



White Paper

Transport Options for Data Center Optical Interconnection

An unprecedented competitive environment along with government regulations for data recovery has made it imperative for many businesses to have 24-hour access to critical information. A successful business continuity strategy requires two or more data centers to protect and ensure availability of business-critical application services. Information is more effectively protected when the primary and redundant data centers are located outside the threat radius. This necessitates a transport service for extending the storage area network (SAN) across or well beyond the metro area. Optical network solutions from Cisco Systems® offer an integrated platform for supporting data center interconnection services, in addition to providing a range of other network services. This white paper explores high-bandwidth, low-latency, and high-density options for reliable data center interconnection.

Introduction

The cost of a data center outage, whether due to natural disasters, power failure, or malicious acts, can be measured in thousands of dollars for each minute of downtime. Several countries have adopted stringent laws for business continuance. The U.S. Government, for example, requires the financial sector to recover business operations the *same day* a disruption occurs. It even specifies that primary and backup data centers be located at least 200 miles apart and be on separate power grids to assure access to information following a data center outage. Additionally, the U.S. Department of Health and Human Services' Health Insurance Portability and Accountability Act (HIPPA) mandates that patient information be backed up for its protection. In Europe and Asia, the Basel II accord requires, among other things, disaster recovery, business continuance, and storage strategies of international banks. Not only do the financial and healthcare segments of an economy need to ensure access to information, in today's digital economy many other types of businesses depend on 24-hour access to vital application services.

For the enterprise to lower or entirely avoid the risk of losing access to critical information, its business continuity strategy must consider three important questions:

- How valuable is the data to the enterprise?
- What will it cost the enterprise if the data is not available?
- How much does the enterprise want to reduce the risk of data loss?

How an enterprise addresses those issues will help it determine a disaster recovery policy from two related perspectives: first, how quickly it must have operations resume following a disaster, in other words, a recovery time objective (RTO), and second, the amount of data loss the enterprise is willing to accept in the event of a data center outage – a recovery point objective (RPO).

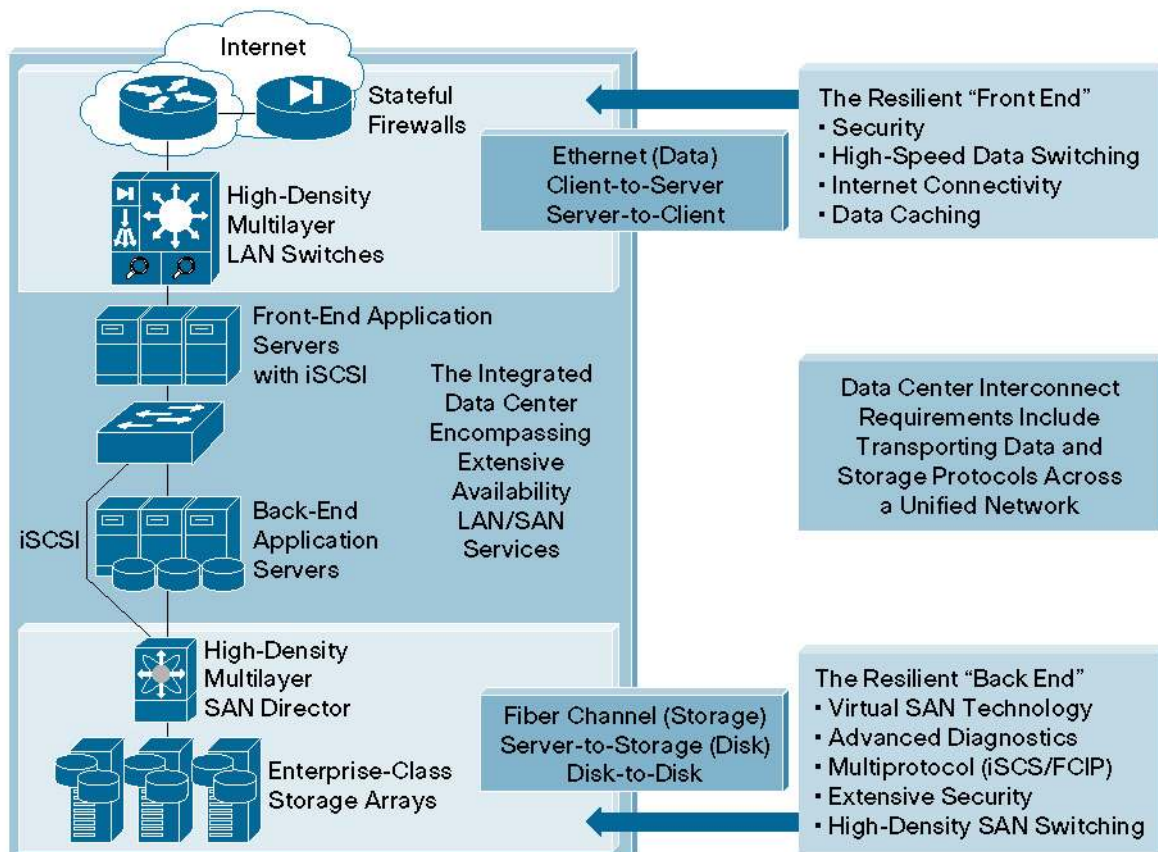
A more stringent RTO/RPO policy understandably comes at a higher cost because it requires considerable duplication, which means the enterprise has to invest in a cold/hot standby data center that mirrors the information stored in the primary data center. Operating dual data centers requires a reliable transport service for interconnecting the primary and backup sites.

Typical Data Center Layout and Networking

The data center has different front- and back-end networking needs because of the way it is generally laid out. In the typical data center (see Figure 1), the front end, in addition to supporting client-to-server communications, provides high-speed server-to-server networking. The server-to-server networking needs are met through Ethernet switches, although InfiniBand, a relatively new I/O technology capable of operating at multigigabit rates, has strong industry support. Together with Ethernet switches or InfiniBand switches, the front-end network consists of routers, firewalls, caching engines, and intrusion detection systems, all of which are optimized for easy data center server access.

Back-end connectivity requirements are met through SAN technologies, such as Enterprise Systems Connection (ESCON)/IBM Fiber Connectivity (FICON) and Fibre Channel, which connect storage devices to servers. A SAN extension service overcomes the distance limitations inherent in SAN technologies, enabling interconnection of geographically dispersed data centers, whether these are located within the same metro area or region, or are at great distances from each other.

Figure 1
Typical Data Center Layout



High-Speed Options for Data Center Interconnection

Traditionally, 1.5-Mbps T1 or 45-Mbps T3 lines were adequate, if relatively costly, for low-bandwidth data storage applications, such as data backup from a branch office to a small data center. Today the enterprise, whether it chooses to self-manage its network or outsource its

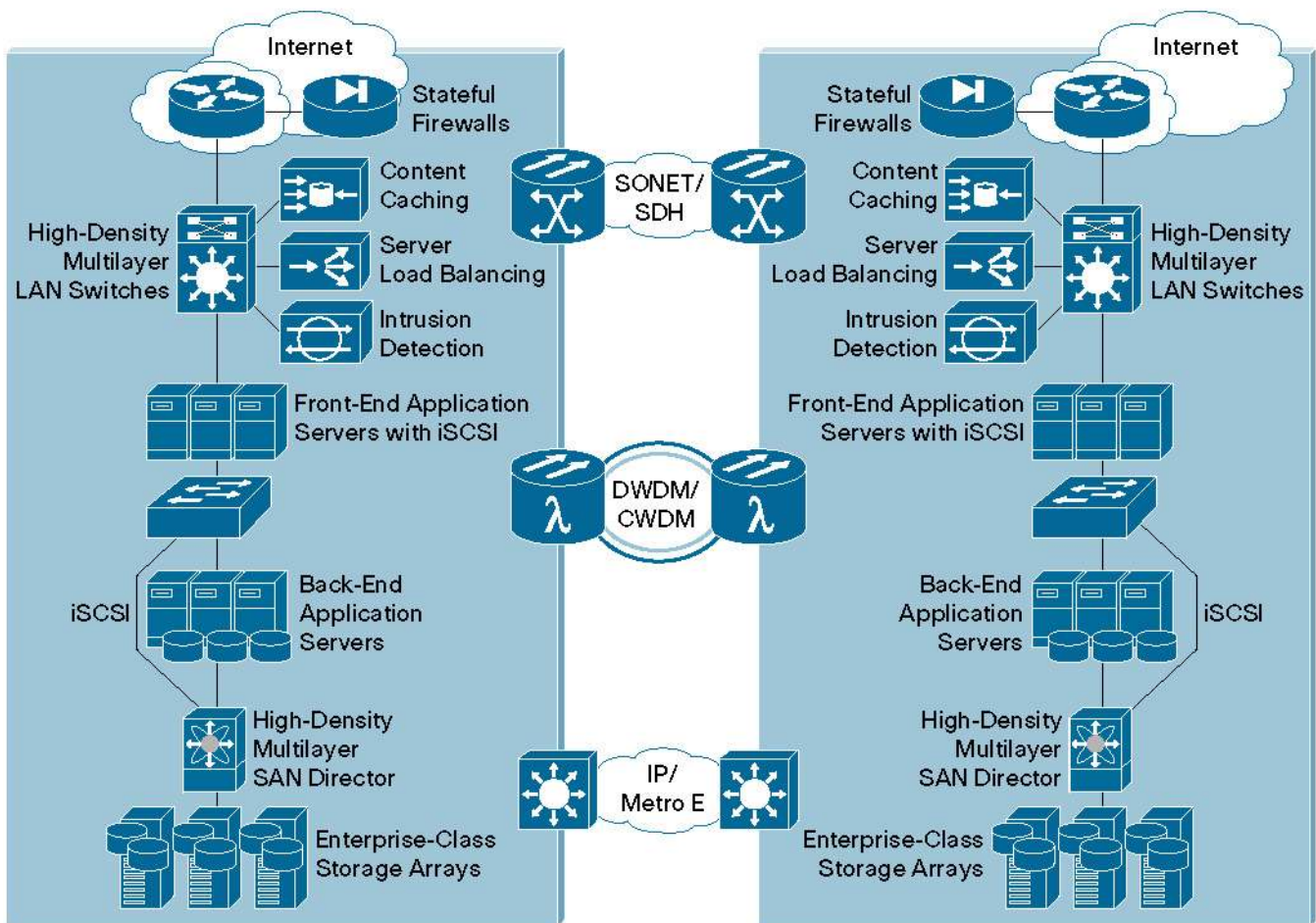
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requirements to a service provider, has more choices in selecting a transport service to interconnect large data centers by effectively extending the SAN islands in the primary and backup data centers (see Figure 2):

- Metro Ethernet
- SONET/SDH
- Wavelength-division multiplexing (WDM)

Figure 2
Data Center Interconnection Choices



All of these technologies scale to provide high-bandwidth services, although how much bandwidth a particular enterprise needs may weigh the choice in favor of a particular technology because of cost and other considerations. Additionally, how much service downtime the enterprise is willing to accept will also be a factor in selecting a service. To illustrate this, the enterprise may insist on having separate fiber conduits or more than one service provider to ensure service availability. The distance between primary and secondary data centers may also be a factor because a particular SAN transport service may be impractical or prohibitively expensive for data center interconnection beyond the metro environment.

Distance between data centers could also impact the choice of interconnection technology in yet another way because the performance of some applications is very sensitive to delay. Delays that occur in extending a SAN signal over increasingly longer distances will determine whether

data can be replicated asynchronously or synchronously between the primary and secondary data center. With asynchronous mirroring, a write (input) is acknowledged after input to a local array cache, so the write/read (input/output) is completed independently of the data replication process. Synchronous replication requires all data to be written to the cache of both local and remote arrays for an I/O to be complete. This usually requires two roundtrips between the primary and backup storage sites, which could impact the performance of a delay-sensitive application.

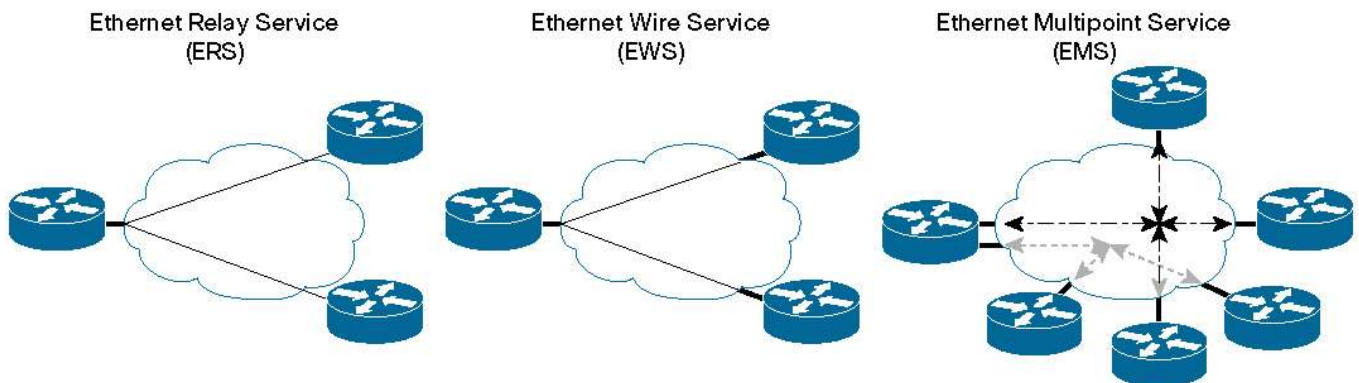
Metro Ethernet: Enabling Multiple Services

Many enterprises will favor Metro Ethernet services because of their long experience with Ethernet technology in corporate LANs. In addition to offering the enterprise a cost-effective interface and bandwidth scalable to 10 Gbps, Metro Ethernet services enable data center interconnection even when these facilities are well outside metro or regional boundaries because a Fibre Channel signal can be transported through IP (Fibre Channel over IP [FCIP]).

Ethernet technology, in fact, allows for delivering a variety of Metro Ethernet services (see Figure 3):

- *Ethernet Relay Service (ERS)* – Provides a point-to-point circuit between customer sites over the service provider’s metro network. Each Ethernet circuit is associated with and mapped to a single virtual LAN (VLAN) within the service provider’s network. A VLAN is analogous to the data link connection identifier (DLCI) in a Frame Relay service and multiple ERS connections can be mapped from a particular customer premises equipment (CPE) device to the user-to-network interface (UNI) of the service provider.
- *Ethernet Wire Service* – Emulates a point-to-point virtual wire connection that to the customer appears as a “clear channel” pipe. The customer does not see the service provider’s network because the connection to that network appears as if it were a local Ethernet segment. All data is transported across the connection transparently with the customer’s VLAN ID untouched. This service is also referred to as a private line service.
- *Ethernet Multipoint Service* – Is a multipoint-to-multipoint virtual wire service. Also known as a transparent LAN service (TLS), this service is an extension of Ethernet Wire Service with which it shares service characteristics, such as data transparency.

Figure 3
Ethernet Services



The choices offered by Ethernet technology provide not only an economical interface for data center interconnection, they also enable the service provider to meet the enterprise’s need for other revenue-generating services, such as VLAN, Layer 2 VPNs, Layer 3 VPNs, and high-speed Internet access.

The service provider, for its part, can offer these Metro Ethernet services using Cisco® optical service solutions that also support a variety of other services. Whether the service provider chooses to offer one or a portfolio of Metro Ethernet services, Cisco Metro Ethernet solutions support quality-of-service (QoS) guarantees through features built into Cisco devices. With the Metro Ethernet solutions, service providers can offer customers tiered Ethernet services based on factors such as bandwidth, service-level agreements (SLAs), and distance.

Service Flexibility of Next-Generation SONET/SDH

Because of its reliability and scalability, SONET/SDH technology has for many years been deployed in service provider and enterprise networks. The capabilities of the Cisco ONS 15454 Multiservice Provisioning Platform (MSPP), however, go far beyond delivering traditional private-line (such as T1/DS-3) and high-speed optical (such as OC-n/STM-n) services. The integration of several technologies in this next-generation SONET/SDH platform enables the Cisco ONS 15454 MSPP to also flexibly and economically deliver data services (using Ethernet, Fibre Channel, and FICON) over the existing SONET/SDH infrastructure.

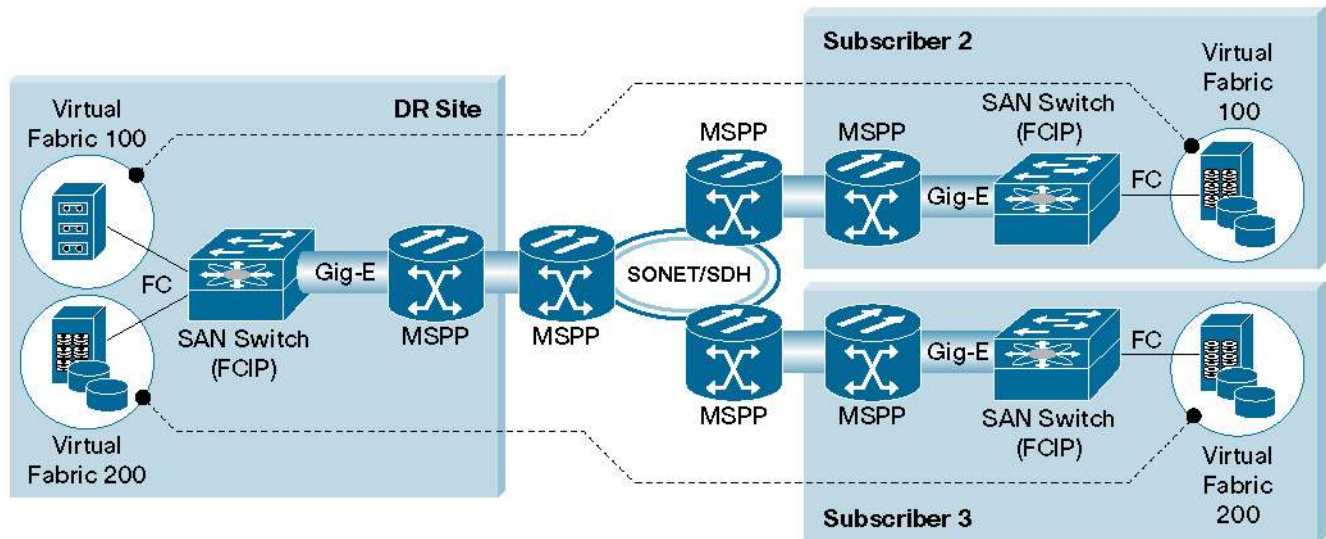
Support for data services in the Cisco ONS 15454 MSPP has been enhanced by the insertion of technologies such as virtual concatenation (VCAT) and link capacity adjustment scheme (LCAS). The two are related technologies that dynamically right-size an optical channel for data traffic and adjust the capacity of the channel to meet changing service demands.

These data interface cards for the Cisco ONS 15454 deliver Ethernet, Fibre Channel, and FCIP services across a SONET/SDH transport network:

- *Cisco E-Series Ethernet cards* – These cards integrate Ethernet switching. The E100T card has 12 10/100-Mbps autosensing RJ-45 copper interfaces. The E1000-2 has two gigabit interface converter (GBIC) interface slots for housing optics for short- or long-reach Gigabit Ethernet applications.
- *Cisco G-Series Gigabit Ethernet cards* – These 4-port Gigabit Ethernet cards use pluggable GBIC optical modules to flexibly support multiple types of client equipment.
- *Cisco ML-Series cards* – These provide multipoint Ethernet service and FCIP. These are among the highest-performance Ethernet and IP switching modules integrated in a SONET/SDH optical transport platform.
- *Cisco CE-Series cards* – These 8-port cards offer 10/100-Mbps standard RJ-45 interfaces for point-to-point Ethernet service.
- *Cisco SL-Series Fibre Channel cards* – These 4-port, 1- or 2-Gbps Fibre Channel/FICON cards use GBIC optical modules for connecting to client equipment.

A Shared Packet Ring (SPR) configuration (Figure 4) is the preferred method for building a Metro Ethernet service over a SONET/SDH infrastructure. The SPR consists of the total of adjacent circuits between ML-Series nodes, with one circuit traveling one direction from a packet-over-SONET/SDH (POS) port and the other circuit traveling in the opposite direction. Each circuit terminates at a POS port on the next Cisco ML-Series Card in the ring. These circuits can be provisioned with or without protection at Layer 1 (which is the synchronous transport signal or STS in SONET, and virtual container or VC in SDH), and more than one ML-Series node can exist in the SONET/SDH network.

Figure 4
FCIP Over Shared Packet Ring



The SONET/SDH network's 50-millisecond (ms) recovery capability makes it an extremely reliable transport infrastructure for supporting SAN extension as well as other data services. Fibre Channel signals can be supported at subrate (less than 1 Gbps) or at full 1- and 2-Gbps line rates across the SONET/SDH network. Spoofing techniques overcome the buffer-to-buffer credit limitation imposed by the flow control mechanism of Fibre Channel SAN switches, allowing SAN extension across distances of more than 2000 kilometers (km) over the SONET/SDH network.

Although SONET/SDH networks are most often deployed in a ring architecture, they can also have linear or mesh configurations to flexibly deliver services where needed. A linear configuration requires 1+1 protection for traffic to be routed to the protected circuit in the event that the working circuit fails. However, the Path-Protection Mesh Networks (PPMN) capability of the Cisco ONS 15454 MSPP enables configuring the SONET/SDH nodes in a mesh. PPMN is a generalization of the unidirectional path-switched ring (UPSR) protection mechanism for SONET/SDH networks because the working and protected paths for a given circuit in the mesh form a ring.

WDM: The Advantages of Protocol Transparency, Increased Fiber Capacity

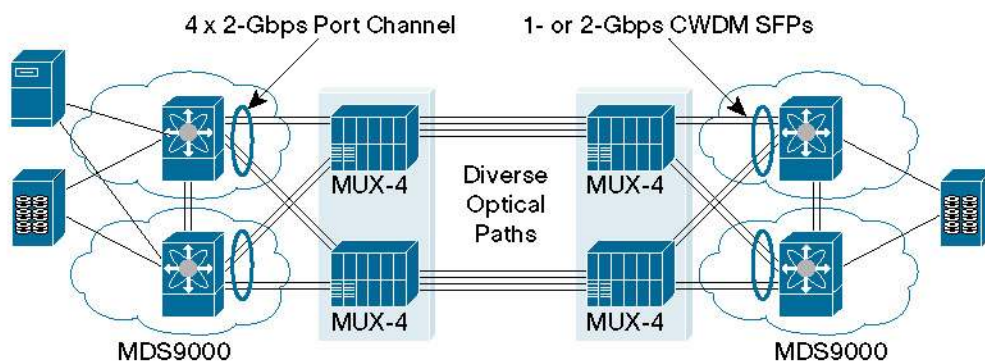
The primary benefits of WDM systems are that they transparently transport any type of traffic (SAN, Ethernet, SONET/SDH, etc.) and greatly increase the capacity of the fiber by transmitting multiple channels or wavelengths on a single fiber strand. There are basically two types of WDM systems – coarse WDM (CWDM) and dense WDM (DWDM) – the main difference being in how they space channels.

CWDM channels are typically spaced 20 nanometers (nm) apart, and because of this wider spacing they use uncooled distributed feedback lasers (DFBs). The more relaxed manufacturing tolerance for CWDM components makes CWDM less costly than DWDM systems. But CWDM systems also support a limited number of channels (the ITU defines 18 lambdas), compared to 32 or more 2.5- and 10-Gbps lambdas typically supported by DWDM technology.

The Cisco CWDM platform provides up to eight wavelengths, making it a very cost-effective yet scalable transport system. It uses GBIC and Small Form-Factor Pluggable (SFP) transceivers for the service provider or enterprise to deploy Fibre Channel and Gigabit Ethernet services in campus, data center, and metro environments. The Cisco CWDM GBIC solution supports any point-to-point and mesh architecture.

Cisco CWDM-based wavelength service is implemented using CWDM SFPs in storage products (Cisco MDS 9000 Family) or IP/Ethernet products as transponders and passive filters, and optical add/drop multiplexers (OADMs) and multiplexer/demultiplexer modules to multiplex and demultiplex signals. Deployment depends on the clients for resiliency and protection. CWDM networks are deployed in access rings for distances of less than 40 km. When deployed in a point-to-point topology, CWDM transponders can traverse approximately 90 km (depending upon the fiber condition). It is easy to extend the reach of CWDM networks as all channels cannot be amplified. CWDM can support both Ethernet and Fibre Channel over the same network. Figure 5 shows a typical data center interconnection using CWDM network for high-bandwidth applications.

Figure 5
Fibre Channel Storage over CWDM



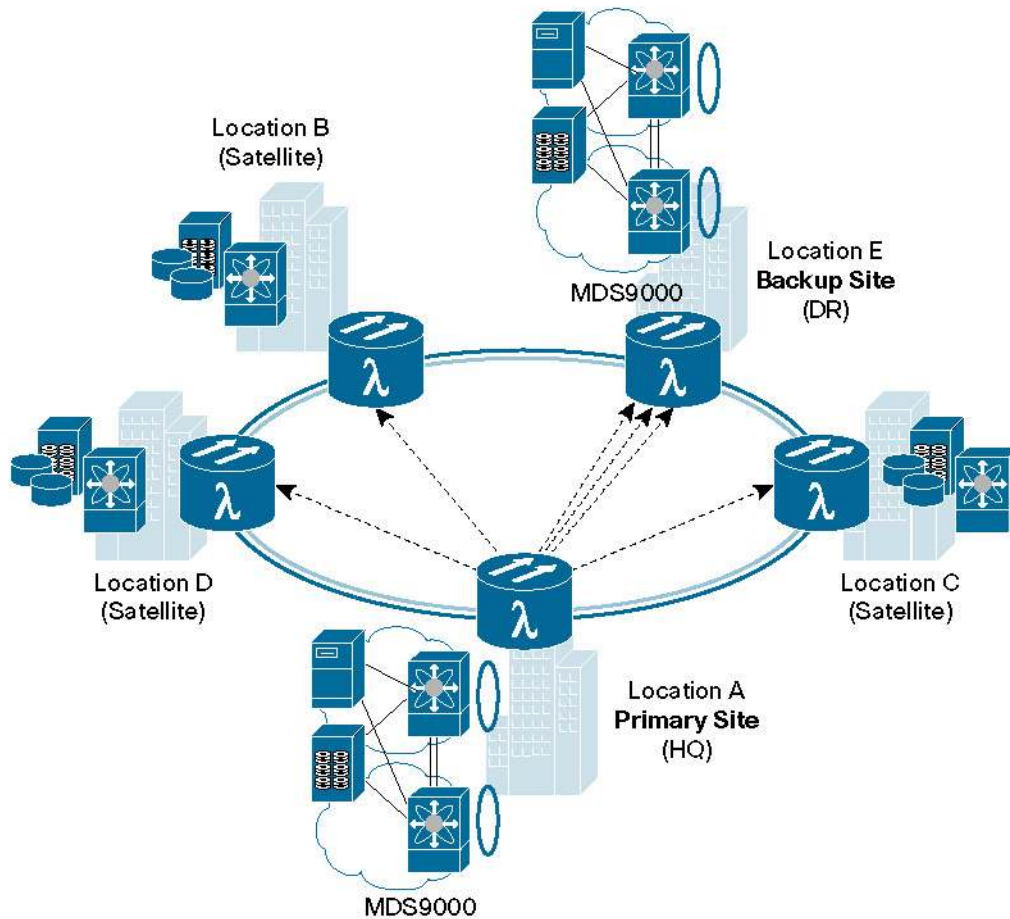
In contrast to CWDM systems, DWDM systems use cooled Distributed Feedback (DFB) lasers to generate more stable wavelengths, and because of this, the wavelengths can be more narrowly spaced at 1.6 nm or much closer. Whereas CWDM was developed for the metro environment, DWDM is also suited for the metro, if many wavelengths are needed, as well as for regional or long-haul applications.

The Cisco ONS 15454 can also be deployed as a multiservice transport platform (MSTP) when it integrates the capabilities of a next-generation DWDM module to provide wavelength services. The Cisco ONS 15454 MSTP supports up to 64 2.5- or 10-Gbps protected wavelengths, giving the service provider or the enterprise a single, high-bandwidth, high-density platform to aggregate and transport time-division multiplexing (TDM)-based services (such as T1/T3, OC-3/STM-1, OC-48/STM-16, etc.) as well as data services (Ethernet/IP, FICON/ESCON, Fibre Channel). Data cards for the Cisco ONS 15454 MSTP allow multiple SAN or Gigabit Ethernet signals to be transported over a single wavelength:

- 8-Port Gigabit Ethernet/Fibre Channel/ESCON 2.5 Datamuxponder Card – A multiservice aggregation card has 8 client interfaces and can transport Gigabit Ethernet, Fibre Channel, and FICON services over a single 2.5-Gbps wavelength.
- 10-Gbps Multirate Transponder Card – Allows using 10-Gbps wavelengths to transport 10-Gbps Ethernet LAN/WAN, 10-Gbps Fibre Channel, and SONET OC-192 services.

Cisco ONS 15454 MSTP's wavelength is provided by incorporating advanced reconfigurable OADM (ROADM) technology (Figure 6), which greatly simplifies deployment of wavelength services.

Figure 6
Multiple Wavelengths for Greater Capacity



ROADMs make it much easier and quicker for the network operator to provide wavelength services because they can remotely add or drop capacity at any node without impacting existing traffic. Wavelengths can be deployed faster because the adjustments in optical parameters that have to be made when OADM are used are made intelligently within the Cisco ONS 15454 MSTP. ROADM technology improves the profit line by reducing onsite maintenance and allowing for network upgrades without disrupting services. It offers a clear benefit for provisioning wavelength services to meet the relatively fast changing traffic demands in the metro environment while allowing for a choice of network topologies (such as point-to-point, linear, and ring).

Several features distinguish Cisco ROADM technology, enabling delivery of any wavelength anytime, anywhere while easing setup and operation of the optical network. The GUI-based MetroPlanner tools provide help in designing a DWDM network based on topology, fiber infrastructure, and supported traffic. The MetroPlanner also generates a file that assists in initial network setup. Automatic power control is built into the Cisco ONS 15454 MSTP to manage amplifier gain during network installation, correction for aging fiber, and restart after a fiber cut.

Cisco also offers several DWDM platforms for metro networks, such as the Cisco ONS 15216, ONS 15530, and ONS 15540. In addition to transparently supporting various services, benefits of these systems include increased capacity (more services, such as Gigabit Ethernet and Fibre Channel/FICON on a fiber pair), high-density service aggregation (many services on a single wavelength), scalability from 2.5- to 10-

Gbps wavelengths, and service mixing (different services on the same wavelength). The Cisco ONS 15216 is a very economical metro DWDM system for delivering wavelength services to the customer premises or between carrier points-of-presence (POPs). Integrating easily with the Cisco ONS 15454 MSTP, the Cisco ONS 15216 supports up to 32 wavelengths which can be used for transporting Fibre Channel/FICON/ESCON, Gigabit Ethernet, POS, and SONET/SDH service across ring, star, and point-to-point networks.

The Cisco ONS 15530 DWDM Multiservice Aggregation Platform maximizes the capacity of dark fiber through its industry-leading service aggregation capability that supports the transport of eight Fibre Channel/FICON/Gigabit Ethernet signals or 40 ESCON signals on each 10-Gbps wavelength. The Cisco ONS 15530 can be deployed for point-to-point networking or reside on the same ring as the Cisco ONS 15540. Additionally, it can also be used as a service aggregation shelf in an existing Cisco ONS 15540 network.

The Cisco ONS 15540 Extended Service Platform can be used to provide up to 32 protected/64 unprotected 2.5-Gbps wavelengths or 16 protected/32 unprotected 10-Gbps wavelengths. These wavelengths can be used to transport a variety of protocols operating from 16 Mbps to 2.5 Gbps, including SANs, Ethernet, SONET/SDH, ATM, and fiber distributed data interface (FDDI). Node topologies can be configured as point-to-point, hubbed ring, or meshed ring.


Mapping Applications to High-Speed Transport

In an increasingly competitive environment, few businesses want to risk the loss of information. Most businesses, therefore, have some kind of a disaster recovery and business continuity plan in place. At one end, it may be sufficient for a business to send tapes daily by truck for offsite storage or perhaps to back up tapes over a relatively slow WAN. On the other hand, a business that has stringent requirements for data protection and access, want information duplicated to a hot standby facility that is ready to take over in the event of a failure at the primary facility.

The storage platform that a business has and, more important, the storage service (such as synchronous/asynchronous mirroring or tape backup) it chooses will affect its selection of a transport technology. Table 1 shows the relationship between storage services, storage platforms, and their supported network protocols, the kind of business that will favor a particular storage service, and the options for a transport technology.

Table 1. Storage Applications Mapped To Transport Technology

Storage Service	Target Customers	Storage Platform	Protocol	Transport Options
Synchronous Data Replication (Real-Time Ext. Distance Data Mirroring)	Require NO data loss High volume, Rev. Impact, Finance, Banking, Brokerage, Telecom, Federal defense disaster recover providers	High-End Storage Platforms	Ethernet FC FICON	DWDM SONET/SDH
Asynchronous Data Replication (Near Real-Time Ext. Distance Mirroring)	Larger market, Healthcare, Life Science Biomedical Engineering	High-End to Midrange Storage Platforms	Ethernet FC FICON	SONET/SDH FCIP WDM
High-Speed Remote Database Backup	Retail, Service organizations, Airlines	High-End to Midrange Storage Platforms	Ethernet FC FICON	SONET/SDH T3/E3/DS-3 IP
Low-Speed Remote Backup	All tier 2, medium-sized businesses	Low-End Platforms (Typically)	FC FICON	SONET/SDH IP
E-mail Archival	All businesses that use e-mail and instant messaging	Custom	Ethernet	SONET/IP



In addition to transport services for the above cited SAN extension and data-backup applications, the enterprise may also need a high-speed, high-bandwidth metropolitan-area network (MAN) for clustering geographically dispersed computing resources to ensure high data availability.

Within the Microsoft environment, a geographic clustering capability enhances Microsoft Cluster Server software by allowing both the active and standby servers to maintain their own storage with an independent, synchronized copy of the cluster data. Because this allows for multiple copies of data to exist, the enterprise is protected even against catastrophic data center failure since the other node of the cluster with its own data is housed at a different facility.

Geo-clustering also applies to the mainframe environment for ensuring high availability of critical business applications. IBM's Geographically Dispersed Parallel Sysplex (GDPS) solution synchronizes mainframe computing resources and, in combination with Cisco Multinode Load Balancing capabilities, allows for load balancing across computing resources. Mainframe geo-clustering assures instantaneous failover to an alternative data center because both facilities are continuously online.

Thus, a high-bandwidth metro optical network is needed for geo-clustering mainframe computing resources or to ensure high availability of cluster-aware applications such as Microsoft SQL Server or Exchange.

Choosing the Right Data Center Interconnection Service

Whether Ethernet, SONET/SDH, or DWDM is the right choice for data center interconnection depends upon several considerations, not the least of which is how far outside the threat radius the enterprise wants the secondary data center to be located.

IP/Ethernet is very cost-effective for transporting SAN traffic over great distances, allowing for the secondary data center to be located virtually anywhere. Higher latency, however, may affect synchronous mirroring of data.


SONET/SDH services are highly reliable and can extend the SAN across distances of 2000 km or more by using spoofing techniques to overcome Fibre Channel's buffer credit constraints, although distance could impact synchronous replication.

DWDM offers transparent transport of SAN and other protocols, high capacity, and is extremely well-suited for synchronous applications because only minimal overhead processing is involved. However, in contrast to IP/Ethernet and SONET/SDH, SAN extension over DWDM is likely to be more practical when both the primary and secondary data centers are located within the same metro region. CWDM systems only offer advantages over DWDM systems for applications that require channel counts of 8 or less. CWDM is becoming a transport option because of its low cost compared to current DWDM systems. Other advantages of CWDM over DWDM are low power dissipation and smaller size. The biggest disadvantages are scalability (number of channels) and distance limitations because of the lack of amplification support for the entire proposed band. CWDM currently supports up to 8 lambdas (ITU defines 18 lambdas) compared to 32 to 64 lambdas or even 128 lambdas currently available for DWDM.

The delays that occur in extending the SAN have varying impact on the performance of different applications; financial trading applications, for example, are extremely latency-sensitive. The rule here is to know the application before selecting a SAN extension service.

Conclusion

Enterprise businesses want to protect information and have 24-hour access to critical application services, requirements that for some are mandated by law. Cisco optical solutions allow these customers to select the transport service – whether IP/Ethernet, SONET/SDH, or WDM – that best meets their recovery time and point objectives for business continuity. Whether the enterprise self-manages its metro or WAN, or outsources its network needs to a service provider, Cisco offers a full portfolio of solutions.



The Cisco ONS 15454, together with a variety of interface cards, delivers a single, integrated platform that supports a broad range of data and other services over a high-density, high-capacity optical network. With this platform, the service provider or the enterprise can offer scalable Ethernet, SONET/SDH, or wavelength services in ways that address the customer's data center interconnection needs, regardless of the distances involved. Cisco ONS 15530/15540 DWDM systems offer choices for increasing the capacity of the fiber and transparently supporting SAN, Ethernet, SONET/SDH, and other protocols.

By deploying these Cisco optical network solutions, service providers and enterprises can address a variety of disaster recovery and business continuity needs, ranging from archiving e-mail to data mirroring with zero information loss.

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