2007 Worldwide Interoperability Demonstration:

On-Demand Ethernet Services across Global Optical Networks

Executive Summary

The 2007 OIF Worldwide Interoperability Demonstration shows end-to-end provisioning of dynamic switched Ethernet services over multiple, control-plane enabled intelligent optical core networks through the use of OIF implementation agreements of UNI 2.0 and E-NNI. In-service Ethernet bandwidth modification and control plane discovery and failure recovery are new features which are demonstrated.

Interoperability testing of various network equipment includes MSPP, routers, Ethernet Switches, cross-connects, OADM in the data plane as well as various implementation approaches in the control plane. The multi-vendor aspects of the interoperability testing give carriers confidence that different vendors and technology domains can work together. Additionally, participating vendors demonstrated mature, stable interoperable products based on OIF specifications and leading edge technology in the use of control plane to open new markets for carriers to deliver advanced Ethernet services through their optical networks more efficiently.

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3 Introduction

Ethernet services in the public networks are growing at a steady pace. Interoperability is required at many levels (i.e., transport, control and management planes) to allow flexibility as the network evolves to support present and future Ethernet services. However, Carriers' Optical transport networks are growing incrementally and have varying infrastructure evolution strategies, which results in heterogeneous domains comprised of a range of bearer technologies, infrastructure granularity options, and survivability mechanisms. Coupled with the heterogeneity in operational support system (OSS) environments, interoperability among network elements is challenging.

Optical Internetworking Forum (OIF) members understand these challenges, which require that control plane solutions be developed in the context of such heterogeneous environments, and are able to co-exist with the existing network. The OIF has long fostered cooperation among a broad and diverse group of carriers, equipment vendors, and telecom service end users in order to accelerate the deployment of advanced, interoperable, and cost-effective optical network architecture solutions. The OIF's consistent, evolutionary effort has resulted in a broad set of Implementation Agreements (IAs) that have been tested and publicly demonstrated in progressively more comprehensive environments.

At SuperComm 2004, OIF successfully demonstrated dynamic end-to-end SONET/SDH connection management between client devices and transport network elements from many vendors in a multi-domain, multi-node transport network spanning multiple carrier laboratories.

At SuperComm 2005, the OIF further demonstrated the use of control plane technology for supporting Ethernet services with dynamic setup and tear down of Ethernet services across a global optical transport network incorporating multiple vendors' equipment.

At ECOC 2007, the OIF takes a giant step in demonstrating new features in the use of control plane and in particular showing dynamic switched Ethernet services and in-service bandwidth modification. Furthermore, control plane recovery and discovery were also demonstrated. These new features are essential for successful deployment of advanced Ethernet services.

4 Demonstration set-up

The OIF test network has global coverage and is based on the test facilities of seven major carriers from Asia, Europe and North America :

- Asia: China Telecom, KDDI
- Europe: Deutsche Telekom, France Telecom Group, Telecom Italia
- North America: AT&T, Verizon

In the carrier facilities, heterogeneous multi-vendor and multi-domain networks with ASON/GMPLS enabled nodes and domains were constructed with equipment from the following vendors:

- Alcatel-Lucent
- Ciena Corporation
- Ericsson AB
- Huawei Technologies
- Marben Products
- Sycamore Networks
- Tellabs
- ZTE

The above carriers' labs and the locally constructed domains were interconnected via an OIF control plane with inter-domain links resulting in a worldwide test network. To support the testing, a global Signaling Communications Network (SCN) was set up based on GRE tunnels over the public Internet secured by IPSec at the endpoints. **Figure 1** gives an overview of the involved carrier sites and the vendor equipment distribution in the carrier labs.

In addition to the transport of signaling and routing protocols, the SCN is used for monitoring, checking and collecting information about the status of established connections and for the display of the connections crossing multiple network domains. The topology display is shown online at the ECOC 2007 exhibition.

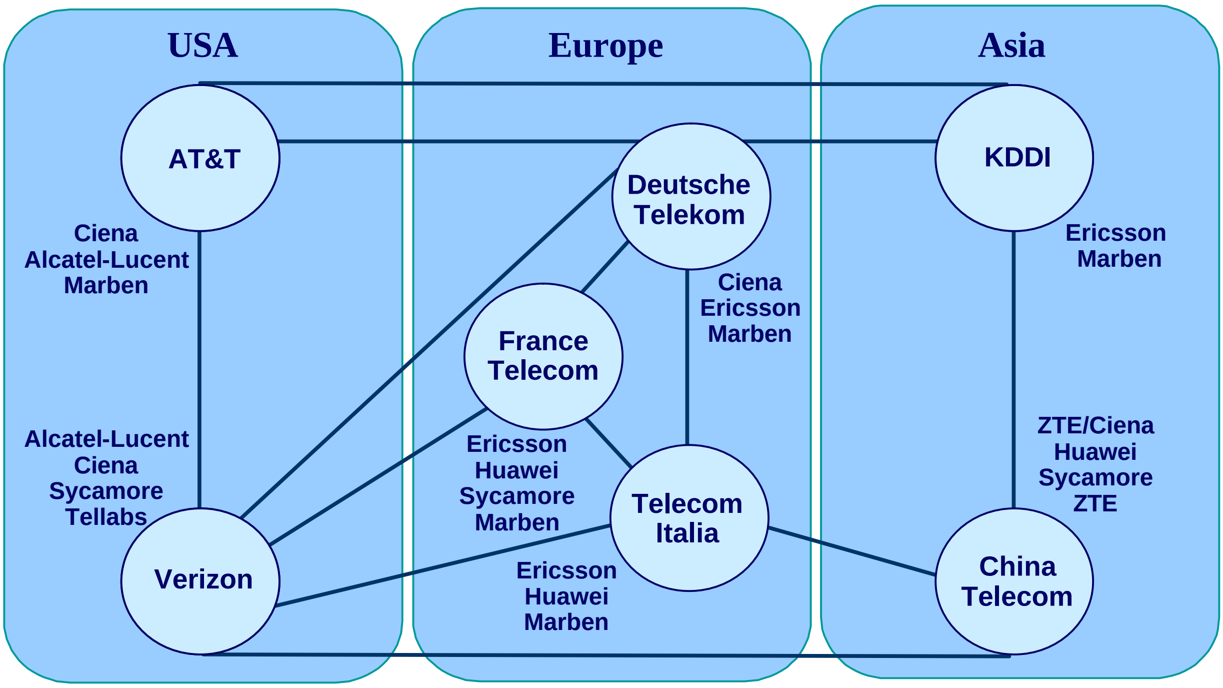

Figure 1: OIF test network topology – carrier sites and vendor equipment distribution

The OIF worldwide test network builds the basis for global interoperability evaluations of control plane with inter-domain interfaces and enabling On-Demand Ethernet service access on a global scale, crossing heterogeneous multi-domain networks composed of various vendors' equipment.

All transport network (TN) domains are interconnected by OIF External Network-Network-Interfaces (E-NNI) and therefore maintain the independence of each implementation within each network domain. The client domains are connected to these TN domains via the OIF User-Network-Interface (UNI 2.0), which support SONET/SDH, OTN and Ethernet signal formats. In this interoperability event Ethernet UNI 2.0 services are used, enabling client sites to request on-demand TN resources using control plane based signaling. The client sides (UNI-C) support Ethernet data links only, while the TN sides (UNI-N) automatically map these Ethernet service requests into the corresponding SONET/SDH parameters. Both UNI 2.0 and E-NNI OIF interfaces enable seamless On-Demand Ethernet service establishment over multiple network domains composed of various vendors' network elements (NE) and support the ITU-T ASON architecture.

5 Interoperability in Global Optical Networks

The key aspects of this interoperability demonstration are:

- The demo implementation employs standards-based solutions. This is essential for transitioning new technology from the labs to deployment in carrier networks
- Heterogeneous network equipment can be connected and interoperate (at both data and control plane levels). The demonstration includes:

    - Data plane equipment interworking between the following types of equipment:

      MSPPs, routers, Ethernet switches, cross-connects and OADMs

    - Control plane interworking between controllers embedded within the network element and proxy controllers that provide control plane functions on a remote platform that communicates with the network element.

- The multi-vendor aspect gives carriers confidence that different vendor/technology domains can interwork
- The carrier labs involvement shows their commitment and vision of the intelligent optical network
- The expected benefits of optical network control plane are:
    - Improved OpEx/CapEx by distributing the network intelligence
    - Intelligence and topology knowledge is in the network itself
    - Rapid turn-up of services

- Enables multi-domain interworking
- Enables customer control of service delivery
- Improved tracking of in-use and available resources

6 Technology employed in the demonstration

6.1 Non-Disruptive Bandwidth Modification for Ethernet Services

At the ECOC2007 OIF Worldwide Interoperability Demonstration, Ethernet services are enhanced by supporting non-disruptive bandwidth modification. When a user requests, via the UNI-C, an increase or decrease in bandwidth for the Ethernet service that is being used, the transport network reacts by modifying the bandwidth of the Ethernet connection and by adjusting the number of members in the Virtual Concatenation (VCAT) group. This is achieved without interruption to the user data transfer or the data plane during the bandwidth modification process. Addition and removal of SONET/SDH connections to the exiting VCAT group are achieved using Link Capacity Adjustment Scheme (LCAS) technique. Generic Framing Procedure (GFP) is used for the encapsulation of Ethernet services for transport over SDH/SONET

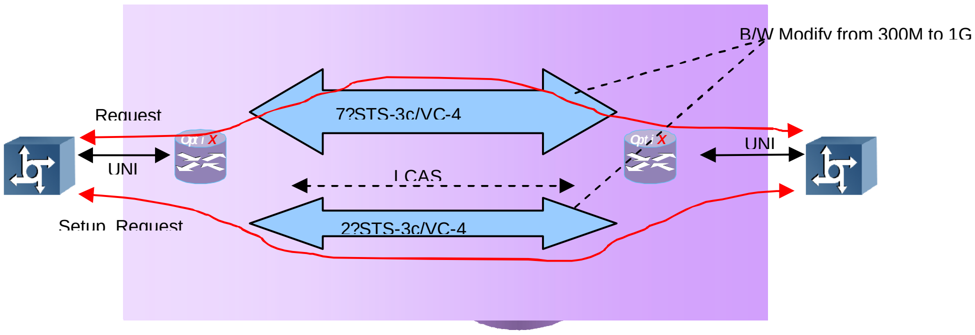

Figure 2: Non-Disruptive Bandwidth Modification

6.2 Control Plane Enhancement for Multi-Layer Networks

In this demonstration Ethernet services are showcased in a multi-layer network architecture. From a signaling perspective, VCAT is treated as an independent network layer and it can be viewed as a service layer for the client Ethernet layer. VCAT layer call establishment is driven by Ethernet client layer call request. The interlayer mechanism is similar to that between the VCAT layer and the SONET/SDH layers. The VCAT layer calls negotiate adaptation parameters through RSVP signaling and VCAT member management. To accommodate these new features, the multi-layer control plane technology is enhanced and utilizes more advanced techniques than the ones demonstrated in previous years' demonstrations. Technology enhancement features in a multi-layer network that are included are described below.

First, to negotiate VCAT parameters between the endpoints of the service, VCAT is treated as a layer, separate from both the Ethernet and SONET/SDH layers. Since this requires VCAT call signaling, RSVP was adapted to carry VCAT layer parameters in VCAT call messages. Furthermore, the VCAT group member sequence is exchanged in the VCAT call message, to map the client Ethernet service into diversely routed connections at SONET/SDH layer whether LCAS is present or not at optical network equipment.

Second, signaling-based client layer discovery in a multi-layer network is implemented in the demonstration to dynamically obtain remote endpoint information at the client layer. This process is driven by the service setup request and the discovered information includes control and data plane identifiers of each remote endpoint at the client layer.

Third, independent calls and connections exist in each layer. Calls and connections in different layers are allowed to use identifiers allocated for the control plane entities in each layer.

6.3 Fault Recovery for Multi-Layer Networks

The reliability of the transmission network is one of the most important features of the network. The separation of the control plane and the data plane ensures that a failure in the control plane does not impact adversely the data plane. This provides the user with a secure and credible service.

The control plane failure can be as a result of either a nodal failure or a control channel failure. After it has been repaired, the control plane synchronizes its state with the neighboring nodes and recovers current status information of the network and services.

7 Ethernet Services Types

The Metro Ethernet Forum (MEF) classifies Ethernet services as E-Line (point to point) and E-LAN (multipoint to multipoint). E-Line is further divided into:

- Ethernet Private Line (EPL), defined by ITU-T Recommendation G.8011.1, where a whole Ethernet port is switched across a provider network, and
- Ethernet Virtual Private Line (EVPL), defined by ITU-T Recommendation G.8011.2, where VLAN sets can be switched to separate destinations.

OIF UNI 2.0 Implementation Agreements (IAs) support both EPL and EVPL. A client (UNI-C) device can dynamically request the establishment of EPL or EVPL service across an operator's network. UNI signaling functions, along with the OIF E-NNI and each domain's I-NNI signaling protocol (the latter not specified by OIF), are used to establish an end-to-end connection.

The 2007 OIF Worldwide Interoperability Demonstration focuses on reliable end-to-end Ethernet connectivity, and enhancements to interoperable on-demand Ethernet Services, offered under the ITU-T Recommendation G.8011.1 EPL model.

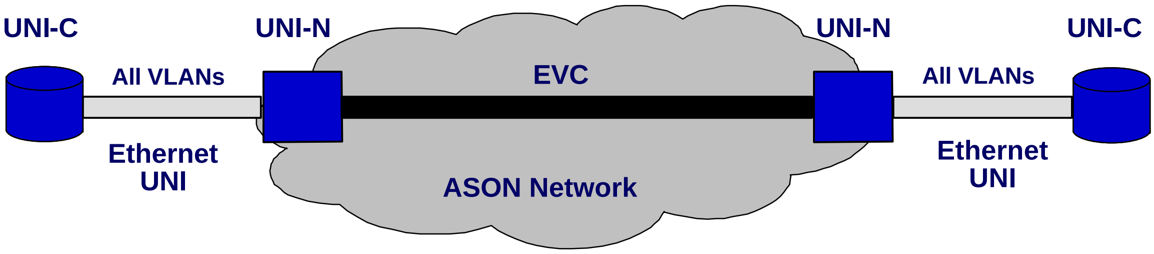

Figure 3: Ethernet Private Line network configuration

8 Applications of optical control plane

A control plane is implemented to overcome the limitations of centralized network management systems to effectively manage network resources in today's environment of ever-growing data traffic. The growth of data traffic challenges carrier networks in terms of traffic volume but also the variable and asymmetrical nature of the traffic. This is driven by the rise in bandwidth-intensive enterprise data networking (locally, regionally and globally) and triple play end user applications. All this causes fluctuating demand for bandwidth. Control plane technology can reduce the amount or need to reserve extra network capacity needed to guarantee contracted service levels thereby improving bandwidth utilization and ultimately realizing CapEx and OpEx savings for carriers. These benefits can be attained through the following applications of optical control plane technology.

- Control plane for bandwidth de-fragmentation
- Provisioning via EMS/NMS and control plane
- Bandwidth on Demand (BoD) in transport networks
- Scheduled BoD including GbE services
- OSS simplification
- Control plane for auto-discovery and self-inventory

9 Benefits to the carriers and users

9.1 Carriers' view

Within the last few years carriers have seen an increasing demand for high-speed, flexible, highly resilient transport services. To provide these services on an end-to-end basis, across multiple network domains, while maintaining resilience and meeting customer expectations, carriers see an increasing need for interoperable technologies and networks that can support cost-effective dynamic bandwidth services in a heterogeneous network environment.

The introduction of Ethernet services in carrier networks provides the ability to offer broadband data services in an efficient and cost-effective manner, using the access solution of choice for supporting a wide set of customer data applications. At the same time SONET/SDH networks have been shown to be the right platform for supporting existing Service Level Agreements (SLAs) due to their built-in resiliency and manageability. Therefore, the control plane, while it brings in added flexibility and speed to service delivery, should enhance network reliability currently established by the use of SONET/SDH technology. As such, control plane reliability and resilience is a major contributing factor towards the carriers' willingness to adopt control plane technology. By implementing a standards-based mapping of Ethernet into SONET/SDH with control plane technologies and protocols, carriers can leverage their existing infrastructure and operational model, while selectively upgrading their networks and enabling dynamic bandwidth services. This results in reduced time to market for the deployment of new services, faster provisioning and retained carrier-grade reliability.

Using VCAT and LCAS in combination brings in additional functionality by allowing dynamic modification of service rates without disruptions to customer traffic.

9.2 Adaptation of Ethernet Services to SONET/SDH networks

To date, Ethernet services are expanding with the growth of Ethernet Private Line and private Local Area Network (LAN) services. Ethernet transport must support a wide set of customer applications in a cost-effective and efficient manner, over multiple service rates.

Efficient and standards-based service adaptation of various client signals into SONET/SDH is a critical capability required to provide interworking between various vendors' equipment. It allows carriers to leverage their widespread SONET/SDH infrastructure to assure reliability, availability, and Quality of Service for both traditional Ethernet best-effort traffic and high-value Ethernet services (e.g., VoIP and videoconferencing). Ethernet over SONET/SDH adaptation utilizes the ITU-T standards for GFP, VCAT, and LCAS.

Standardized mapping of Ethernet over SONET/SDH using GFP bridges the gap between packet-based services and circuit-based transmission. Combining GFP and VCAT capabilities allows carriers to efficiently map services to the transport network infrastructure by concatenating only the number of payloads necessary to support the customer throughput request. Further increasing network flexibility, use of LCAS enables carriers to adjust network usage in response to changing customer requests in a hitless manner. LCAS also minimizes the impact of network failures on customer service by adjusting the service transport by mapping the data stream to unaffected units.

9.3 Carriers' use of optical control plane

An optical control plane is the key to realizing the full potential of transport networks to support dynamic bandwidth services. For example, the control plane supports rapid turn-up of services, efficient allocation of bandwidth in the network and reliable tracking of available resources. Standardized UNI/ENNI interfaces provide an effective mechanism to interconnect both different vendors' equipment and different carriers' domains.

The introduction of network intelligence at the optical layer improves the provisioning process, enabling carriers to define new services and bring them to the market in a timely manner. Furthermore, intelligent networks keep updated network information (inventory, topology) within the network itself, thus alleviating the problem of synchronizing external databases. This network concept allows devices within the network to actually manage themselves and facilitate network provisioning in a matter of seconds. Initial economic analysis (qualitative and quantitative) of the impact of control plane on high-speed circuit provisioning and revenue realization indicates OSS simplification resulting in cost savings and significant opportunities for new bandwidth services with early revenue realization.

9.4 User's View

Today's users of high speed telecommunications are increasingly savvy and are looking for services allowing them to control their networks' topology and bandwidth assignment while continuing to expect high reliability. Layer 1 dynamic optical network services are being offered by carriers and are using the flexibility provided by the control plane. As technology advances, customer flexibility and control will become increasingly available also for management and allocation of Ethernet services and Savvy customers will take advantage of the new capabilities enjoying the benefits of flexible, resilient and cost-effective networks supporting their business needs.

9.5 Value to the Industry

The evolution of the optical transport infrastructure has been an incremental process that has resulted in a heterogeneous network made up of a wide variety of network elements. To allow flexibility as the network continues to evolve, standards-based interoperability is a requirement.

The OIF's work supports prototyping and validation of the concepts of optical internetworking and provides essential feedback for the improvement of optical standards, especially for the control plane. The OIF UNI and E-NNI can be used by carriers to efficiently manage transport networks with diverse equipment such as Multi-Service Provisioning Platforms, SONET/SDH grooming switches, wavelength cross-connects, DWDM transport systems, and Reconfigurable Optical Add/Drop Multiplexers. Ethernet over optical transport networks is a further step that will enable cost-effective transport of high-speed data, using control plane functionality.

The 2007 OIF Worldwide Interoperability Demonstration proves the effective coexistence of Ethernet Services over intelligent optical networks. Furthermore it showcases the network flexibility achieved by bringing together the qualities inherent to each layer using network intelligence as the catalyst for service evolution. It confirms the long established rule in the carrier market that services are the primary drivers for technology adoption and network build-out.

10 Related Standards Activities

In parallel to the OIF effort, a number of standards organizations are working on technologies for supporting Ethernet service across a global transport network. There is a strong synergy between OIF's efforts and other standard group's activities.

Three critical technologies are used for this OIF demonstration: GFP, VCAT and LCAS are all developed by ITU-T, i.e., Recommendations G.7041, G.707/G.783/G.798 and G.7042 respectively. ITU-T study group 15's latest development G.8010 lays out Ethernet Architecture, G.8011 describes various Ethernet services and G.8012 delineates Ethernet interface. Both OIF UNI/NNI signaling protocols and OIF E-NNI routing protocols as used in this demonstration are also based on ITU-T's G.7713 and G.7715 respectively.

Metro Ethernet Forum (MEF) has specified a set of Ethernet services, including point-to-point E-Line and multipoint-to-multipoint E-LAN. Detailed MEF reference documents are available at

http://metroethernetforum.org/PDF_Documents/metro-ethernet-services.pdf.

E-Line service as defined by MEF is further divided according to ITU-T G.8011 into EPL and EVPL. The OIF Worldwide Interoperability Demonstration 2007 is focusing on the EPL service model as defined by MEF and ITU-T
Signaling protocols developed by the IETF (RFC3471-3477) lay out the basis for OIF UNI and E-NNI signaling implementation agreements. Routing protocols developed by IETF (RFC 4202-4203) lay out the basis for the OIF E-NNI routing implementation agreement.

11 Conclusion

The 2007 OIF Worldwide Interoperability Demonstration shows end-to-end provisioning of dynamic switched Ethernet services over multiple, control plane-enabled intelligent optical core networks through the use of OIF implementation agreements for UNI 2.0 and E-NNI. In-service Ethernet bandwidth modification, control plane discovery and failure recovery are new features which are demonstrated.

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12 Appendix A: List of Contributors

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13: Appendix B: About the OIF

Launched in April of 1998, the OIF is the only industry group uniting representatives from data and optical networking disciplines, including many of the world's leading carriers, component manufacturers and system vendors. The OIF promotes the development and deployment of interoperable networking solutions and services through the creation of Implementation Agreements (IAs) for optical, interconnect, network processing and component technologies, and optical networking systems. The OIF actively supports and extends the work of standards bodies with the goal of promoting worldwide compatibility of optical internetworking products. Working relationships or formal liaisons have been established with the IEEE 802.3, IETF, ITU-T Study Group 13, ITU-T Study Group 15, IPv6 Forum, MFA Forum, MEF, MVA, ATIS OPTXS, ATIS TMOC, Rapid I/O, TMF, UXPi and the XFP MSA Group. Information on the OIF can be found at www.oiforum.com http://www.oiforum.com.

14: Appendix C: Glossary

ASON: Automatically Switched Optical Network	OADM: Optical Add/Drop Multiplexer
BoD: Bandwidth on Demand	OAM&P: Operations, Administration, Maintenance & Provisioning
DWDM: Dense Wavelength Division Multiplexing	OIF: Optical Internetworking Forum
CoS: Class of Service	OSS: Operations Support System
E-NNI: External Network-to-Network Interface	OTN: Optical Transport Network
EMS: Element Management System	OXC: Optical Cross-Connect
EPL: Ethernet Private Line	PC: Protocol Controller
EVC: Ethernet Virtual Connection	ROADM: Re-configurable Optical Add & Drop Multiplexer
EVPL: Ethernet Virtual Private Line	RSVP: Resource Reservation Protocol
GFP: Generic Framing Procedure	SCN: Signaling Communications Network
GMPLS: Generalized Multi-Protocol Label Switching	SLA: Service Level Agreement
GRE: Generic Routing Encapsulation	SONET/SDH: Synchronous Optical Network/Synchronous Digital Hierarchy
IA: Implementation Agreement	STS: Synchronous Transport Signal
I-NNI: Internal Network-Network Interface	TDM: Time Division Multiplexing
IPSec: IP security	TN: Transport Network
LAN: Local Area Network	UNI: User-to-Network Interface
LCAS: Link Capacity Adjustment Scheme	UNI-C: User-Network Interface-Client
LSP: Label Switched Path	UNI-N: User-Network Interface-Network
MEF: Metro Ethernet Forum	VC: Virtual Container
MSPP: Multi-Service Provisioning Platform	VCAT: Virtual Concatenation
NE: Network Element	
NG-SONET/SDH : Next Generation-SONET/SDH	
NMS: Network Management System	