ASON/GMPLS in the XDM® Family

Technical Overview

ASON/GMPLS in the XDM Product Line
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October 2007

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General

Document Scope

This document presents the ASON architecture in the XDM family which describes the gradual migration towards an XDM based intelligent network, capable of providing a more efficient transmission solution and integration of multiple technologies in a single shelf for a cost-effective solution.

Introduction

Transmission network traffic is moving towards Ethernet-based oriented services. Traffic patterns and protection requirements are changing, presenting a shift from dedicated to less demanding shared protection schemes. The XDM family supports this evolution from ring protection to efficient mesh protection schemes, in order to make more efficient use of bandwidth resources.

ECI's innovative networking framework enables carriers to reduce CAPEX and OPEX by efficiently planning and operating intelligent optical networks using ASON architecture and GMPLS protocols. XDM facilitates revenue-generating services, such as Gigabit Ethernet, Optical Virtual Private Networks (O-VPN), Bandwidth on Demand (BoD), and differentiated Class of Service (CoS). These networking tools are based on emerging standards from ITU, IETF, and OIF, as well as advanced distributed control plane architectures. As part of BoD applications, UNI for SONET/SDH and DWDM enables client equipment to request the creation, tear down, and modify trails.

The key components of XDM management and control suite include automatic topology discovery, resource dissemination, point-and-click connection provisioning, automatic user initiated setup, end-to-end Performance Management (PM) across a SDH circuit, and network-wide end-to-end path protection and restoration.

Service providers know that OPEX is dramatically influenced by ease of service provisioning and ongoing network maintenance. XDM's automatic discovery capabilities help carriers reduce OPEX, as they include Plug&Play neighbors and resource introduction, as well as status and topology identification.

This distributed dynamic routing capability allows for rapid cost-effective of new nodes and additional bandwidth, without the extensive offline operations required today.

The XDM provides a variety of bandwidth-efficient protection and restoration schemes, while supporting ring, mesh, and point-to-point network topologies. Protection modes include linear MSP, fast mesh restoration, SNCP, and MS-SPRing.

The new ASON capabilities offer new types of protection schemes, in order to increase network survivability with the 1++ (SNCP based) protection for very high CoS services, and 1+R (unprotected based) protection for low CoS services.

With XDM, *the network is the database*.

Control Plane, ASON, ASTN, and GMPLS

The need for intelligent optical networking in carrier networks triggered an ongoing effort by leading standardization bodies towards unified control plane architecture. By adopting well-proven protocols and approaches, this would enable the buildout (evolution) of a new generation of transmission networks. These new networks enable fast provisioning and restoration along multiple carrier domains using infrastructure from multiple vendors. The leading standardization bodies include the ITU-T, IETF, and OIF.

The ITU-T focuses on the switched transport control plane as the ASTN umbrella of specifications. The set of standards relating to ASTN include the ASON architecture, plus multiple generic and specific standards for issues such as call connection management (signaling), discovery and link management, routing and other standards.

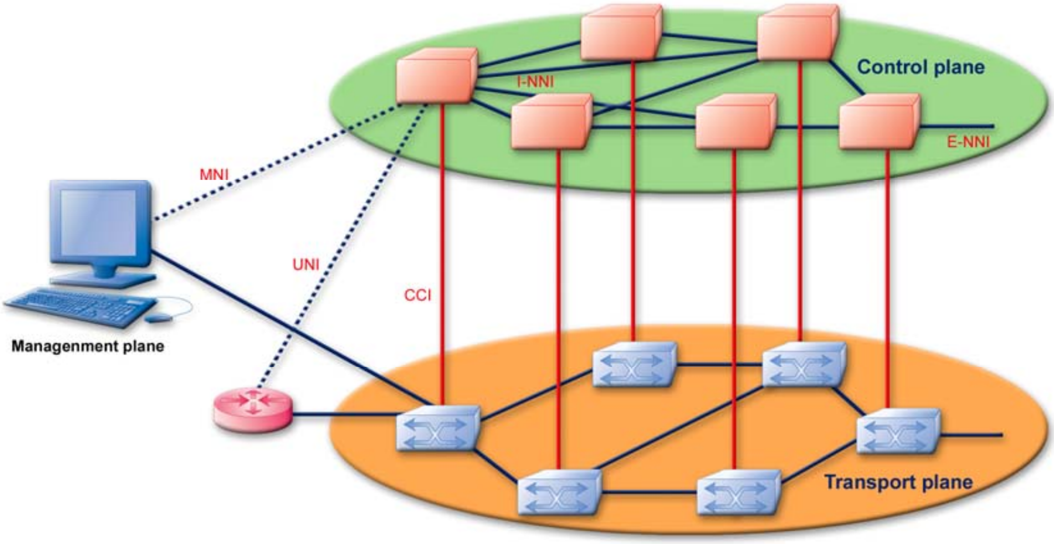

Figure 1: Control plane architecture

The well-known GMPLS architecture and protocols, which extend MPLS for circuit-switching as well as other non-IP-based systems, has been defined by the IETF. GMPLS protocols include signaling protocols (RSVP-TE), routing protocol (OSPF-TE), and others, which, in turn, enable advanced switching platforms such as XDM to add “intelligence” by integrating a control plane.

OIF is mostly focused on integration and interoperability issues. This is addressed by defining the User-to-Network Interface (UNI) and the External Network-to-Network Interface (E-NNI). With these standards, the gaps between ASON and GMPLS architectures are overcome, enabling a smoother integration of carrier networks.

Transport Layer

The Transport Layer is responsible for transporting the services, including switching and multiplexing. The Transport Layer is implemented from the assembly of intelligent components and subsystems that make up switching elements and line systems. The Transport Layer also includes gateways for service adaptation.

Control Plane

The Control Plane enables mesh restoration and intelligent optical networking. The Control Plane consists of individual processors (Control Plane instances) running Control Plane software and using a communication channel to create an overlay plane that controls the switching elements. The Control Plane is mainly responsible for restoring failed connections, for which it establishes, releases, and supervises connections. A signaling communication network (SCN) supports Control Plane instances by providing the communication channel necessary for its operation.

Management Layer

The Management Layer is expanded to accommodate the operations, administration, maintenance, and provisioning (OAM&P) of control plane-related functionalities. Components of the control plane are modeled as managed entities within the management plane, fitting into the existing OAM architecture to minimize disruption to existing operational procedures.

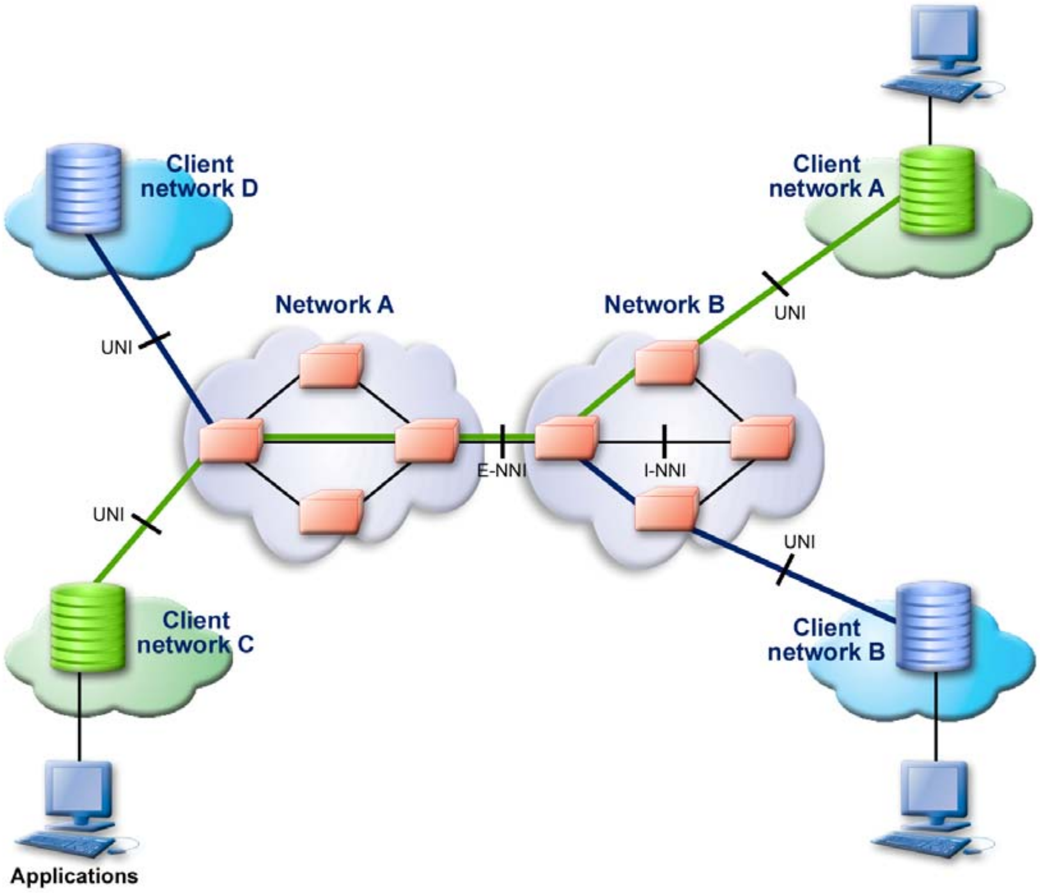

Figure 2: Control plane interfaces

I-NNI

The Internal Network-to-Network Interface (I-NNI) is a bidirectional signaling interface between control plane instances within the same routing domain. Complete topology and routing information is exchanged using the OSPF-TE routing protocol over I-NNI and connection requests are propagated across the control plane using RSVP-TE signaling protocol. Routing and signaling traffic is carried over the SCN. The signaling design complies with ITU-T G.7713 and ITU-T G.7713.2 standards, and routing with ITU-T G.7715 and ITU-T G.7715.1 standards.

E-NNI

The External Network-to-Network Interface (E-NNI) is a bidirectional signaling interface between different routing domains and different administrative domains. E-NNI is a key enabler for rapid delivery of services that span across multiple domains. The E-NNI interface passes reachability and domain level routing information only (not complete routing information as for I-NNI). It is a UNI-like interface with some NNI functions for exchanging address and topology summaries. The RSVP-TE protocol is used for E-NNI protocol.

UNI

The User-to-Network Interface (UNI) allows a client to signal for an optical connection to be set up or torn down. The UNI is used by client systems like routers. It is also used by elements of a higher layer transport network to request an optical connection or modify the service attributes. No topology or routing information is exchanged over UNI. This interface uses OIF-UNI 1.0 R2 standard.

NMI

The Network-to-Management Interface (NMI) handles the interactions between the management layer and the control plane.

ASON/GMPLS in XDM

The XDM family offers ASON control plane architecture, which is capable of offering intelligent services in new and existing XDM transport networks. This is achieved by adding a GMPLS control plane that enhances XDM networks by adding restoration to the sub-50 msec protection schemes and automated service provisioning. It also adds other capabilities that contribute to increased CAPEX and reduced OPEX. The XDM control plane architecture, protocols, and functionalities are described below.

ASON–XDM Family Portfolio

The ASON-XDM family solution is based on the “Add-On” concept that adds unique capabilities to existing and new networks. The XDM provides seamless integration of Network Elements (NEs) to dynamic end-to-end ASON-based applications.

Moreover, the XDM provides an integrated solution of HO and LO VC-12/3/4 switching capabilities with capacities ranging from 30G on the XDM-100 up to 240G on XDM-3000 shelves. With multiple line cards per shelf and bit rates ranging from E1 up to STM-64, as well as L1 and L2 MPLS/Ethernet over SDH, the XDM is an ideal platform for metro-edge, metro-core, and regional networks, capable of implementing both ring-based and extremely efficient meshed networks.

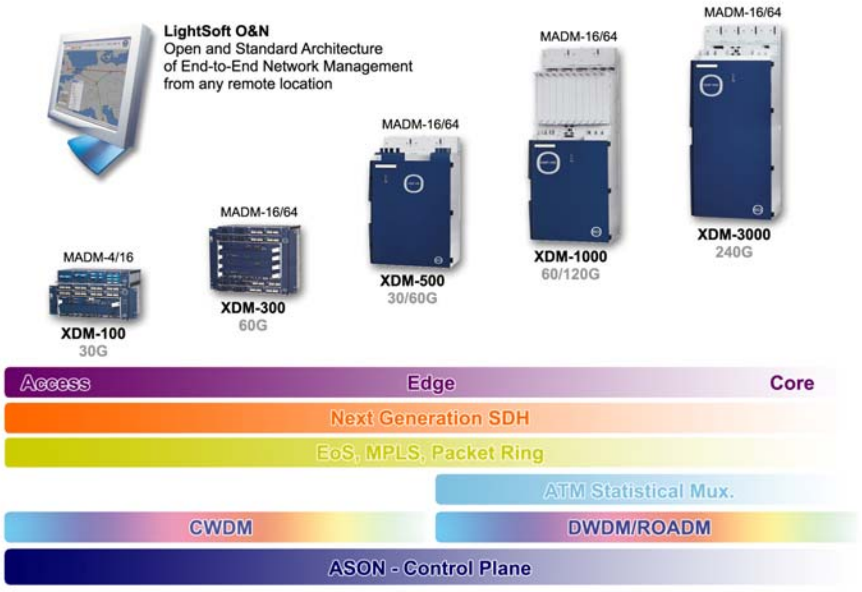

Figure 3: ASON-XDM family portfolio

XDM Optical Control Plane Architecture

XDM implements ASON-compliant network architecture (ITU-T G.8080). A high-level view of the ASON architecture in XDM is shown in Figure 4. The XDM architecture provides interworking with systems that do not have Optical Control Plane technology, as well as other vendor equipment. It is mainly composed of three layers or planes:

- Transport Plane
- Control Plane
- Management Plane

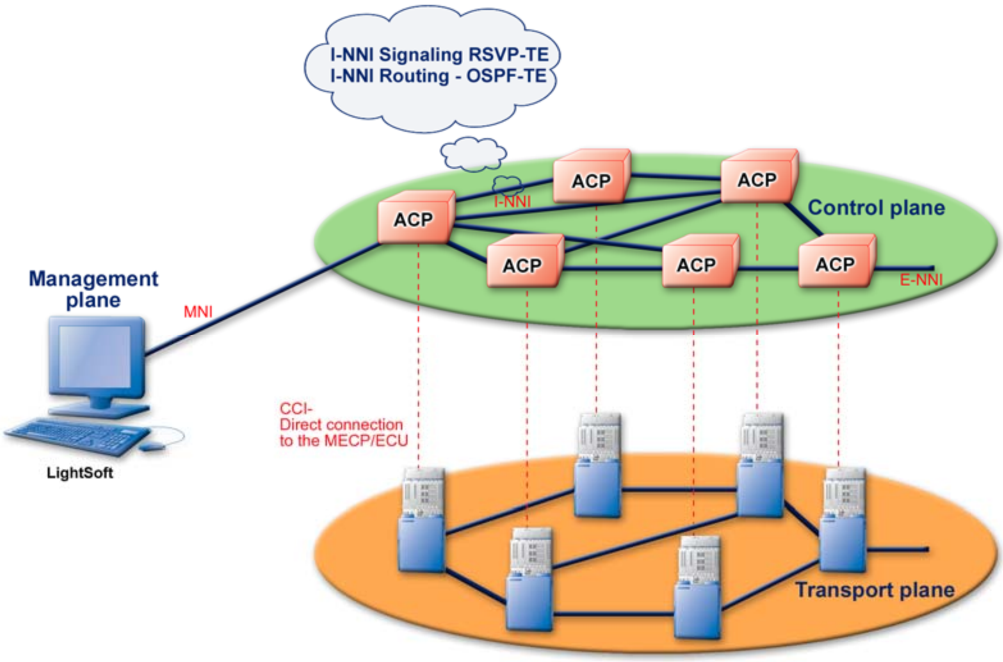

Figure 4: XDM-ASON add-on

The Transport Plane represents the switching equipment. This carries the client payload between endpoints of a connection (trail) over any number of NEs. Legacy transmission networks use the management plane for provisioning, as well as operation (FCAPS) of NEs in the Transport Plane.

The control plane in XDM networks is composed of a set of processing machines within each and every XDM NE. The control plane uses various standard protocols that eventually implement the different roles of the ASON architecture. The control plane software interoperates with the transport place via a CCI (Connection Control Interface), and control plane processors are interconnected with an I-NNI interface over a dedicated DCN (in- or outbound).

The interface towards client equipment is implemented over UNI where, as E-NNI, it is used to expand enabled connections over other domains (other carrier, other layers, or third party equipment). A dedicated interface called MNI is used as an interface between the control plane and NMS.

The following paragraphs describe each plane in more detail.

Transport Layer

With XDM, the Transport Layer is the XDM shelf itself. Among other value-added features, the non-blocking lower order cross-connect capabilities of XDM (the largest LO switch on the market today) is a key asset for carriers in metro networks in general and meshed networks in particular. Since both TDM traffic and Ethernet-over-SDH services are usually generated at VC-12 granularity, the XDM non-blocking solution enables carriers to provision services between any two endpoints without having to consider the limitations that exist when going through an HO trunk layer. Apart from simplifying the planning and provisioning stage, this also improves the effective line utilization.

XDM also offers state-of-the-art built in CWDM and DWDM layers. Equipped with the latest Reconfigurable Optical Add Drop Multiplexer (ROADM) technology and full-range tunable lasers, XDM further simplifies carrier networks by integrating two transmission layers into a single shelf. This is managed with a single NMS and offers networks far more flexibility than legacy WDM networks.

The XDM Transport Plane implements two capabilities that are critical for the implementation of ASON architecture. These are Automatic Discovery and DCN, both compliant with ASON standards, explained in the following paragraphs.

Control Plane

The control plane in the XDM is implemented in a dedicated card named ACP (ASON Control Plane), which is available in three versions:

- ACP-3000: suitable for the XDM-3000 shelf; installed in dedicated ASON slots.
- ACP-1000: suitable for XDM-500 and XDM-1000 shelves; installed in any one of the CCP slots.
- ACP-100: suitable for XDM-100 and XDM-300 shelves; installed in any one of the IO slots.

Each XDM shelf may be equipped with 2 ACP cards for 1:1 protection, preventing single point of failure.

The control plane in XDM implements I-NNI, E-NNI, UNI, and MNI as defined by ITU-T ASON standards, and OIF, based on GMPLS standards.

Management Layer

The management layer, ECI field-proven LightSoft NMS, provides full support of the network. This includes: Fault, Configuration, Administration, Performance, and Security management (FCAPS). This approach is also further extended when ASON is used to create an intelligent network.

Functional Control Plane Description

Signaling Communications Network (SCN)

In an ASON-based network with a distributed control plan where each NE has its own ASON card, signaling communication between NEs is a critical issue. Moreover, when a failure occurs, no restoration is performed. High reliability is therefore required to always maintain “live” management connection between the NEs. The SCN is a data communication channel that enables communication between the ACP cards. Operators may implement the DCN both in-band and out-of–band, as follows:

- SDH IP-DCC in the XDM
- Clear Channel (the DCC is encapsulated into a VC-12)
- External DCN through the Ethernet port in the ACP

The SC channel, whether in- or out-of-band, can be implemented with existing SDH links between the ASON domain NEs.

Auto-discovery

Auto-discovery in XDM supports resource management and link management. The auto-discovery design complies with ITU-T G.7714 and ITU-T G.7714.1 standards. Various levels of auto-discovery are supported: self-discovery, adjacency discovery, topology discovery, and link bundling, These are described below.

XDM Self-discovery

The NE Self-discovery process is handled at the transport layer, i.e., by XDM shelves, similar to any XDM-based SDH network. Upon NE commissioning, the network element automatically detects installed circuit packs, software configuration, and initializes the circuit packs to default settings. The NE continuously monitors the state and attributes of its local facilities. It learns the local facility characteristics and port attributes, and reports them to the ACP control plane card, which, in turn, updates its local XDM topology database.

Adjacency Discovery

Adjacency Discovery is a process in which an individual NE automatically detects logical and physical connectivity to its neighboring NEs (link adjacency) on a per-port basis by a simple exchange of unique interface identifiers (auto-discovery tags). This exchange of identifiers is done in-fiber, over J0 byte. The use of J1 is also allowed when it is not possible to use J0.

An auto-discovery identifier is exchanged on each optical interface. Once validated and accepted by the network operator, the adjacency information is sent to the control plane for analysis (peer/neighbor discovery) and to the management plane. Adjacency Discovery complies with ITU-T G.7714.

The XDM continuously monitors link adjacency as long as the interface is configured. Mismatches, as well as topology changes, are reported to the control plane and the management system.

Network Topology Discovery

The control plane itself uses OSPF for the discovery of the control plane and network architecture. Each ACP learns the network topology and builds its topology database. The routing mechanisms use this information in automated route computation. The objective is that each control plane instance holds a complete and identical view of the network topology and resources.

Link Bundling

The XDM control plane bundles ports/facilities with the same link attributes into a single link bundle. Link Bundling provides an efficient way to distribute link information for multiple links at the same time instead of one at a time. This approach provides a scalable architecture for large networks.

Routing

Routing is responsible for network topology and resource discovery, and for automatic route computation. It complies with ITU-T G.7715 and ITU-T G.7715.1 standards.

A distributed link state routing protocol, OSPF-TE, is used for automatic discovery of the network topology and resources, and for maintaining a local topology database on each control plane instance. In particular, each ACP is responsible for discovering its neighboring NEs and the set of links that connects them. It then advertises the identities of its adjacent neighbors and the cost/weight of each link. This information is advertised among control plane instances by periodic exchange of link state packets. Thus, each ACP is armed with a dynamic map of the network topology and resources. Using this information, the ACP is capable of computing routes to any destination.

Both implicit and explicit path determination are supported at call creation. Implicit call is a call for which only the source and destination points are specified for its connection(s), along with other service attributes (i.e., rate, granularity, CoS, etc.).

Explicit routing refers to the cases for which the route is specified by the LightSoft NMS system, which in turn passes route specifications to the control plane. With explicit routing, no calculation is required from the control plane. An explicit call may still benefit from the dynamic connection management capabilities of the control plane by using precalculated mesh restoration.

Signaling

Optical signaling provides the underlying mechanisms for dynamic call and connection management. The signaling mechanisms handle connection requests, such as connection creation or restoration. The signaling design complies with ITU-T G.7713.2 and GMPLS RSVP-TE standards.

Once a route is determined by the ACP of the source node, signaling is used to set the connection. Label request messages are sent from source node to the destination node. The receipt of notification messages from the destination node to the source node are used by each ACP along the way to set the local cross-connect that services the entire connection end-to-end.

Two connection types may be supported:

- Soft Permanent Connections (SPC): the optical connection is requested by LightSoft (on behalf of client devices).
- Switched Connections (SC): the optical connection is requested directly by the client at the edge of the network.

Management and Operation

LightSoft is today's NMS for all XDM families. With Corba north- and southbound interfaces, it implements the MTNM architecture. LightSoft interoperates with EMS-XDM as well as other ECI and third party EMS systems to complete the management system in large networks.

LightSoft – NMS

XDM's NMS system, LightSoft, works in conjunction with EMS-XDM to deliver a full FCAPS suite. LightSoft's role is to ensure consistency between the network resources and the carrier's internal database, in addition to other features related to fault reporting, accounting, performance monitoring, and security. With the introduction of EMS-XDM, it also becomes the management system of the control plane.

The role of LightSoft is to prepare the configuration data to enable the control plane, acting as a real-time tool, to set up and tear down services, and preserve them in the event of network failures. Traffic engineering tools are one such application; they provide the right configuration parameters for optimal distributed routing decisions. Once correctly configured, the control plane is able to operate even if LightSoft is unavailable. On the other hand, LightSoft is capable of overriding the control plane if necessary. For example, faulty resources may be hidden from the control plane, enabling the operator to repair them.

Protection and Restoration

The unique value proposition of ASON for carriers is the ability to improve existing network resiliency by introducing the well-known restoration approach of IP networks. With ASON, the network itself monitors services and restores them in the event of failure. This approach of service re-establishment in case of failure has been the basic feature of SDH-based transmission networks, which offer service protection in less than 50 msec. SDH technology defines various shared and dedicated protection schemes. Over the years, these protection schemes have proven to be highly reliable. They have managed to achieve multi-vendor interoperability, and have paved the way to SDH technology becoming the most reliable transmission technology available.

This high reliability of SDH is achieved by allocating networking assets for protection. Linear protection schemes, such as MSP1+1, use a dedicated standby line. MS-SPRing uses 50% of the ring capacity for protection. Path protection, which is suitable for mesh topologies, uses 50% of the overall network bandwidth by duplicating all traffic at its origin.

Adding ASON to SDH-based networks brings added benefits without affecting the already superior performance of SDH today. With ASON, the control plane is capable of restoring services in case of multiple failures in the network. Furthermore, network capacity can be more efficiently utilized by sharing protection resources.

Differentiated classes of service (CoS) are supported by XDM architecture. Any compromise in protection schemes allows network planners to choose between the protection switching time and dedicated resources. For mission-critical services, XDM provides distributed restoration mechanisms with 50 msec service recovery and dedicated protection. For less critical services, distributed shared mesh restoration schemes can be implemented.

The XDM control plane supports the coexistence of multiple protection and restoration schemes. The XDM control plane introduces new restoration schemes, as well as combined protection/restoration solutions, as follows:

- 1++ (“1+1 forever”): similar to path protection with SNCP where a failed path is restored by the control plane to prepare for the next possible failure
- 1+R: re-route restoration (1+R) dynamic restoration
- Unprotected
- 1+1 path protection

1++ (“1+1 forever”)

With “1+1 forever”, a sub-50 msec restoration time is kept for any number of failures, as long as a restoration path is found for the failed connection. Basically, this functionality is an extension of 1+1 path protection, where failure in the main or protection path results in the restoration of the failed path. Restoration is in addition to protection at the SDH layer, which continues to be performed in less than 50 msec.

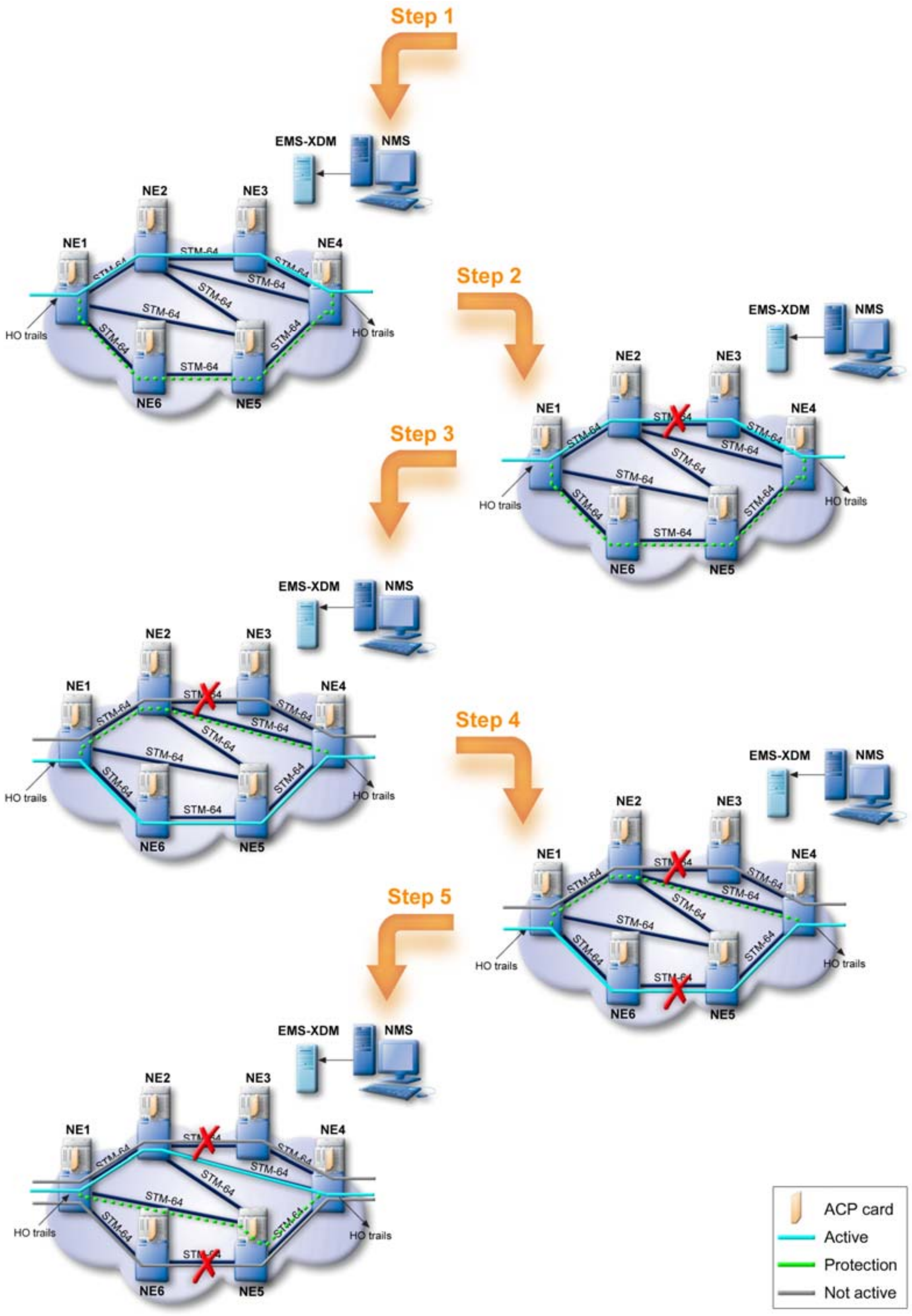

Figure 5: 1++ protection

This protection scheme consumes the most BW as traffic is duplicated at all times.

1+R (Mesh/Shred Restoration)

Dynamic Restoration enables shared protection with prioritization. This protection scheme is an extension of unprotected trails where failure in the path results in restoration of the trail in a new path. The unused traffic may be used for low priority traffic at all times.

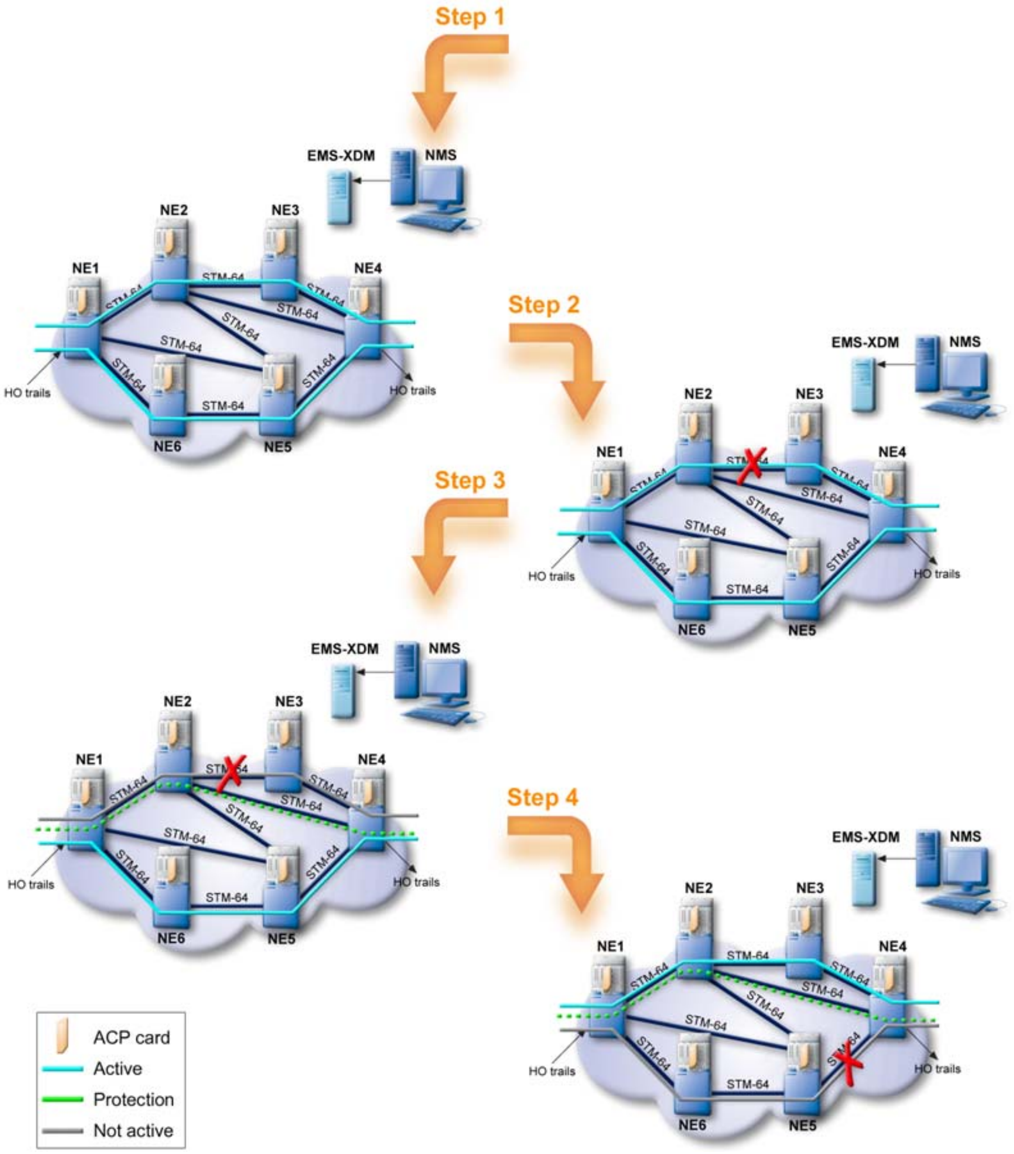

Figure 6: 1+R protection

Preplanned Shared Protection

Preplanned Shared Protection enables shared protection with prioritization. Preplanned priority reacts faster than dynamic restoration as the processing time is performed in advance.

Path Computation

The protection and restoration capabilities of links and the Shared Risk Link Groups (SRLG) associated with links can also be advertised by the routing protocols. Based on the LightSoft Physical layer, SRLG constrains the information and capabilities provided by the GMPLS routing and signaling protocols. The path computation algorithm CSPF (Constrained Shortest Path First) can select disjointed paths based on link, node, or SRLG diversity.

Abbreviations and Reference Documents

Abbreviations

ASON	Automatically Switched Optical Network
ASTN	Automatic Switched Transport Networks
BGP	Border Gateway Protocol
BLSR	Bidirectional Line Switched Ring
CAPEX	CAPital EXpenditures
CCAMP	Common Control and Management Protocol
CLI	Command Line Interface
CoS	Class of Service
CP	Control Plane
CR-LDP	Constraint Routing-Label Distribution Protocol
CSPF	Constraint Shortest Path First
DCC	Data Communication Channel
DWDM	Dense Wavelength Division Multiplexing
E-NNI	External Network to Network Interface
EMS	Element Management System
GMPLS	Generalized Multi-Protocol Label Switching
I-NNI	Internal Network to Network Interface
IETF	Internet Engineering Task Force
IP	Internet Protocol
IS-IS	Intermediate System-Intermediate System
ITU-T	International Telecommunication Union -Telecommunication Standardization Sector
LDP	Label Distribution Protocol
LMP	Link Management Protocol
LSA	Link-State Advertisement
LSP	Label Switched Path
LSR	Label Switching Router
MPLS	Multi-Protocol Label Switching
MS-SPRing	Multiplex Section Shared Protection Ring
MSP	Multiplex Section linear Protection
NMI	Network to Management Interface
NMS	Network Management System
NNI	Network to Network Interface
OAM&P	Operations, Administration, Maintenance and Provisioning

OIF	Optical Internetworking Forum
OPEX	OPerating EXpenditures
OSPF	Open Shortest Path First
QoS	Quality of Service
RFC	Request for Comments
RSVP	Resource ReSerVation Protocol
RSVP-TE	Resource ReSerVation Protocol - Traffic Engineering
SCN	Signaling Communication Network
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SNCP	SubNetwork Connection Protection
SONET	Synchronous Optical NETwork
SRLG	Shared Risk Link Group
TDM	Time Division Multiplexing
TE	Traffic Engineering
UNI	User-to-Network Interface
UPSR	Unidirectional Path Switched Ring
VPN	Virtual Private Network
WDM	Wavelength Division Multiplexing

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21. draft-ietf-isis-gmpls-extensions-19.txt, IS-IS Extensions in Support of Generalized Multi-Protocol Label Switching
22. draft-ietf-mpls-bundle-06.txt, Link Bundling in MPLS Traffic Engineering
23. draft-ietf-mpls-lsphierarchy-08.txt, LSP Hierarchy with Generalized MPLS-TE

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24. OIF-UNI-01.0-R2-Common, User Network Interface (UNI) 1.0 Signaling Specification, Release 2: Common Part
25. OIF-UNI-01.0-R2-RSVP, RSVP Extensions for User Network Interface (UNI) 1.0 Signaling, Release 2
26. OIF-SEP-01.1, Security Extension for UNI and NNI
27. OIF-SMI-01.0, Security Management Interfaces to Network Elements
28. OIF-E-NNI-Sig-01.0, Intra-Carrier E-NNI Signaling Specification