Applications

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LIGHTWAVE

Multiservice platforms require complex schemes

Incumbent carriers must evolve their installed base of legacy SONET/SDH equipment to service data traffic. While this evolution is driving the emergence of new data-plane technologies such as generic framing procedure (GFP), virtual concatenation (VC), and link capacity adjustment scheme (LCAS), it also entails significant changes in equipment architectures.

These changes will help lower carriers' capital and operational expenditures. However, the new architectures require complex automatic protection switching (APS) control schemes and provide less predictable performance (especially under typical network loading conditions). As a result, a new category of SONET/SDH functional test is required to characterize the system performance of next-generation SONET/SDH (NGS) equipment.

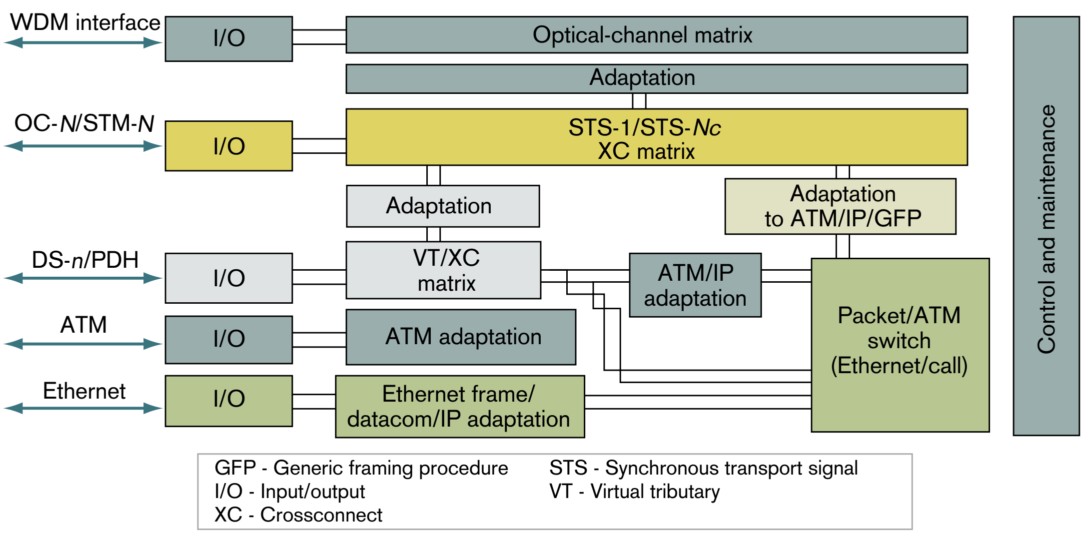
Multiservice platforms

Incumbents' networks were built using add/drop multiplexers (ADMs) to multiplex lower-speed signals containing TDM voice traffic onto higher-speed SONET/SDH rings. As networks evolve to support data services, ADMs are being replaced with newer types of devices known as multiservice provisioning platforms (MSPPs) or multiservice transport platforms. MSPPs not only offer all the functionality of ADMs, they also provide aggregation, grooming, crossconnect (XC), or switching capability as well as Layer 2 functionality such as Ethernet switching.[1]

The aggregation function not only includes the aggregation of lower-speed SONET/SDH signals and electrical DS-*n*/E-*n* PDH signals, but also the combination of data signals such as 10/100Base-T and Gigabit Ethernet (GbE). Some MSPP manufacturers support ATM, and there is increasing demand to support video, storage-area networking, and Fibre Channel.

The grooming function involves the removal of unequipped signals from the incoming traffic and combing the signal into a more efficient use of the bandwidth. Traditionally, grooming and switching functions were handled by a digital crossconnect (DXC), causing some to view the MSPP as a combination of an ADM and a DXC.

MSPP with crossconnect cards



A heightened demand for incumbent networks to support data traffic has led to Ethernet over SONET/SDH (EoS) or NGS. EoS refers to the encapsulation of mainly Ethernet data into GFP framed containers with VC to efficiently use the bandwidth and LCAS protocols to dynamically allocate the bandwidth based on customer demand.

NGS also refers to the synchronous transport signal (STS) and virtual tributary (VT) XC/switching functions within MSPPs (see Figure 1). In fact, the addition of STS and VT XC/switching is debatably a bigger architectural change than GFP or VC within the device itself. It is the addition of this XC/switching functionality that makes APS more complicated with respect to MSPPs.

Another type of NGS device is the multiservice switching platform (MSSP), which on a simplistic level is classified as an MSPP without the aggregation functions. Larger in scale, the MSSP is found in the core of the network. While the MSPP typically has tens of ports with medium switching capacity, an MSSP can have hundreds of ports and a correspondingly larger switching capacity. MSSPs tend to support only higher-speed optical SONET/SDH interfaces with some

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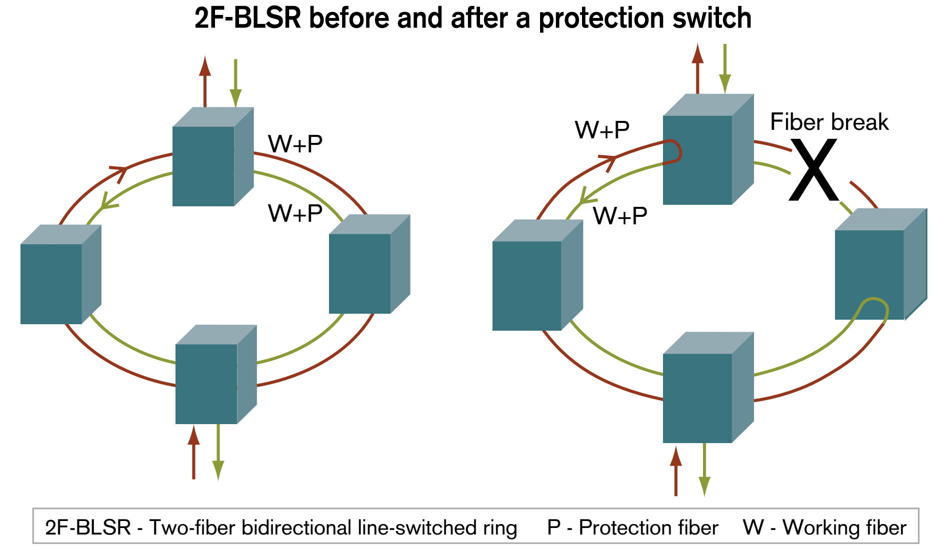

Figure 2. In a two-fiber bidirectional line-switched ring, fibers run in opposite directions, each carrying traffic in STS-1–24. If a break in the fiber occurs, traffic switches to STS-25–48 on the other fiber.

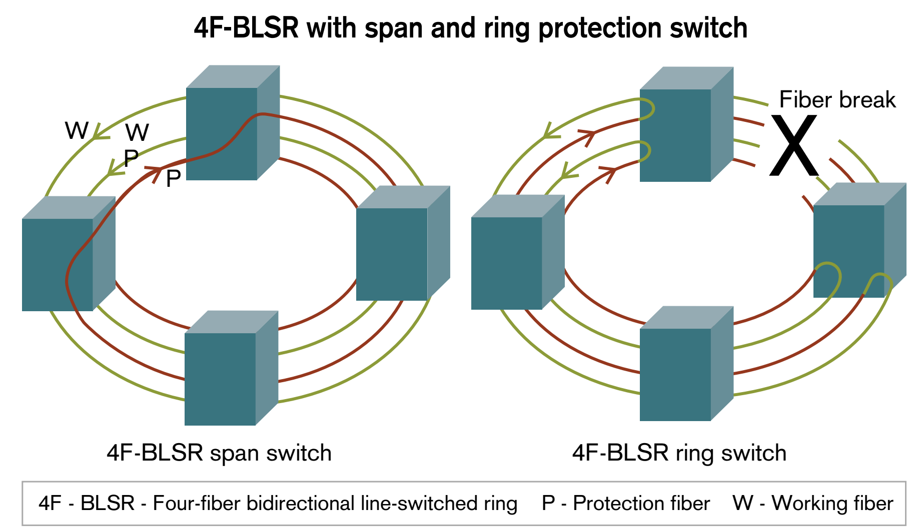

Figure 3. In a four-fiber bidirectional line-switched ring (4F-BLSR), if a failure occurs between two adjacent nodes, span switching restores the network by switching to a different fiber between the two nodes. Ring switching provides network protection by wrapping circuits onto the protection bandwidth in a manner similar to two-fiber BLSR.

platforms having optical GbE and a few even containing 10-GbE interfaces (see Table).

Protection schemes

Traditional protection switching on point-to-point networks was very simple with the link simply protected by the addition of a separate port. That could be a protection port on the same line card or tributary card or alternatively a separate card, which was dedicated to protecting the working traffic. The protection-scheme mechanisms could be 1+1 protection or 1:*n*. The same signal content for 1+1 protection is sent on both the working and protection fibers.

In a 1:*n* protection scheme, the receiving node detecting the failure must coordinate with the other node to determine which of the *n* working lines needs backup by the protection fiber. Under 1:*n* protection schemes, the protection fiber remains unused until a failure occurs. As such, some operators may use the bandwidth on the protection channel for carrying lower-priority traffic. This "extra" traffic is dropped whenever the protection line is used to back up a working line after a failure event.

More complex APS protocols such as two- and four-fiber bidirectional line-switched rings (2F-BLSR and 4F-BLSR) were implemented when ADMs were deployed in SONET/SDH rings. 2F-BLSRs consist of two fibers running in opposite directions. On each fiber, half of the available bandwidth is reserved for protection. In OC-48, STS-1–24 is for working traffic and STS-25–48 for protection traffic. In reality, STS-25–48 may be utilized for additional unprotected traffic or set as unequipped. Fibers run in opposite directions, each carrying traffic in STS-1–24. If a break in the fiber occurs, traffic switches to STS-25–48 on the other fiber (see Figure 2).

4F-BLSR is a robust architecture that can withstand two simultaneous network failures. It utilizes both span and ring protection schemes (see Figure 3). If a failure occurs between two adjacent nodes, span switching restores the network by switch-

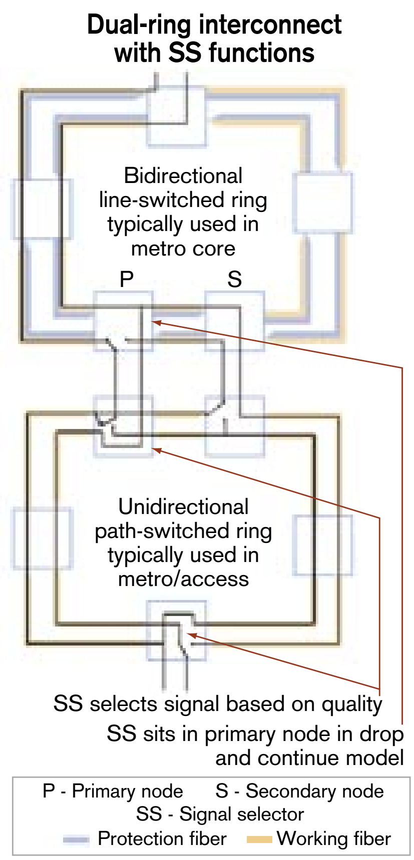

Figure 4. A dual-ring interconnect protection scheme with signal selector functionality enables path protection to work between rings.

Different attributes of MSPP vs. MSSP

	Aggregation	Switching	Grooming	Typical switching capacity	Number of ports	Typical interfaces
MSPP	Yes	STS + VT	Yes	~50 Gbits/sec	>10	OC-*N*, GbE, 100Base-T, DS-1/E1, DS-3, SAN, ATM
MSSP	No	STS	Yes	~500 Gbits/sec (scalable to Tbits/sec)	>50	OC-*N*, GbE, 10-GbE

GbE – Gigabit Ethernet; MSPP – Multiservice provisioning platform; MSSP – Multiservice switching platform; STS – Synchronous transport signal; VT – Virtual tributary

ing to a different fiber between the two nodes. Ring switching provides network protection by wrapping circuits onto the protection bandwidth in a similar manner to 2F-BLSR.

The disadvantage of 4F-BLSR is that it is more expensive to deploy because it requires twice as much fiber and twice as many line side ports on each network element (NE). Carrying low-priority unprotected traffic on the extra fibers can mitigate some of this added cost.

Unidirectional path-switched rings (UPSRs) provide duplicate fibers around the ring. The working traffic flows one way on one fiber, while the protection traffic flows in the other direction on the other fiber. Both fibers carry all traffic. If a problem occurs, the receiving node switches to the equivalent path coming from the opposite direction. The NE processor determines the protection switching process based on performance monitoring (PM) data detected in the line card.

The XC card activates the switch at the path level and the UPSR is implemented on the STS and VT paths. Each path is configured with a signal-fail and signal-degrade threshold on an STS B3 or a VT BIP-2 error ratio—which is used along with the PM data—to initiate the switch.

As such, UPSR tends to be deployed in the access network where service-level agreements on a per path basis are more important. BLSR on the other hand is deployed in the metro core network since the protection is based on the entire line signal.

One of the problems with both UPSR and BLSR is that although they are excellent solutions for protecting traffic within the ring, they do not help protect traffic between rings. It's possible to use 1+1 or 1:*n* protection on the link between two adjacent rings, but the problem is that if the node connecting the rings dies, all the traffic carried between the two rings is lost. The solution to this problem is another more sophisticated protection switching mechanism known as dual-ring interconnect (DRI).

DRI allows protection schemes to work across rings to ensure survivability. It provides path-level protection as opposed to line-level protection such as BLSR. It is very similar to UPSR in concept because all of the provisioning is done on a path basis. All other subsystems work in the same unchanged manner as BLSR and UPSR. DRI does the extra work to offer more protection for the inter-ring traffic and a signal selector selects the signal based on quality. That is the same concept as the UPSR path selector in which monitor points are dynamic. Essentially, DRI has no affect on K1K2 or any other SONET overhead bytes because it is achieved by building more intelligence into the nodes (see Figure 4).

There is one big difference between ADM and multiservice-platform protection switching in regards to protection-scheme mechanisms. Unlike ADMs, all signals will pass through the STS XC card. The STS XC capacity is designed to equal the maximum input of all the traffic slots in the MSPP. That means during a protection switch such as a 2F-BLSR or 4F-BLSR

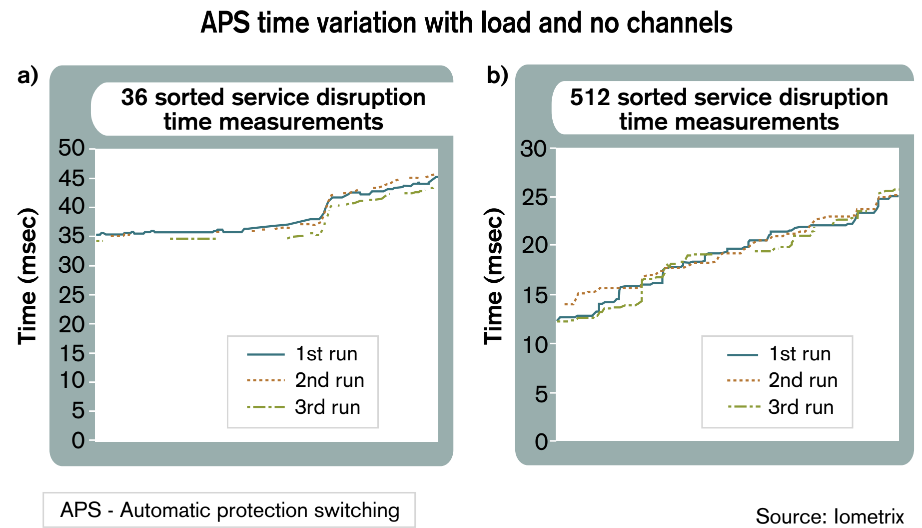

Figure 5. Iometrix test results show automatic protection switching performance of multiservice platforms varies under load conditions depending on the payload size and number of channels. In the single two-fiber bidirectional-line-switched-ring (2F-BLSR) service disruption test (a), it takes longer to switch the larger payload containers, while in the multiple 2F-BLSR service disruption test (b), protection switching increases with the number of channels being switched.

ring switch, all STS paths may be switched and reconfigured via the STS XC. The same is also true of UPSR rings: All signals will pass through the STS XC, and during a path protection switch all the paths may be reconfigured, including fault-free paths. If VT switching is present in a UPSR ring, then the same is true for all the switched VT paths.

It's important to understand that multiservice-platform protection switching isn't implemented purely in hardware. Software is involved in configuring the STS XC card and reconfiguring the XC card when a protection switch occurs.

In an effort to lower operational expenditures, network operators increasingly want to deploy mesh networks with optical control planes using protocols such as GMPLS,[2] which deals with link management and topology/resource discovery (GMPLS routing) as well as signaling during provisioning and restoration. GMPLS or any mesh restoration protocol does not replace any of the existing APS mechanisms. From a signaling perspective, restoration is simply reprovisioning a connection after failure.

Provisioning can be achieved through a management system or based on signaling. Restoration needs to be completed quickly, requiring both a signaling-based approach and distributed control plane. It is not likely nor is it the intention for mesh restoration to meet the Telcordia GR-253 50-msec APS time limit. Switching times in seconds are much more likely, and the switching times will largely degree depend on the size and topology of the mesh network.

Port loading and APS

Iometrix conducted a recent study on metro transport and protection switching times that involved stress testing new MSSPs.[3] The focus of the large-scale network simulation and stress test entailed fully loading the devices and verifying the performance, particularly the Telcordia GR-253 50-msec APS performance limit, under high-load conditions.

The key objective was to simulate a metro network and evaluate its performance under realistic major failure conditions. The main measures were bit-error rate (BER), service disruption times, and connectivity (channels are switched and routed correctly). Other areas covered in the test plan were mixed mappings. The test results shown in Figure 5 point to the following conclusions:

- APS times vary depending on the payload structure carried on each port.
- Mixed payloads of STS-1, STS-3, and STS-12 will exhibit different performance than a uniform payload.
- Higher-bandwidth containers take longer to switch.
- APS times increase when the number of channels increases on the element.

Thus, the performance of MSPPs and MSSPs varies under load conditions depending on the number of channels, payload size, and/or mixed payloads. Single channel and homogeneous payload testing does not verify the true APS performance of an MSPP or MSSP--unlike traditional ADMs. Additionally, it is important to note that NEs must adhere to the 50-msec APS time standard regardless of the load.

Testing protection switching times is fairly easy with ADMs. The general practice is to test one SONET/SDH path at a time, making it easy to determine the worst-case protection switching times through the device. The worst possible change in paths through the ADM is calculated, then tested, with the knowledge that all other protection switching times will be smaller. The worst possible case could be a protection switch from the first card to the last card in the device. It's only necessary to test a single path during a protection switch because other paths are not affected. In addition, it's only necessary to verify APS on each hardware change because protection switching is primarily implemented in hardware and protection switching times are not dependent on the different revisions of software.

The evolution to MSPP devices, which route all paths through STS XC cards, has a number of test implications making it essential to test:

- All channels or paths since it is not known which path through the MSPP is the worst.
- All channels or paths because they may be reconfigured during protection switching and it is vital to verify that all channels or paths are switched correctly.
- APS times on each software release since the switching times could potentially change.
- A mixed-payload structure because mixed payloads and higher-bandwidth signals take longer to switch.
- A fully loaded payload since APS times increase with the loading.

A new breed of devices known as multiservice platforms is displacing ADMs. These systems are architecturally different than ADMs since they send all signals through an STS XC card to provide DXC functionality. The XC card can switch all channels/paths, including those with no faults. That happens regardless of the APS scheme, which has been deployed. The performance of MSPPs and MSSPs varies under load conditions.

Therefore, multiservice-platform performance can't be tested with only one path or stream of traffic. Single-channel and/or homogeneous payload testing does not verify the true APS performance of an MSPP or MSSP. And NEs must adhere to the 50-msec APS time standard regardless of the load. As a result, NGS testing platforms must provide unique capability to test MSPPs, offering simultaneous all-channel APS and BER measurements and mixed-payload capability.

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