic Demand Matrix (in STS-1s)

- SONET bandwidth only comes in 4x increments
  - OC-3, OC-12, OC-48, and OC-192
- All spans on ring must be the same
  - Leads to stranded capacity

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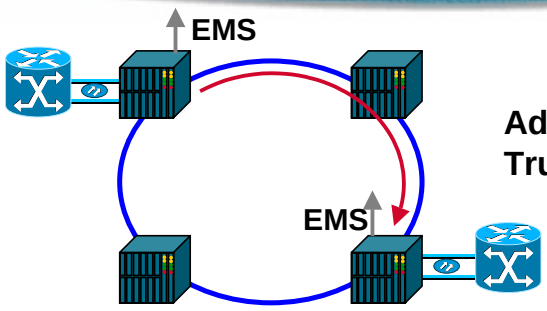
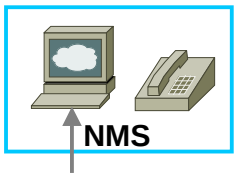
Provisioning of SONET Rings



Add a Truck

Network Operations Center



- Time slots are assigned by Element Management Systems (EMS) talking to Network Management System (NMS)
  - Automation is vendor dependent
  - Can take weeks or months

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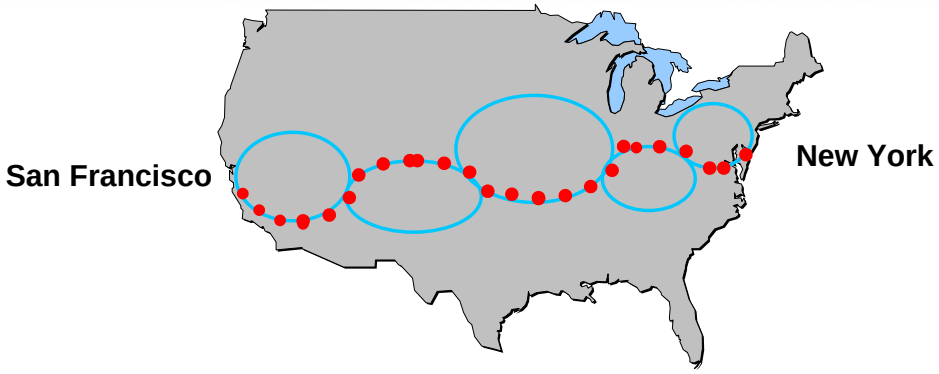
Multiring Deployments



- Most services providers use about five SONET rings to go coast-to-coast
  - All five must scale as demand grows
  - Provisioning done segment by segment

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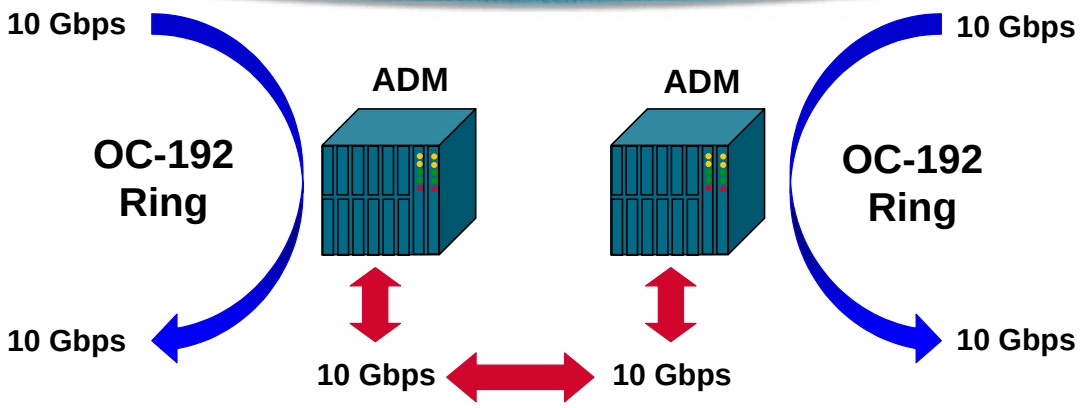
Provisioning Between Rings with Add/Drop Multiplexers



- Interconnects use tributary ports
  - Generally limited to 1/2 ring bandwidth
  - Interring and add/drop share this bandwidth

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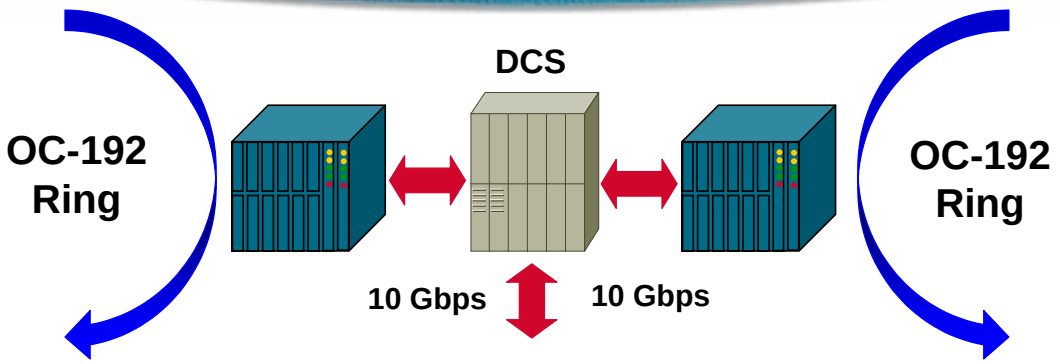
Provisioning Between Rings with Digital Cross Connects



- DCS adds grooming capability
- But further frustrates interconnections
  - DCS ports limited to OC-3 or OC-12
  - DCS and ADM management not integrated

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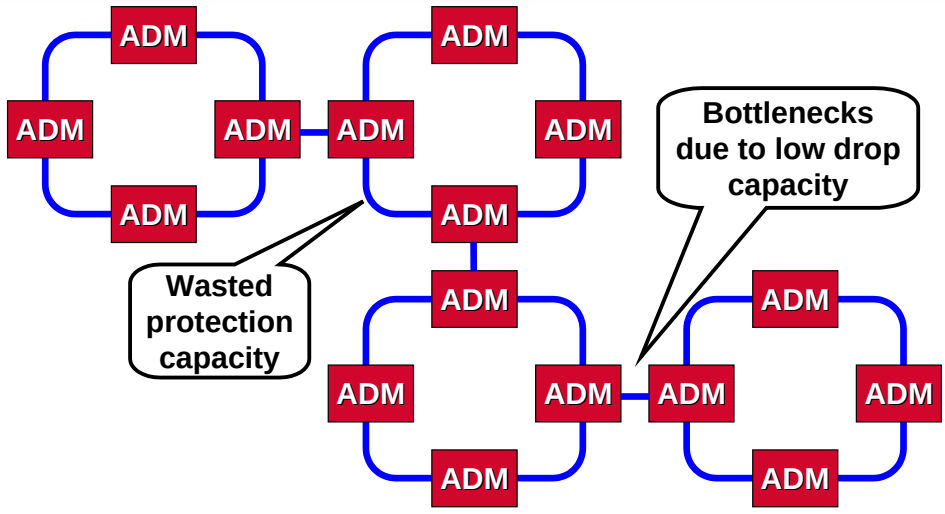
Inefficiencies of SONET Ring Networks



- Management is vendor specific
- Provisioning can take weeks, or longer

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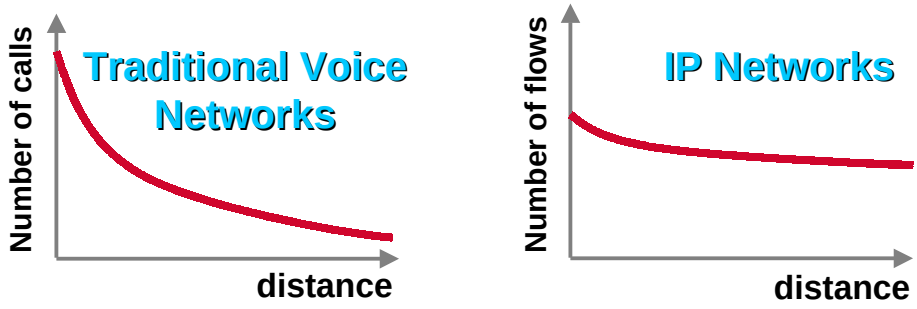
SONET Architecture and IP



- IP is largely independent of distance
- This complicates SONET provisioning
  - Traffic matrix constantly changing
  - High volume of interring traffic

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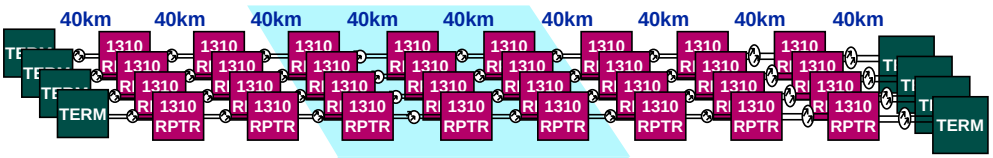
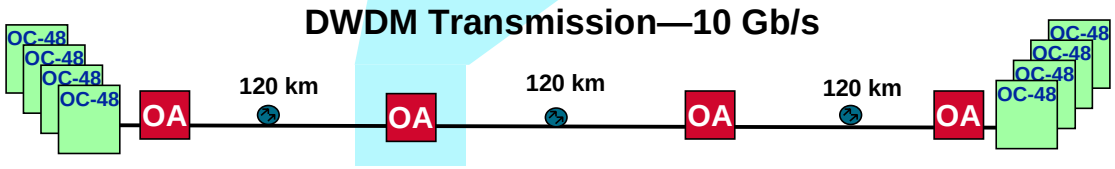
DWDM for Fiber Gain

DWDM Offers Compelling Economics





4 Fibers **1 Fiber**
32 Regenerators **4 Optical Amplifiers**

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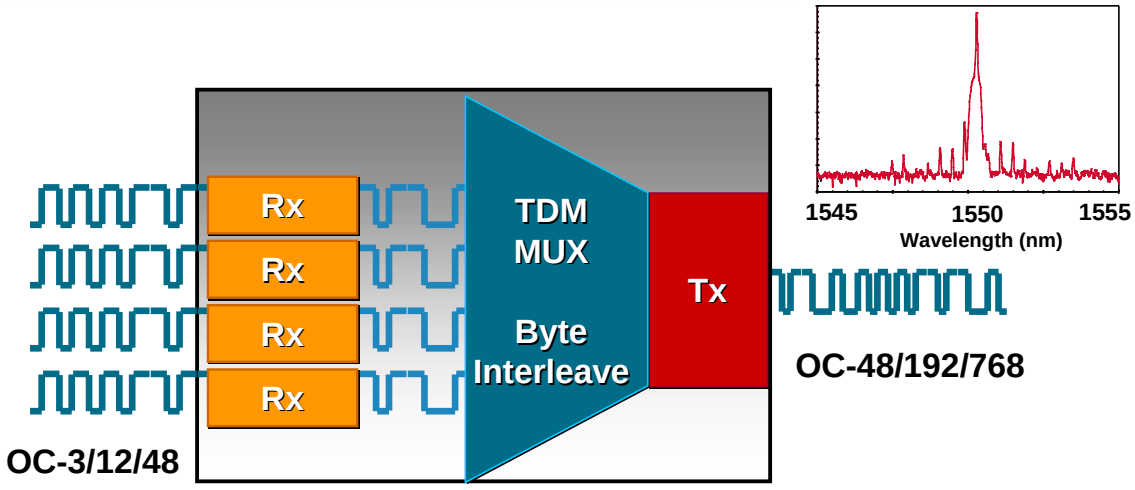
TDM Transmission



- **Signals are multiplexed in the time domain**

Inputs limited to 25% of line rate (SONET)

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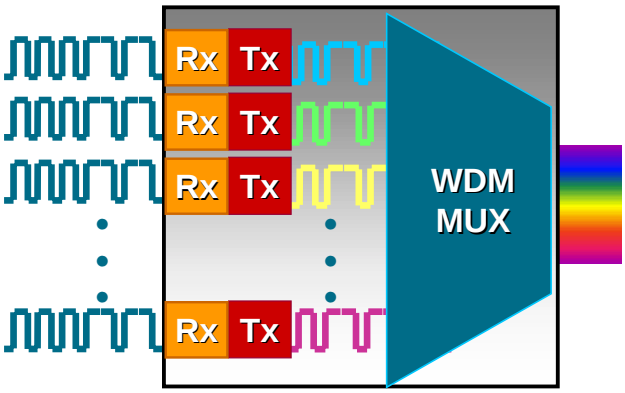
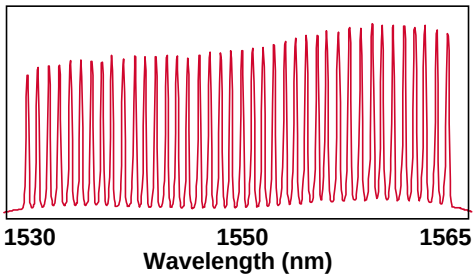
DWDM Transmission



OC-48/192

Composite Optical Signal



OC-192 x 16 ch. = 160 G/bs
OC-48 x 128 ch. = 320 G/bs
OC-192 x 128 ch. = 1280 G/bs

- **Signals are multiplexed in the wavelength domain**

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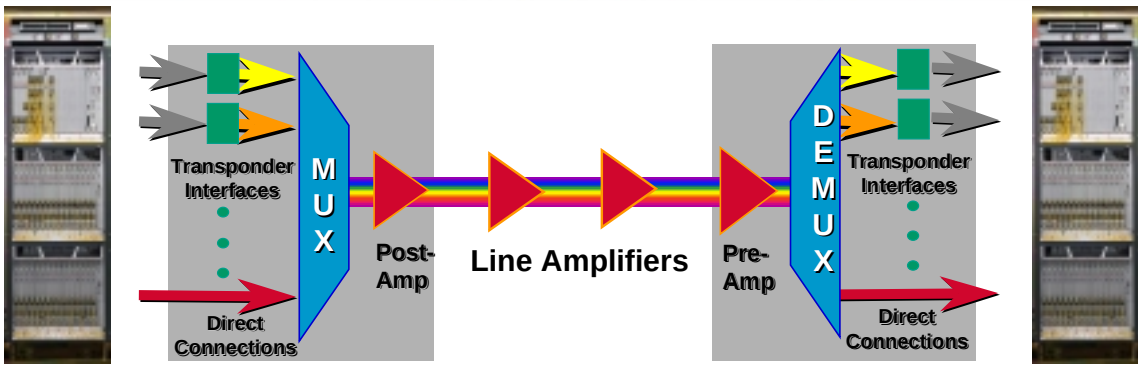
Anatomy of a DWDM System



Basic building blocks

- **Transponders**
- **Optical Multiplexers**
- **Optical Amplifiers**

Typical configurations

- **7 x 20 dB**
- **5 x 25 dB**
- **3 x 33 dB**

(Fiber loss = 0.25 dB/km)

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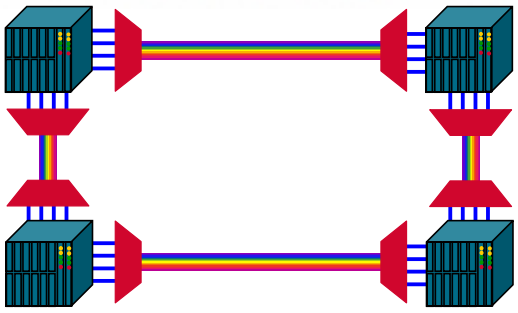
DWDM in SONET Rings



- **DWDM first used to solve fiber exhaust in SONET rings**
  - **Simple, cost effective fiber gain**
  - **Span by Span upgrades**
- **Leads to concentric or stacked rings**

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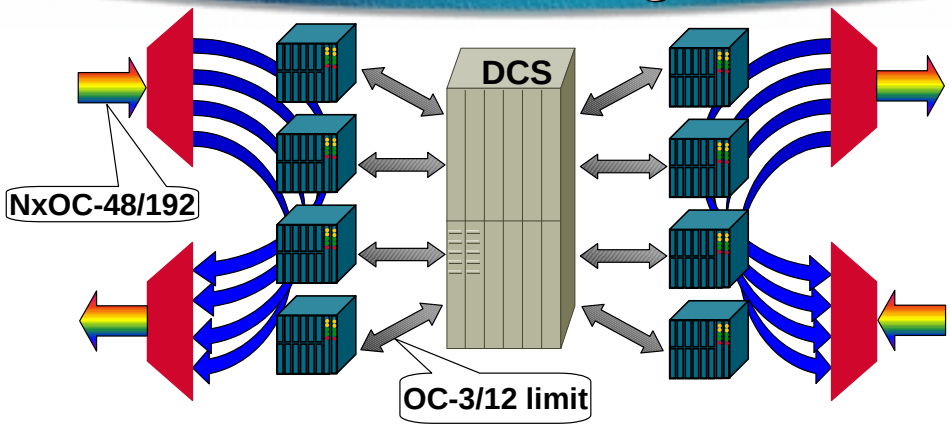
Provisioning Stacked SONET Rings



- **Provisioning is still done through the ADMs and DCS**
  - **Interoperability between EMSs is vendor-dependant**
- **DWDM's capacity multiples provisioning complexity**
  - **Requires one very large DCS**

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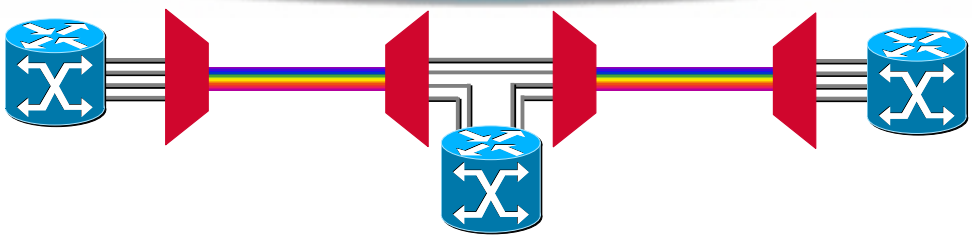
IP Over DWDM



- **IP over DWDM simplifies the network**
  - **Direct connections at OC-48c/192c**
- **SONET is in the router**
  - **Fully compliant SONET NE**
  - **Multiplexing becomes statistical**
- **Enables migration from rings to mesh**

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DWDM Element Management

- **EMS provides visibility and intelligence**
  - **Performance management/fault isolation**
  - **Topology information/configuration mismatches**
  - **Database management and security**
  - **Communicate with NMS**

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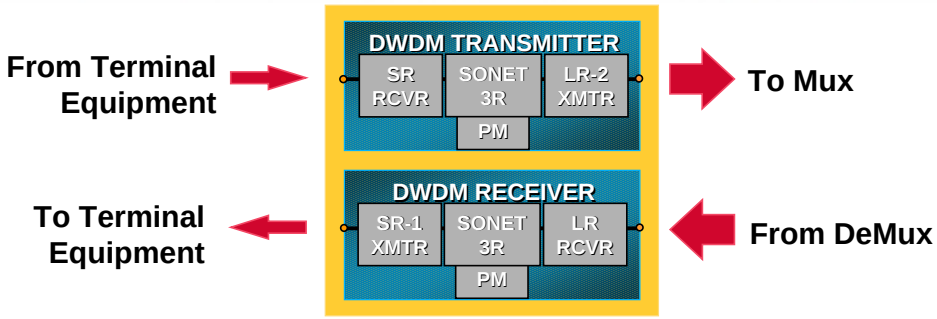
DWDM Performance Monitoring



- SONET/SDH PM performed on a per wavelength basis through transponders
- Computation of B1 and monitor J0 at each channel input and output
- No modification of SONET/SDH overhead

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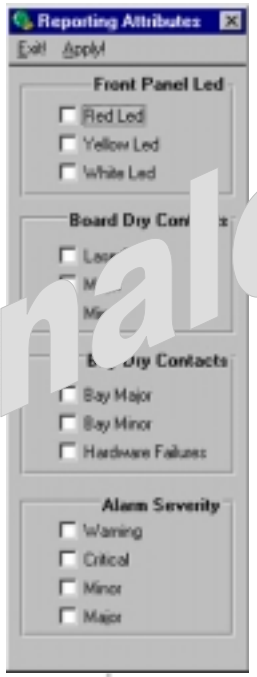
Complete Monitoring Suite

- **Receiver**
  - Output Power Level
  - Grating Temperature
  - SONET B1/J0 Monitor
  - Laser Output Power
  - Laser Current
- **Transmitter**
  - Laser Power
  - Laser Temperature
  - Laser Current
  - TEC Current
  - Heat Sink Temperature
  - Grating Temperature
  - SONET B1/J0 Monitor
  - Input Signal Level
- **Service Channel Modem**
  - Laser Power
  - Laser Temperature
  - Laser Current
  - TEC Current
  - Heat Sink Temperature



- **Pump Laser**
  - Laser Power
  - Laser Temperature
  - Laser Current
  - TEC Current
  - Heat Sink Temperature
- **Amplifier**
  - Output Power Level
  - Input Power Level
- **Add/Drop Amplifier**
  - Output Power Level
  - Input Power Level
  - Through Ch Input Power Level
  - Add Channel Input Power Level
- **Add/Drop Filter**
  - Grating Temperature
- **Power Supply**
  - Backplane Temperature

Analog

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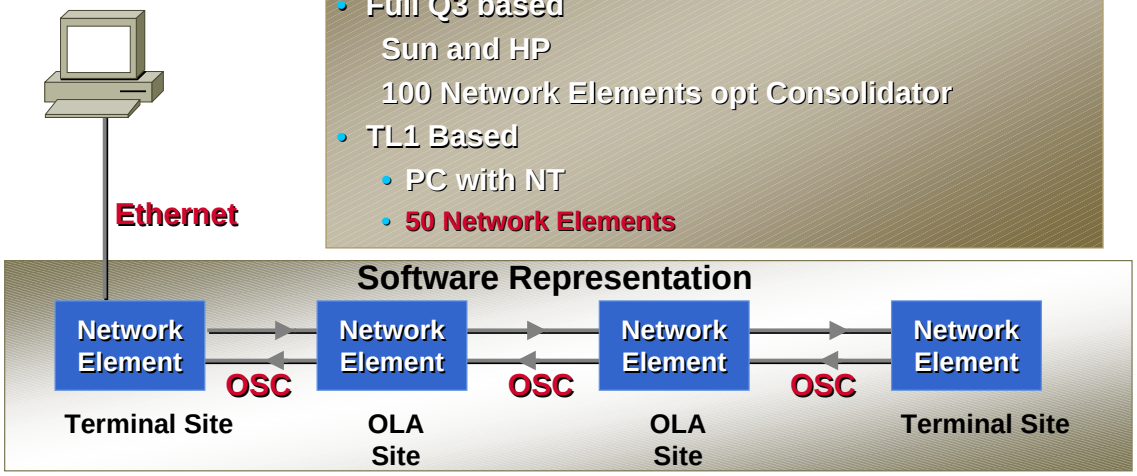
DWDM Network Management

- Proprietary based
  - Sun
  - 100 Network Elements opt Consolidator
- Full Q3 based
  - Sun and HP
  - 100 Network Elements opt Consolidator
- TL1 Based
  - PC with NT
  - 50 Network Elements



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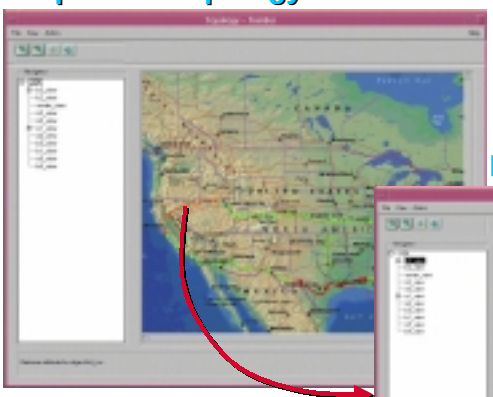
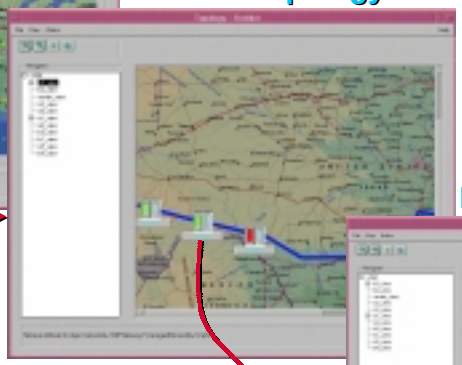
View from the NOC

Top Level Topology

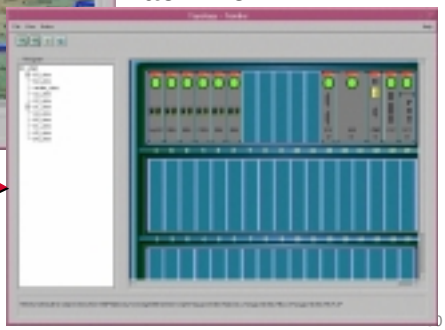


DWDM EMS/NMS provides complete monitoring of transport from links to cards

Detailed Topology View



Rack View



DWDM EMS/NMS does not solve the SONET provisioning problem because it doesn't make connections

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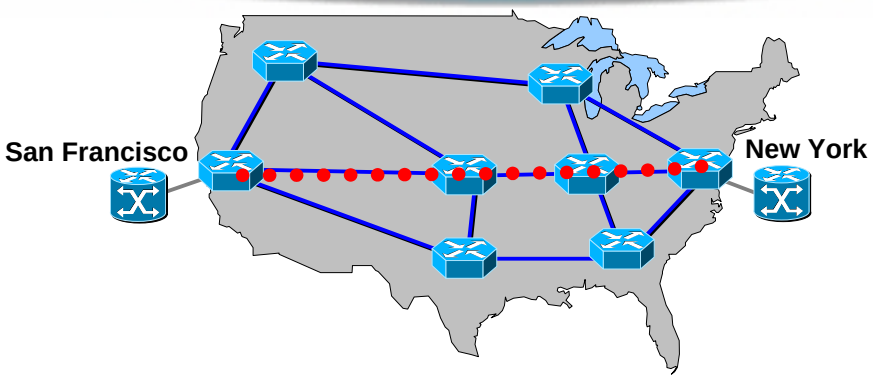
Enter Optical Cross Connects



- Optical cross connects (OXCs) change the architecture from rings to meshes
  - Rapid provisioning and tiered restoration
  - Traffic engineering at OC-48c/192c

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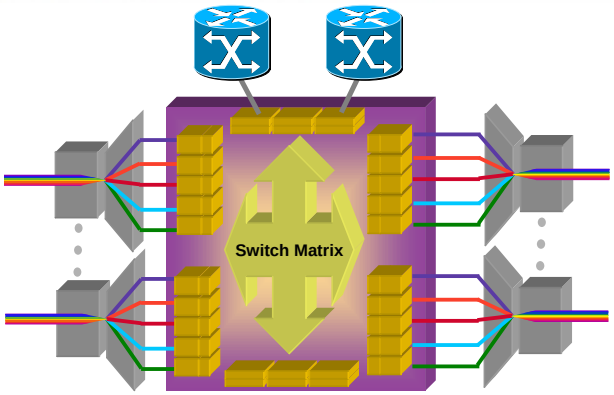
Optical Intelligence



- OSPF-like protocols provide topology and network state information
  - Each node maintains copy of database
  - Information is distributed in SONET overhead

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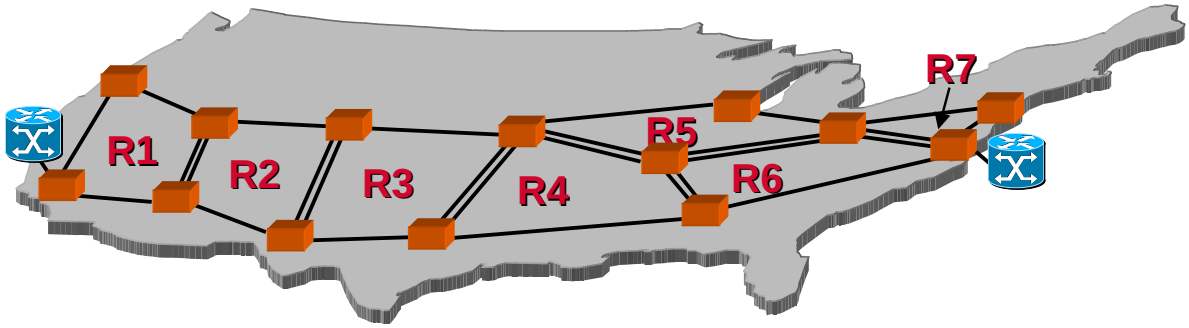
From SONET Rings...



- Typical service provider BLSR deployment
- Network partitioned into multiple rings
  - Slow to provision
  - Stranded bandwidth

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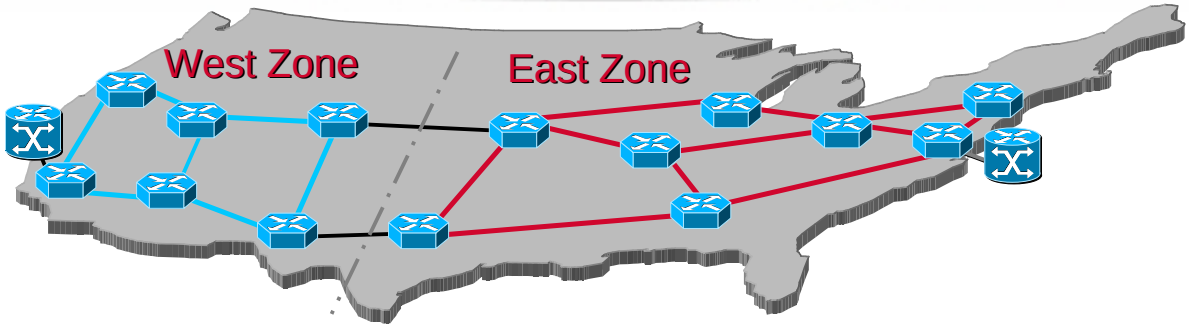
…to Intelligent Mesh



- OXCs replace ADMs and DCSs
- Capacity allocated on point-to-point basis
- Very large networks divided into zones
  - Similar to IGP and EGP

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Core Transport Comparison

	Mesh Network	BLSR Network
Restoration Time	<50 ms	>50ms per Ring
BW Efficiency	43.3% Less	43.3% More
Provisioning Time	Seconds	Weeks/Months?
Rapid Scalability	Yes	No
Differentiated CoS	Yes	No
Source/Destination Provisioning	Yes	No

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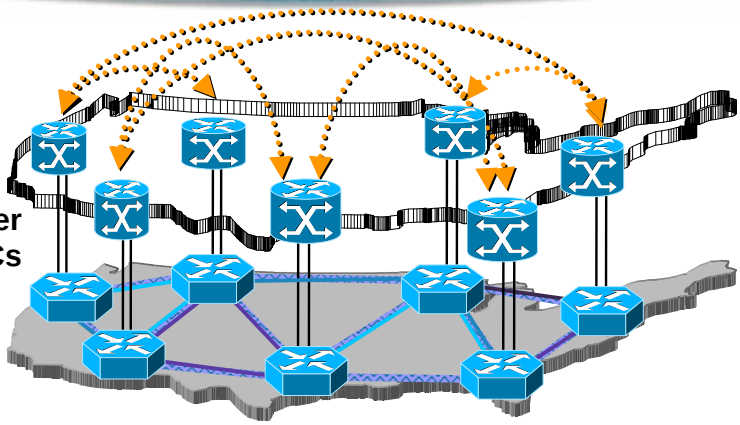
Provisioning IP Over Optical

IP Core Routers Over Intelligent OXCs



- View network as fluid bandwidth pool
- "Point and click" provisioning in seconds
- Scale up by adding links to paths and adding new lambdas to links

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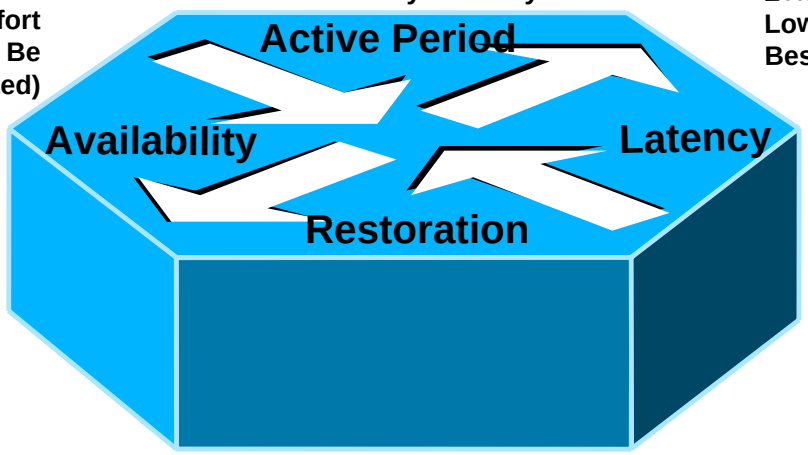
Lambda Service Primitives

Guaranteed to Best-Effort (Can Be Preempted)

Time-of-Day to Always

Least Possible, Lowest Available, Best Effort



Time-to-Restore: 50 ms to Best-Effort; Latency Guarantee

Rapid, Multiclass Provisioning and Restoration

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Differentiated Lambda Services

Mission Critical V/V/D
- Guaranteed Availability
- Least Latency Possible
- 50ms Restoration

Premium Intranet
- Very High Availability
- Lowest Latency Available
- 50ms Restoration

Public Internet
- Moderate Availability
- Best-Effort Latency
- 250ms Restoration

Bulk Transport
- Best-Effort Availability
- Best-Effort Latency
- Best-Effort Restoration

Sample Products, Service Provider Can Define Own Services

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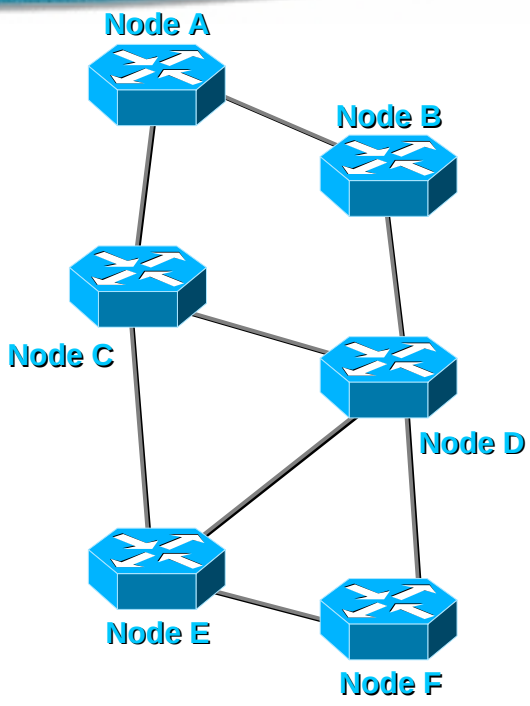
Fast Provisioning Example

- Example based on ONS 15900 running WaRP
- Uses in-band signaling
  - Line DCC bytes
  - 9.218 Mbps channel
- Hello protocol to share network view
  - Initialize ports, keep alives
  - Link-state-advertisements



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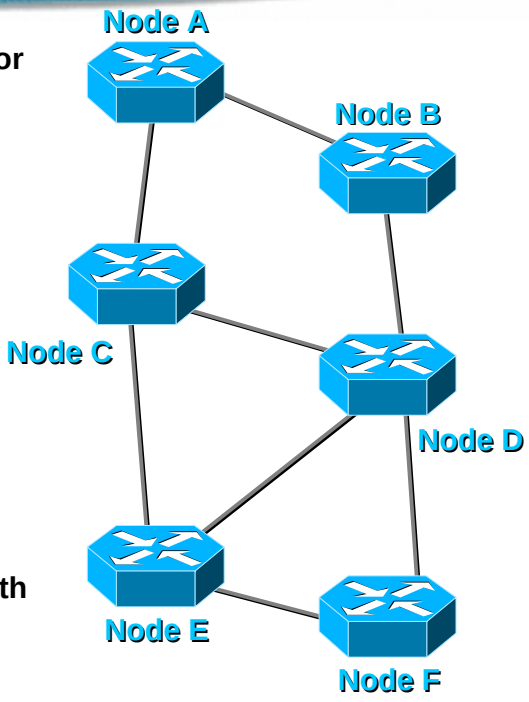
Fast Provisioning Example

- Select source and destination nodes for VWP and VWP Name
- Select Restoration Type(s)
  - ☐ Unprotected ☑ Fast Dynamic (default)
  - ☐ Fast Reserved ☐ Rings
- Select Path Selection Rules
  - ☑ Least Cost (default)
  - ☐ Least Hops
  - ☐ % Available Bandwidth
- Select Links (Optional)
  - ☐ Link A-B ☐ Link C-E
  - ☐ Link B-D ☐ Link E-F
- EMS Prompts User with Suggested Path
- Modify Path (Optional)
- NE uses WaRP to establish path



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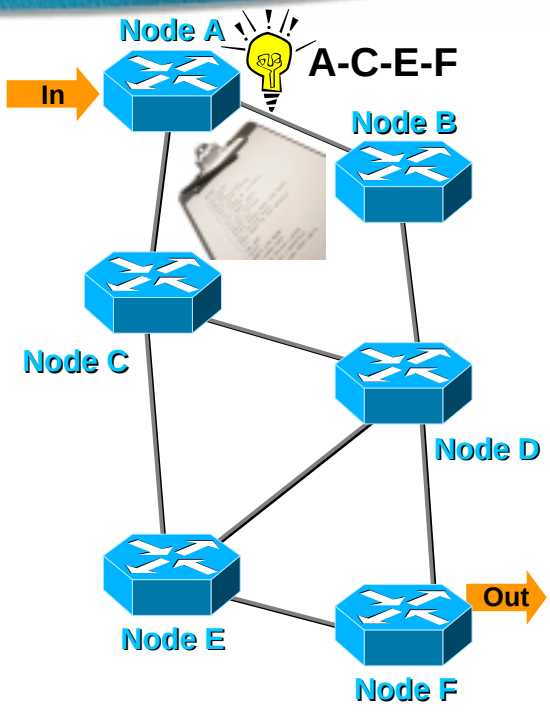
Fast Provisioning Example

Provisioning a path from Node A to Node F

- Source node receives request, local or EMS
- Source node checks its routing table
- Source node finds route, and sends path request



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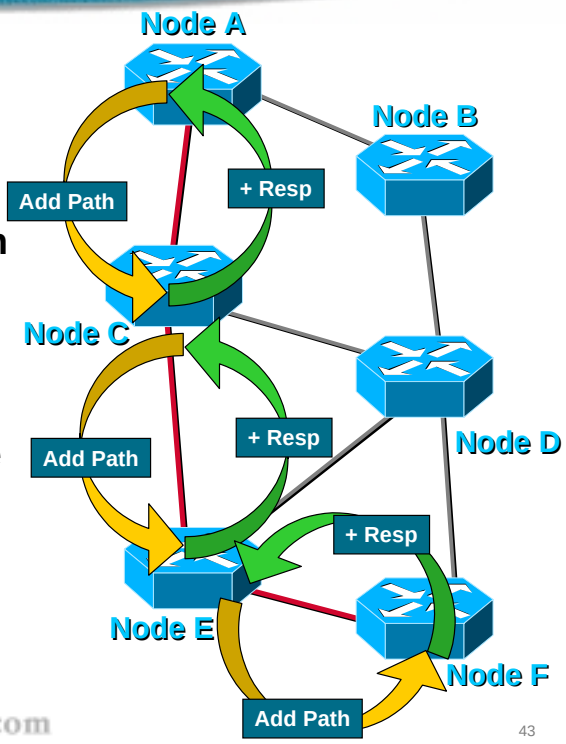
Fast Provisioning Example

- Source node sends add path request
  - Add Path request sent only on links in path
  - Each node selects local ports to use
  - Bandwidth reserved along the route
  - X-points set as positive response comes back from destination



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Agenda

- What Is a Lambda Service?
- SONET Provisioning Bottleneck
- Impact of DWDM Deployments
- Intelligent Transport in the Core
- Intelligent Transport in the Metro
- What's Coming Next

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Intelligence in the Metro

- The same Layer 3 intelligence emerging in the core is beginning in the metro
- Dynamic topology discovery protocols allow “point and click” provisioning
- Services include TDM circuits as well as lambdas

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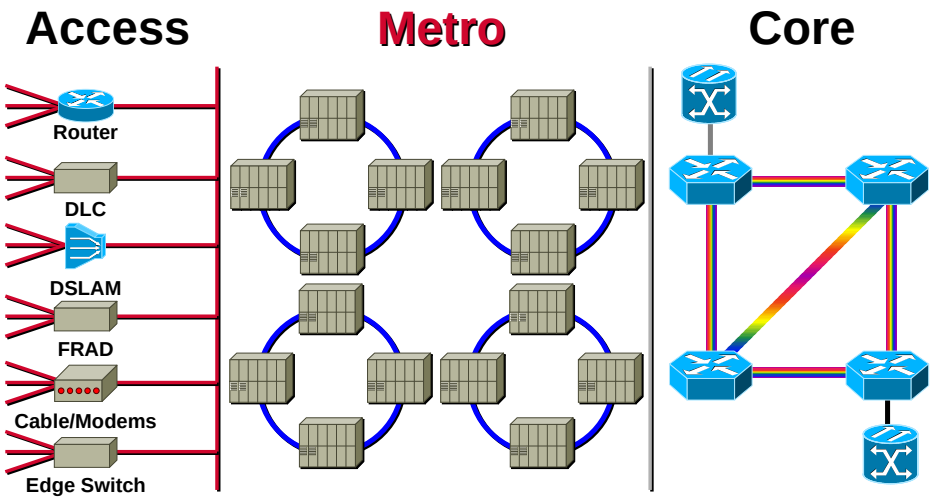
The Metro Bottleneck



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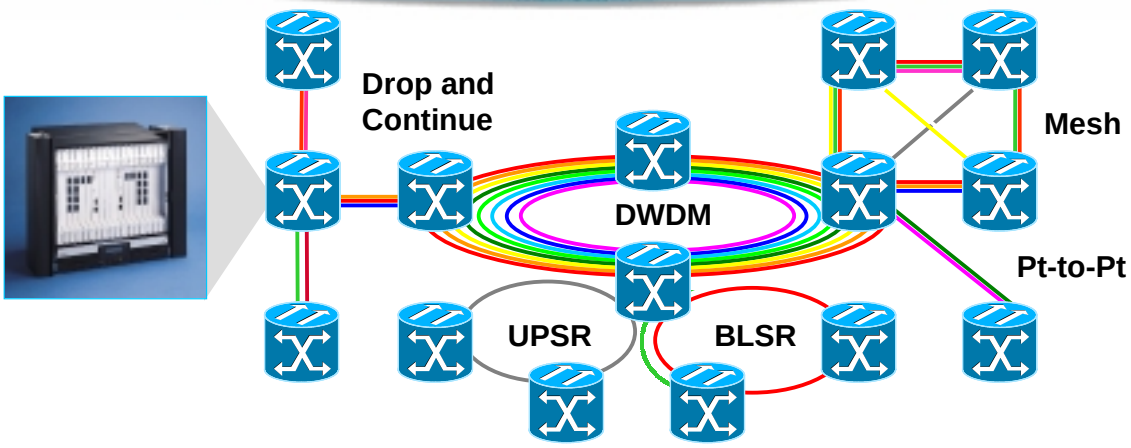
Integrated Optical Networking



- One versatile platform replaces many
- Massive network capacity expansion
- Seamless migration from TDM to IP

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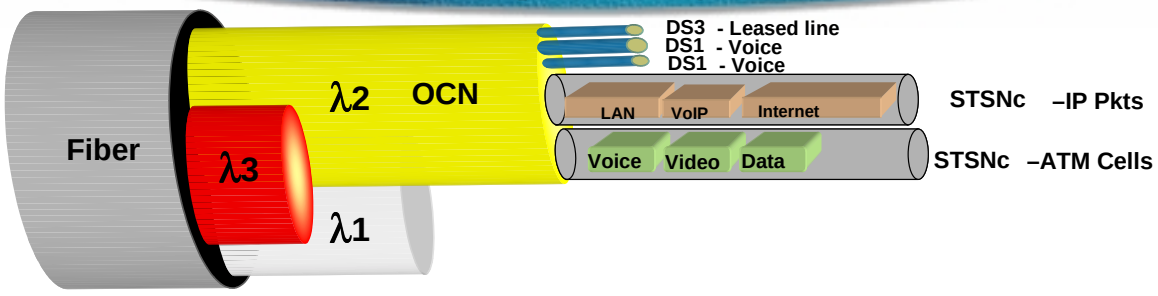
Unprecedented Multiservice Capability



- TDM aggregation from DS1 to OC-192
- DWDM at OC-48c and OC-192c
- Service modules for Ethernet, ATM and video
- Statistical multiplexing for bursty data traffic

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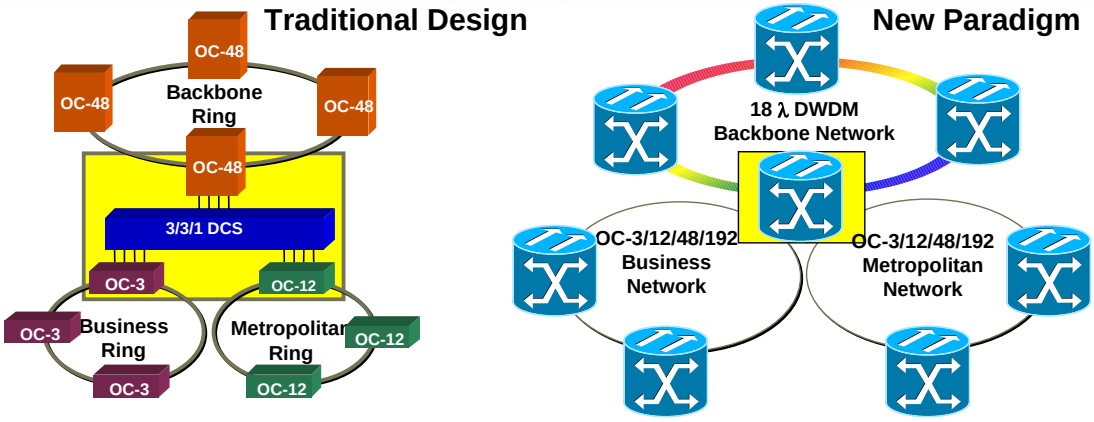
Optical Networking Efficiency



- **Fewer network elements**
- **Lowest initial and lifecycle cost**
- **Easy to engineer, install and use**

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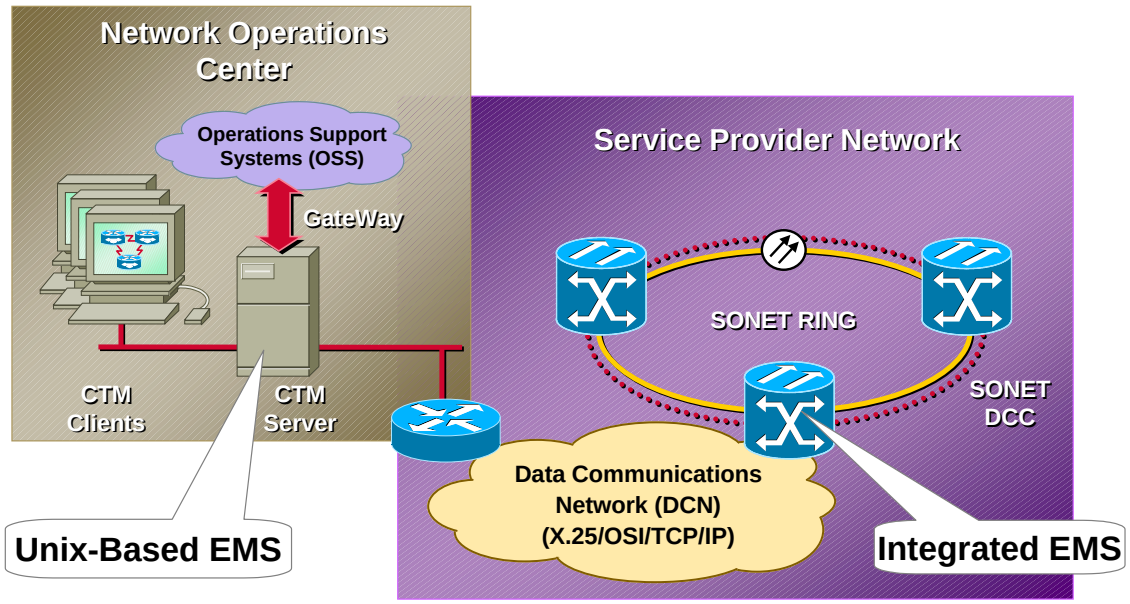
EMS Architecture



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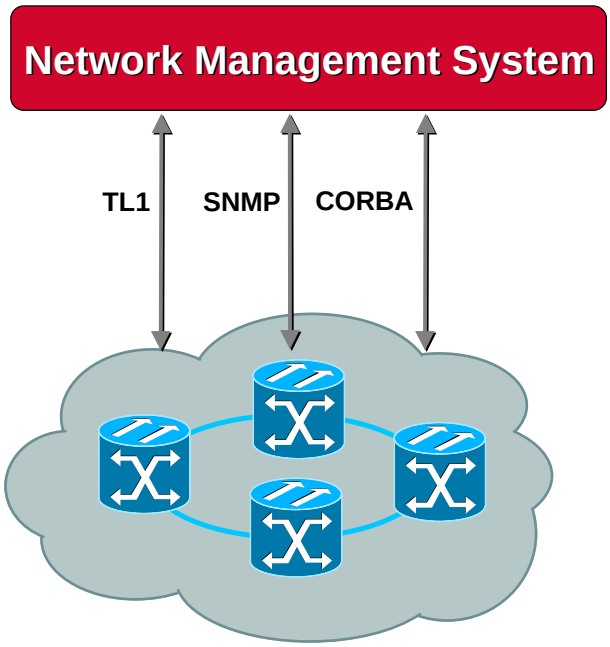
Network Management Options

- TL1
  - Alarm and event reporting
  - Configuration and PM
  - NMA support
- SNMP
  - Trap and Gets support
  - IETF standard MIBs
  - SNMP v2c
  - Tested with HP Openview
- CORBA
  - Alarm and event notifications
  - Performance management
  - Connection management
  - Equipment Inventory
  - CORBA 2.1



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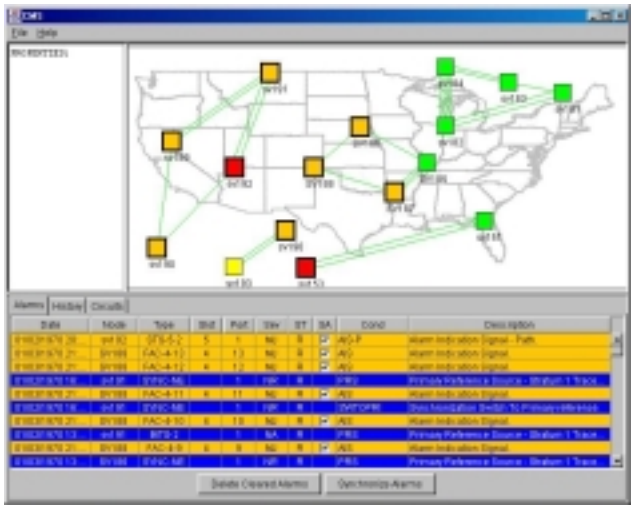
Cisco Transport Controller

- Instant-On, real time provisioning across multiple rings
- Element and network level management capabilities
- Autodiscover DCN and DCC-connected ONS 15454 nodes
- Graphical representations of network topology, conditions, and shelf configurations
- Launch from any platform running Java web browser



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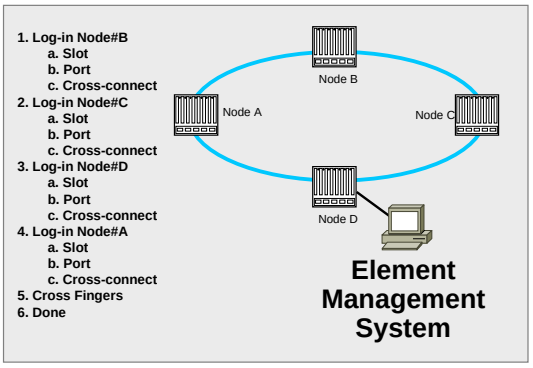
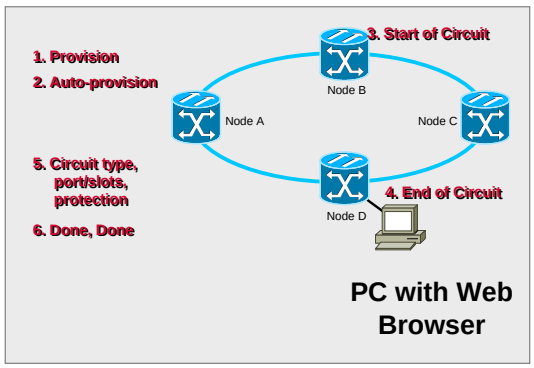
Provisioning Comparison

Traditional Provisioning



- Point and click GUI interface for provisioning, via vendor specific application
- Node by node provisioning

Rapid Provisioning



- Point and click GUI interface for provisioning, via open web browser application
- End to end provisioning

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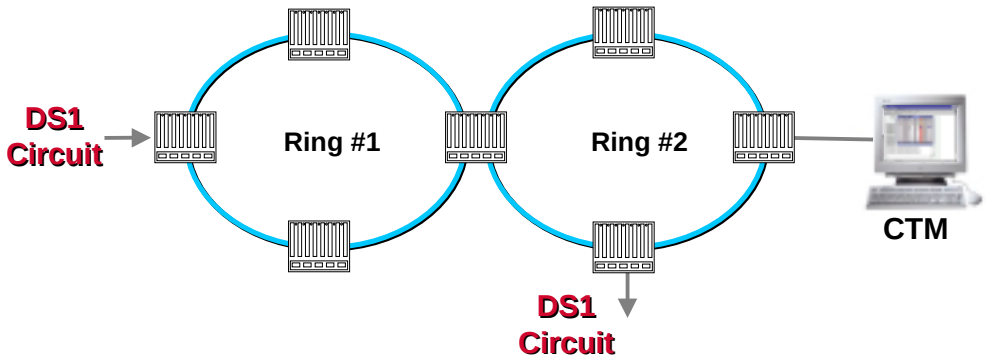
Multiple Ring Provisioning



- Point and click GUI operates over multiring deployments
- Single platform allows integrated ADM and DCS management

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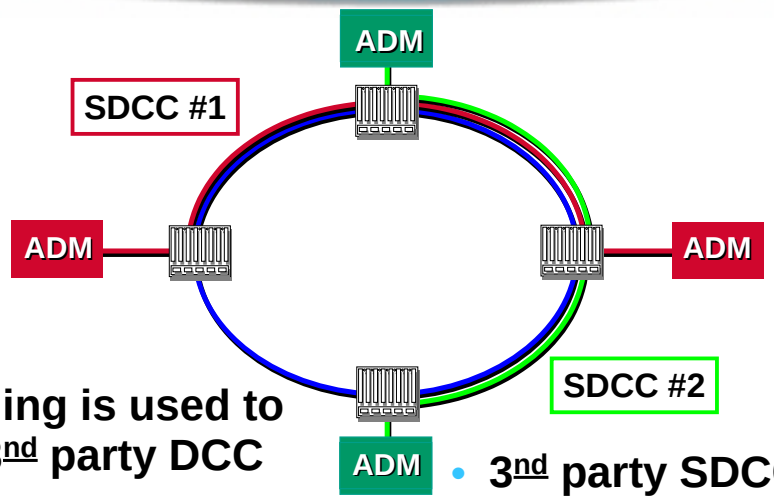
Digital Communication Channel Tunneling



- Tunneling is used to carry 3nd party DCC
  - Simplifies deployment over legacy networks
  - Eliminates need for out-of-band data network
- 3nd party SDCC is carried over LDCC
- Tunnels supported on point-to-point basis

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Intelligent Optics Is Good

- **Intelligence has come to optical transport**
  - **Metro solutions (SONET-based)**
  - **Core solutions (lambda-based)**
- **It brings important new benefits**
  - **Rapid provisioning**
  - **Differentiated restoration**
  - **Mesh transport efficiencies**

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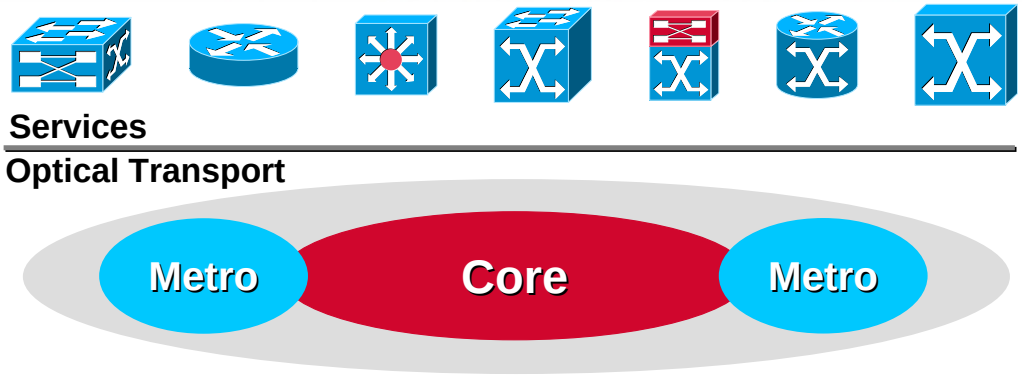
But Today it's Limited



- **Intelligence is first generation and proprietary, which leads to isolation**
  - **Within the optical layer**
  - **Between the optical layer and higher layers**

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Standards Are the Way Forward

- Optical internetworking standards are needed
  - Seamless operation and management
  - Lower operations costs
  - Interoperability/second sources
  - Optimization with upper layers
- The basis is an open control plane

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Existing Control Planes

Network Element	Standard Body	Routing	Signaling	Available
Optical Cross Connect	None	Proprietary	Proprietary	Future
ATM Switch	ATM Forum	PNNI	PNNI	Deployed
MPLS IP-LSR	IETF	Constraint Based	LDP/ RSVP	Deployed

Source: John Drake—MPLS Conference 1999

- Separate control planes exist for L1/2/3
- Limited communication creates isolation
- Results in an overlay network model

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Observations

- A single unified control plane is possible
  - Packets
  - Cells
  - Circuits/wavelengths
- It provides for a continuous spectrum of control options
  - From overlay to peer models
  - Migration strategy for legacy systems

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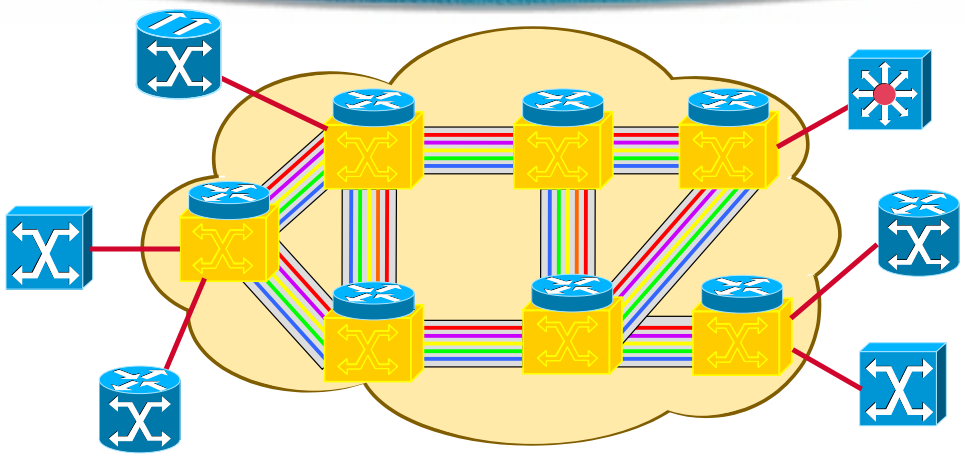
Overlay Model



- Service provider operates transport network
- Customers own the routers and switches
- Focus on transport, need for isolation

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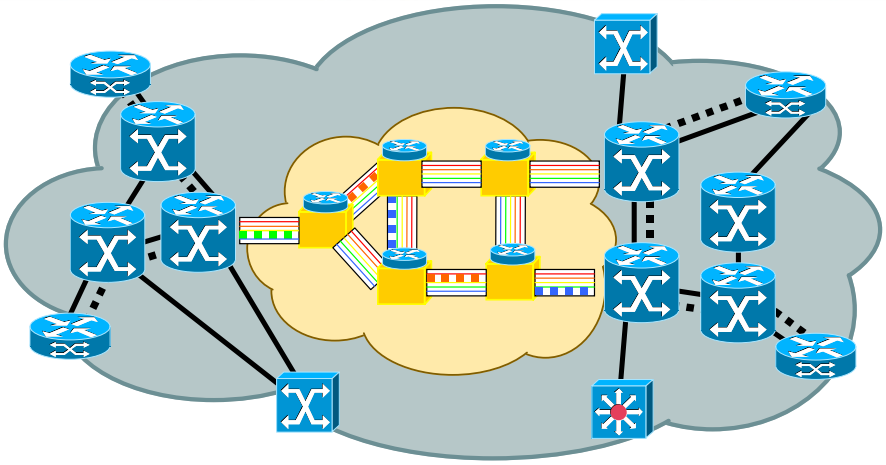
Peer Model



- Mixed environment with routers, switches and transport under common management
- Focus on services, desirable to integrate

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A Possible Unified Control Plane

Network Element	Standard Body	Routing	Signaling	Available
Optical Cross-Connect	IETF	Constraint Based	MPLS-TE	Future
ATM Switch	IETF	Constraint Based	MPLS-TE	Trials
MPLS IP-LSR	IETF	Constraint Based	MPLS-TE	Deployed

- MPLS has already unified packet and cells
- OXCs and LSRs are isomorphic
- MPLS can be extend to circuits and lambdas

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MPλS Has Momentum in IETF

- Extensions to OSPF, IS-IS, MPLS and RSVP have been defined
- Over 16 drafts are in process in MPLS WG

draft-awduche-mpls-te-optical-01.txt
draft-basak-mpls-oxc-issues-01.txt
draft-berstein-mpls-sonet-00.txt
draft-ceuppens-mpls-optical-00.txt
draft-chaudhuri-ip-olxc-control-00.txt
draft-fan-mpls-lambda-signaling-00.txt
draft-ip-optical-framework-00.txt
draft-krishnaswamy-mpls-son-00.txt
draft-lang-mpls-lmp-00.txt
draft-mannie-mpls-sdh-control-00.txt
draft-rstb-optical-signaling-framework -00.txt
draft-saha-rsvp-optical-signaling-00.txt
draft-shew-lsp-restoration-00.txt
draft-tang-crldp-optical-00.txt
draft-wang-ospf-isis-lambda-te-routing-00.txt
draft-lang-mpls-rsvp-oxc-00.txt

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Related Talks

- Session 3000: “Introduction to Optical Technology and Components” (Level 1)
- Session 3002: “Deployment and Design issues for IP over Optical Networks” (Level 2)
- Session 3005: “Deploying Services over a Optical Internetworking Infrastructure” (Level 2)
- Session 3007: “Advanced Optical technology and concepts” (Level 3)
- Session 3009: “Optical Internetworking Product Update”

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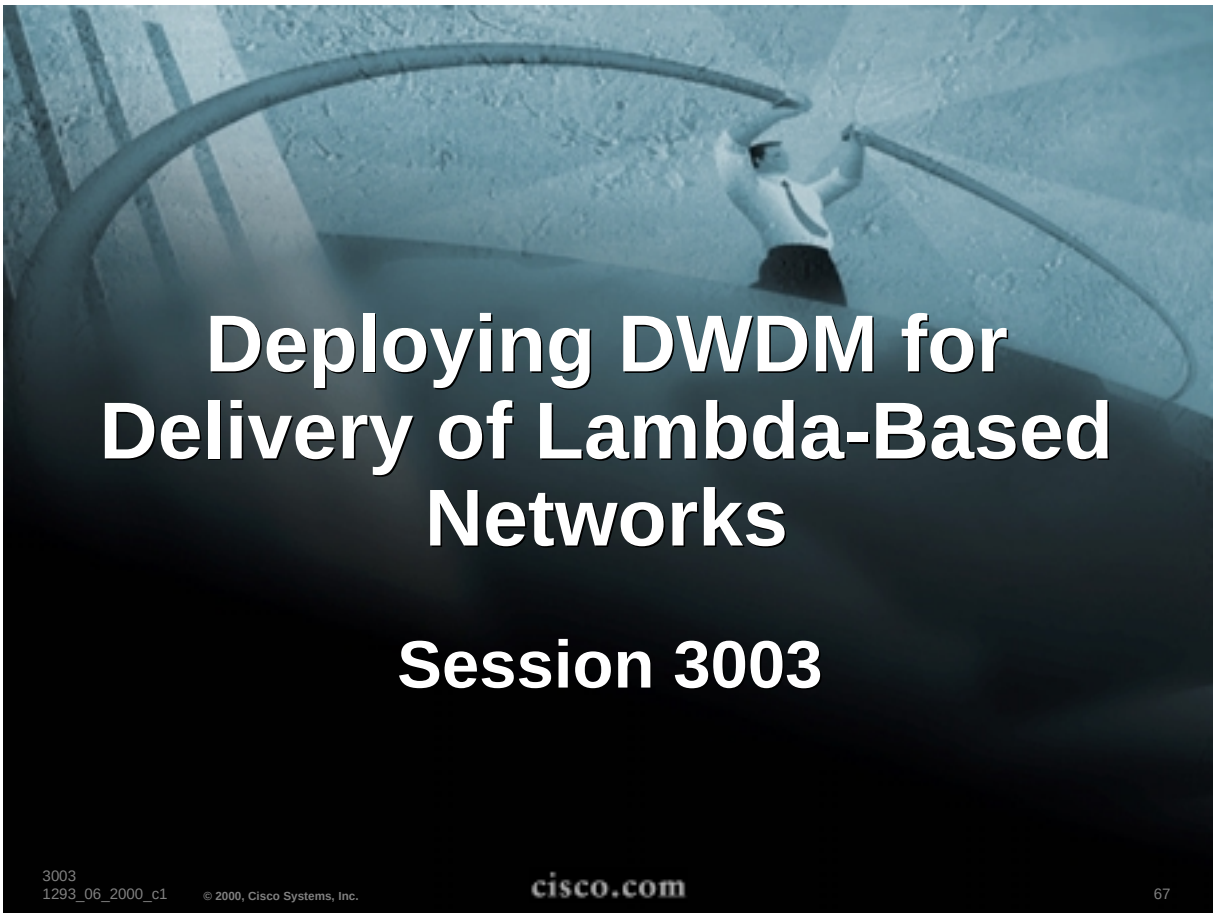

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