



WHITE PAPER

EFFICIENT AND FLEXIBLE TRANSPORT OF NEXT-GENERATION DATA SERVICES OVER SONET/SDH USING GFP, VCAT AND LCAS

Service providers today face an increasing number of challenges in addressing customer demand for new services while continuing to deliver traditional voice and private line services. Until recently, new services such as Ethernet and storage area networks (SANs) could not efficiently be delivered over existing SONET/SDH networks despite the proven value of, and considerable investment in this infrastructure. However, the maturity of three new technologies—Generic Framing Procedure (GFP), Virtual Concatenation (VCAT), and Link Capacity Adjustment Scheme (LCAS)—can transform this infrastructure to make it both an efficient and flexible transport network to meet the demand for Layer 2 and Layer 3 services. This white paper offers an overview of the benefits these three stable and mature technologies bring to SONET/SDH networks, thereby allowing service providers to extract greater value from their networks.

EVOLVING THE SONET/SDH INFRASTRUCTURE FOR DELIVERY OF DATA SERVICES

INTRODUCTION

Over the years, service providers have invested considerable amounts of capital and expertise in their SONET/SDH networks. These networks have proven their value because they offer bandwidth and infrastructure scalability; operation, administration, maintenance, and provisioning (OAM&P) capability; and reliable network protection and restoration. However, SONET/SDH technologies were developed almost three decades ago to transport 64-kbps (DS0) voice circuits, not for data services. Today, service providers are under intense pressure because of the market's rapid migration from voice and traditional private line to new IP-based services, such as voice over IP (VoIP) VPNs, videoconferencing, IP television, and online gaming, just to name a few. These changes are occurring in parallel with customers' increased need for all types of Layer 2 network connectivity, particularly Ethernet, Enterprise Systems Connection (ESCON) Fiber Connection (FICON) for mainframe applications, and Fibre Channel, an open protocol for SANs.

Three mature technologies—GFP, VCAT, and LCAS—together solve the following issues that exist in an infrastructure optimized for DS0 services:

- Difficulty of mapping newer (Ethernet, SANs) services to the existing transport network
- Inefficient use of the transport network in delivering data services
- Inability to increase or decrease available bandwidth to meet the needs of data services without impacting traffic

This demand for multiple services is being addressed by multiservice provisioning platforms (MSPPs), such as the market-leading Cisco® ONS 15300 Series and the Cisco ONS 15454 MSPP. These platforms today offer service providers a way to economically and efficiently transport all types of traffic over their installed SONET/SDH networks. The insertion of GFP, VCAT, and LCAS capabilities in the Cisco MSPPs enhances the investment in these platforms by allowing service providers to quickly and flexibly offer new revenue-generating services while continuing to support traditional services.

GFP: MAPPING NEW SERVICES TO SONET/SDH

To make the existing infrastructure more data-friendly, the ITU, ANSI, and IETF have specified standards for transporting various services such as IP, ATM, and Ethernet over SONET/SDH networks. Until recently, however, there was no single protocol for transporting all packet-oriented traffic, whether IP, Ethernet, or SAN, over the existing infrastructure. Standards groups have filled this gap by releasing Generic Framing Procedure (GFP), an all-purpose protocol for encapsulating packet over SONET (POS), ATM, and other Layer 2 traffic on to SONET/SDH networks. GFP is defined in ITU-T G.7041 and ANSI T1-105.02 standards.

There are actually two types of GFP mechanisms—frame mapped GFP (GFP-F) and transparent mode (GFP-T)—for adapting data traffic to SONET/SDH networks. A detailed discussion of these two types of GFP is beyond the scope of this document (there are differences in encoding schemes, latency, memory requirements, etc.). Suffice it to say that GFP-F is intended for Ethernet traffic whereas GFP-T is a low-latency solution that supports a variety of client protocols, including Fibre Channel, FICON, ESCON, and Digital Video Broadcast–Asynchronous Serial Interface (DVB-ASI), which is a protocol used by cable television providers, as well as Ethernet. Thus GFP is the initial step for running these different services across the SONET/SDH infrastructure.

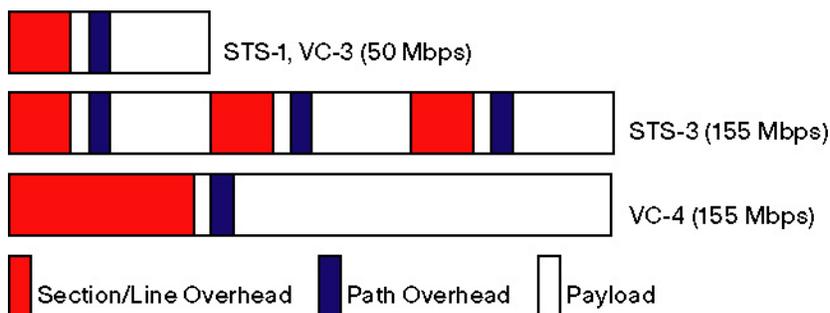
VCAT: USING NETWORK BANDWIDTH EFFICIENTLY

Fixed, Contiguous SONET/SDH Payload

High-speed data applications using protocols such as ATM, Frame Relay, and Packet over SONET (POS) have over the years taken advantage of fast SONET/SDH transport, where the basic unit of bandwidth in the SONET infrastructure is Synchronous Transport Signal-1 (STS-1) and, for an SDH network, Virtual Container-4 (VC-4). The STS-1 provides slightly more than 51 Mbps of bandwidth while the VC-4 provides approximately 155 Mbps. In each instance, a portion of the bandwidth is reserved for overhead while the much larger portion, roughly 50 Mbps in an STS-1 and 150 Mbps in a VC-4, serves as a container or envelope for the actual payload. The VC-4 container can be made up of three VC-3s, which are very similar in size to the STS-1 (see Figure 1).

Figure 1

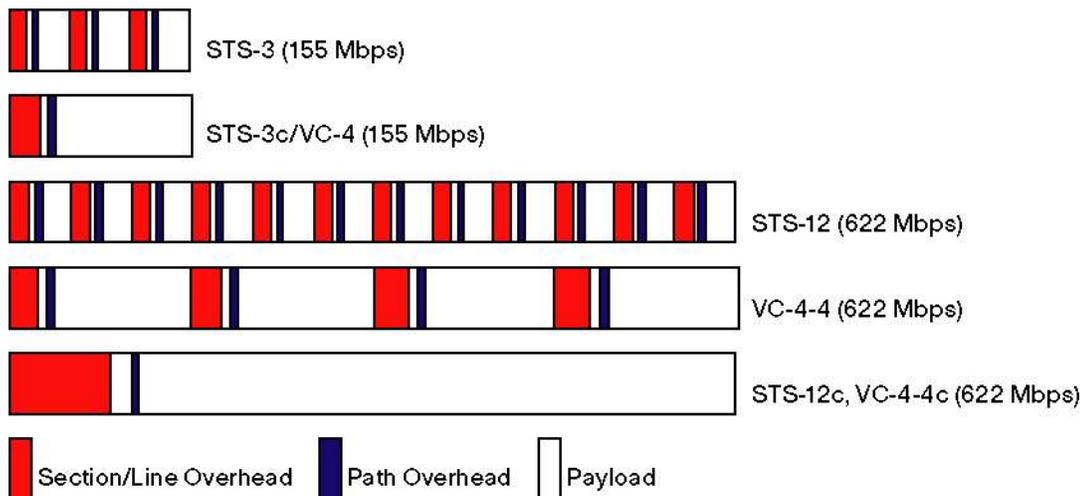
Fixed STS and VC Payloads



These STS-1/VC-3 time slots are sufficient to carry low-speed signals such as DS-1/E1 and DS-3, which range in size from 1.544 Mbps to 45 Mbps. However, data-oriented protocols, such as ATM and POS, typically operate at higher rates (such as 155 Mbps or 2.5 Gbps). To transport these protocols, the SONET/SDH network has to provide higher capacities than an STS-1/VC-3/VC-4 payload. The network does this by contiguously concatenating, in other words binding together, a number of STS-1/VC-3/VC-4 payloads, which are then transported and switched across the network as a single module.

By mapping protocols such as ATM and POS to larger SONET/SDH payloads, the transport network is able to accommodate these protocols, which, in fact, were developed to take advantage of SONET/SDH concatenation capabilities. Figure 2 shows examples of nonconcatenated and concatenated 622-Mbps signals in SONET/SDH networks, with the *c* denoting a concatenated payload. Note that in SONET networks a concatenated 622-Mbps signal is called an STS-12c; in SDH networks it is called a VC-4-4c, the first 4 representing the VC-4 frame format and second 4 denoting the total bandwidth.

Figure 2
Contiguous Concatenation

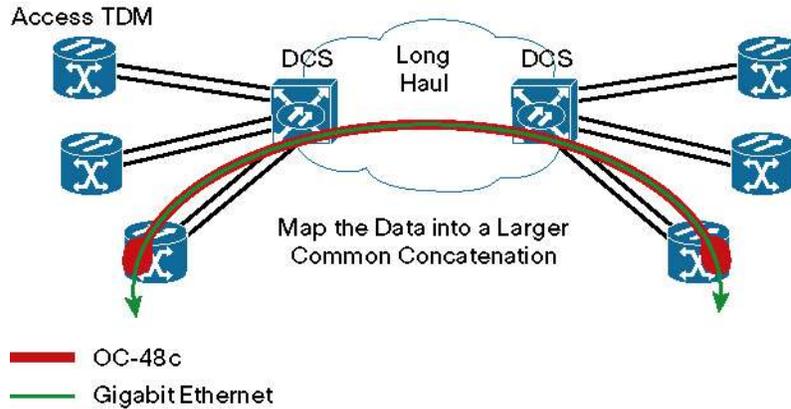


Starting with STS-1/VC-4 time slots as the base unit of bandwidth, SONET/SDH concatenation scales in increments of three, the typically supported concatenations being STS-3c/VC-4, STS-12c/VC-4-4c, STS-48c/VC-4-16c, and STS-192c/VC-4-64c.

With this typical or common concatenation, a circuit from one access device is simply mapped to another access device because all devices in the path support the same concatenation scheme. Although many next-generation SONET/SDH devices support uncommon concatenation (for instance, at 1.2-Gbps STS-24c/VC-4-8c to more efficiently map Gigabit Ethernet or 1-Gbps Fibre Channel to SONET/SDH payloads), there still is an issue with existing Digital Crossconnect Systems (DCSs) that continue to play a role in the network core. Specifically, many access rings have been built with next-generation devices, such as the Cisco ONS 15300 Series and the Cisco ONS 15454, and these access rings interconnect to installed DCSs, which do not support cross-connection of an uncommon concatenated circuit, such as an STS-24c/VC-4-8c.

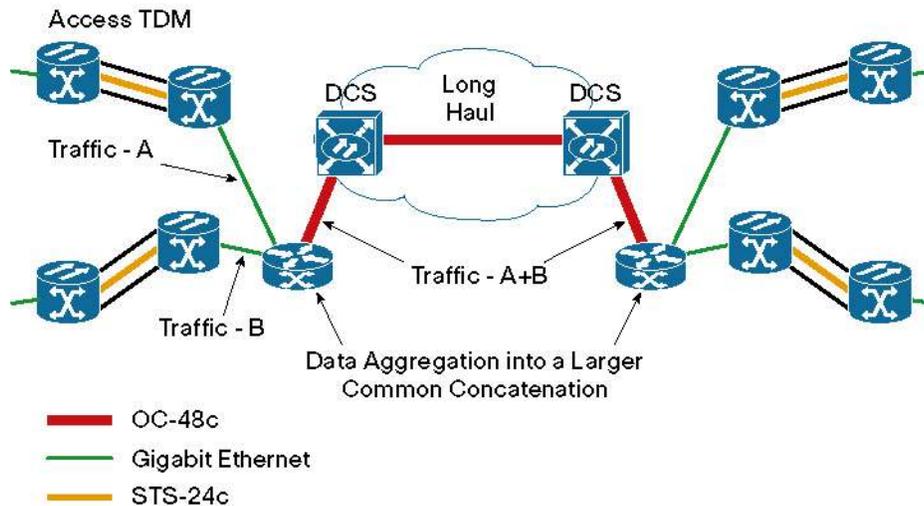
There are two possible solutions to this problem. The first would be to simply map the Ethernet or Fibre Channel traffic to a larger, commonly concatenated payload across the entire span, in this case 2.5-Gbps STS-48c/VC-4-16c. Although this would allow for inter-ring traffic, it would be a very inefficient use of bandwidth (Figure 3).

Figure 3
Multiple-Ring Cross-Connection Using Large Concatenation



The second solution would be to aggregate smaller, uncommon concatenated flows, such as an STS-24c/VC-3-8c, into a larger, common concatenated flow. For example, two Gigabit Ethernet signals (traffic A and traffic B) could be mapped to an STS-48c/VC-4-16c POS circuit (traffic A+B in Figure 4). This method makes better use of network bandwidth, but the downside is that the cost of POS ports on aggregation routers is much higher than Gigabit Ethernet or even 10-Gbps Ethernet ports because of pricier optics used for SONET/SDH and more stringent timing requirements.

Figure 4
Multiple-Ring Cross-Connection Using the Aggregation Model



Inefficiencies of Fixed Payloads and Contiguous Concatenation

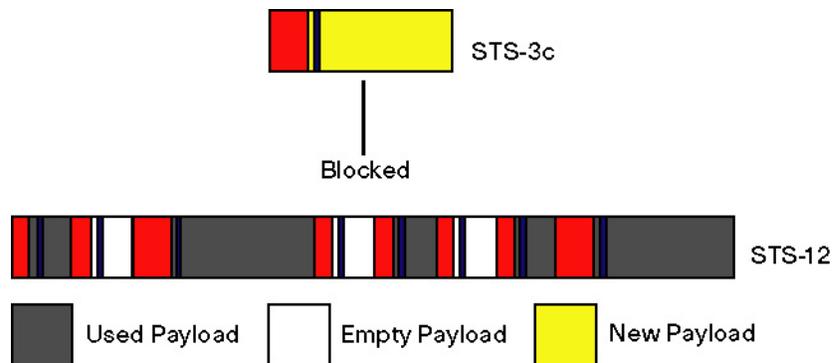
Although contiguous concatenation offers the benefit of larger flows, there are two areas where the inefficiencies of fixed payloads and contiguous concatenation result in wasted bandwidth.

Fragmented bandwidth deprives the carrier of using available network bandwidth. Even when well-understood rules are followed to avoid bandwidth stranding, fragmented bandwidth can still happen. Moreover, the higher the line rate, the greater the chance of fragmented bandwidth. When this occurs, established circuits have to be reprovisioned to make room for the new circuit, all of which takes time and possibly a degradation or even interruption of customer service. With older systems it can take hours or even a full day to establish a new circuit when bandwidth is stranded in the network, which requires more time and effort from the service provider.

Figure 5 illustrates the problem of stranded bandwidth in an STS-12. Here, an STS-9 is in use and a new STS-3c needs to be inserted. Although a sufficient number of STS-1 time slots are available, they are not contiguous, and so there is insufficient space to establish an STS-3c.

Figure 5

Stranded Bandwidth in an STS-12



While stranded bandwidth might be avoidable, there is, however, no getting around the inefficiencies of fixed payloads and contiguous concatenation when it comes to the transport of Ethernet and SAN traffic over SONET/SDH networks. Table 1 shows the inefficiencies of transporting data protocols over SONET/SDH networks. VCAT overcomes these inefficiencies.

Table 1. Inefficiencies of Stranded Bandwidth

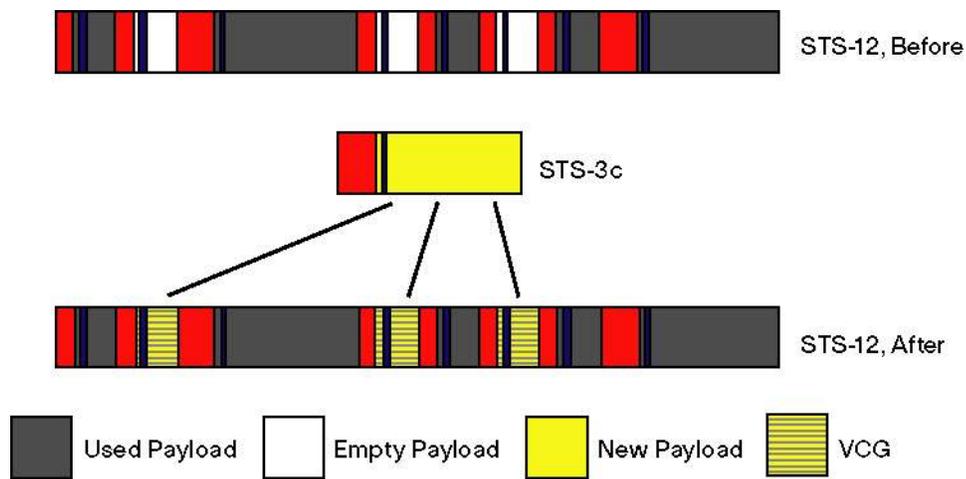
Service	Bit Rate	Utilization
Fast Ethernet	100 Mbps	STS03c/VC-4 (67%)
Gigabit Ethernet	1000 Mbps	STS-48c/VC-4-16c (42%)
Fiber Channel	200 Mbps	STS-12c/VC-4-4c (33%)
Fiber Channel	1000 Mbps	STS-48c/VC-4-16c (42%)
ESCON	200 Mbps	STS-12c/VC-4-4c (33%)

Bandwidth Efficiencies of Virtual Concatenation

VCAT technology is the solution to the inefficiencies inherent in fixed payloads and contiguous concatenation. In a nutshell, VCAT is the ability to transmit and receive a number of noncontiguous STS-1s/VC-3/VC-4s as a single flow. This grouping of noncontiguous timeslots is called a Virtual Concatenation Group (VCG). Using the previous example, where an STS-3c could not be added to the network because a sufficient number of contiguous STS-1s/VC-3s were unavailable, Figure 6 shows how the STS-3c can now be transported across the network as a VCAT payload.

Figure 6

VCAT Mapping into a Virtual STS-3c



Unlike VCAT, contiguous concatenation maps bandwidth end-to-end, which means that contiguous concatenation capability is required not just in the source and destination devices, but also at every intermediate device in the SONET/SDH network. VCAT, on the other hand, breaks the bandwidth into individual payload containers at the source transmitter but represents them as a VCG, in other words, a single flow. Because members of the VCG are individually routed and transmitted, VCAT capability is required only at the source and destination devices.

The basic building blocks of a VCG are STS-1/STS-3c containers for SONET and, for SDH networks, VC-3/VC-4 containers. Thus, for example, an STS-12c circuit can be broken down and transported across the SONET network as an STS-1-12v or as an STS-3c-4v, meaning that in the first instance 12 STS-1 containers and in the second instance four STS-3c containers are being used to constitute a VCG carrying the STS-12c signal. The *v* notation in these examples indicates a VCAT payload in SONET/SDH networks.

Table 2 shows the bandwidth efficiencies that VCAT brings to the transport of Layer 2 and Layer 3 services as compared to transporting them over SONET/SDH networks that have not implemented VCAT.

Table 2. Comparison of Bandwidth Utilization without and with VCAT

Service	Bit Rate	Utilization Without VCAT	Utilization With VCAT
Fast Ethernet	100 Mbps	STS03c/VC-4 (67%)	STS-1-2v/VC-3-2v (100%)
Gigabit Ethernet	1000 Mbps	STS-48c/VC-4-16c (42%)	STS-3c-7v/VC-4-7v (95%)
Fibre Channel	200 Mbps	STS-12c/VC-4-4c (33%)	STS-1-4v/VC-3-4v (100%)
Fibre Channel	1000 Mbps	STS-48c/VC-4-16c (42%)	STS-3c-7v/VC-4-7v (95%)
ESCON	200 Mbps	STS-12c/VC-4-4c (33%)	STS-1-4v/VC-3-4v (100%)

For Ethernet services in particular, VCAT allows service providers to offer tiered Ethernet services with service-level agreements (SLAs). Service providers can offer Ethernet services in 50-Mbps increments all the way up to Gigabit Ethernet because VCAT streams are comprised of standard STS-1/VC-3 and STS-3c/VC-4 streams, which are supported by almost all SONET/SDH devices.

In fact, VCAT technology is capable of supporting even more granular Ethernet services. This is because what has been discussed so far is High Order VCAT (HOVCAT), which noncontiguously concatenates relatively large containers (roughly 51 Mbps if STS-1/VC-3 are used and 155 Mbps if STS-3c/VC-4 are used). Low Order VCAT (LOVCAT) allows the transport and switching of sub-STS-1 payloads because the base timeslot for LOVCAT in a SONET network is roughly 1.5 Mbps, referred to as Virtual Tributary 1.5 (VT1.5), while the corresponding timeslot in an SDH network is 2 Mbps and is called VC-12. This more granular bandwidth provided by LOVCAT allows service providers to even more efficiently use network capacity because they can now support a 1-Mbps Ethernet service using a VT1.5 or a VC-12, or a 10-Mbps Ethernet service using seven VT1.5s or five VC-12s.

MODIFYING TRAFFIC PATTERNS WITHOUT DISRUPTION USING LCAS

Despite the many benefits of VCAT, service providers know all too well that customers' bandwidth requirements are seldom static. When customers' needs for capacity change, they want the change to occur without any disruption in the service. Link Capacity Adjustment Scheme (LCAS), a VCAT control mechanism, provides this capability. As a capacity-control mechanism, LCAS allows for the addition or reduction in the payload capacity of a VCG to meet the bandwidth needs of the application. It does this whether bandwidth needs are being met through implementation of HOVCAT, LOVCAT, or both. Individual payloads can be transparently added or removed in a VCG to resize bandwidth without impacting service.

Without these capabilities, changing a customer's bandwidth is always problematic for service providers. The best-case scenario for doing this without disrupting service is to have sufficient capacity in the network for the old and new services to coexist during the reprovisioning process. In this situation, the service provider would do a "bridge-and-roll," switching the customer from the old to the new circuit, a transition that requires both circuits to be in service for a period of time. Without such overcapacity in the network, the customer could expect some service outage during the "maintenance window" the service provider would need to tear down the old circuit before the new circuit could be established. With VCAT and LCAS, bandwidth changes are not disruptive.

In addition to in-service resizing of bandwidth, LCAS offers other benefits:

- Dynamically replacing failed member links within a VCG without removing the entire VCG
- Unidirectional control of a VCG allows for asymmetric bandwidth
- Interworking of an LCAS transmitter with a non-LCAS receiver, and vice versa
- A broader range of SLAs because VCG bandwidth can be resized dynamically
- Aids in the creation of customer-based, on-demand services

From what has been discussed thus far, it is easy to see ways in which service providers can take advantage of VCAT and LCAS technologies to efficiently and flexibly provide the required capacity for data services and to adjust bandwidth in-service to meet changing customer needs.

To illustrate the benefits of VCAT and LCAS, consider the following example: a metro service provider offering voice, data, and video services leases an OC-48 (48 STS-1s) from a long-distance carrier to interconnect its metro rings across the country. Using VCAT/LCAS, the metro service provider could transport different services through one or more VCGs made up of noncontiguous, nonstandard-size traffic payload. The metro service provider would thus be optimizing the use of the OC-48 connection and possibly deferring the need for additional intercity facilities. As the number of subscribers for the metro service provider's IP service increases, using LCAS, the service provider could easily modify the capacity partitioning between voice and IP services in favor of the latter because VCAT/LCAS would only be required at those points at which the metro service provider interfaces with the backbone provider.



Another example would be an end-to-end service provider that wants to use its SONET/SDH network to deliver optical Ethernet services. Although the service provider might have a number of unused STS-3s/VC-4s in the network, these may be noncontiguous and therefore unusable for Ethernet services. VCAT would allow the service provider to use these fragmented STS-3s/VC-4s to create a bandwidth pool for Gigabit Ethernet service. As a result, the service provider would not have to immediately add new capacity to the network and would only have to deploy VCAT capabilities at the edges of the metro network where Gigabit Ethernet service requirements exist.

Migrating from Voice to Data Services

As service providers move to address customers' rapidly increasing need for Layer 2 and Layer 3 services, the Cisco ONS 15300 Series and Cisco ONS 15454 are the MSPPs of choice. These platforms allow service providers to offer high-bandwidth services for advanced data applications. For the fast growing IP/Ethernet services market, Cisco Carrier Ethernet (CE) Series interface cards for Cisco MSPPs allow service providers to quickly provision point-to-point Ethernet services across SONET/SDH networks in the same way they currently provision voice and time-division multiplexing (TDM) circuits.

The Cisco Multilayer Series (ML-Series) Ethernet interface cards are unique in the industry because they offer both Layer 2 switching and Layer 3 routing, allowing service providers to support an intelligent multipoint network across a SONET/SDH infrastructure. With multilayer intelligence, they can provide tiered services with SLAs to support advanced data applications such as VoIP, videoconferencing, video on demand, television broadcasting, and VPNs.

CONCLUSION

SONET/SDH networks represent a significant investment for service providers, one that has proved its value over the years. New technologies now allow service providers to bring greater efficiency and flexibility to these existing networks for data transport. Using GFP to map data services to the SONET/SDH infrastructure is the first step in using this investment by making it data friendly. The injection of VCAT further increases the value of the network by right-sizing network capacity to match native data rates and using what otherwise would be stranded bandwidth. VCAT's capability to provide very granular bandwidth for data services also allows service providers to offer a range of SLAs. The addition of LCAS further enhances the value of VCAT by allowing service providers to make bandwidth adjustments to meet customers' changing needs in a manner transparent to customers.

Far from being short-term fixes, together these technologies offer nothing less than an evolutionary transformation of the SONET/SDH network, one that allows service providers to simultaneously protect their investment in the existing transport infrastructure and meet the challenge of delivering new services in an efficient and flexible manner.


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