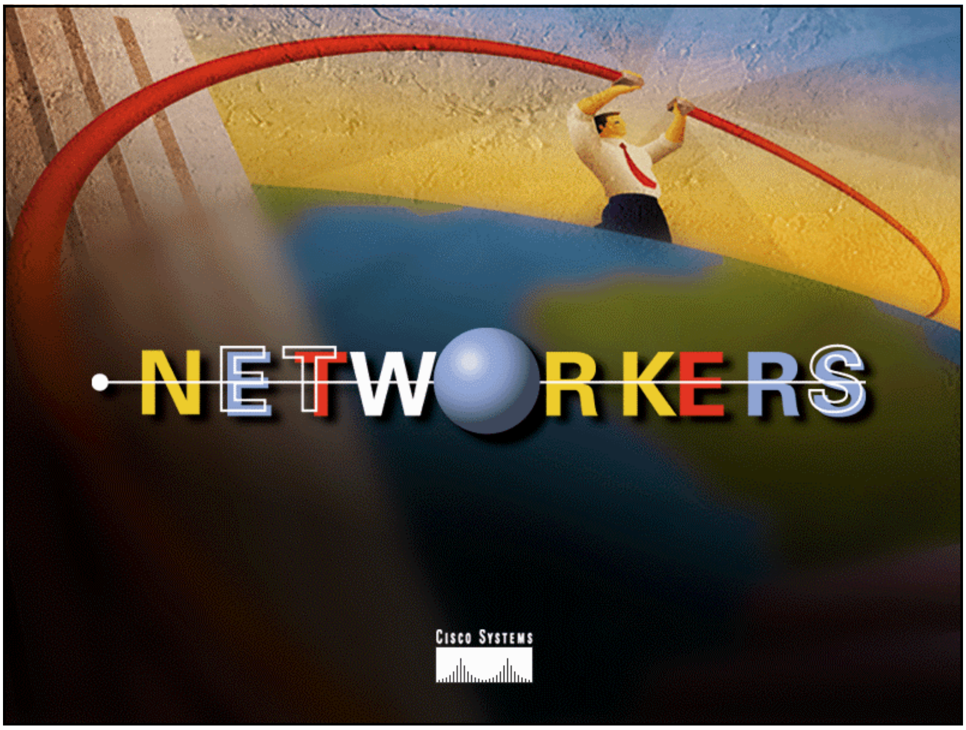
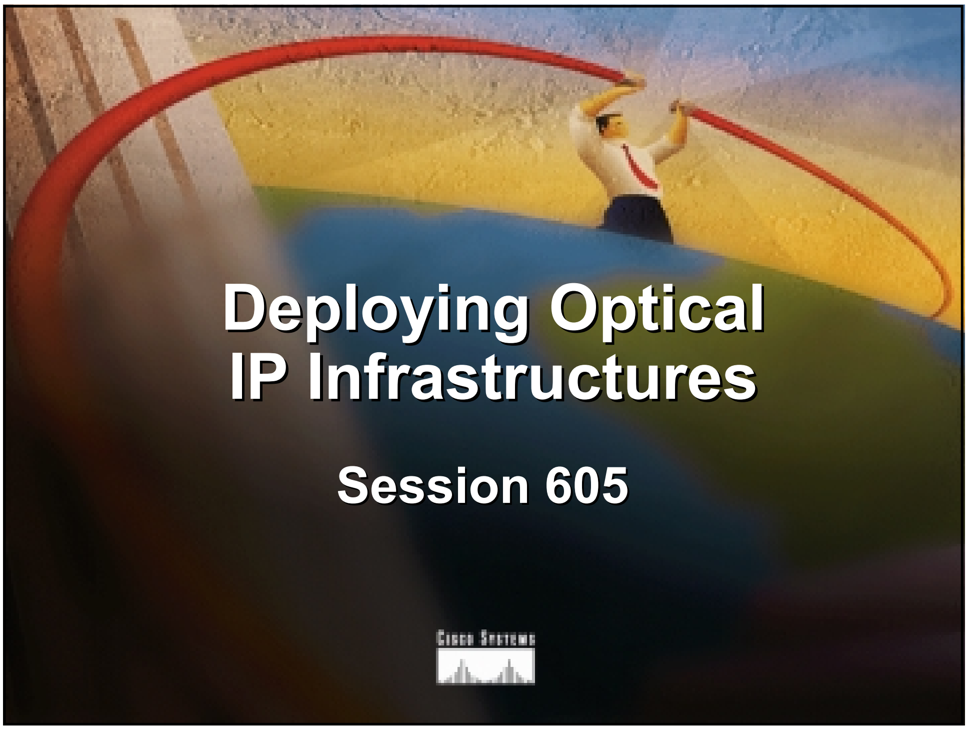

NETWORKERS
Cisco Systems


Deploying Optical
IP Infrastructures
Session 605
Cisco Systems

Agenda

- Introduction
- Transmission Alternatives
- IP Network Architecture
- Summary

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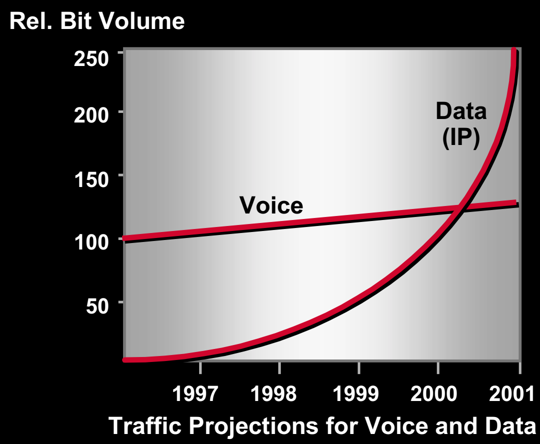
Applications Driving IP Traffic Growth

- E-commerce
- E-mail
- Information search/access
- Conferencing/ multimedia
- Video/imaging



"From 2000 on, 80% of service provider profits will be derived from IP-based services."
— CIMI Corp.

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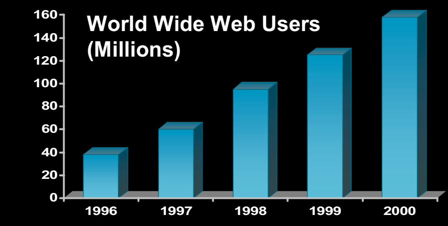
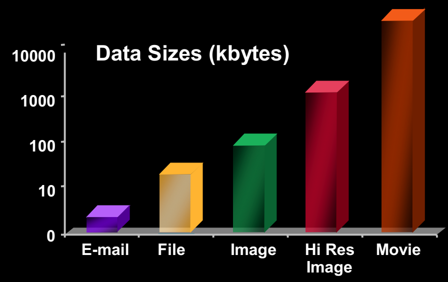
Internet Bandwidth Drivers

- Internet hosts growing exponentially (16 million in Jan '97)
- Web users expected to reach 160 million by 2000
- TCP-WWW now accounts for 75% of Internet traffic
- Traffic type changing rapidly from text to image to video



Source: IDC



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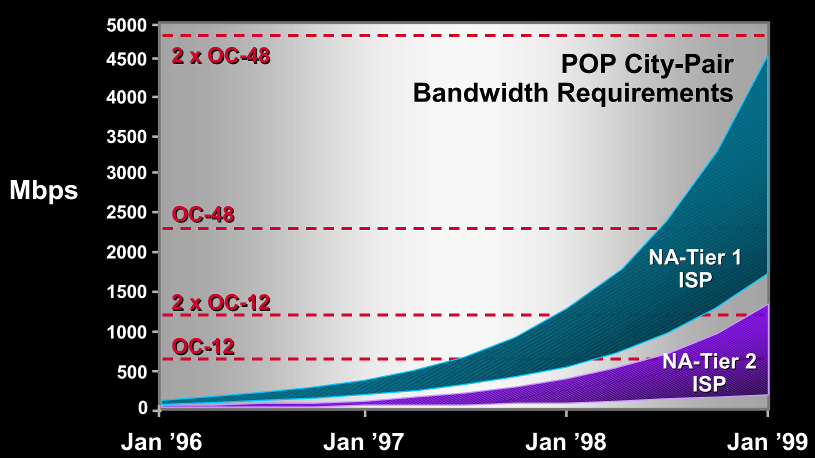
Projected IP Backbone Bandwidth Requirements



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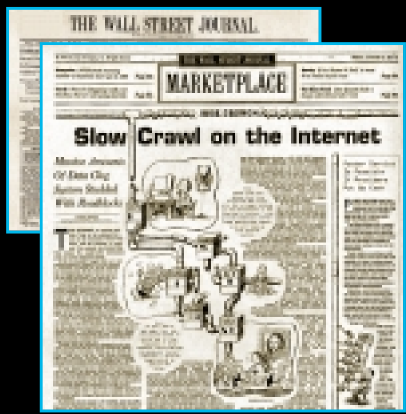
Current Network Not Optimized for Packet-Based Services

- Most service provider infrastructures are based on circuit switched technologies
- These infrastructures are optimized for n x DS0 for implementing voice, leased line services



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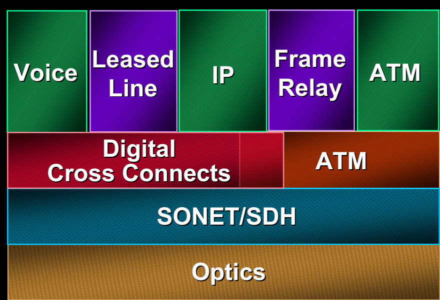
Circuit Switched Infrastructures

- Circuit switched infrastructures were used first to offer voice and leased line services and early IP services
- ATM was used as a more efficient circuit switched infrastructure and for Frame Relay and IP transport



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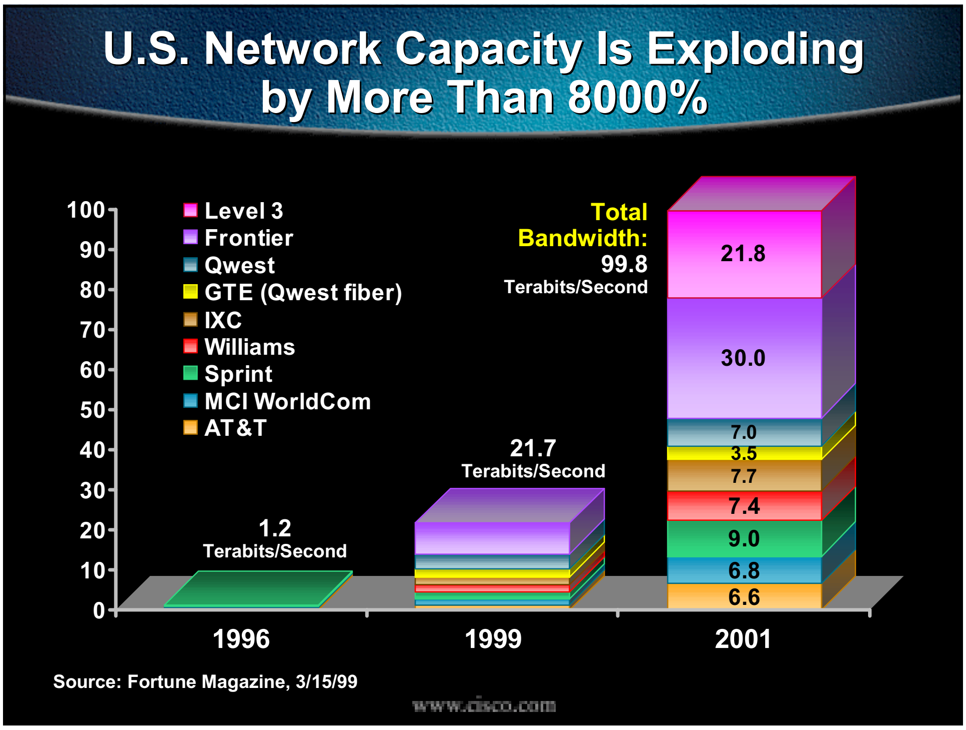
U.S. Network Capacity Is Exploding by More Than 8000%
100
90
80
70
60
50
40
30
20
10
0
Level 3
Frontier
Qwest
GTE (Qwest fiber)
IXC
Williams
Sprint
MCI WorldCom
AT&T
Total Bandwidth:
99.8
Terabits/Second
21.8
30.0
7.0
3.5
7.7
7.4
9.0
6.8
6.6
21.7
Terabits/Second
1.2
Terabits/Second
1996
1999
2001
Source: Fortune Magazine, 3/15/99
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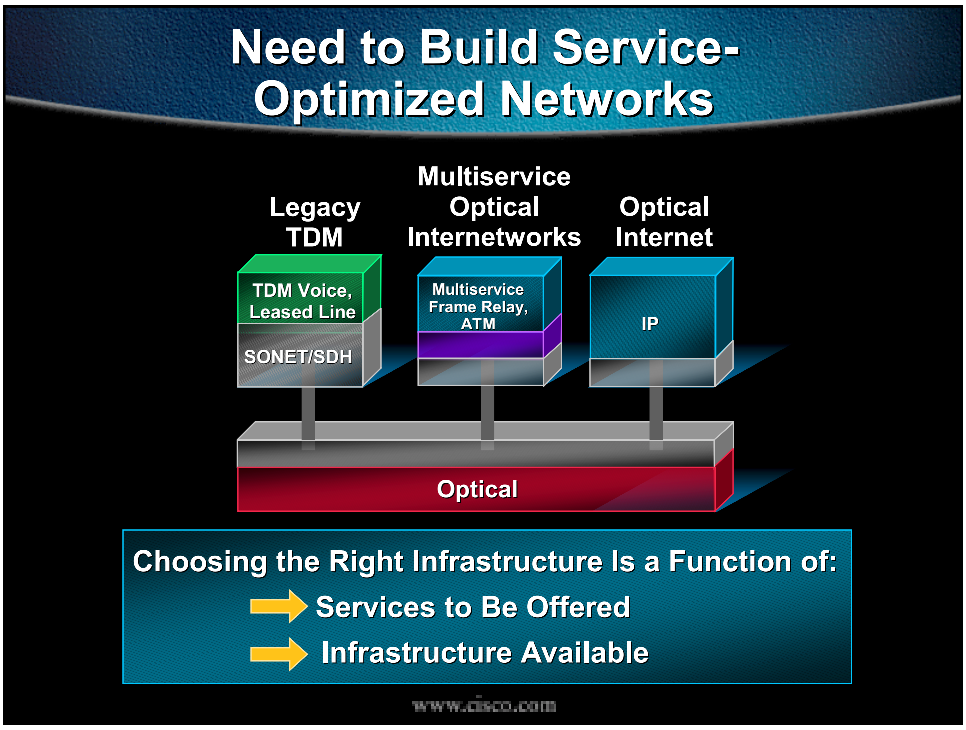
Need to Build Service-Optimized Networks
Legacy TDM
Multiservice Optical Internetworks
Optical Internet
TDM Voice, Leased Line
SONET/SDH
Multiservice Frame Relay, ATM
IP
Optical
Choosing the Right Infrastructure Is a Function of:
Services to Be Offered
Infrastructure Available
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Agenda

- Introduction
- Transmission Alternatives
  - Dark Fiber
  - SONET/SDH
  - DWDM
- IP Network Architecture
- Summary

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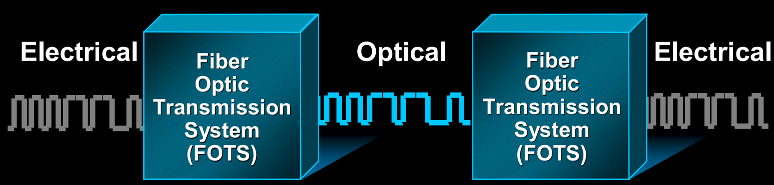
Fiber Networks



- A basic fiber optic system consists of:
  - A transmitting device, which generates the light signal
  - An optical fiber cable, which carries the light
  - A receiver, which accepts the light signal transmitted
- Single time-division multiplexed information stream
  - 2.5 Gbps (OC-48/STM-16) is current state of the art
  - 10 Gbps (OC-192/STM-64) is next generation

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Using Dark Fiber

- Considerations when deploying IP infrastructures over dark fiber
  - Fiber plant—capacity and topology
  - Power budgets, optics reach
  - Signal loss
    - Optical attenuation (dB/km)
    - Dispersion—chromatic and modal

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Using Dark Fiber

- Effective alternative if fiber capacity is not constrained
- Typical case for networks that have a limited geographic coverage
- Lighting up fiber with routers provides lowest cost/bit infrastructure
- Network design must address restoration

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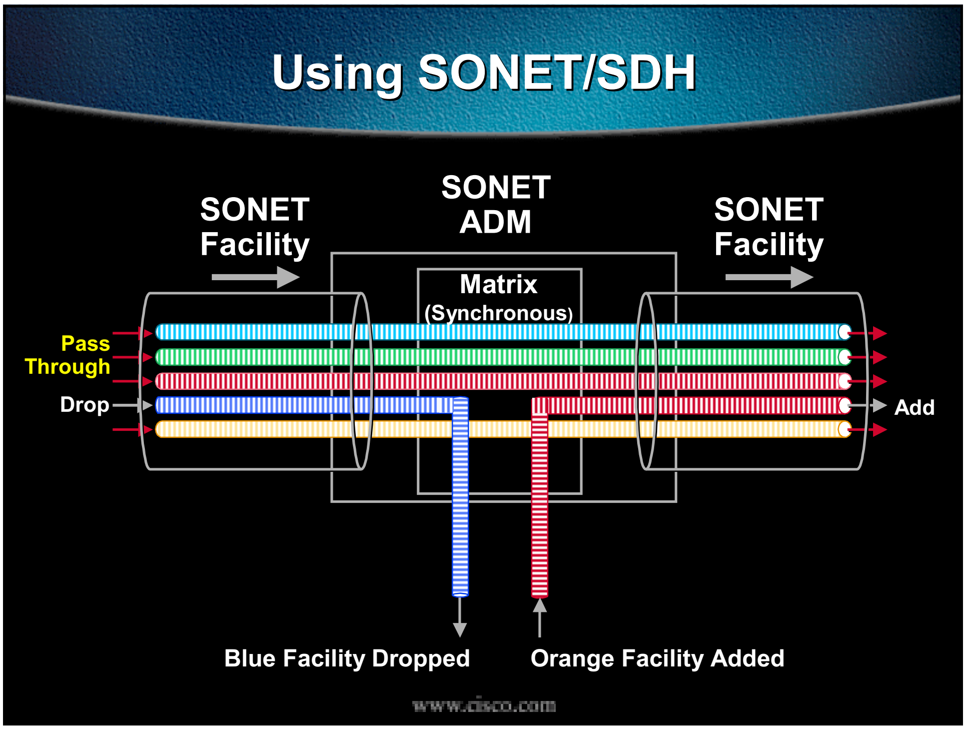
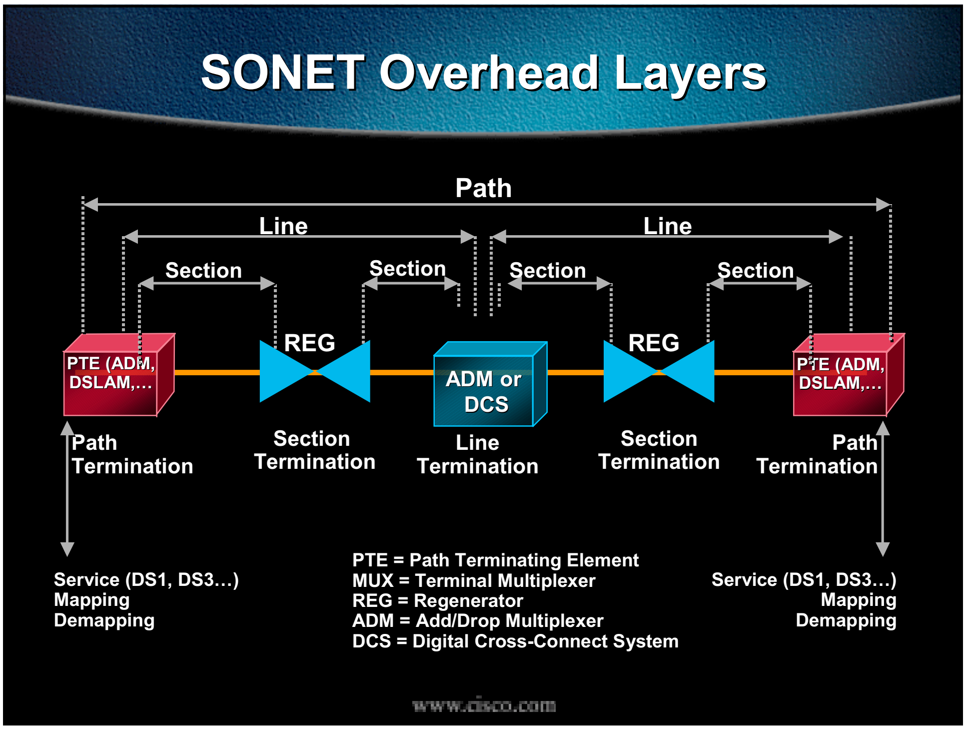
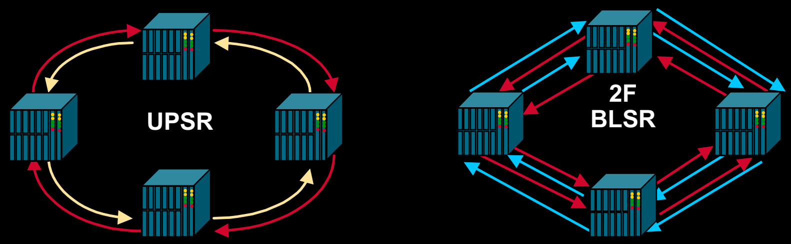

Using SONET/SDH
SONET Facility
SONET ADM
SONET Facility
Matrix
(Synchronous)
Pass Through
Drop
Add
Blue Facility Dropped
Orange Facility Added
www.cisco.com


SONET Overhead Layers
Path
Line
Line
Section
Section
Section
Section
REG
REG
PTE (ADM, DSLAM,…
ADM or DCS
PTE (ADM, DSLAM,…
Path Termination
Section Termination
Line Termination
Section Termination
Path Termination
Service (DS1, DS3…)
Mapping
Demapping
PTE = Path Terminating Element
MUX = Terminal Multiplexer
REG = Regenerator
ADM = Add/Drop Multiplexer
DCS = Digital Cross-Connect System
Service (DS1, DS3…)
Mapping
Demapping
www.cisco.com

SONET Ring Configurations



- Unidirectional Path Switched Ring (UPSR)
- Deployed in MANs for access and aggregation
- All traffic homing to central node

- Bi-directional Switched Ring (BLSR)
- Deployed in WANs
- Neighbor-to-neighbor traffic

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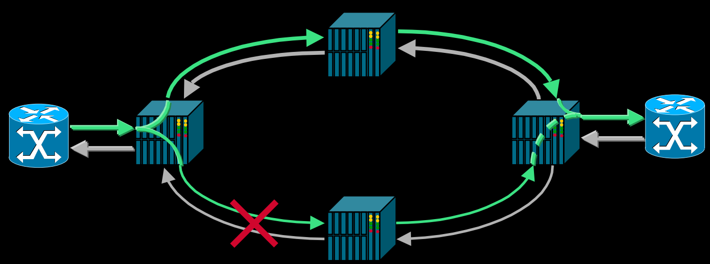
UPSR Protection: Simplicity at the Expense of Capacity



- 2 fiber ring topology
- Head end bridge, tail end switch (1+1)

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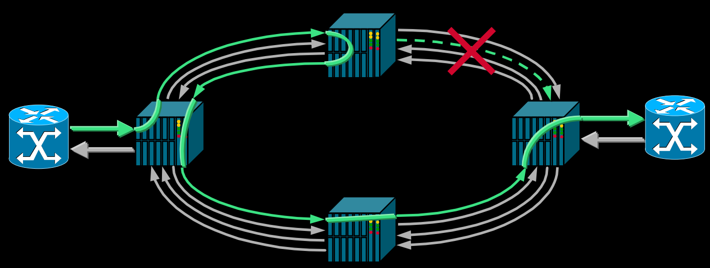
BLSR Protection: Supports Both Span and Ring Switching



- 4 fiber ring topology
- Supports both span and ring switching
- Requires signaling between ADMs

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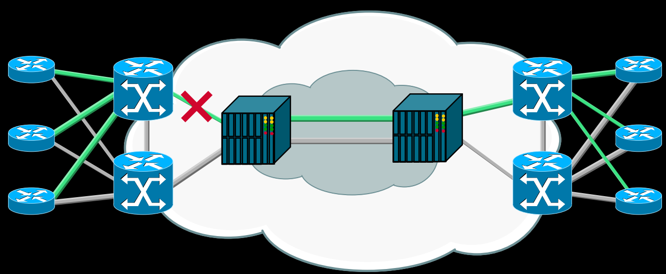
APS Between Routers and ADMs



- APS is used to extend SONET protection to tributaries
- All traffic goes to working router, protect router is idle

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Limitations of SONET Protection

- SONET only protects the transmission infrastructure
- SONET protects all traffic equally

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Using SONET/SDH

- Accepted transport architecture in most service provider networks, except some ‘Greenfield Carriers’
- Used primarily to transport Circuit Switched traffic and some packet-based traffic
- Provides performance monitoring and self healing (50 msec switchover) but at the expense of bandwidth efficiency (BLSR)
- Limited availability of 622 Mbps and 2.5 Gbps tributary interfaces is not readily available or economical

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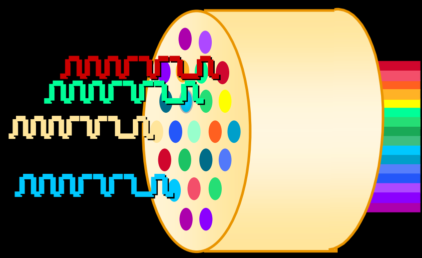
Dense Wave Division Multiplexing Provides Fiber Gain

- 16 channel x 2.5 Gbps = 40 Gbps
- 24 channel x 2.5 Gbps = 60 Gbps
- 40 channel x 2.5 Gbps = 100 Gbps
- 80 channel x 2.5 Gbps = 200 Gbps

- 4 channel x 10 Gbps = 40 Gbps
- 16 channel x 10 Gbps = 160 Gbps
- 128 channel x 10 Gbps = 1280 Gbps



- Multiplexed wavelengths can be amplified as one composite signal using Erbium Doped Fiber Amplifiers (EDFAs)
- Fiber non-linearities such as attenuation and dispersion impose limits on speed and distance

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Using DWDM

- Used in several service provider networks
- Used to provide bandwidth gain (example: 40 channels of 2.5 Gbps on a single fiber instead of a single channel)
- High cost for systems can easily be justified in areas where additional fiber deployment may be required (typically in long-haul networks); for example, a link between Cheyenne and Omaha:
  - DWDM equipment costs $17 million
  - Laying new fiber costs $190 million
- Network design must address restoration

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Summary of Transmission Alternatives

- Use of dark fiber makes sense if there are no capacity constraints; this is typical for limited geographic areas
- SONET/SDH is widely deployed today and accepted for transporting circuit based traffic due to the self-healing capabilities
- DWDM makes sense in long-haul networks where additional fiber deployment is extremely expensive

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Agenda

- Introduction
- Transmission Alternatives
- IP Network Architecture
    - Core
    - Aggregation
    - Access
- Summary

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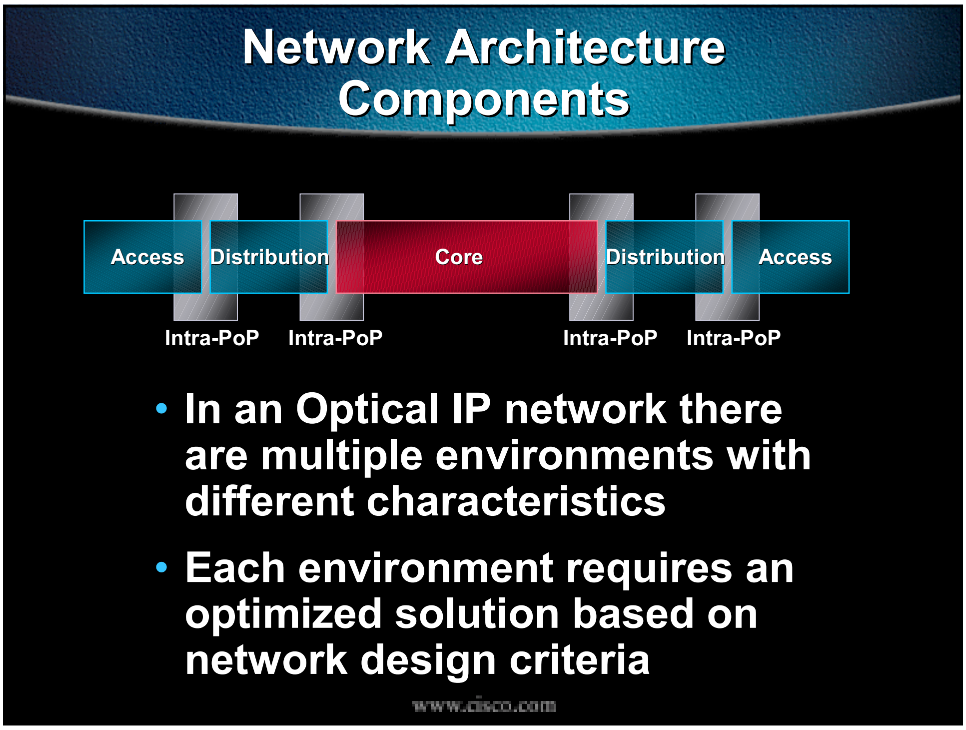
Network Architecture Components
Access
Distribution
Core
Distribution
Access
Intra-PoP
Intra-PoP
Intra-PoP
Intra-PoP
• In an Optical IP network there are multiple environments with different characteristics
• Each environment requires an optimized solution based on network design criteria
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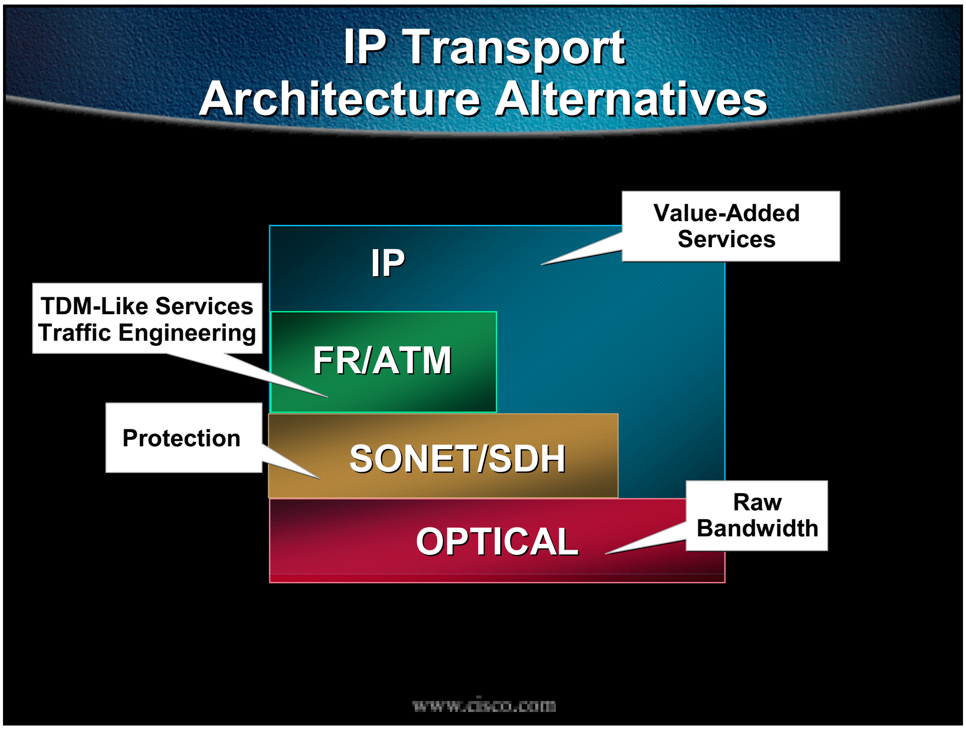
IP Transport Architecture Alternatives
Value-Added Services
IP
TDM-Like Services Traffic Engineering
FR/ATM
Protection
SONET/SDH
OPTICAL
Raw Bandwidth
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IP Network Core

- There are multiple alternatives for building a core infrastructure for IP
  - Frame Relay/ATM
  - Packet over SONET/SDH
  - Dynamic Packet Transport
- Either one of these can utilize any transmission alternatives

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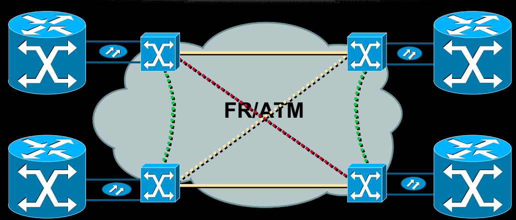
FR/ATM Core



- Network design
  - FR/ATM switches connect to transmission equipment
  - Routers connect to ATM switches via UNI interfaces
  - FR/ATM connections provide appropriate CoS between routers
- Design considerations
  - Network capacity and scale—622 Mbps ATM interfaces on routers
  - Layer 3 network design—full peering requires n(n-1)/2 connections
  - Restoration could be achieved in
    - Physical layer (diverse fiber routes or SONET/SDH)
    - Logical layer (routing in FR/ATM switches)

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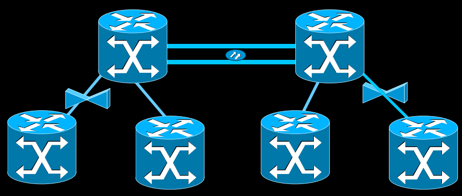
Packet over SONET/SDH Core



- **Network design**
  - Point-to-point POS connections over dark fiber, SONET/SDH, DWDM directly attached to routers
  - Optical regenerators may be required to extend reach beyond 80 km per span
  - Use IP Class of Service techniques (ACL, CAR, WRED, DRR)
- **Design considerations**
  - Network capacity—up to 2.5 Gbps interfaces available today
  - Traffic distribution—hub/spoke
  - Restoration could be achieved in
    - Physical layer (diverse fiber routes or SONET/SDH)
    - Network layer (load-share over multiple paths)

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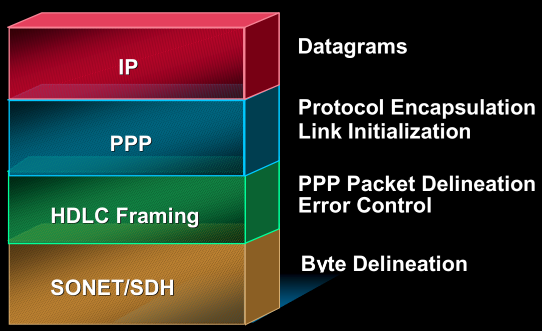
Packet over SONET/SDH (PoS)

- **Point-to-Point Protocol, IETF RFC 1661**
- **PPP in HDLC—like framing, IETF RFC 1662**
- **PPP over SONET/SDH, IETF RFC 1619**



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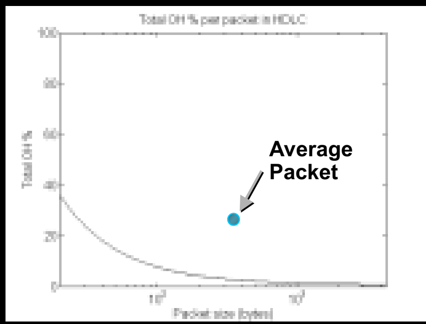
PoS Performance

	Total OH % Per Packet
Min. Packet (20 Bytes)	35.78
Ave. Packet (354 Bytes)	2.76
Max. Packet (4352 Bytes)	0.94



- Total overhead is the sum of byte-stuffing and header/trailer overhead

  OH% = 0.78 + 7/N

- Total overhead for average packet is < 3%

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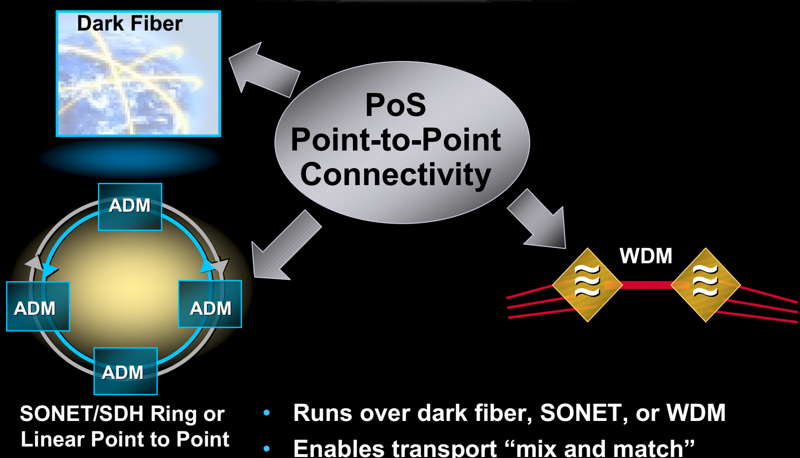
POS Enables Flexible Connectivity



- Runs over dark fiber, SONET, or WDM
- Enables transport “mix and match”
- Provides efficient evolution path for incumbents
- Provides optimized transport for greenfield builds

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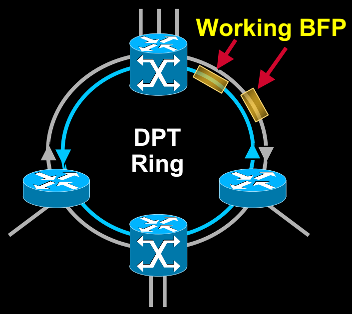
Dynamic Packet Transport Core

- Network Design
  - Packet-based ring
  - Optical Regens may be required to extend reach
- Design Considerations
  - Network capacity—622 Mbps interfaces
  - Traffic distribution—distributed sources/sinks of traffic
  - Restoration
    - Provided by Intelligent Protection Switching in the Spatial Reuse Protocol (50 msec switchover time for a 16 node ring)



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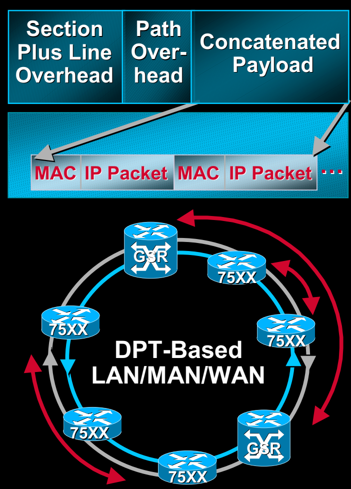
Spatial Reuse Protocol

- New Layer 2 MAC technology **SRP (Spatial Reuse Protocol)**
  - Uses SONET/SDH framing
  - Bandwidth efficient
  - Fairness (SRP-fa)
  - Scalable
  - Fast protection switching and service restoration
  - Multicasting and priority
- Enables DPT functionality



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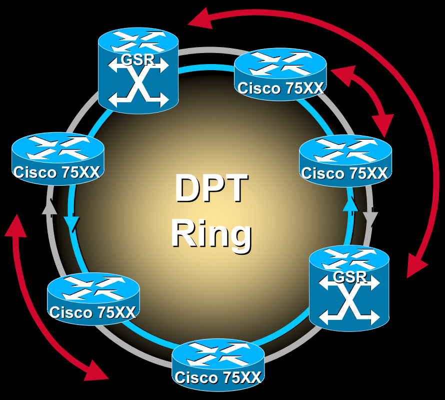
Spatial Reuse

- Destination stripping
- Bandwidth consumed only on traversed segment
- Multiple nodes transmit concurrently
- Dynamic, per-packet spatial reuse
- Control via SRP-fa instead of token passing



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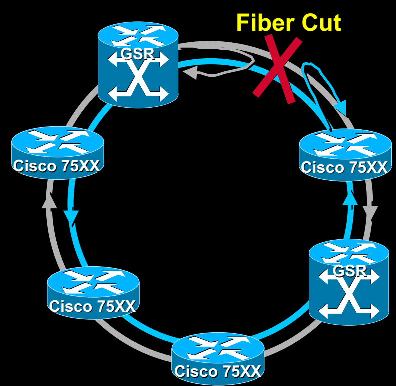
Intelligent Protection Switching

- Like SONET/SDH, DPT provides:
  - Proactive performance monitor and self-healing via ring wrapping
  - Fast 50-ms restoration
  - Protection switching hierarchy
- Unlike SONET/SDH, DPT provides:
  - Signaling via explicit control messages
  - Multilayer awareness and elastic cooperation
  - Differentiated handling by priority
  - Enhanced pass-through mode
  - Fast IP service restoration on large rings
  - No dedicated protection bandwidth and intelligent rehoming after wrap
  - Minimal configuration and provisioning



Detects Alarms and Events and Wraps Ring ~50 ms

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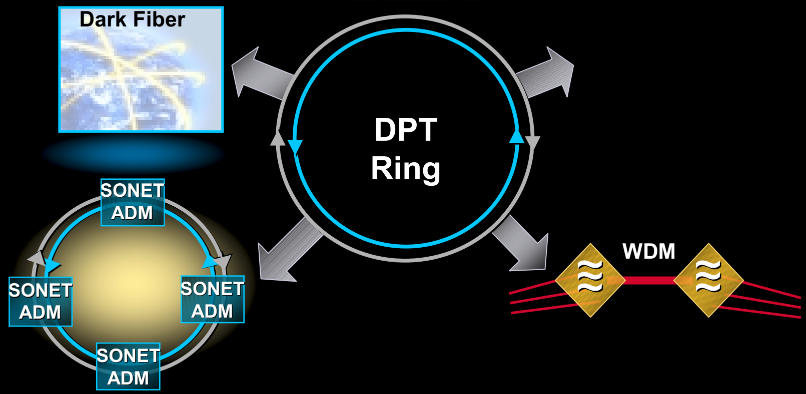
DPT Enables Transport Flexibility and Evolution



SONET/SDH Ring or Linear Point to Point

- Runs over dark fiber, SONET, or WDM
- Enables transport “mix and match”
- Provides efficient evolution path for incumbents
- Provides optimized transport for greenfield builds

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Sample Core Architecture

- Majority of IP core backbones being deployed today use DWDM or SONET/SDH as the transmission media directly connected to PoS interfaces on routers
- Majority of IP core backbones are operating at 2.5 Gbps

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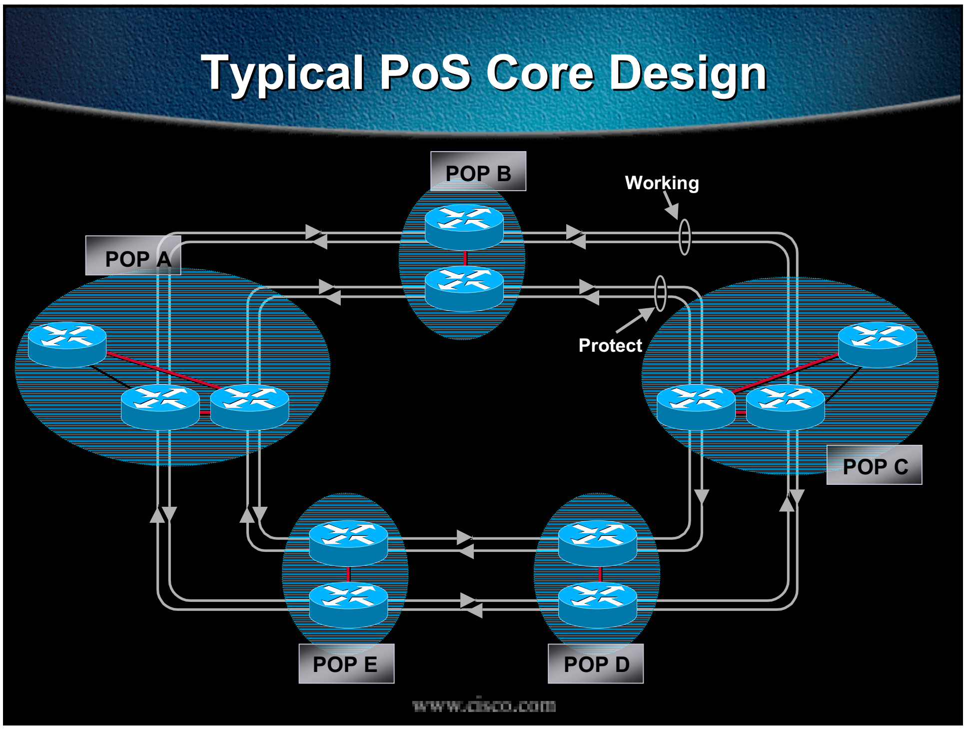
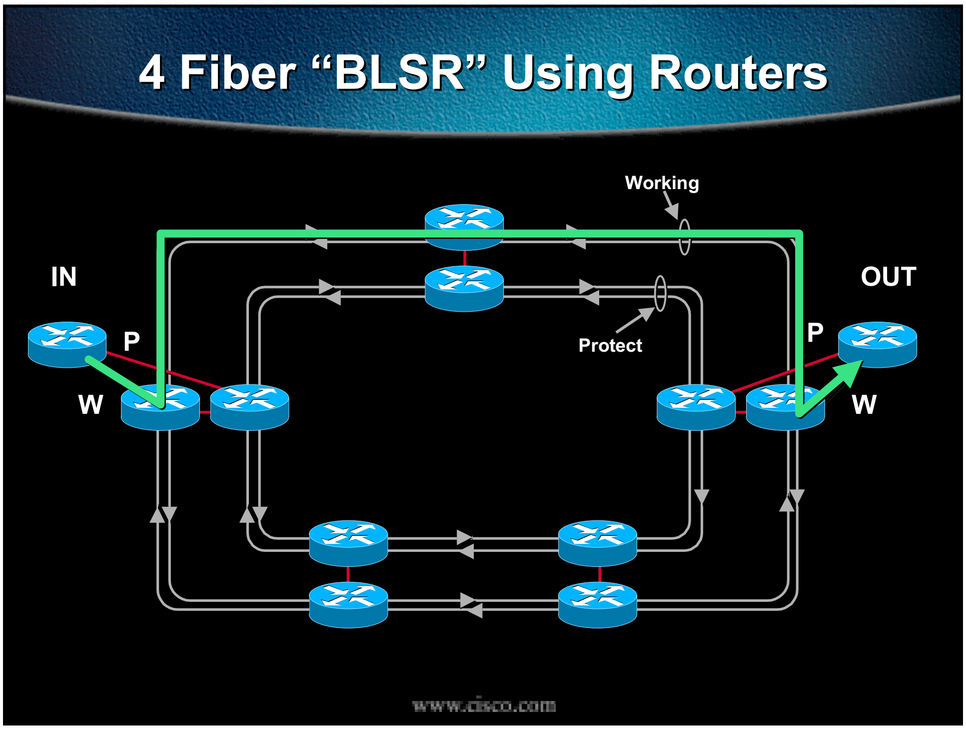
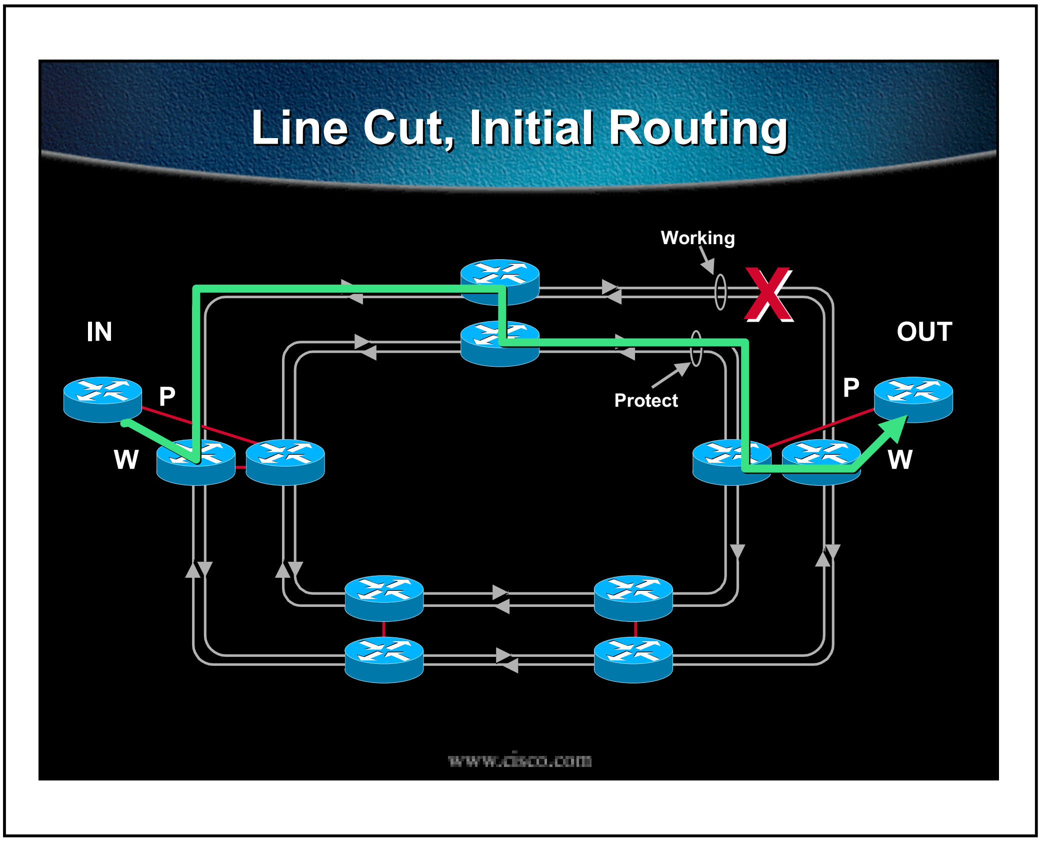
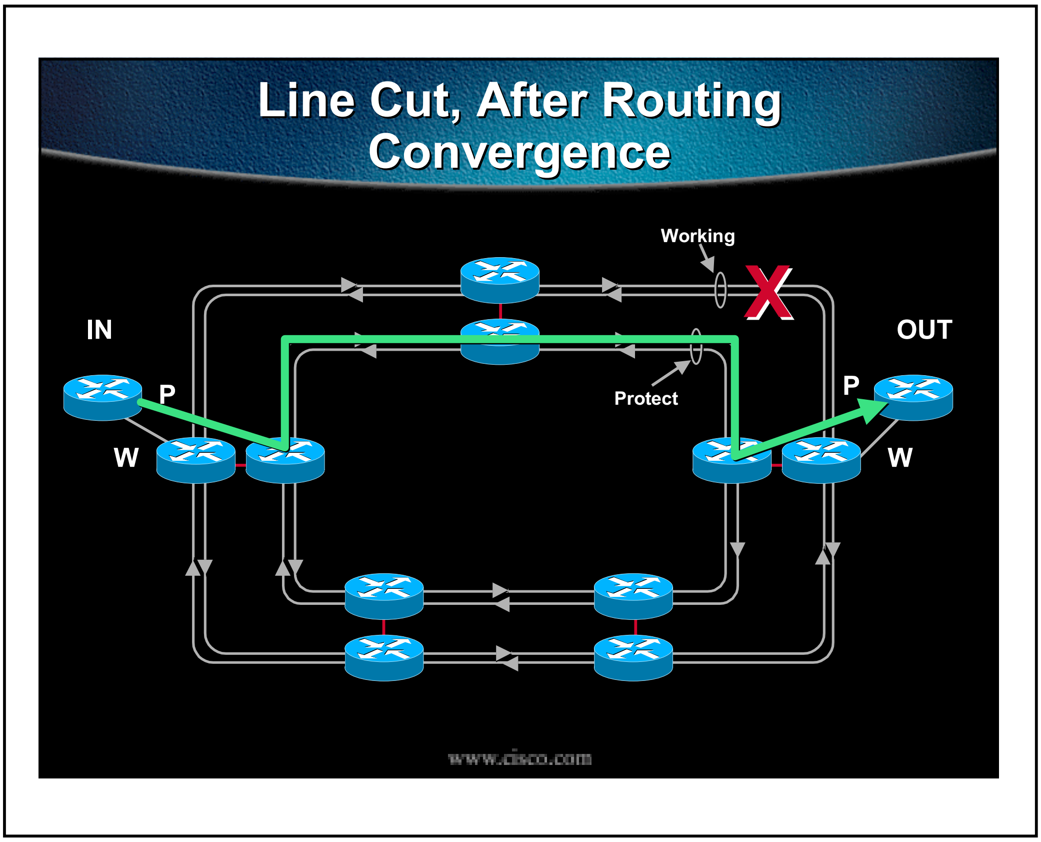

Typical PoS Core Design
POP B
Working
POP A
Protect
POP C
POP E
POP D
www.cisco.com


4 Fiber "BLSR" Using Routers
Working
IN
OUT
P
P
Protect
W
W
www.cisco.com


Line Cut, Initial Routing
Working
IN
OUT
P
Protect
P
W
W
www.cisco.com


Line Cut, After Routing Convergence
Working
IN
OUT
P
Protect
P
W
W
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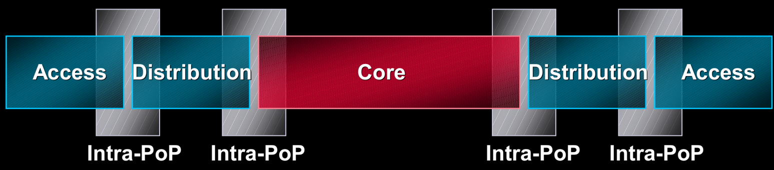
Network Architecture Components



- The distribution network connects to multiple access networks
- The distribution network must provide the interface breadth, density and termination to connect efficiently to current and future transmission infrastructures
- The distribution network must exhibit efficient traffic aggregation

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Aggregation Network

- An IP aggregation network must be able to collect traffic from various access networks
  - Dedicated access
  - SONET
  - Multiservice (FR, ATM)
  - DSL

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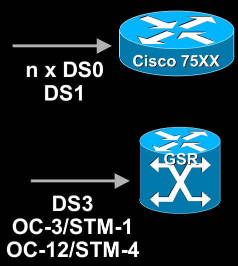
Dedicated Access Aggregation

- Aggregation interfaces from n x DS0 to OC-12c/STM4c
- Typical access rates are increasing (256 kbps to 45 Mbps)
- OC-3/STM1 and OC-12/STM-4 accesses becoming available



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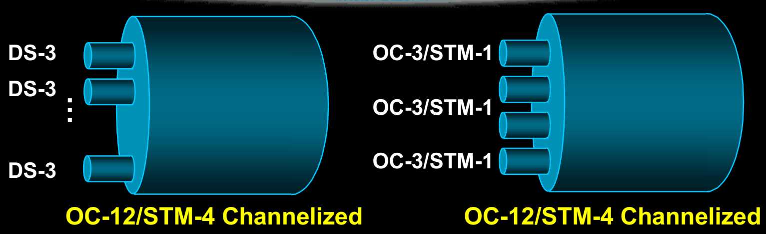
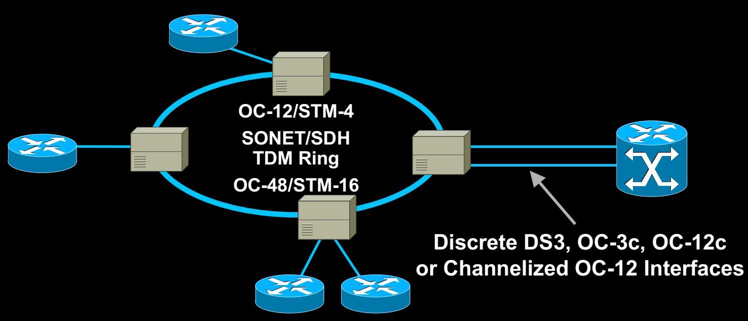
SONET/SDH Aggregation





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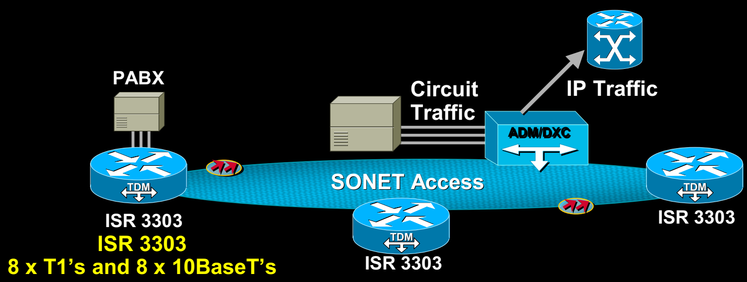
SONET Access Solutions

- SONET devices like Cisco ISR3303 can be used for local access loops
- At the PoP, circuit traffic can be directed to the circuit network and the IP traffic can be aggregated into the IP edge via appropriate interfaces



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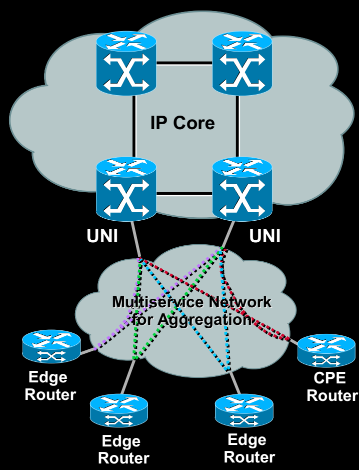
Multiservice Aggregation Applications

- Allows aggregation of IP traffic from multiple remote locations
- Connect routers via ATM interfaces to multiservice network



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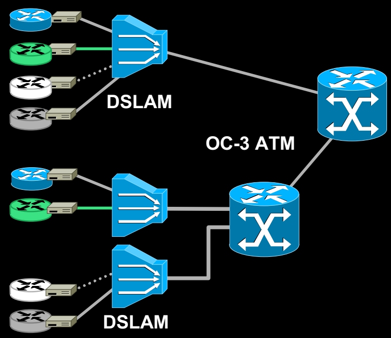
Aggregating IP Traffic from DSL Edge



- IP traffic coming over DSL links can be aggregated into routers via ATM interfaces (OC-3/STM-1 or OC-12/STM-4)

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Metro Aggregation Requirements

- All of the PoPs that aggregate traffic from multiple accesses need to efficiently aggregate the traffic
- This aggregation network must be:
  - IP optimized
  - Scalable
  - High reliability/availability

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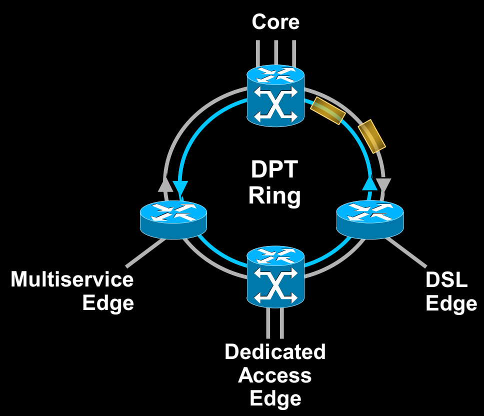
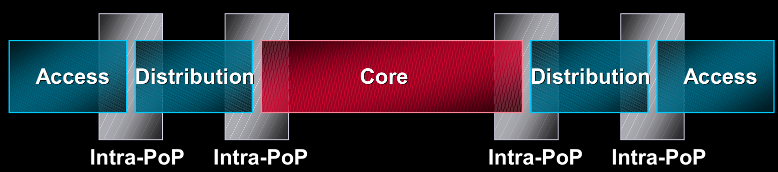
Dynamic Packet Transport (DPT) Aggregates Traffic

- DPT can be used to efficiently and reliably aggregate traffic from multiple PoPs in a metropolitan network



Network Architecture Components



- As the number services and users, an efficient design is needed to efficiently implement and scale the PoP

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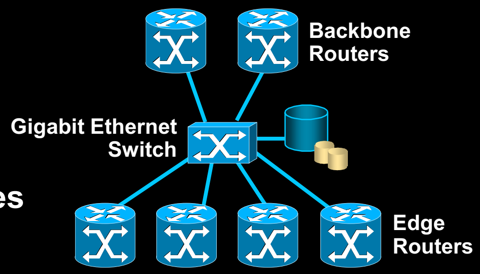
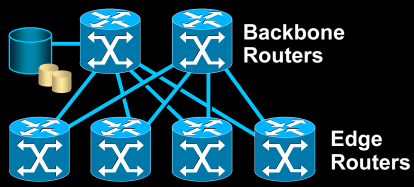
Layer 2 Intra-PoP Architecture

- Backbone routers connected to edge routers or servers using Layer 2 switches



- Backbone routers connected to edge routers or servers directly using Layer 2 (typically GE or FE) interfaces



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DPT Offers an Alternative PoP Architecture

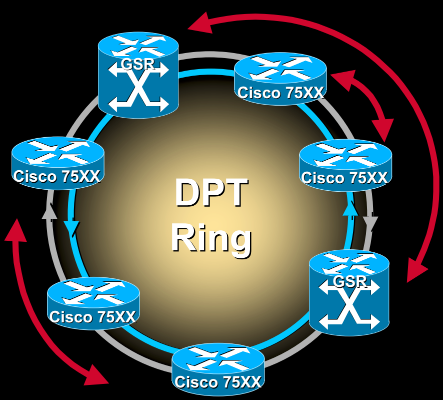
- Dynamic Packet Transport is an efficient alternative for intra-PoP connectivity
- Benefits

  Cost-effective (uses less slots)

  Bandwidth efficient

  Self healing

  Configuration ease



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Agenda

- Introduction
- Transmission Alternatives
- IP Network Architecture
- Summary

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Summary

- IP traffic growth and optical infrastructure availability is paving the way for Optical Internetworking
- Several transmission alternative available—dark fiber, SONET/SDH, DWDM
- IP network architecture is comprised of several environments—core, aggregation, access
- Optimal design is a function of the services to be offered and infrastructure available

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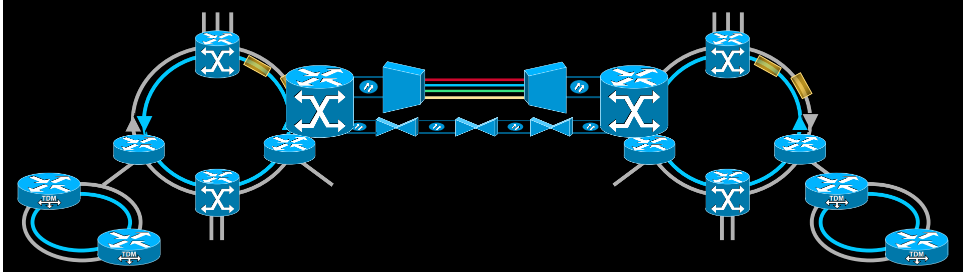
Optical IP Networks Sample Architecture



Metro Access	Metro Aggregation	Backbone	Metro Aggregation	Metro Access
Hybrid TDM, Data Rings Using ISR 3303	DPT Rings Dark Fiber Using GSR 12000 and 7500	Point-to-Point PoS over SONET/SDH, DWDM, or Dark Fiber Using GSR 12000	DPT Rings Dark Fiber Using GSR 12000 and 7500	Hybrid TDM, Data Rings Using ISR 3303

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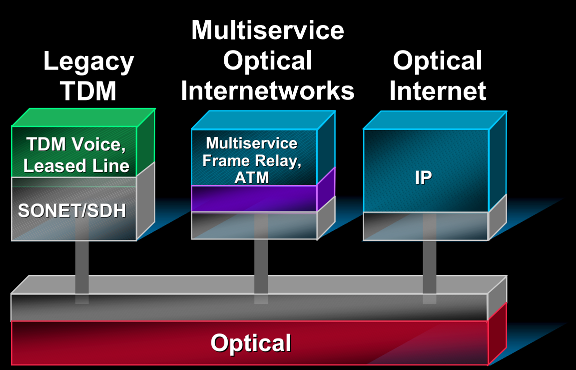
Case Study Discussion



Choosing the Right Infrastructure Is a Function of:

- Services to Be Offered
- Infrastructure Available

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Other Sessions to Attend

- **Session 604**

  Introduction to Optical Internetworking

- **Session 606**

  Advanced Optical Technology Concepts

- **Session 1202**

  GSR Product Update

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