Solution Overview

Enabling VoIP: Data Considerations and the Evolution of Transmission Network Design

Introduction

Years ago when voice services transitioned from using analog to digital circuits, the new technology demanded significant changes in customer networks. Voice services are again undergoing a major transition, this time from fixed digital circuits to voice-over-IP (VoIP) networks. Both service providers and private enterprise customers understand the cost and technological benefits of a converged network that supports all types of traffic. Customers, long appreciative of the economics and scalability of Ethernet technology in their LANs, are today expanding Ethernet services not only for their data traffic, but also for their voice traffic.

This paper is for service providers, enterprises, and IT professionals who are looking to deliver voice services or implement voice as an application in their network. It offers a detailed overview of voice transmission, quality requirements, VoIP efficiencies, and the role that Cisco® optical solutions can play in supporting voice systems, whether digital time-division multiplexing (TDM), VoIP, or a transition from one to the other.

Voice Transmission: TDM to Packet

Most service providers and many medium to large-sized enterprises currently use one or more SONET/SDH networks as part of their backbone core for data transmission. These SONET/SDH networks have their roots in TDM. Although TDM services continue to be widely deployed to support both voice and data applications, customers increasingly favor Ethernet services for both their voice and data needs. Two major advantages include:

- Ethernet's wide acceptance
- Greater efficiency, flexibility, and scalability compared to fixed, TDM-based circuit-switched networks

This is pressuring network designers and architects to increase their Ethernet service offerings and to better utilize these services by having them support voice, video, and high-speed data applications. Because of the predominance of these TDM-based SONET/SDH networks, there is tremendous advantage to implementing advanced data applications and services across these existing networks when possible.

"In a clear demonstration of wide acceptance, 77 percent of the service provider employees surveyed said they had already deployed VoIP networks. Another 13 percent expect to deploy them in the next 12 months." – Light Reading.com

Quality of Service

QoS Explained – A Critical Requirement for VoIP

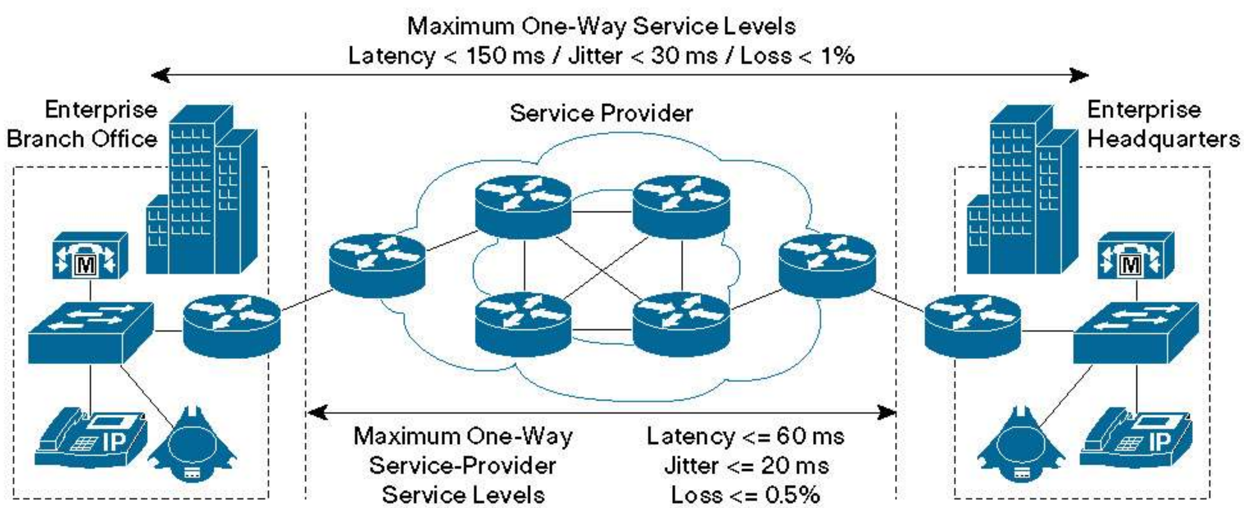
In the TDM world, one standard voice circuit, known as a digital signal, level 0 (DS-0) uses 64 Kbps of bandwidth and adheres to certain quality requirements. These quality requirements reflect elements of circuit quality degradation, and include signal distortion, signal delay, signal level (as measured in decibels), and signal-to-noise ratio. Consumers have become accustomed to very high audio quality in voice circuits, and intolerant of anything less. There are 24 DS-0s in a digital signal, level 1 (DS-1) circuit.

In a packet-based network, the performance of any application (such as e-mail, Web browsing, VoIP, etc.) depends on the quality of service (QoS) assigned to a particular application. To support voice traffic as a data application, equivalent quality standards must be met for acceptable voice services (see Figure 1). Specifically, four factors – bandwidth, latency, jitter, and packet loss – define QoS. How each is managed determines how effectively the network supports Ethernet (and VoIP) traffic. A fifth factor, protection switching, is also an important consideration to help protect critical customer traffic.

- **Bandwidth** – The size of the pipe (for example, 64 Kbps up through 10 Gbps). Several compression/decompression (codec) algorithms recommended by the ITU-T can reduce the amount of bandwidth needed for one VoIP circuit to a fraction of the traditional 64 Kbps of bandwidth reserved for calls in circuit-switched networks.
- **Latency or delay** – The length of the pipe – how long it takes for a packet to travel through the network. A 200-millisecond (ms) delay for e-mail or Web browsing will probably go unnoticed, but a voice caller using the same network will notice this delay. Maximum latency should be less than 150 ms total, end to end.
- **Jitter or delay variation** – The perceived variation in the length of the pipe – the regularity with which packets arrive at their destination. Jitter buffers can temporarily delay incoming packets to compensate for some delay variations, but buffers have limits and excessive buffering can result in additional latency. Maximum jitter should be less than 30 ms total, end to end.
- **Packet loss** – The leak in the pipe. Packets can get lost because of collisions on the LAN, overloaded network links, or for many other reasons. Loss of packets beyond a very small percentage will degrade voice quality. Note that VoIP uses the User Datagram Protocol (UDP), which, unlike TCP used in data applications, does not provide retransmission of packets. Maximum packet loss should be less than 1 percent total, end to end.
- **Protection switching** – Identifying and replacing the broken pipe. The defined circuit-protection switching requirement for SONET and SDH standards is 60 ms (10 ms for fault detection plus 50 ms for protection switching). TDM circuits with failures exceeding this parameter are subject to being dropped. To enable reliable Ethernet traffic transmission, alternative traffic-protection schemes (Resilient Packet Ring [RPR], Rapid Spanning Tree, etc.) must be able to meet or exceed this same requirement.

Figure 1

Minimum QoS Standards for Implementing VoIP Solutions



Managing QoS

Cisco Systems® provides a complete toolset of QoS features and solutions to address the diverse needs of voice, video, and multiple classes of data applications. Cisco QoS technology allows complex networks to control and predictably service a variety of business-critical applications and traffic types. Network managers can effectively control bandwidth, delay, jitter, and packet loss with these mechanisms. Many parts of this QoS toolset are built into Cisco IOS® Software, and run at the IP layer (Layer 3 of the 7-layer OSI model) on Cisco routers, Layer 3 switches, and optical equipment. Other parts of the toolset are based on the data-link layer (Layer 2) on Cisco Catalyst® switches and in Cisco optical infrastructure equipment. Cisco optical equipment helps preserve QoS throughout a service provider's network.

The Cisco QoS Toolset

The Cisco QoS toolset includes the following tools:

Classification and Marking Tools

The first element to a QoS policy is to identify and classify the traffic that is to be treated differently. Following classification, marking tools can set an attribute of a frame or packet to a specific value. QoS policies can be applied to traffic after it has been positively classified. To avoid the need for repetitive and detailed classification at every node, packets can be marked according to their service levels. Marking tools can be used to indicate respective priority levels by setting attributes in the frame or packet headers, so that detailed classification does not have to be recursively performed at each hop. Within a service provider network, marking is typically done at either Layer 2 or Layer 3, at the edge of the network, using IEEE standard 802.1Q/P class of service (CoS), the IP type of service (ToS) byte, differentiated services code points (DSCPs) and per-hop behaviors (PHBs), and IP explicit congestion notification (IP ECN).

Policing and Markdown Tools

Policing tools (policers) determine whether packets are conforming to administratively defined traffic rates and take action accordingly. Such action could include marking, re-marking, or dropping a packet.

A basic policer monitors a single rate. Traffic equal to or below the defined rate is considered to *conform* to the rate, while traffic above the defined rate is considered to *exceed* the rate. On the other hand, the algorithm of a dual rate policer is analogous to a traffic light. Traffic equal to or below the principal defined rate (green light) is considered to *conform* to the rate. An allowance for moderate amounts of traffic above this principal rate is permitted (yellow light) and such traffic is considered to *exceed* the rate. However, a clearly defined upper-limit of tolerance is set (red light), beyond which traffic is considered to *violate* the rate.

Scheduling Tools

Scheduling tools determine how a frame or packet exits a device. Whenever packets enter a device faster than they can exit it, such as with speed mismatches, then a point of congestion, or bottleneck, can occur. Devices have buffers that allow for scheduling higher-priority packets to exit sooner than lower-priority ones, which is commonly called queuing.

Queuing algorithms are activated only when a device is experiencing congestion and are deactivated when the congestion clears. The main Cisco IOS Software queuing tools are Low Latency Queuing (LLQ), which provides strict priority servicing and is intended for real-time applications such as VoIP and video, and Class-Based Weighted Fair Queuing (CBWFQ), which provides bandwidth guarantees to given classes of traffic and fairness to discrete traffic flows within these traffic classes.

Link-Specific Tools

These tools include:

- Shaping tools, which typically delay excess traffic above an administratively defined rate using a buffer to hold packets and shape the flow when the data rate of the source is higher than expected.
- Link fragmentation and interleaving tools, which reduce the serialization delay caused by the excessively long time to place large data packets on the wire – time that can easily cause a VoIP packet to exceed its delay and jitter threshold.
- Compression tools such as compressed Real-Time Protocol (cRTP), which minimize bandwidth requirements and are highly useful on slow links. cRTP is discussed in more detail later in this document.
- Transmit ring (Tx-Ring) tuning which ensures that a frame is always available when the interface is ready to transmit traffic, so that link utilization is driven to 100 percent of capacity.

AutoQoS Tools

AutoQoS tools are Cisco IOS Software mechanisms that automatically reduce the complexity required to deploy effective QoS in a network.

Call Admission Control Tools

After performing the calculations to provision the network with the required bandwidth to support voice, video, and data applications, network designers must ensure that voice or video do not oversubscribe the portion of the bandwidth allocated to them. While many QoS features are used to protect voice from data, Call Admission Control (CAC) tools are used to protect voice from voice and voice from video. CAC tools are generally local, measurement, or resource-based and essentially restrict the number of calls or video streams transiting a network. This is particularly important in the low-bandwidth environments typical in WAN connections.

More Details on the QoS Toolset

Details regarding the use of the Cisco QoS toolset are beyond the scope of this document. Interested readers should refer to the *Enterprise QoS Solution Reference Network Design Guide* located at: http://www.cisco.com/warp/public/779/largeent/it/ese/srnd.html.

IP SLA

IP SLA is a Cisco IOS Software feature set to assure IP service levels. Using IP SLA, service providers can measure and provide service-level agreement (SLA) information to their customers. Enterprise customers can verify service levels, verify outsourced SLAs, and understand network performance for new or existing IP services and applications. IP SLAs use unique metrics and methodologies to provide highly accurate, precise service-level assurance measurements.

Depending on the specific IP SLA operation, statistics are monitored within the Cisco device and stored in both command-line interface (CLI) and Simple Network Management Protocol (SNMP) MIBs. The packets have configurable IP and application-layer options such as source and destination IP address, UDP/TCP port numbers, a ToS byte (including DSCP and IP prefix bits), VPN routing/forwarding instance, and URLs. The statistics include values for:

- Delay
- Packet loss
- Jitter
- Packet sequence connectivity
- Path

- Server response time
- Download time

IP SLAs use generated traffic to measure network performance between two networking devices, such as routers. IP SLAs start when the source device sends a generated packet to the destination device. After the destination device receives the packet, and depending on the type of IP SLA operation, the device will respond with time-stamp information for the source to make the calculation on performance metrics. An IP SLA operation is a network measurement to a destination in the network from the source device, using a specific protocol such as UDP for the operation.

Because IP SLA is accessible using SNMP, it also can be used in performance-monitoring applications for network management systems (NMSs) such as CiscoWorks and the CiscoWorks Internetwork Performance Monitor (IPM). IP SLA notifications also can be enabled through Systems Network Architecture (SNA) network management vector transport (NMVT) for applications such as NetView.

For general IP SLA information, refer to the Cisco IOS IP Service-Level Agreements technology page at: http://www.cisco.com/en/US/products/ps6602/products_ios_protocol_group_home.html.

For information on configuring the Cisco IP SLA feature, see the "Network Monitoring Using Cisco Service Assurance Agent" chapter of the *Cisco IOS Configuration Fundamentals Configuration Guide, Release 12.2.* at: http://www.cisco.com/en/US/products/sw/iosswrel/ps1835/products_configuration_guide_chapter09186a008030c773.html.

Ethernet Advantages in Optical Networks for Voice

Bandwidth Flexibility

Because of statistical multiplexing efficiencies, Ethernet circuits offer immediate advantages over fixed circuits. But when Ethernet was introduced to SONET/SDH, there was also some inefficiency introduced into the optical network's capacity. For example, a 100-Mbps Ethernet service required a 155-Mbps OC-3/STM-1 optical channel.

As Ethernet over SONET/SDH evolution advanced, solutions for these challenges have helped to develop further flexibility for Ethernet-based circuits and services. These solutions are outlined as follows:

- *Virtual concatenation (VCAT)* allows users to provision data circuits in increments more suitable for Ethernet (10/100/1000 Mbps), as opposed to standard bandwidth units used in SONET and SDH, which were designed entirely for fixed-bandwidth voice circuits. Using low-order VCAT and high-order VCAT, service providers can now provision circuits in 1.5-Mbps or 50-Mbps increments, respectively, and customize Ethernet connections to match customers' bandwidth needs.
- *Link capacity adjustment scheme (LCAS)* allows service providers to dynamically adjust the bandwidth of a circuit with no impact on existing service. Using LCAS, service providers can fulfill customer requests for bandwidth upgrades in minutes, instead of requiring days or weeks as with previous point-to-point Ethernet services.
- *Generic framing procedure (GFP)* provides a universally operable means of mapping Ethernet over SONET or SDH, helping ensure that data traffic can be supported by any GFP standards-based platform across the network.

Using the earlier example, after mapping 100-Mbps Ethernet service for SONET/SDH transport, only two 51-Mbps STS-1 timeslots would be required (instead of three) to handle the Ethernet signal because VCAT technology allows more effective utilization of network bandwidth.

Bandwidth Efficiency

In addition to the above QoS and IP SLA considerations, there are a few other factors that must be taken into account for VoIP to make optimal use of network bandwidth. All IP packets are composed of data (payload) and header information (overhead). While the size of the voice samples in the data field can vary based on the codec used, the number of associated header bits is constant and can be significantly more than the actual data payload bits. There are tools built into Cisco IOS Software that may be employed to reduce the associated overhead packets, increasing bandwidth efficiency.

Compressed Real-Time Protocol (cRTP) – One technique to reduce overhead bits is to use a header compression program. As an example, cRTP minimizes bandwidth requirements and is highly useful on slow links with limited bandwidth capacity. For example, the header portion of a VoIP packet is very large and can account for nearly two-thirds of the entire packet. To avoid the unnecessary consumption of available bandwidth, cRTP can be used on a link-by-link basis. cRTP compresses IP/UDP/RTP headers from 40 bytes to 2–5 bytes. Because some header information can be redundant, this can result in substantial saving in overall packet size.

Silence suppression – Further gains in bandwidth efficiency can be achieved using silence suppression. Because conversations in a voice call are not constant and contain a significant amount of silence (each person typically listens half the time, and the person speaking sometimes pauses between words), VoIP technology allows for better use of network bandwidth by taking advantage of this silence. Instead of transmitting packets of silence over the network, VoIP gateways that implement voice activity detection (VAD) can interleave data traffic with VoIP traffic for better bandwidth utilization. Generally speaking, not only will VAD free up about a third of the bandwidth, it also generates “white noise” or “comfort noise” so users do not mistake the silence as a disconnected call.

Cisco Optical Solutions

Cisco Optical Ethernet Cards

The following cards are available in both the Cisco ONS 15454 and 15310 platforms.

Cisco CE Series

These Carrier Ethernet cards provide mapping of Ethernet ports into SONET payloads, making use of VCAT, GFP, Point-to-Point Protocol (PPP), and High-Level Data Link Control (PPP/HDLC) framing protocols. Cisco CE-Series cards also support LCAS, which allows hitless dynamic adjustment of SONET link bandwidth. For more information, please visit: http://cisco.com/en/US/products/hw/optical/ps2006/products_data_sheet0900aecd8020a734.html.

Cisco ML Series

These multilayer cards provide Layer 2 and 3 interface functionality supporting Ethernet payloads across SONET/SDH paths, making use of VCAT, LCAS, and GFP. The Cisco ML-Series cards incorporate Cisco IOS Software technology, the leading Ethernet and IP delivery vehicle. The Cisco ML-Series cards offer an advanced set of QoS features to allow the network administrator to fine-tune the network and enable the creation and support of a wide range of SLAs. For more information, please visit: http://cisco.com/en/US/products/hw/optical/ps2006/products_data_sheet09186a00801136f8.html.

Resilient Packet Ring and the Cisco ML-Series Cards

With Cisco ML-Series cards, service providers have the choice of configuring their optical network with Ethernet circuits configured as point to point, hub and spoke, or Resilient Packet Ring (RPR) in their metro optical network.

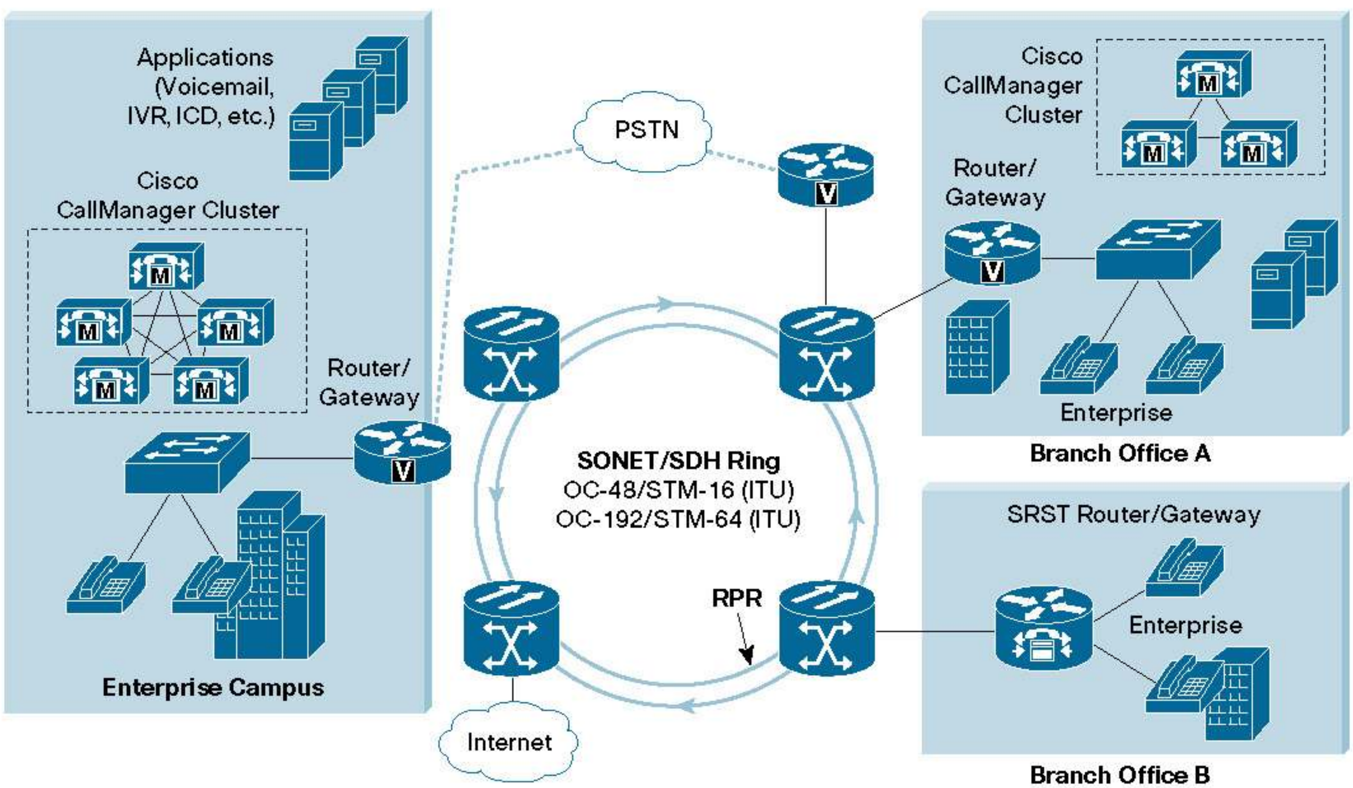
Configured over SONET/SDH networks, an RPR passes Layer 2 Ethernet traffic around the configured ring. But an RPR has its own protection mechanism that provides SONET/SDH-like network protection in the event of a fiber cut, node failure, or node insertion by supporting ring convergence times of less than 50 ms.

By contrast, providing standard Ethernet services across a SONET/SDH network requires the use of SONET/SDH protection schemes to ensure network uptime in the event of a fiber cut or node failure. This means that when providing SONET/SDH protection, every working circuit used to transport the traffic utilizes a second, unused protect circuit.

Because RPR eliminates the need for reserving redundant bandwidth in the protected SONET/SDH model, this unused protect circuit can also be utilized for traffic, *effectively doubling the capacity of the Ethernet circuit*. In the event of protection activation, the bandwidth is then cut in half until the necessary repairs are completed. While this may cause some congestion on a fully utilized network, packet prioritization and LLQ will ensure that VoIP traffic will continue to pass as higher-priority traffic. See Figure 2.

Figure 2

Interconnection of Voice Network Across Optical Ring Using RPR



Delivering VoIP-Enabled Ethernet

For many years, service providers have been using Cisco optical solutions to deliver traditional voice services as well as a variety of IP, Ethernet, and other data services over a SONET/SDH infrastructure. In the past, data traffic was simply carried through the TDM pipe without regard for its contents or application. Web download packets were treated in exactly the same way as a VoIP packet in a phone call.

There are two options for network operators looking to support VoIP as well as other advanced data services (such as videoconferencing, video on demand, and IP-based VPNs) that require stringent adherence to SLAs.

- **Option 1:** Continue using the TDM model to provision Ethernet services through a mesh of physical point-to-point circuits; in effect, dedicating bandwidth to voice but in a different format (packets). For customers who prefer the simplicity of Ethernet Private Line circuits, the Cisco CE-Series cards offer network operators the ability to provision point-to-point services across a SONET/SDH infrastructure the same way they provision TDM voice circuits, but with the option to implement VCAT, LCAS, and GFP features.
- **Option 2:** Deploy intelligent multipoint IP networks over the SONET/SDH infrastructure and use Layer 2/3 switching intelligence to maximize efficient use of bandwidth while ensuring adherence to the necessary SLA for each type of service. Customers who prefer Ethernet Private LAN can use Cisco ML-Series cards offering Layer 2 switching and Layer 3 routing. In addition to increased bandwidth efficiency through utilization of RPR technology, advanced QoS options are available and provide tremendous advantages. These options are part of the Cisco ML-Series Exclusive IP SLA feature set and include:
  - Traffic identification using IP packet inspection (DSCP)
  - Ethernet packet inspection (VLAN or CoS)
  - Rate limiting
  - Bandwidth policing
  - Packet scheduling and prioritization utilizing LLQ
  - Assurance of minimum packet loss, jitter, and latency

Cisco ML-Series cards help network operators to provide Layer 2 and 3 switching with the necessary QoS to support VoIP, while adhering to predetermined SLAs. The QoS to meet VoIP requirements is implemented when there is a way to identify and mark Ethernet frames and IP packets, and schedule them to exit a network device ahead of those with lower or no priority. Classification technologies used by the Cisco ML-Series cards include 802.1Q/P for Ethernet, and ToS and DSCP for IP packet classification. To ensure that VoIP traffic receives priority through the network, the Cisco ML-Series cards use a number of scheduling technologies, including LLQ. By monitoring and controlling latency, jitter, and packet loss, Cisco ML-Series cards support IP SLAs for VoIP and other high-priority applications on SONET/SDH rings.

Cisco ML-Series cards lead the industry with Layer 2 and 3 data capabilities. By extending IP SLA capabilities into SONET/SDH transport, the Cisco ML-Series cards continue to build on this technology leadership position.

Cisco CE-Series and ML-Series interface cards give users the choice of either point-to-point or multipoint Ethernet services, supporting diverse traffic needs across assorted networks. This service flexibility helps ensure that different types of services are handled appropriately, allows for close monitoring of circuit quality, and supports new revenue-generating applications such as VoIP.

Additionally, because most Cisco switches and routers offer IP SLA support through Cisco IOS Software, service providers can take advantage of Cisco Ethernet leadership by deploying Cisco optical solutions.

Regardless of circuit type (point-to-point, hub-and-spoke, or multipoint configuration), circuits can be configured through the same GUI-based Cisco Transport Controller that is used for provisioning TDM services when configuring Cisco ONS 15454 and 15310 platforms. Cisco ML-Series interface configurations are made using Cisco IOS Software. Transaction language (TL-1) is also supported for easy integration with many third-party management systems.

Making the TDM-to-VoIP Transition with Cisco Optical Solutions

Despite the quickly increasing popularity of VoIP, many providers will need to continue offering TDM services. Fitting easily into existing SONET/SDH infrastructures, next-generation SONET/SDH platforms, such as the market-leading Cisco ONS 15454, make it more economical to provision traditional services to customers. Electrical and optical cards for the Cisco ONS 15454 offer greatly increased port densities and cross-connect capacities to meet customer demand for TDM and optical services. High-density cards for the Cisco ONS 15454 platform include:

- **56-Port DS-1/E1 Interface Card** – Provides 56 DS-1 or 56 E1 interfaces per card. For more information, please visit: http://cisco.com/en/US/products/hw/optical/ps2006/products_data_sheet0900aecd8031a1de.html.
- **48-Port DS-3/EC-1 Interface Card** – Provides 48 C-Bit or M2/3 framed or unframed interfaces operating at 44.736 Mbps, or 48 EC-1 interfaces operating at 51.840 Mbps received over 75-ohm coaxial cable. For more information, please visit: http://cisco.com/en/US/products/hw/optical/ps2006/products_data_sheet0900aecd801b95d6.html.
- **12-Port DS-3 Transmultiplexer Card** – Provides 12 DS-3 C-Bit or M2/3 framed interfaces operating at 44.736 Mbps. The card demultiplexes a channelized DS-3 into 28 DS-1s, maps each DS-1 to a VT1.5, then multiplexes the 28 VT1.5s into a VT-mapped STS-1 before hand-off to the Cisco ONS 15454 cross-connect card. The 12-port DS-3 transmultiplexer card offers grooming flexibility by supporting two ways to receive the DS-3 signal, ported or portless. Ported terminations refer to DS-3 interfaces that are received through 75-ohm coaxial cables from the shelf assembly's electrical interface adapter (EIA) panels. Portless termination is a channelized DS-3 signal received over an STS-1 circuit from a SONET optical line (OC-n). The portless capability eliminates the need to terminate a channelized DS-3 signal on the shelf assembly and then reinsert. For more information, please visit: http://cisco.com/en/US/products/hw/optical/ps2006/products_data_sheet0900aecd801b95c1.html.
- **12-Port SFP-Based Multirate Optics Card** – This multirate card supports up to 12 Small Form-Factor Pluggable (SFP) modules, helping enable multirate SONET/SDH and multiple-reach capabilities. The MRC-12 card operates in either Cisco ONS 15454 SONET or SDH systems, supporting optical line rates including OC-3/STM-1, OC-12/STM-4, and OC-48/STM-16 and optical reaches from short-reach/interoffice to long-reach/long-haul including DWDM and CWDM. For more information, please visit: http://cisco.com/en/US/products/hw/optical/ps2006/products_data_sheet0900aecd8031cddb.html.
- **High-Order/Low-Order Cross-Connect Card (XC-VXC-10G)** – Supports the much higher capacities of the high-density TDM cards with cross-connect capacities of 1344 bidirectional VT1.5s and 576 bidirectional STS cross connects in SONET, or 1344 bidirectional VC-11s, 1008 bidirectional VC-12s, or 384 bidirectional VC-3 or VC-4 cross connects in SDH. For more information, please visit: http://cisco.com/en/US/products/hw/optical/ps2006/products_data_sheet0900aecd8031a2d6.html.

In addition to high-density TDM and SONET capabilities, Cisco CE-Series and ML-Series cards are available for use in both Cisco ONS 15454 and ONS 15310 platforms. This helps ensure a more economical and flexible data-delivery solution across the optical network.

Cisco VoIP Solutions

VoIP: An Opportunity for Service Providers

From individual subscribers to large service providers, customers appreciate the value of feature-rich IP telephony services delivered over the same connections that they use for their data applications. Incumbent local exchange carriers, competitive local exchange carriers, and cable operators also understand the economics of delivering multiple services over a converged IP network while offering customers a choice of connectivity options.

Although many large VoIP users may want to deploy an IP telephony solution onsite and self-manage it, others, particularly small- and medium-sized businesses (SMBs), may prefer a managed solution, either because they do not have the time or money to invest in specialized resources to support a new technology, or because they would rather take advantage of the reliability and scalability of the service provider's infrastructure to ensure a high QoS.

Cisco offers service providers a broad and flexible selection of tested solutions to enable them to add new revenue, differentiate their services, and lower network operating costs. All of the solutions and products can take advantage of Cisco optical components to help ensure reliable and cost-effective operations and deployment. Cisco service provider VoIP solutions include the following:

Cisco Cable Multimedia Communications Solution – This solution complies with the CableLabs® PacketCable™ architecture. It provides integrated voice and data to end customers today, and prepares the service provider to evolve to future multimedia standards such as PacketCable 2.0 and IP Multimedia Subsystem (IMS).

Cisco Broadband Local Services Solution for Commercial Customers – This solution helps service providers deliver data, voice, and video over a variety of access networks. Using existing access lines, the solution helps service providers offer a bundle of packet-based services, including local and long-distance voice services and high-speed data. By providing multiple services over a common infrastructure, a carrier can increase its revenue and profits, while offering SMB customers a better telecommunications value. The solution has been implemented over T1/E1, DSL, cable, Metro Ethernet, and fixed wireless networks.

Voice Infrastructure and Applications (VIA) Solution for Wireline Carriers – Cisco VIA is a VoIP solution designed to lower network costs and rapidly deliver a multitude of revenue-generating, carrier-class voice transport services. These services include ASP Termination Services, National and International Transport Services, Prepaid and Postpaid Calling Card Services, Voicemail, and Unified Messaging.

Cisco Business Voice Solutions for Wireline Carriers (BVS) – Cisco gives service providers a portfolio of managed business voice services over a common infrastructure, targeting all segments from SMBs to enterprises. These services include: Business Phone Services, Site-to-Site Voice, PSTN Access, Unified Communications, and Remote Network Operations. In addition, by offering IP telephony management services, the service provider can increase average revenue per user (ARPU) and reduce customer turnover.

For more details on any of these solutions for service provider voice, please visit: http://www.cisco.com/go/sp-voice.

Private Enterprises

Cisco is the leading provider of VoIP telephony solutions to enterprises, large and small. These private enterprise customers use the Cisco AVVID (Architecture for Voice, Video, and Integrated Data) to deliver business-class telephony services. Cisco IP telephony solutions use a single network infrastructure for the transmission of data, voice, and video traffic, delivering the business benefits of a converged network (increased productivity, greater business flexibility, and reduced operational costs) to enterprise-level organizations.

Cisco IP telephony solutions include:

- Cisco CallManager – This software-based call-processing agent extends enterprise telephony features and functions to packet telephony network devices such as IP phones, media-processing devices, VoIP gateways, and multimedia applications. Smaller call-control applications can benefit from Cisco CallManager Express, a Key system based on Cisco IOS Software that provides robust and feature-rich IP PBX functionality.
- Cisco IP phones and VoIP endpoints – Cisco IP phones combine the functions of traditional telephone with Ethernet and optional customizations such as access to stock quotes, employee extension numbers, and Web-based content.
- Cisco infrastructure – Cisco access routers, Ethernet switches, and voice gateways provide a robust foundation for VoIP and IP-enabled voice applications.

- Cisco unified communications and voicemail – Cisco Unity® solutions deliver powerful unified messaging (e-mail, voice, and fax messages sent to one inbox) and intelligent voice messaging (full-featured voicemail providing advanced functions) to improve communications, boost productivity, and enhance customer service capabilities across an organization.
- Cisco customer contact solutions – Service-oriented, multichannel contact centers play a crucial role in winning customer loyalty in today's marketplace. Enterprises with call centers can also reap all the benefits that a converged network offers. With IP-enabled contact-center solutions based on the Cisco IPCC product line, businesses can dramatically improve customer service and increase business efficiencies.
- Cisco MeetingPlace® – This integral component of the Cisco IP Communications system is a complete rich-media conferencing solution that easily integrates voice, video, and Web conferencing capabilities. Cisco MeetingPlace is deployed "on network," behind the firewall. This solution integrates directly with an organization's private voice and data networks and enterprise applications, providing significant cost savings, high security, and an enhanced user experience.

For more details about Cisco IP telephony solutions and Cisco AVVID, please visit:
http://www.cisco.com/en/US/netsol/ns340/ns394/ns165/networking_solutions_packages_list.html.

Conclusion

The need for high-speed data services combined with the economics of operating a single network is accelerating the demand for Ethernet services over SONET/SDH. Cisco optical solutions support service providers, utilities, and enterprises by offering an increasing variety of services, from high-density TDM to high-speed data. These services include the extremely efficient and reliable Resilient Packet Ring with advanced QoS and IP SLA features. Users can support their voice, video, and high-speed data needs both now and in the future. They can take full advantage of economically, efficiently, and flexibly supporting multiple data applications and services from the same platform they use to deliver traditional TDM and optical services. Cisco optical solutions help enable a smooth migration from traditional voice to VoIP while protecting and maximizing investment in customers' existing SONET/SDH infrastructures.

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Printed in the USA

Pa/LW10340 01/06