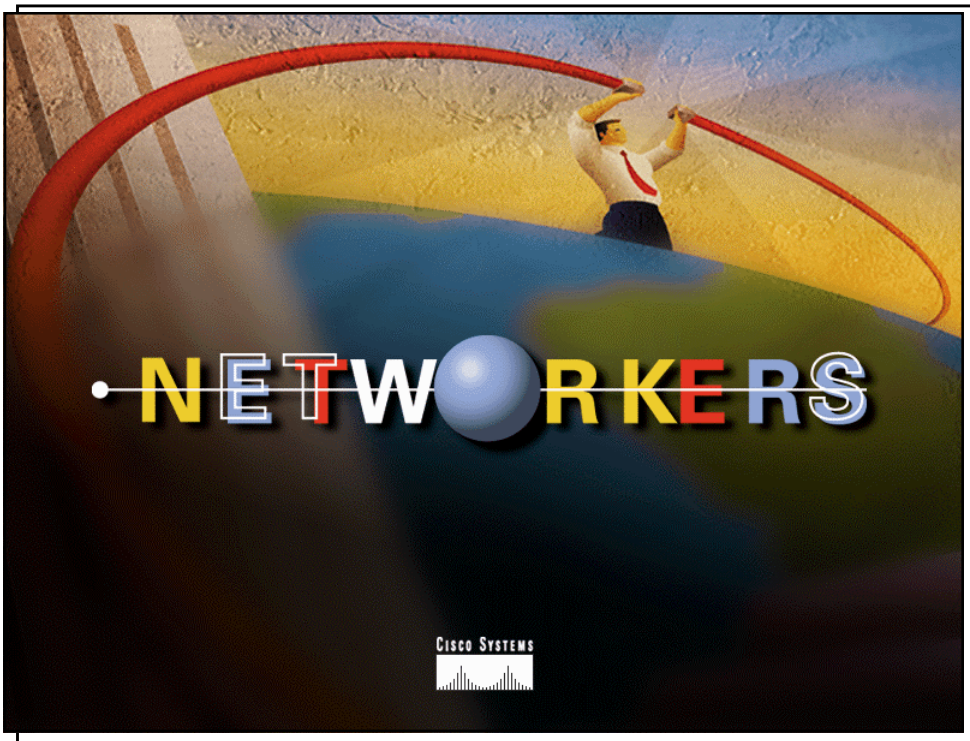

Agenda

- System Overview
- Switch Fabric
- Line-Card Architecture
- Interfaces
- Software

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Cisco GSR 12000 IP Backbone Leadership

- World wide Internet proven deployment since 1997
- Carrier-class architecture
- Premier IP-routing software
- Leading interface breadth
- Technology innovation

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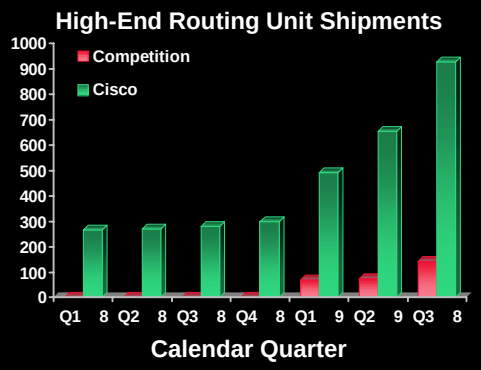
Cisco Is the Leader in High-End Routing

Cisco 12000 GSR Continues to Be the Platform of Choice

- 100+ terabits of deployed IP capacity
- Over 5500 GSR systems sold
- Over 3000 2.5 Gbps IP interfaces
- Over 400 customers



Source: Synergy Research Cisco Internal Data

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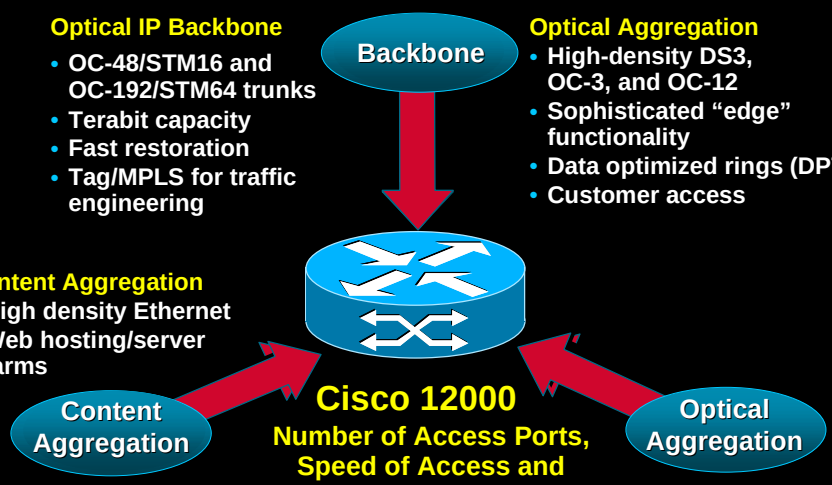
Leveraging the Cisco 12000 for POP Consolidation

Optical IP Backbone
- OC-48/STM16 and OC-192/STM64 trunks
- Terabit capacity
- Fast restoration
- Tag/MPLS for traffic engineering

Optical Aggregation
- High-density DS3, OC-3, and OC-12
- Sophisticated "edge" functionality
- Data optimized rings (DPT)
- Customer access

Content Aggregation
- High density Ethernet
- Web hosting/server farms



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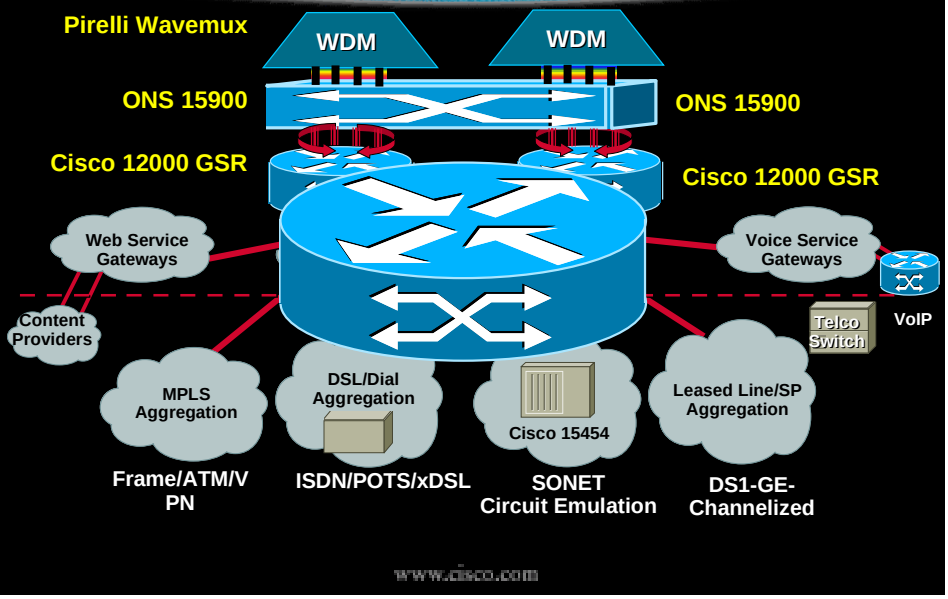
Building a New World IP POP



Scaling The Internet Infrastructure

	Cisco 12008	Cisco 12012	Cisco 12016
Bandwidth	40 Gbps	60 Gbps	320 Gbps
Chassis Slots	8	12	16
IO Slots	7	11	15
Fabric Slots	5	5	5
Systems Per Rack	3	1	1
Size	24.9"H x 17.5"W x 21"D	56"H x 17.5"W x 21"D	72"H x 17.5"W x 21"D
Power	AC, DC	AC, DC	AC, DC
Redundancy	RP, Power, Line Card, Mbus, Fabric, Fans	RP, Power, Line Card, Mbus, Fabric, Fans	RP, Power, Line Card, Mbus, Fabric, Fans

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New! Cisco 12016

- Cisco 12016
  - Scalable to 320Gbps
- OC-192c/STM64c Packet-over-SONET/ SDH interface
  - Currently in field trials
- Cisco 12000 terabit system
  - Scalable to 5 Tbps

www.cisco.com

Cisco 12016 GSR Scalable to 320 Gbps and Beyond

NEW

- Switching performance
- High-speed and denser interfaces
- Service enablers
- Carrier class/robustness

All Line Cards Can Be Used in Cisco 12016

www.cisco.com

Cisco 12016 Specifications

- **Physical**

  Installs in a single seven foot tall, 19" telco rack

- **Power**

  International AC or DC power system with redundancy option

- **Configuration**

  Two interface shelves, 16 slots, one dedicated slot for RP, 15 for linecards

  One fabric shelf, with five slots

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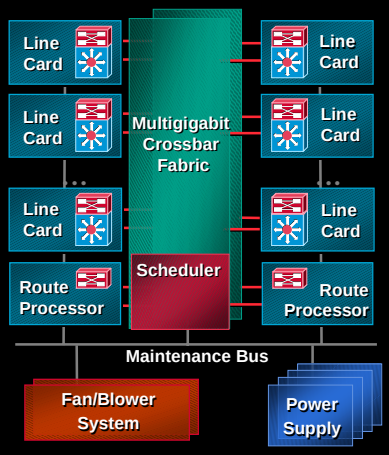
GSR Architecture
Carrier Class Design

- NEBS compliant
- Redundancy
- Automatic Protection Switching (APS)/Multiplex Section Protection (MSP)
- Online Insertion and Removal (OIR)
- Separate maintenance bus
- Extensive environmental monitoring



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Architecture For Performance, Real Time Services and Resiliency

Carrier Class Resiliency

Support for Real Time Services with Low Latency

"The test results pointedly underscore the fact that the Cisco 12000 Series GSR is well suited to Internet Service Providers (ISPs) who require core routing products that not only provide line-rate processing, but also offer advanced traffic management capabilities."

The Tolly Group, 8/99

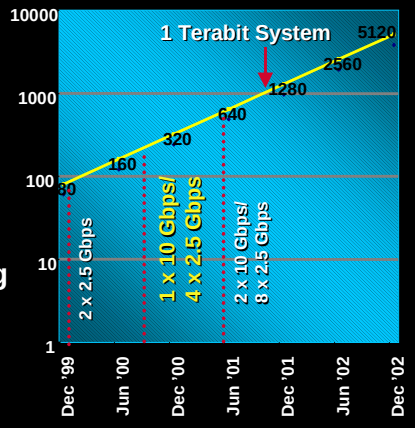
Wire Speed

www.cisco.com

OC-192/STM64 POS

Meeting Growing Backbone Bandwidth Demand

- Backbone capacity
  - Most intercity links are 2 x 2.5 Gbps today with low average utilization
  - Expectation for 1 x 10 Gbps by mid CY '00
  - Backbone bandwidth doubling every six to nine months
- OC-192/STM64 currently in trials



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Scaling to Terabits

Requirements for Terabit Routing Platform

- Support high-bandwidth PoP requirements
- Support existing capabilities of Internet control plane
- Scale services breadth
- Lower operational costs

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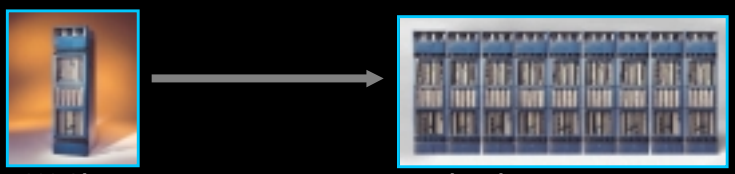
Scaling to Terabits

Cisco 12000 Terabit System

- Utilizing Internet proven GSR platform
- Building on extensive control plane and service enablers in Cisco IOS®
- Simple scalability from 320 Gbps to five Tbps
- Investment protection



320 Gbps Five Tbps

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The Cisco 12000 Terabit System

Scalability with Stability and Services

- Infrastructure stability
- Lower operational costs
- Services
- Scalability on demand
- Manageability

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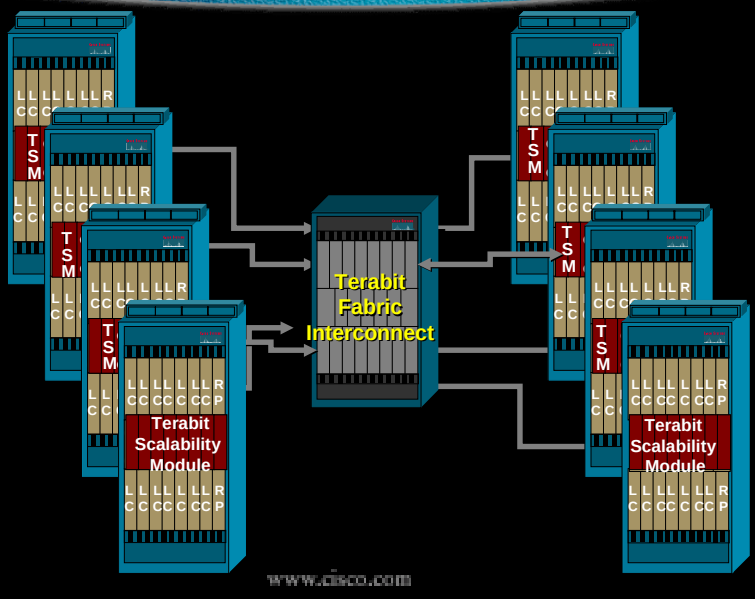
Terabit Scalability on Proven GSR Platform



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Agenda

- System Overview
- Switch Fabric
- Line-Card Architecture
- Interfaces
- Software

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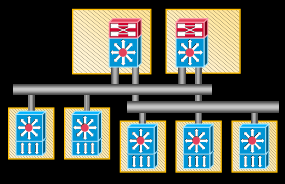
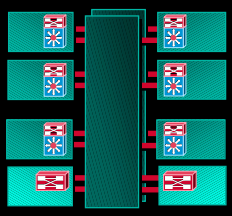
Architecture For Scaling to Gigabit Routing



Cisco 7500 Series

- Bus-based interconnect
- Centralized/distributed forwarding
- Software-based services support



Cisco 12000 Series

- Cross-bar switching fabric
- Fully-distributed forwarding
- Hardware-based services support

Cisco IOS Network Services

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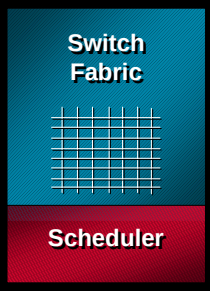
GSR Switch Fabric Architecture

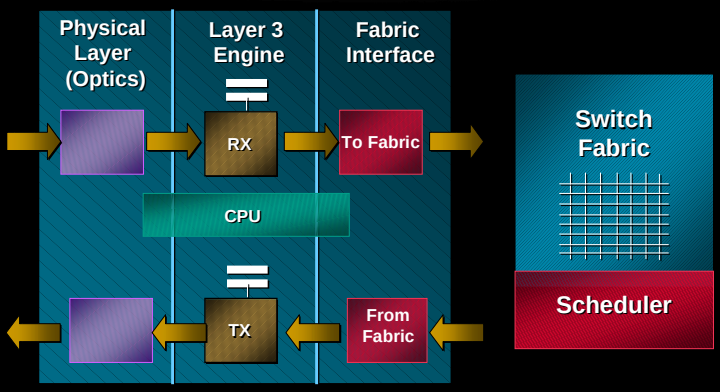
- Crossbar switch fabric
- Distributed over multiple cards: SFC and CSC
- Fabric supports redundancy with no data loss on switchover



System Capacity

- Five 1.25 Gbps serial lines per slot
- Switch capacity per slot = 4 x 1.25 Gbps/slot = 5 Gbps/slot
- Cisco 12008 system capacity:
  - 5 Gbps/slot x 8 = 40 Gbps
- Cisco 12012 system capacity:
  - 5 Gbps/slot x 12 slots = 60 Gbps
- Cisco 12016 system capacity (four sets):
  - 5 Gbps/slot/set x 4 sets = 20 Gbps/slot
  - System capacity = 20 Gbps/slot x 16 slots = 320 Gbps

Inherent Scalability of Cisco 12000 Architecture



- Modular linecard architecture separates fabric Interface functionality
- Scalable crossbar fabric with Virtual Output Queuing (VoQ)
- Scaling is a function of the fabric interface and crossbar units

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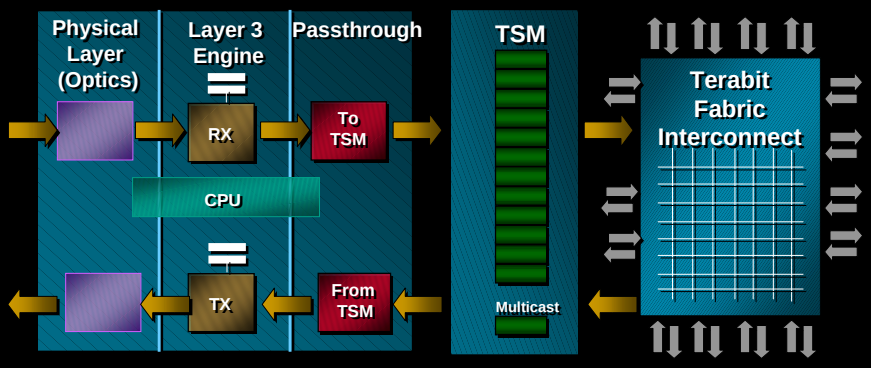
Terabit Scalability of Cisco 12000 Architecture

- Linecard has physical layer, Layer 3 engine and simple FIFO to TSM
- Terabit scalability modules implement the fabric interface and voqs
- Required to interface with 255 other slots in a five terabit system



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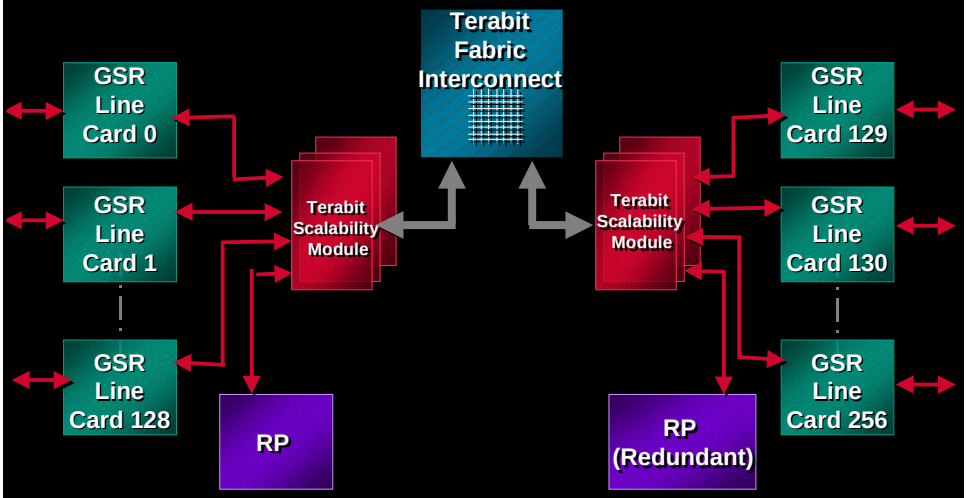
System Overview
Architecture for Scale and Performance



Note: All cards interconnected via extended M-Bus (not shown)

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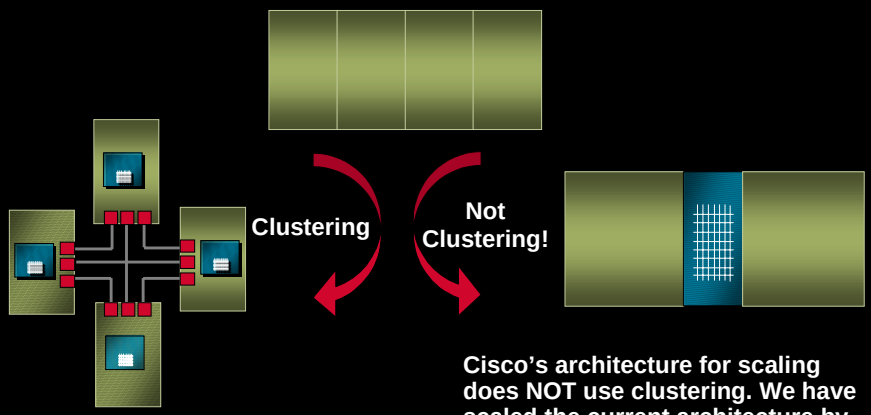
How Are We Scaling?
It's Not Clustering!



Clustering involves interconnecting lots of single shelf units with I/O ports

Cisco's architecture for scaling does NOT use clustering. We have scaled the current architecture by scaling the switch fabric and connecting to multiple I/O shelves

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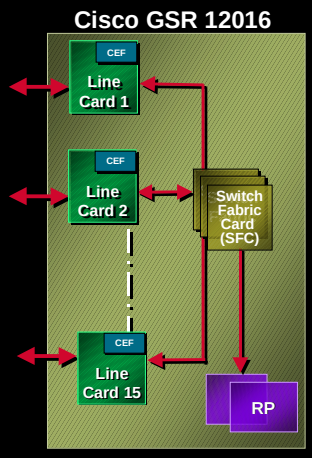
The Cisco 12000 Architectures Extends for Smooth Scalability to Terabits



Step 1: Cisco GSR 12016 standalone system

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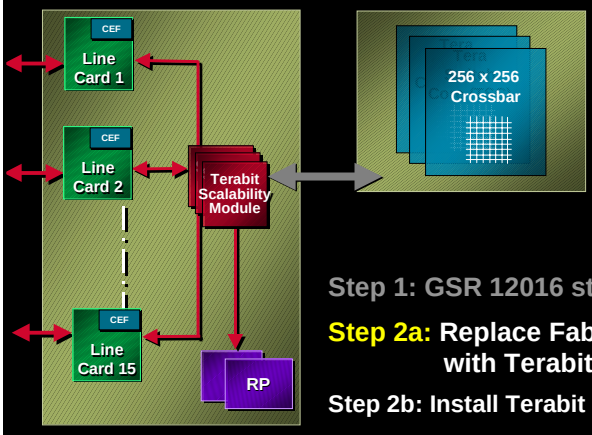
The Cisco 12000 Architectures Extends for Smooth Scalability to Terabits



Step 1: GSR 12016 standalone system

Step 2a: Replace Fabric Cards in GSR 12016 with Terabit Scalability Module

Step 2b: Install Terabit Fabric Interconnect

Step 3: Add up to 15 additional 12016 nodes

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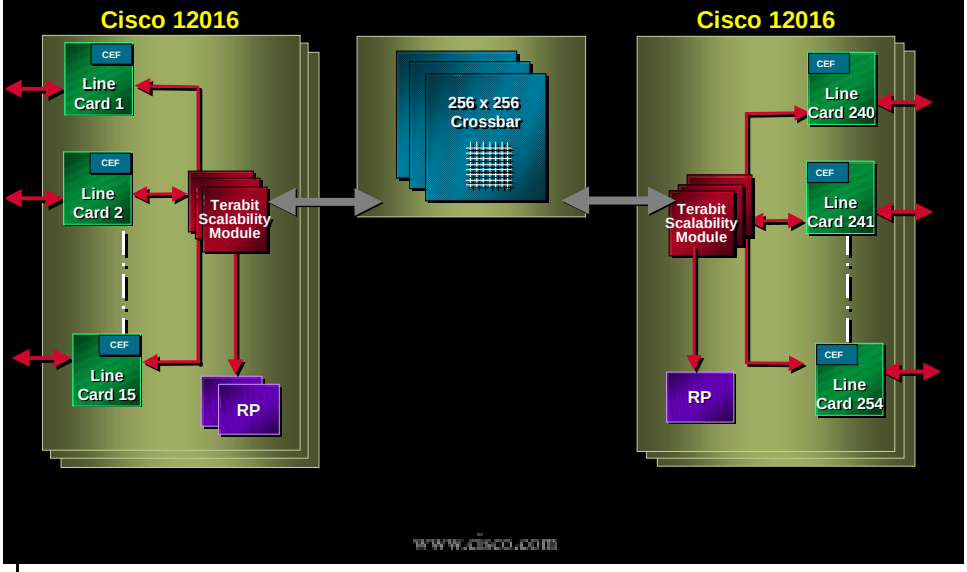
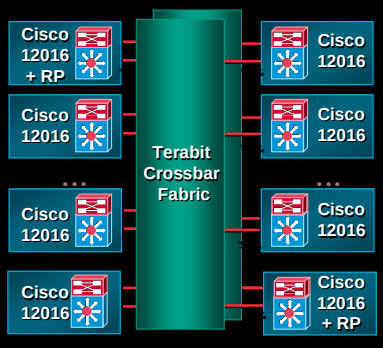
The Cisco 12000 Architectures Extends for Smooth Scalability to Terabits



Cisco 12000 Terabit System Architecture Availability Features

- Dual-route processors
- Distributed forwarding tables
- Switch fabric redundancy
- Redundant power supplies
- Redundant cooling systems
- Maintenance bus
- Line card protection



Agenda

- System Overview
- Switch Fabric
- Line-Card Architecture
- Interfaces
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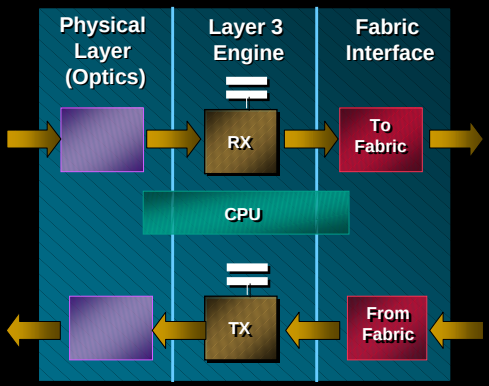
Line Card Architecture

- Line card components
  - Physical layer (optics, framer, SAR, etc.)
  - Layer 3 engine (router)
  - Fabric interface (line card to/from fabric interface)
  - Central processor (CPU)



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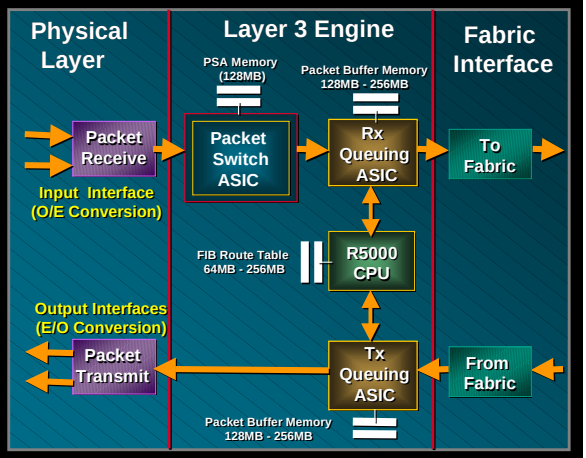
Line Card Architecture Packet Flow

- Physical layer
  - Optics, framer and packet extraction
- Layer 3 switching engine
  - PSA—ASIC-based forwarding
  - CPU—Processor-based forwarding
  - (ICMP, IP options and non IPv4 packets)
- Fabric interface
  - Tx/Rx from other LCs



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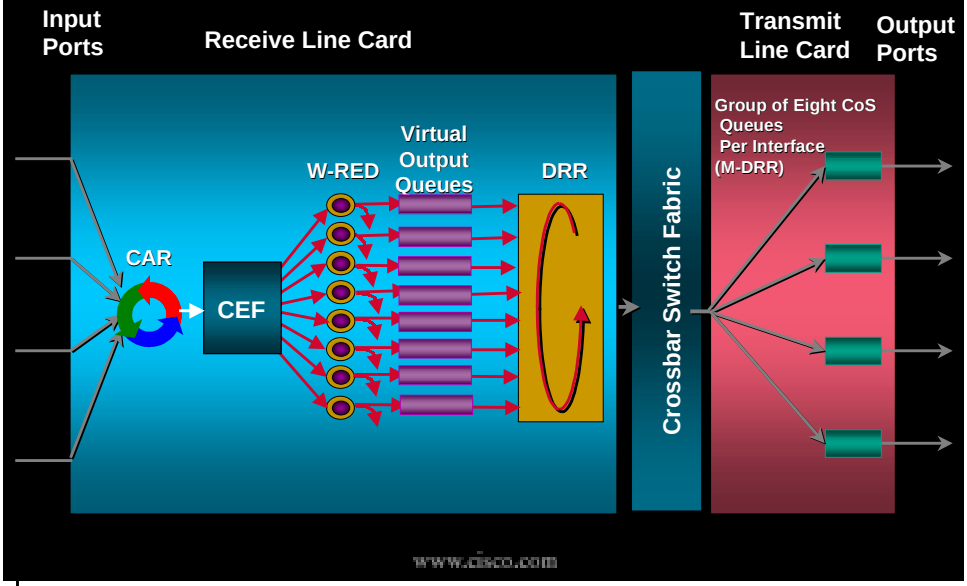
Putting it All Together



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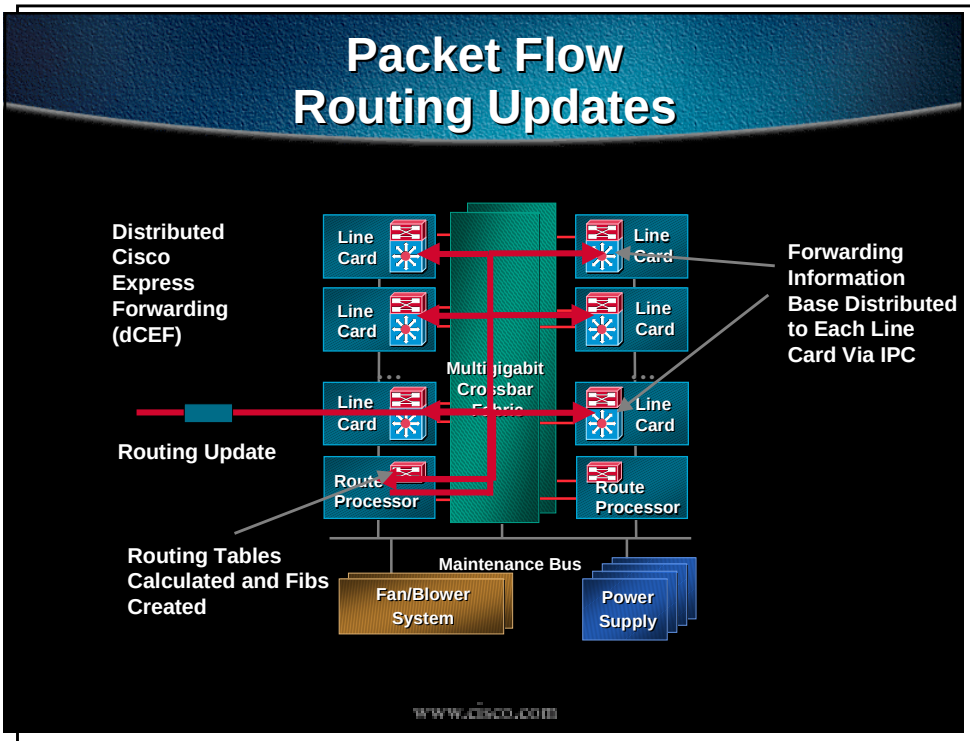
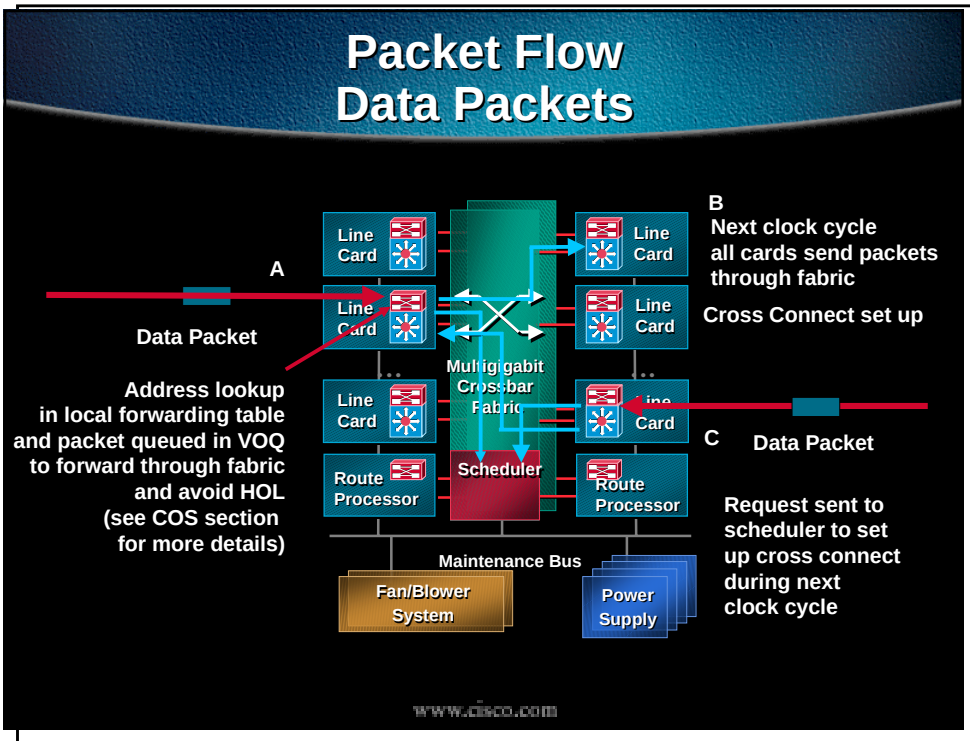
Packet Flow
Routing Updates



Packet Flow
Data Packets



Agenda

- System Overview
- Switch Fabric
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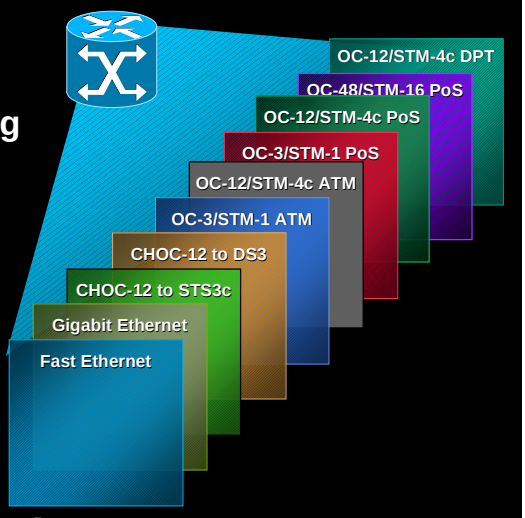
Cisco 12000 Interface Overview

- Industry leading interface breadth
- Optimized for queuing and forwarding
- Hardware assist for high-performance switching
- Silicon queuing engine for QoS
- Multiple optics



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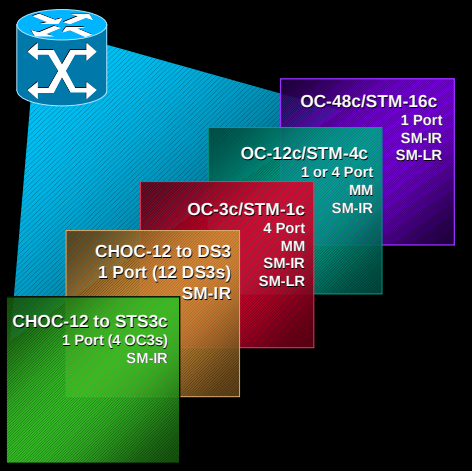
Packet over SONET/SDH Interfaces

- Cisco was first to market with PoS interfaces
- Offered in a variety of data rates (OC-3/STM1 OC-48/STM16)
- Multiple optics
  - Multimode (OC-3/STM1)
  - Single-mode intermediate Reach (OC12/STM4)
  - Single-mode long reach (OC-3/STM1 and OC-48/STM16)



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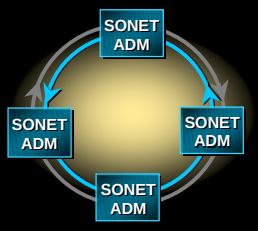
Packet-over-SONET/SDH Enables Flexible Connectivity



PoS Packet-over-SONET/SDH

- Runs over dark fiber, SONET, or WDM
- Enables transport “mix and match”

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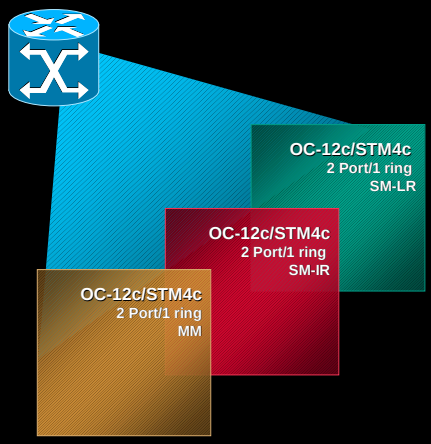
Dynamic Packet Transport (DPT) Interfaces

- Ring-based packet transport
  - Eliminate SONET/SDH equipment while retaining benefits
  - Maximize bandwidth efficiency
- Offered in OC-12c/STM4c rates on Cisco GSR 12000 and Cisco 7500
- Multiple optics
  - Multimode single mode
  - Intermediate reach
  - Single-mode long reach



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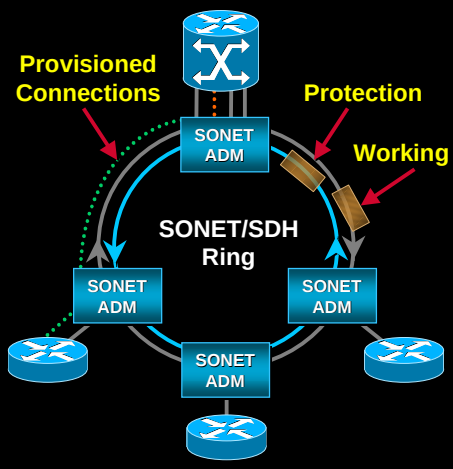
SONET/SDH-Based TDM Transport

- Accepted transport architecture
- Performance monitoring and self healing
- Expensive and inefficient for packets
  - Multiple equipment layers
  - Bandwidth inefficiency



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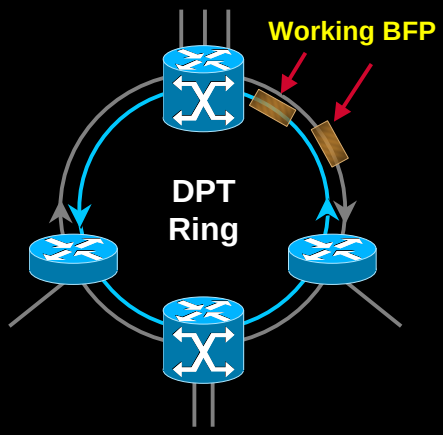
DPT Ring-Based Packet Transport

- Eliminate SONET/SDH equipment while retaining benefits
- Maximize bandwidth efficiency
- Extend rich IP functionality over metro area
- Minimize provisioning and configuration requirements



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DPT Multiplies Ring Bandwidth

	The Old Math SONET/SDH Ring	The New Math SRP Ring
Fiber BW	50% of Bandwidth Nailed-Up for Protection	Two Working Fibers
Statistical Multiplex	Per-Provisioned Connection	Two Big Fiber Pipes Access and Backbone Factors
Spatial Reuse	Static, Provisioned Time Slots	Dynamic, per Packet
Ring Wrap	Wrap onto Dedicated Protection Time Slots	Rehome via Topology Discovery and ARP

Bandwidth Efficiency Is Key Economic Driver

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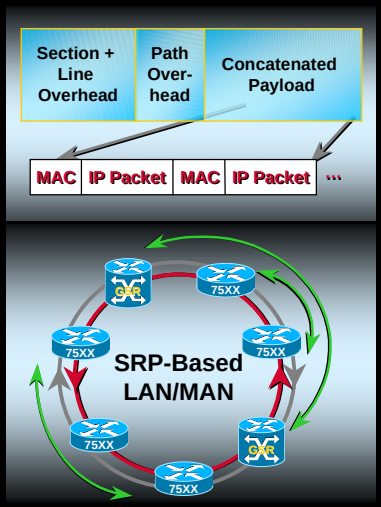
DPT Overview

- Layer 2 MAC protocol—SRP
- Uses SONET/SDH framing
- Bandwidth efficient
- Fairness algorithm
- Scalable
- Fast protection switching and service restoration
- Multicasting and priority



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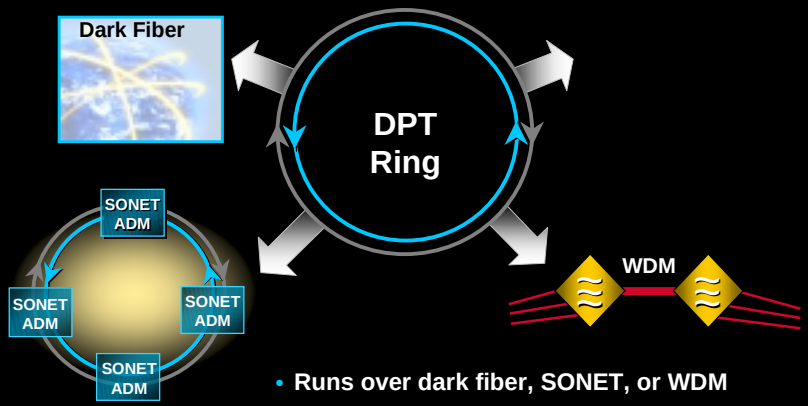
DPT Enables Transport Flexibility and Evolution



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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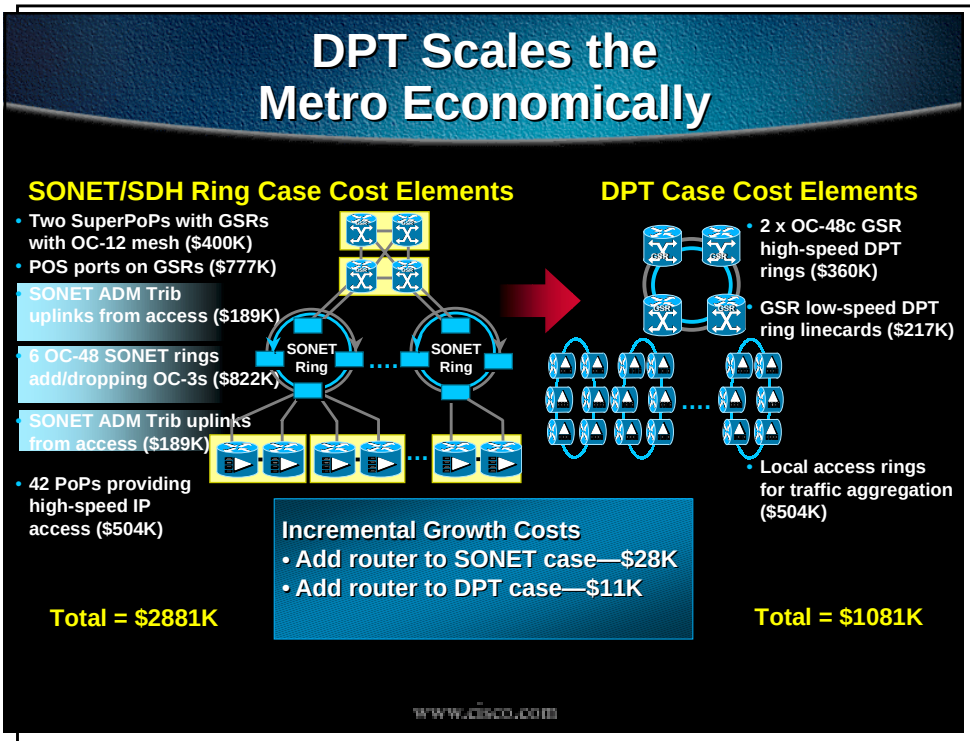
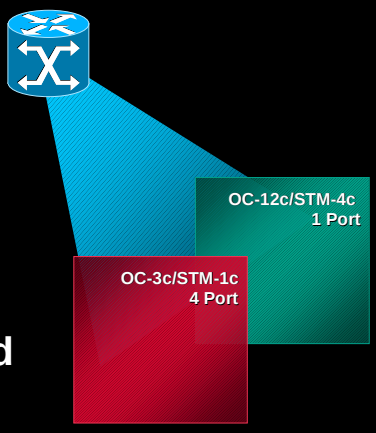
DPT Scales the Metro Economically



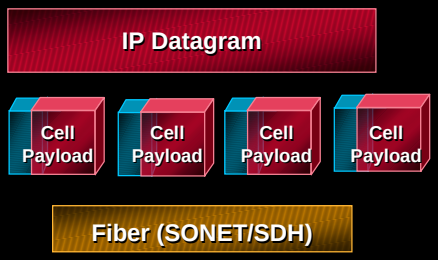
Asynchronous Transfer Mode (ATM) Interfaces

- Offered in a variety of data rates
  - OC-3/STM1
  - OC-12/STM4
- Used for aggregation and backbone connectivity



ATM on Cisco GSR 12000

- ATM interfaces allow GSRs to be connected to ATM switches/networks
- ATM Layer is used for transport
- Segmentation Assembly and Reassembly (SAR) functions incorporated on interface cards



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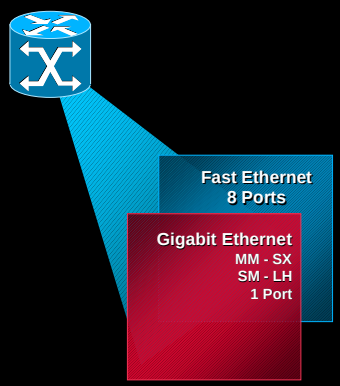
Ethernet Interfaces

- Gigabit Ethernet interface available
- 8-port FE available
- Used primarily for IntraPoP applications



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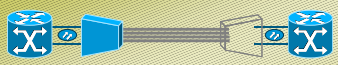
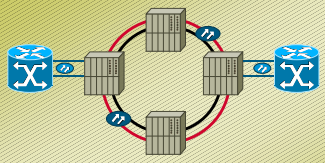
Backbone Applications



Connect to transponders in a WDM system (typically OC-12c/STM4c or OC-48c/STM16c)

Interconnect Cisco 12000 GSR directly over dark fiber with regenerators to extend the distance of LR interfaces (typically OC-48c/STM16c)



Connect to tributary interfaces on SONET/SDH muxes (OC-3c/STM1c to OC-48c/STM16c POS)

Cisco 12000 GSR backbone interconnected via VPs/VCs through public/private ATM network (OC-3c/STM1c or OC-12c/STM4c)

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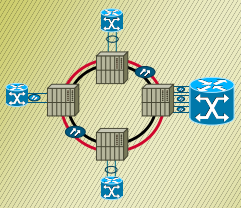
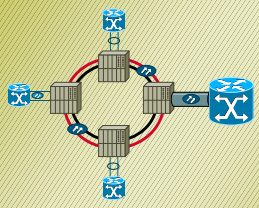
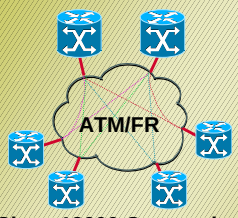
Aggregation Applications



Connect to Other Routers Via a SONET/SDH Access Ring, With Multiple Tributary Connections Between the Cisco GSR at the Pop—One for Each (OC-3c/stm1c to OC-48/stm16c)



Connect to Other Routers Via a SONET/SDH Access Ring, with Channelized Interface to Connect to Tributary Side to Aggregate Multiple Sites on to One Physical Interface (DS3 to OC-3/STM1 on CHOC-12/STM4)



Cisco 12000 Gsrs and Remote Routers Connect to Frame Relay/atm Network. Remote Routers Connect to Cisco 12000 GSR Interfaces. Allows Aggregation of Multiple Remote Locations into a Single Router Interface

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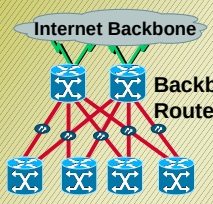
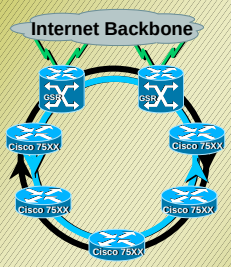
Intra-PoP Applications



Connect Edge Routers to Backbone Routers Within a Pop/data Center Using Dual Homed, Point-to-Point POS Connections

- OC-3c/stm1c
- OC-12c/stm4c
- OC-48c/stm16c



Connect Edge Routers to Backbone Routers Within a Pop/data Center Using DPT Ring

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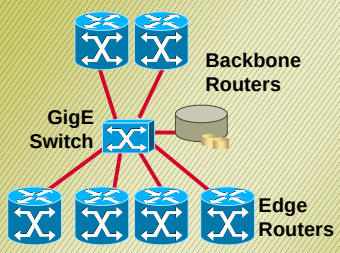
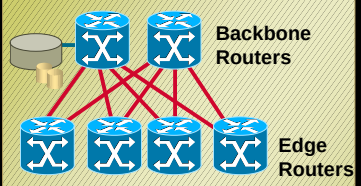
Intra-PoP Applications



Backbone Routers Connected to Edge Routers or Servers Directly Using Gigabit Ethernet Interfaces



Backbone Routers Connected to Edge Routers or Servers Using Gigabit Ethernet Interfaces Via an LAN Switch

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Agenda

- System Overview
- Switch Fabric
- Line Card Architecture
- Interfaces
- **Software**

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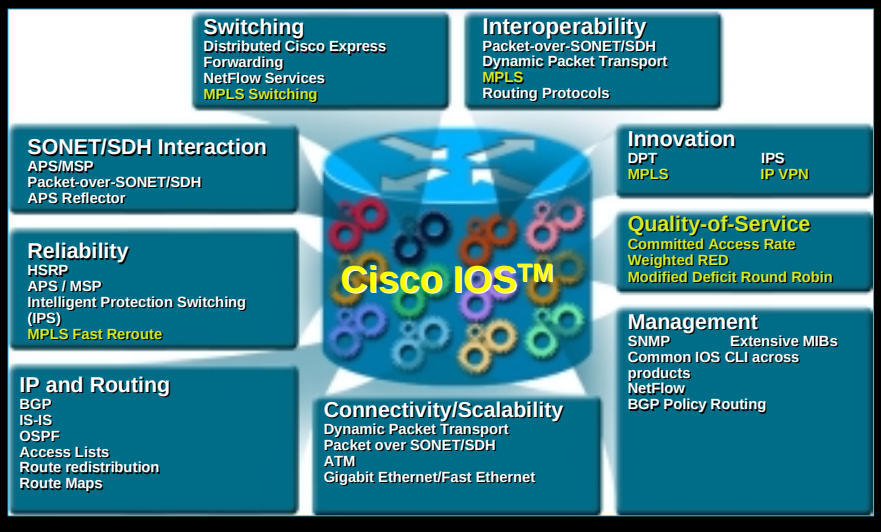
Cisco IOS Delivers Leading Intelligent Service



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Class of Service Features

- Admission control
  - Access lists (ACL), extended ACL (EACL)
- Packet classification/rate limiting
  - Committed access rate
- Congestion avoidance
  - Random early detection (RED)
  - Weighted random early detection (WRED)
- Queue scheduling
  - Deficit round robin (DRR)

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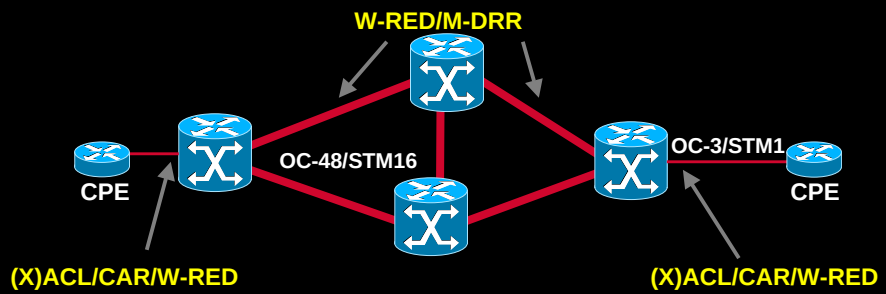
QoS/CoS—Edge vs. Core



- Separate QoS mechanisms for edge and core
- Admission control (X-ACL) and traffic classification (CAR) at the .edge of the network
- Congestion management (W-RED) and traffic class prioritization (M-DRR) in the core

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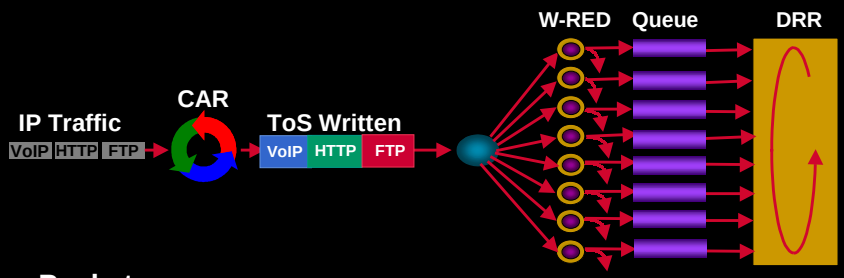
Class of Service Putting it All Together

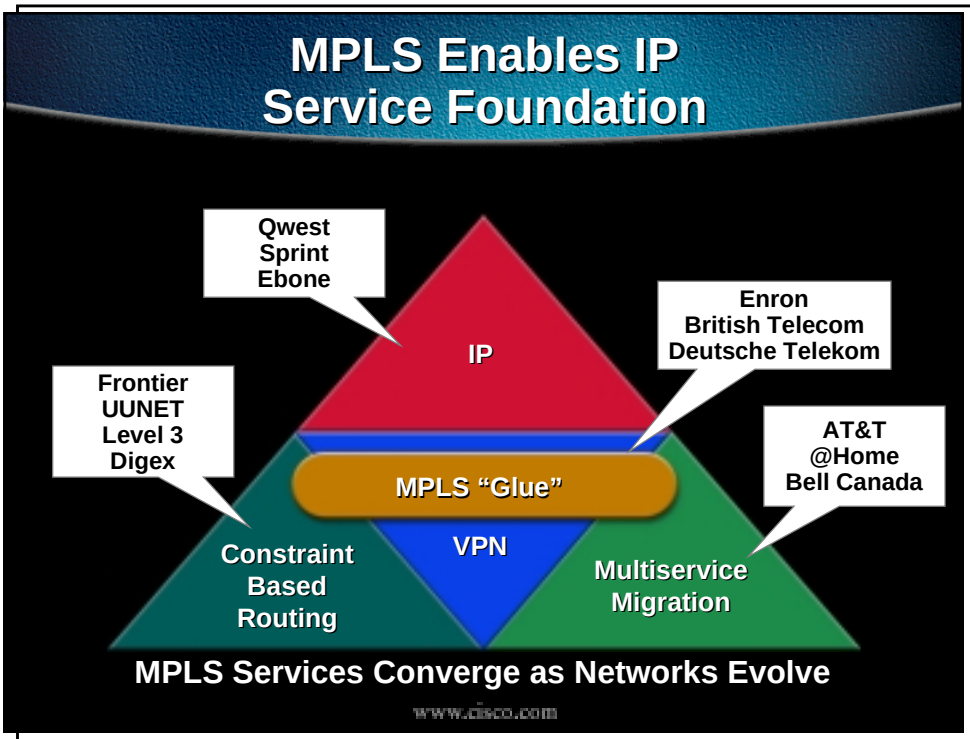


- Packets are:
  - Colored (ToS set) at Ingress
  - Classified and potentially discarded by W-RED (congestion mgmt)
  - Assigned to the appropriate outgoing queue
  - Scheduled for transmission by DRR

MPLS Feature Support

- Push/pop/swap performed at line rate
- Routing with resource reservations for traffic engineering and restoration
- VPN services functionality
- Support for MPLS CoS
  - Precedence mapping based on label precedence field
- Support for Frame Relay over MPLS services
- Support for MPLS multicast

MPLS Enables IP Service Foundation



MPLS Services Converge as Networks Evolve

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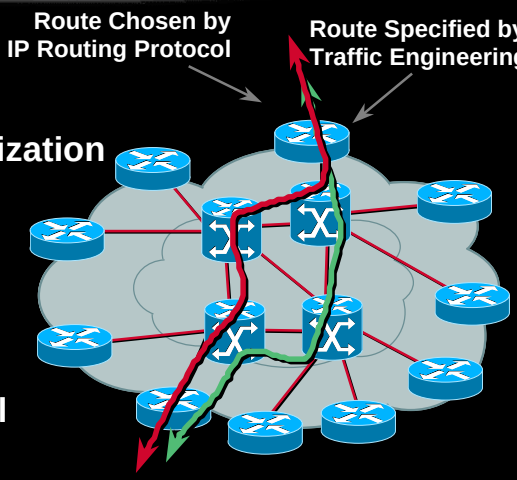
Traffic Engineering with MPLS



- Optimize network utilization
- Traffic follows prespecified path
- Path differs from normally routed path
- Analagous to a virtual circuit, but at IP level

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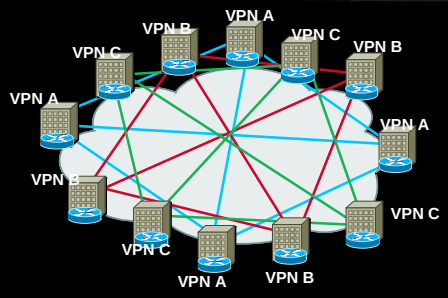
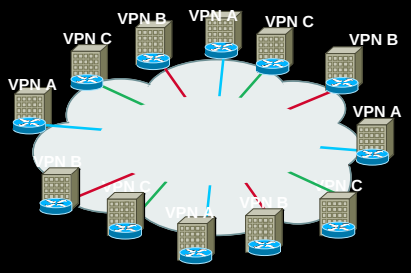
Benefits of Internet-Scale VPNs



Connection-Oriented
VPN Topology



Connectionless
VPN Topology

VPN Aware Network :
Vpns Are "Built in" Rather Than "Overlaid"

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Summary

Cisco 12000 Series

- Worldwide Internet-proven platform
- Extendable carrier-class architecture
- Premier IP routing software
- Scalability with stability and services
- Continuous technology innovation

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