# Metro IP Technology and Architectures

## Executive Summary

Tremendous technology developments are transforming the dynamics of the metropolitan-area network (MAN). These include the explosion of bandwidth in local-area networks (LANs), the deployment of low-cost Gigabit Ethernet and the growth of dense wavelength division multiplexing (DWDM) in long-haul wide-area networks (WANs). These developments are creating exciting new revenue opportunities for service providers that deliver services to the MAN.

The challenge service providers face today is how best to take advantage of these opportunities. Most existing metro networks have been built using Synchronous Optical Network/Synchronous Digital Hierarchy (SONET/SDH) equipment. Legacy SONET/SDH equipment, optimized for time division multiplexing (TDM)-based, voice-oriented traffic, has proven to be inefficient in handling the unique demands of data traffic based on IP.

To meet the demands of metropolitan IP-optimized networks, Cisco Systems has developed Dynamic Packet Transport (DPT) as part of the Cisco IP+Optical solution. DPT is a resilient packet ring (RPR) technology based on the Cisco developed Spatial Reuse Protocol (SRP), which combines the intelligence of IP routing with the bandwidth efficiencies and restoration requirements of optical rings. Deployed in environments as diverse as Internet service provider (ISP) points of presence (POPs), regional metro networks, and metro access networks, DPT-based networks are delivering dramatic advantages to service providers today, such as:

- Cost efficiency
- Legacy and enhanced IP services support
- Network robustness
- Future migration paths

### Cost Efficiency

Packet rings enable a new cost structure for service providers with:

- Decreased capital expenditures on expensive and packet bandwidth-inefficient TDM equipment such as SONET/SDH Add Drop Multiplexers (ADMs)
- Substantial increases in bandwidth efficiency as packet ring solutions take advantage of bandwidth multiplication capabilities such as statistical multiplexing on larger transport pipes and spatial reuse; thus, service providers maximize revenue for each unit of installed bandwidth
- New “plug-and-play” functionality and integrated network management capabilities that minimize time and expense associated with provisioning, configuring, and managing switching and transport networks


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### Extending Legacy and Enhanced IP Services

With packet ring technology, service providers can extend the range of revenue-producing and cost-saving services—such as voice and video over IP and virtual private networks (VPNs), as well as Internet access, wholesale Ethernet delivery, and transparent LAN services (TLS) to the MAN and WAN.

### Network Robustness

Packet ring technology also maximizes network reliability and availability by providing:

- Proactive performance and fault monitoring and fault isolation capabilities
- Intelligent protection switching with multilayer awareness for rapid IP service restoration

### Future Migration

DPT technology is a key component for defining and planning for IP-optimized, network architectures by:

- Providing structures such as SONET framing that take advantage of embedded base transport capabilities while providing the flexibility for efficient migration to new architectures
- Providing scalability to handle continued exponential growth in packet traffic and service requirements

## Introduction

Exponential growth in IP traffic volumes is associated with the following trends:

- Continued strong growth of Internet and enterprise intranet network usage
- Continued deployment of TLS and wholesale Ethernet services
- Rapid emergence of advanced IP services based on voice-over-IP (VoIP) and multicasting capabilities
- Cost-effective, high-bandwidth residential connectivity via xDSL and cable modem technologies

These trends have led to increasing demand for flexible, resilient, high-bandwidth, IP-based connectivity for service provider POPs, regional metropolitan area networks, and metro access environments.

Concurrently, SONET/SDH technology and ring architectures have been met with widespread deployment in the service provider environment and interest in the high-end enterprise marketplace. SONET/SDH rings have provided major innovations for the transport market and implement important capabilities such as leveraging fiber optic capacity at OC-48/STM-16 and OC-192/STM-64 line rates, proactive performance monitoring, and self-healing through automatic protection switching (APS). SONET/SDH rings have also provided a base for a major innovation in the area of high-speed data transport, namely packet-over-SONET (POS)/SDH tributaries running at data rates of 155 Mbps and higher.

However, entering the new world of ubiquitous high-speed IP connectivity and services, interconnection of IP routers via SONET/SDH equipment raises a number of important issues:

Bandwidth efficiency—SONET/SDH rings have dedicated protection time slots that reserve half of the ring bandwidth at all times (Figure 1). SONET/SDH rings are also TDM technology based on provisioning point-to-point connections that consume bandwidth regardless of the actual usage (for example, a 155-Mbps connection between router tributaries would reserve an STS3c regardless of the fact that usage varies widely over time).


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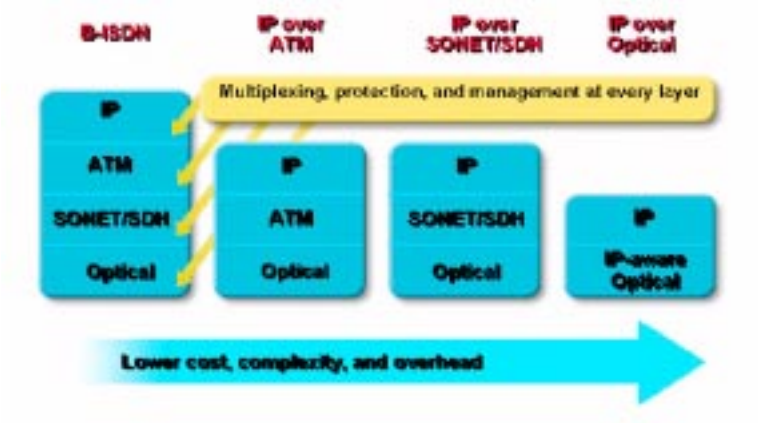
Figure 1 SONET/SDH Bandwidth Allocation


Cost and complexity—Various protocol stacks are being utilized or proposed to transport high-speed IP over fiber (Figure 2). Reducing the number of layers in the stack serves to minimize capital expenditures and decrease overhead to maximize useful transport bandwidth. This also minimizes complexity in provisioning, operations, fault detection and resolution, network planning and engineering, and network restoration. The four-layer model of the legacy TDM equipment includes IP for content-bearing traffic, Asynchronous Transfer Mode (ATM) for traffic engineering, a SONET/SDH transport network, and the optical layer. This model requires multiplexing, protection, and management at every layer. This functional overlap is not only bandwidth inefficient, it is also much more complicated, requiring multiple specialists in each area and dramatically driving up network operations cost. According to market researcher Probe Research, operations, accounting, management and provisioning (OAM&P) account for 49 percent of a service provider's network costs.

Figure 2 IP Transport Alternatives




The IP world has long recognized the value of ring-based architectures and extensive efforts have been made to develop solutions such as Token Ring and FDDI. However, these solutions were not able to meet the rapidly evolving IP transport and service delivery challenges summarized below:

- Tracking IP traffic volume and fiber bandwidth growth
- Maintaining high-bandwidth utilization—even under congested situations—and rapidly adapting to changing traffic patterns
- Accommodating large-scale ring topologies both in terms of the number of nodes and distances between the nodes, such as metropolitan and wide area rings, as well as intrabuilding rings
- Ensuring internodal fairness and avoiding bandwidth starvation
- Accommodating multiple traffic classes with varying bandwidth and delay requirements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- Recovering rapidly from faults including transport media and node failures
- Operating in plug-and-play mode for insertion, removal, and recovery of ring nodes with minimal configuration and provisioning requirements

To address the market needs and technological challenges described above, Cisco offers DPT—an innovative, packet-optimized, optical transport technology. DPT takes advantage of a new MAC layer protocol called the Spatial Reuse Protocol (SRP) and two new patent-pending algorithms:

- The SRP fairness algorithm (SRP-fa)
- Intelligent protection switching (IPS)

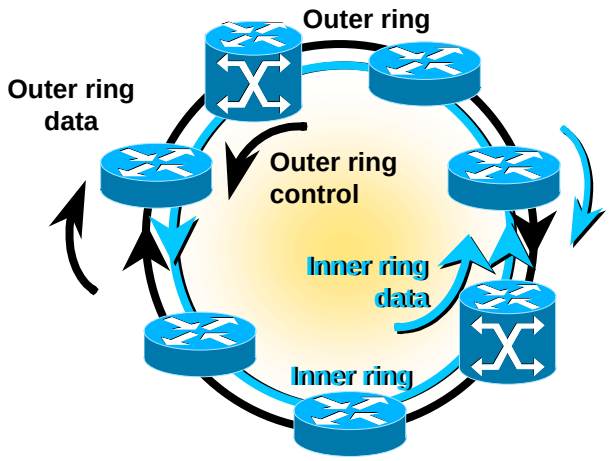
DPT makes possible a new generation of optical internetworking—fiber rings optimized for scalable, survivable IP packet transport at gigabit speeds.

## DPT Technology and Features

### DPT Ring Basics

The DPT ring consists of two counter-rotating fibers, each of which can be concurrently used to pass both data and control packets (Figure 3).

Figure 3 Dynamic Packet Transport Ring Basics




To distinguish between the two rings, one is referred to as the “inner” ring and the other as the “outer” ring. DPT operates by sending data packets in one direction (“downstream”) and by sending the corresponding control packets in the opposite direction (“upstream”) on the other fiber. Unlike SONET/SDH networks, which reserve half of the ring for protection, DPT uses both fibers concurrently, allowing the service provider to maximize revenue for each unit of installed bandwidth.

### Transport Flexibility and Evolution

DPT uses SONET/SDH framing and thus runs transparently over all key fiber transport infrastructure options including:

- Dark fiber
- Wavelength division multiplexing (WDM)
- SONET/SDH point-to-point and ring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This infrastructure transparency capability also allows DPT to be run in a hybrid environment. For example, a DPT ring can have several nodes connected by dark fiber while concurrently having several other nodes connected via SONET/SDH or WDM equipment. DPT rings can also be run entirely over SONET/SDH or WDM transport. In this case DPT functionality will maximize the bandwidth efficiency and IP functionality of the transport equipment.

The transparency capability discussed above provides a strategic migration path for service providers with an extensive embedded base of SONET/SDH equipment. IP services can be initially deployed using spare capacity on SONET/SDH equipment. Then, as the IP traffic grows it can be quickly and efficiently migrated to packet-optimized transport based either on dark fiber or WDM equipment. In addition, DPT takes advantage of the customer's pre-existing SONET/SDH knowledge base and network equipment test tools, which makes DPT deployment simple and cost effective from a network administration perspective.

Another major benefit of DPT's use of SONET/SDH framing is SONET and SDH both have well-understood and standardized requirements and thresholds for operations, administration, management, and provisioning (OAM&P). For example, B1, B2, and B3 error thresholds; IP digital cross connects (DCC); and SONET/SDH hierarchies (such as lockout, forced wrap, signal fail, and signal degrade) are all supported and have associated Simple Network Management Protocol (SNMP) traps. The SONET Management Information Base (MIB) RFC 1595/2558 is supported in all DPT systems. High-accuracy Stratm® clocks are used to ensure proper timing and synchronization.

Transport cross sections carrying more than 155 Mb of IP traffic should be carefully evaluated for migration to an IP optimized infrastructure in view of the superior economic value and functionality described above. Finally, while service providers consolidate TDM traffic growth on embedded base infrastructures (such as SONET/SDH) and set a limit on capital expenditures on this equipment, they also should rapidly migrate IP traffic to IP-optimized infrastructures and focus future capital expenditures on IP traffic and services—the key contributors to future revenue and profit growth.

### Optics Options

DPT products provide optics options to match key application requirements:

- Multimode and very short range (VSR) for intraPOP connectivity
- Single-mode intermediate reach (IR) and long reach (LR) for MAN and WAN interPOP and regional connectivity applications
- For ring applications with extended internodal distances (greater than 80 km), DPT ring products also integrate with the Cisco ONS 15104 OC-48/STM-16 bidirectional optical regenerator, and with third-party SONET/SDH regeneration equipment as well.

### Ring Bandwidth Multiplication

One of the key drivers of the cost effectiveness of the DPT ring is bandwidth efficiency. The ring uses several sophisticated capabilities described below to multiply available packet bandwidth, minimizing both initial capital and growth costs for the service provider.

Spatial reuse—SRP derives its name from the protocol's destination-stripping operation. Previous data-ring technologies such as Fiber Distributed Data Interface (FDDI) or Token Ring used source stripping. For example, packets circulated (and used bandwidth) around the entire ring before being removed by the sender. In contrast, SRP uses destination stripping—in which the destination node strips the packets from the ring and the full bandwidth on other segments of the ring is available for utilization by other packets. Thus, because each ring node can source packets onto the ring concurrently, the network maximizes ring bandwidth. Figure 4 provides an example of the benefits of spatial reuse. For example, in an aggregation


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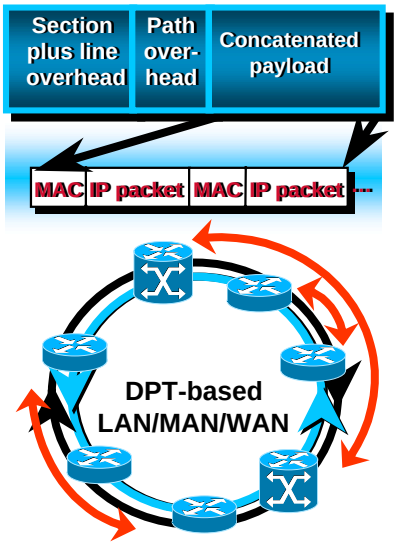
application where the traffic flows are largely between routers 4, 5, 6 and A and separately between routers 1, 2, 3 and B, spatial reuse can easily provide a (x2) bandwidth multiplier. Substantially higher gains can be derived in applications with more traffic locality and communities of interest (such as distributed VPN services).

Figure 4 Spatial Reuse




SRP fairness algorithm—Each node on the DPT ring executes a distributed copy of an algorithm called the SRP-fa designed to ensure that global fairness, local bandwidth optimization and bandwidth scalability (as described below) are delivered on all segments of the DPT ring.

- Global fairness—Each node gets its fair share of ring bandwidth by controlling the rates at which packets are forwarded onto the ring from upstream sources versus the rate at which packets are sourced by the ring node. The goal is to ensure that neighboring ring nodes cannot use all the bandwidth, creating either bandwidth starvation or excessive delay conditions.
- Local optimization—This ensures that ring nodes take advantage of the spatial reuse properties of the ring so they can utilize more then their fair share of bandwidth on local ring segments as long as other ring nodes are not adversely impacted due to traffic locality.
- Scalability—The SRP-fa is designed for highly efficient and scalable bandwidth control to handle rings with large numbers of routers (up to 128 nodes) running at high speeds (OC-48c/STM-16c and OC-192c/STM-64c) over widely distributed geographic areas.

Dual fiber—DPT rings are dual-fiber rings and both fibers can be concurrently used to pass working traffic (unlike SONET rings which have dedicated protection bandwidth). This results in a (x2) bandwidth multiplier.

Statistical multiplexing—Unlike TDM rings there are no time slots and no dedicated bandwidth or provisioned connections. Instead, DPT maximizes the ring's traffic-carrying capacity by providing statistical over-subscription with highly elastic burst-handling capabilities. Service providers also have the flexibility to engineer over-subscription factors to fit the ring application (such as access rings versus backbone rings).

### Robust Resiliency and Restoration

The DPT ring uses a set of features known as intelligent protection switching (IPS) to provide proactive performance monitoring, rapid self-healing, and IP service restoration after ring node or fiber facility events and faults.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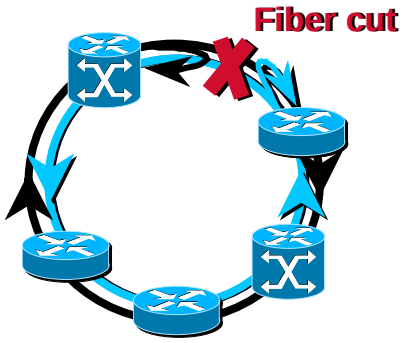
SONET/SDH rings provide a set of performance monitoring and self-healing capabilities called automatic protection switching (APS). Like APS, IPS provides:

- Proactive performance monitoring and fault detection and isolation via the SONET/SDH overhead bytes
- 50 ms self-healing via ring wrapping after Layer 1 fault and event detection
- Protection switching hierarchy for cases of multiple concurrent faults and events

Figure 5 Intelligent Protection Switching Self-Healing




However, unlike APS, IPS provides an additional set of packet-optimized capabilities including the following:

- Does not rely on SONET/SDH overhead bytes, allowing it to operate over non- SONET/SDH infrastructure (such as dark fiber and WDM)
- Provides 50 ms IP service restoration (including large rings with more than 16 nodes) without Layer 3 routing protocol reconvergence
- Requires no dedicated protection bandwidth (so you need not set aside 50 percent of ring bandwidth for protection) and optimally rehomes packet path selection after ring wraps
- Provides multilayer awareness by monitoring and handling events at Layers 1, 2, and 3 instead of just Layer 1 and providing additional packet-optimized capabilities such as packet pass-through mode to avoid ring wraps in the case of service-impacting Layer 3 events
- Does not require extensive provisioning and configuration operations involving ring node name or address and topology map construction through its plug-and-play operation

### IP Service Enablers

Several key features of DPT enable existing and developing IP services to be transparently extended over the MAN and WAN:

- Packet priority—Data packets are classified and scheduled as either high or low priority packets. Low-priority packets receive best-effort treatment on the ring. High-priority packets receive preferential treatment appropriate for services requiring delay and jitter controls or bandwidth guarantees (several representative services are discussed below)
- Multicasting—The DPT ring supports native IP multicasting and thus directly supports a host of current and future revenue-producing, enhanced services including multipoint information distribution and high-quality video broadcasting
- Bandwidth scalability—the DPT ring provides big, fat pipes (BFPs) with line-rate packet handling and bandwidth multiplication capabilities to minimize both packet loss and delay characteristics. The ring is designed to readily scale from the initial OC-12c/STM-4c product offerings to OC-48c/STM-16c and OC-192c/STM-64c rings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Finally, the SRP MAC layer cooperates with the extensive Layer 3 IP class of service (CoS) capabilities of the router (such as Committed Access Rate [CAR] precedence setting and rate controls, Deficit Round Robin [DRR] scheduling and bandwidth allocation, and Random Early Detection [RED] congestion controls) to provide Layer 3 service-level agreements.

### Plug-and-Play Operations

Unlike previous data ring or metro ring technologies (such as FDDI or SONET/SDH), DPT does not require extensive station management or lengthy manual procedures for configuration and provisioning. Instead, DPT capabilities minimize provisioning and configuration requirements for ring node insertion and removal and ongoing operations are handled via automatic procedures. These capabilities include:

- Globally unique, permanently assigned MAC layer addresses
- IPS procedures to rapidly insert new nodes and remove existing nodes from the ring
- IPS procedures for automatic self-healing (ring wrapping and unwrapping) around service impacting events
- Automatic topology discovery, Address Resolution Protocol (ARP), and routing procedures for information dissemination and dynamic packet path selection

### Network Management

DPT enables a comprehensive, integrated, SNMP-based management paradigm for both the packet switching (router) and packet transport (router and IP regenerator) network elements. In contrast, current networks require extensive (and expensive) separate management technology and procedures for the router and transport networks.

DPT network elements provide the following network management capabilities:

- RFC 1595 SONET/SDH MIB for events, alarms, current, and historical near-end and far-end performance monitoring information
- MAC layer packet counters for monitoring, debugging, and ring traffic engineering
- Topology MIB for node-by-node view of ring routing and status information

## DPT Applications

DPT technology enables a wealth of revenue-producing and cost-saving IntraPOP, regional metro, and metro access applications. These applications are discussed in the following sections. For more in-depth economic value analysis of these applications, refer to the “The Economics of Cisco’s Metro IP Solution” white paper.

### Building Hierarchy

DPT rings provide excellent support for both local access aggregation and MAN/WAN connectivity via ring hierarchy. Access aggregation rings are used to terminate large numbers of customer access pipes and aggregate them up to high-speed routers acting as traffic consolidation and distribution points. These routers are then interconnected via higher-speed distribution rings as well as providing mesh connectivity to the Internet backbone (Figure 6).


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Figure 6 Dynamic Packet Transport Ring Hierarchy


## IntraPOP Applications

A key issue facing large-scale IP service providers is robust, high-performance intraPOP connectivity. With the continued tremendous growth of IP traffic and the advent of DPT technology the SONET/SDH approach is suboptimal from both economic and functionality perspectives. Figure 7 shows a traditional intraPOP mesh architecture using POS interfaces.

Figure 7 SONET/SDH IntraPOP Connectivity

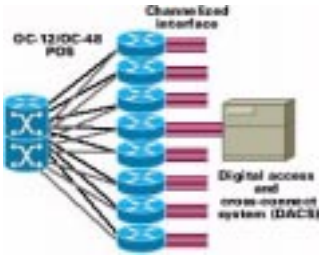


Figure 8 shows the same POP redesigned using DPT technology. In this example, Cisco 12000 Series Internet routers, equipped with DPT cards, are placed directly on the fiber.

Figure 8 DPT IntraPOP Connectivity


Clearly, the topology of the POP becomes much more simple with a DPT architecture, with only one ring for network administrators to manage, and fewer subnets to configure. In addition, the reduction in router inter-connect ports drastically reduces both the costs (see "The Economics of Cisco's Metro IP Solutions" white paper) and the maintenance associated with equipment.


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### Regional Metro Applications

Figure 9 shows a service provider network using DPT in the regional metro. In this example, Cisco 12000 Series Internet routers equipped with DPT cards are placed directly on the fiber. (Customers could also use the Cisco 7200 and 7500 series routers equipped with DPT cards in the regional metro area.) This flattens the network, eliminating multiple unneeded layers, DACSs and ADMs of the old TDM infrastructure.

Figure 9 DPT in the Regional Metro


Again, as in the IntraPOP, with a DPT architecture in the regional metro, there is only one ring for network administrators to manage, and fewer subnets to configure, as well as reduced costs and maintenance associated with equipment.

The key issues with POP and regional metro architectures include:

- Scaling to higher bandwidth (2.5 Gbps and 10 Gbps soon thereafter)
- Proactive performance monitoring and rapid self-healing and restoration in case of service-impacting faults
- Port count explosion due to dual homing requirements and growth in number of access routers
- High complexity resulting from multiple technologies and increased number of network elements (such as intermediate switches) and bandwidth-inefficient load-balancing schemes

The DPT ring provides an ideal solution for this challenging environment with the following characteristics:

- Scales bandwidth—DPT rings start at 622 Mb (before statistical multiplexing and spatial reuse factors are included) and readily scale to 2.5 Gb and 10 Gb solutions. A DPT ring also eliminates the heavy management overhead of creating point-to-point linkages as the ring scales. For example, with DPT running on a Cisco 12000 Internet Router, once the router has reached capacity, the service provider places another Cisco 12000 onto the DPT ring. This limits the impact on the other line cards on the other routers because each card is already connected to the ring. Therefore, no manual configuration is necessary to create the mesh between all of the line cards and the new router, which lowers operations costs dramatically and simplifies scalability.
- Reduces port counts—Each router simply requires a DPT ring card, not the creation of linkages between the new router and each affected line card on the existing aggregation routers. This is cumbersome to manage and difficult to scale. A typical POP may have 50 to 100, or more, aggregation routers. A POP may have multiple POS links at OC-3 through OC-192 on each aggregation router that are configured to connect into multiple routers. As bandwidth demands increase, the service provider must continue to add interface cards to a POS router.
- Eliminates the complexity associated with intermediate Layer 2 switching solutions
- Provides native proactive performance monitoring, dual homing, self-healing, and load-balancing capabilities
- Provides carrier-class performance with less than 50-ms restoration, SONET/SDH framing for OAM&P capabilities
- Offers future proof migration path for the current installed base of SONET/SDH networks, allowing customers to run legacy TDM services while adopting a new approach for data services. Over time, data traffic can be moved from running on top of SONET/SDH gear to running in parallel on a DPT network, making this solution suitable for greenfield providers (over dark fiber or WDM) as well as incumbent providers (over SONET/SDH)


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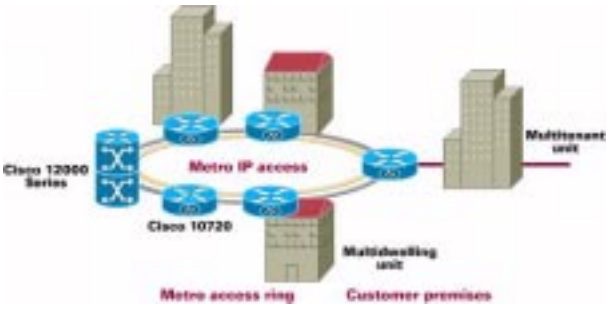
### Metro IP Access Rings

Another important application of DPT technology is shared metro or suburban IP access rings (Figure 10).

Figure 10 Metro Access Rings




These rings provide access to multiple tenants in high-rise business and residential buildings as well as suburban business parks. A router in the building basement provides access for multiple building tenants to TLS and wholesale Ethernet services, a range of robust, high-bandwidth IP services including VPNs and Internet access, and low cost, voice and video over IP services sold by aggressive IP service providers.

In the metro access area, providers are increasingly concerned about offering a range of connectivity options and enhanced IP managed services, while keeping equipment costs low due to the decreasing cost, and increasing the service possibilities, of Ethernet and IP in the metro area.

### Enhanced IP Service Examples

DPT technology enables enhanced IP services to be transparently extended over the metro area. Key examples include the following:

- VoIP and video over IP services—The DPT ring combines high-bandwidth, line-rate packet processing, priority scheduling, and Layer 3 IP CoS internetworking to provide excellent support for real-time services requiring tight delay and jitter controls such as voice and video.
- Protected services—Service providers can take advantage of the excellent proactive performance monitoring, protection switching, and fast service-restoration capabilities of IPS in combination with priority scheduling to offer cost-effective protected bandwidth services such as charging premium rates for protected T1/E1 and T3/E3 access services.
- IP VPN and managed bandwidth services—The DPT ring provides excellent support for multisite IP VPN services including high-bandwidth interbuilding connectivity, scheduling support for mission-critical applications and high-speed Internet access services, and MAC layer-based address filtering for security. The ring also provides a nice upgrade from SONET/SDH-based managed bandwidth services by providing lower infrastructure costs for service providers and cost-effective, flexible, high-bandwidth packet transport support for large corporate customers.

The need for service providers to deploy increasingly scalable transport solutions has resulted in widespread deployment of optical technologies in the wide area, and now metro area optical solutions and IP ring topologies are becoming more prevalent.

MANs or metro-based access rings are becoming more and more common for ISPs and competitive local exchange carriers (CLECs) as they begin to provide IP-based transport services. For ISPs, interexchange carriers (IXCs) and CLECs, a typical MAN will connect through the existing metro SONET/SDH and DWDM-based transport infrastructure. This fits well with ring networks already installed in the metro areas by competitive access providers (CAPs) and CLECs.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New providers are beginning to bypass the SONET/SDH infrastructure and connect routers directly to the fiber using DPT. This is a cost-effective solution for newer IP transport providers who want to offer customers the ultimate service—Ethernet access via intelligent edge routers— without having to give up SONET-like reliability.

New IP CLEC players who want to displace the current operators are focusing purely on an IP infrastructure. They need to be very efficient from an infrastructure perspective. Specifically, they need to minimize the number of network elements and optimize their network operations. The only way for these operators to accomplish this objective is to extend IP to the edge of the network or to the building over a fiber infrastructure. Of course, DPT solutions are suitable not only for greenfield carriers (over dark fiber or WDM) but incumbent carriers (over SONET/SDH) as well. DPT offers a migration path for the current installed base of SONET/SDH equipment whereby the provider can continue to run legacy TDM services while adopting a new approach for data services. Over time the data portion can move from running on top of SONET/SDH to running in parallel.

## Summary

Given the inherent limitations of SONET/SDH and switched Gigabit Ethernet everywhere solutions as transport infrastructures for delivering IP services to the metro area, a new IP transport alternative is needed. That alternative is DPT. DPT clearly offers the most scalable, reliable, and simple architecture for IP services including not only TLS and wholesale Ethernet, but IP VPNs, VoIP, video over IP, and more. DPT does not require a wholesale upgrade. Rather it allows service providers to limit their TDM expenses and shift to packet-based investments with minimal disruption to their existing architecture and business model. Over time, TDM transport will be phased out as voice becomes just another application on the metro IP network, running on a DPT architecture. Technology and the service provider business model will dictate the timing of such a drastic shift, and while it may still be off in the future, the DPT metro IP network is fully optimized for the total shift toward packet transport that is undeniably coming.

## DPT Products

### Cisco 7200 and 7500 Series DPT Line Cards

The industry's first OC-12c/STM-4c RPR solutions for Internet routing platforms, the DPT port adapter is a dual-width OC-12c port adapter that provides a shared IP over SONET capability in a Cisco 7200 Series, Cisco 7200 VXR, or Cisco uBR7200 Series router. The DPT port adapter is available in three models, including PA-SRP-OC12MM (multimode fiber), PA-SRP-OC12SI (single-mode fiber, intermediate reach), and PA-SRP-OC12SL (single-mode fiber, long reach). The DPT port adapter provides the Cisco 7200 Series, Cisco 7200 VXR, or Cisco uBR7200 Series router with two SC duplex ports. Each SC duplex port provides the physical connection to an adjacent device in a DPT ring. The DPT port adapter is designed for deployment in SONET OC-12 DPT rings. DPT rings can also be connected to SONET ADMs, thus allowing for the creation of small or very large DPT rings.

The DPT ring interface processor for Cisco 7500 Series routers occupies one full router chassis slot and provides one interface port. The interface processor is also available in a choice of multimode or single-mode optics. The DPT interface processor provides powerful hardware-based speed mismatch and adaptation features such as receive-side payload buffering and priority-based queuing. The DRR algorithm is adopted for preferential handling of high-priority packets. The DPT interface processor also provides hardware-based RED capabilities for proactive congestion management. These powerful features enable lower-speed devices to participate on higher speed rings such as DPT-OC-12c/STM-4c and DPT-OC-48c/STM-16c.

### Cisco 12000 Series Internet Router DPT Line Cards

The industry's first OC-12c/STM-4c and OC-48c/STM-16c RPR solutions for Internet routing platforms, the DPT ring interface processors for Cisco 12000 Series routers occupy one full router chassis slot and provide one interface port. The interface processors are available in OC-12c/STM-4c or OC-48/STM-16c, both in multimode or single-mode options.


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### Cisco 10720 Internet Router

The Cisco10720 (Figure 11), provides a shared IP ring over a SONET/SDH, dark fiber, or DWDM capable infrastructure in the metropolitan area, and is located predominantly in the basement of multitenant business dwellings. The Cisco 10720 connects to the rest of the regional metro and core network generally through Internet routers—specifically Cisco 12000 Series routers. The Cisco 10720 offers high-speed services including data, voice and video integration on top of a unified IP infrastructure that is scalable, reliable, simple, and cost effective.

Figure 11 Cisco 10720 Internet Router

### Cisco ONS 15104 Optical Regenerator

The Cisco ONS 15104 is a bidirectional OC-48/STM-16 regenerator that transmits optical signals over the longest distance possible. It supports single-mode long reach optical-fiber transmission when connected to an OC-48/STM-16 line card that is installed in a Cisco 12000 Series Internet Router.

### Cisco ONS 15194 IP Transport Concentrator

The Cisco ONS 15194 is a high-density, high-performance IP transport management platform offering carrier-class IP transport services within the POP, regional metro, and metro access rings. Designed with support for OC-48/STM-16, the Cisco ONS 15194 is a superior scaling and management solution for RPR and POS networks, and is also a central management point.

### DPT Product Evolution

DPT constitutes a hugely significant technological innovation and Cisco has aggressive plans to evolve the technology to continue to provide major improvements in both functionality and cost effectiveness to meet customer needs.


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Corporate Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-4000
800 553-NETS (6387)
Fax: 408 526-4100

European Headquarters
Cisco Systems Europe
11, Rue Camille Desmoulins
92782 Issy Les Moulineaux Cedex 9
France
www.cisco.com
Tel: 33 1 58 04 60 00
Fax: 33 1 58 04 61 00

Americas Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-7660
Fax: 408 527-0883

Asia Pacific Headquarters
Cisco Systems Australia, Pty., Ltd
Level 17, 99 Walker Street
North Sydney
NSW 2059 Australia
www.cisco.com
Tel: +61 2 8448 7100
Fax: +61 2 9957 4350

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