2005 OIF Worldwide Interoperability Demonstration:

Dynamic Setup of Ethernet Services over Global Optical Networks

1. Introduction

Ethernet services in 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. At the same time, carriers have heterogeneous core optical transport networks 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 operate effectively within 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 that have been tested and publicly demonstrated in progressively more comprehensive environments.

At SUPERCOMM 2004, OIF successfully demonstrated dynamic end-to-end 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 takes a major step in the use of control plane technology for supporting Ethernet services, with a demonstration that showcases the dynamic setup and tear down of Ethernet services across a global optical transport network incorporating multiple vendors' equipment. Furthermore, in addition to dynamically controlled Ethernet Private Line services, the SUPERCOMM 2005 demonstration also includes the delivery of Ethernet Virtual Services over the optical transport network.

1.1 Worldwide Interoperability

The demonstration network is a truly global network which is built in the facilities of seven carriers around the globe:

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

Furthermore, the demonstration network is a multi vendor network with the involvement of 13 vendors: Alcatel, Avici Systems, Ciena Corporation, Cisco Systems, Inc., Fujitsu, Huawei Technologies, Lambda OpticalSystems, Lucent Technologies, Mahi Networks, Marconi, Nortel, Sycamore Networks and Tellabs.

Figure 1 shows the involved carrier sites, the vendors participating at each site, and the connections between them.

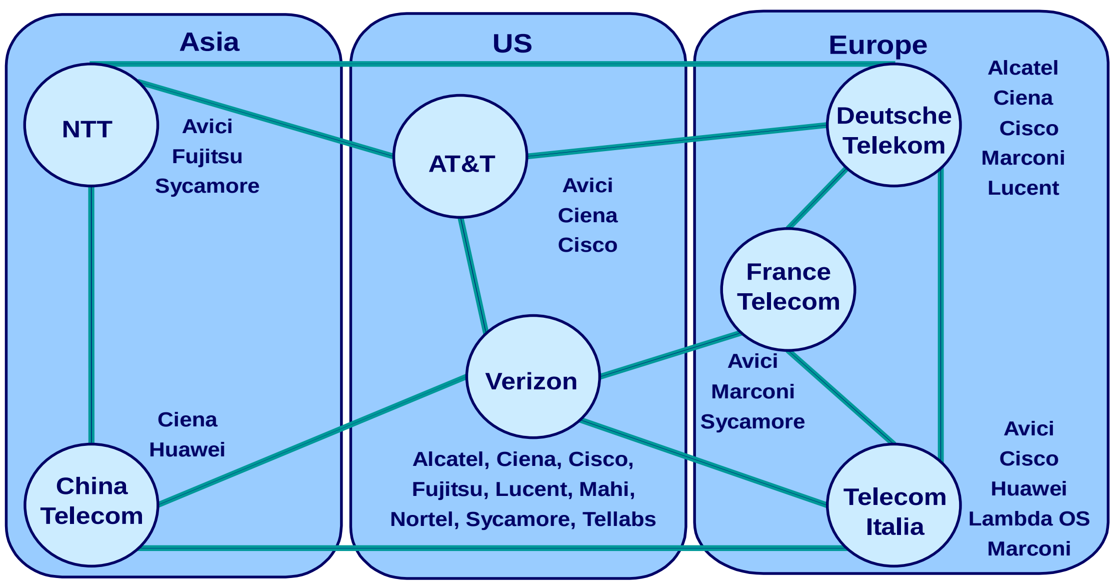

Figure 1: Connections among Carriers and Vendors

1.2 Demonstration Setup

Figure 2 shows a high level view of the demonstration network. It consists of client networks and a multi-carrier network which has several administrative domains. The carrier network is delivering Ethernet services to its clients. Client networks can dynamically request connections from the carrier network via the UNI2.0 signaling interface controlling a Gigabit Ethernet access link. The different administrative domains in the carrier network cooperate via the OIF E-NNI control interface to deliver the dynamically requested connection using optical transport network resources.

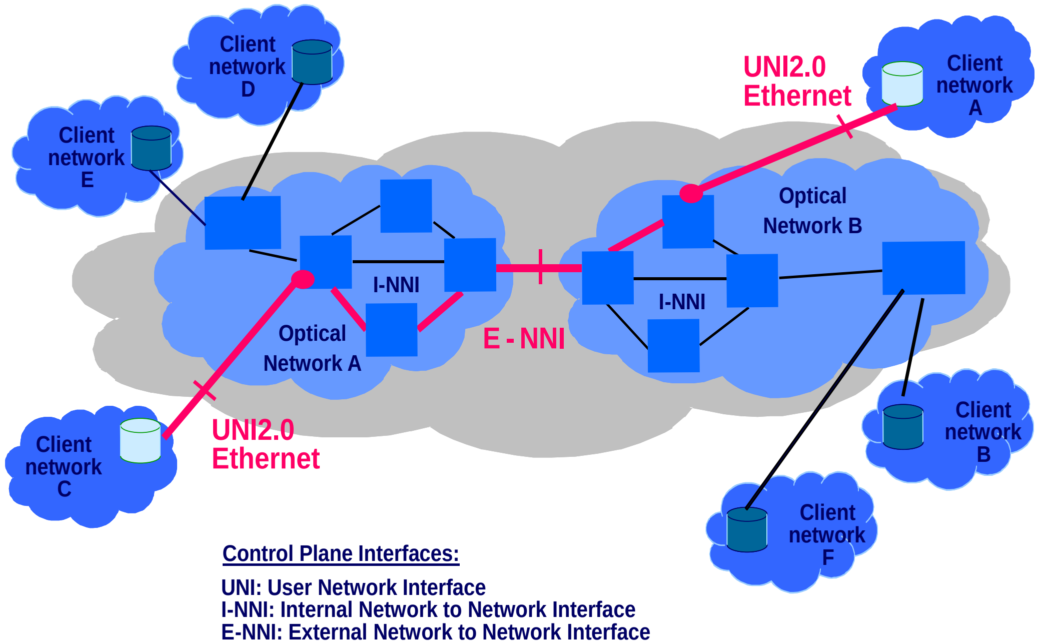

Figure 2: An Example of 2005 Demonstration Network

The optical control plane defined in the OIF Implementation Agreements and in the ITU-T ASON Recommendations relies on separation (physical or logical) between the data plane and control plane. Exchange of control messages must be supported by a Signaling Communications Network (SCN) connecting Network Elements. Here the SCN is implemented as an out-of-band data network connecting the carrier sites and the SUPERCOMM booth. The SCN utilizes connecting GRE tunnels transported over the public Internet, secured by IPSec at the endpoints.

The SCN also serves to connect monitoring sites for checking the health of the signaling network and collecting real-time information on topology and connectivity for display on the SUPERCOMM booth screens. The monitoring system intercepts RSVP control plane signaling messages to build displays of current network topology and call maps as connections are built and torn down. Both the end-to-end Ethernet connection and its supporting SONET/SDH server layer connections are displayed.

2. Carrier View

With growing demand to support end-to-end broadband services, carriers see an increasing need for interoperable technologies and networks that can support cost-effective dynamic bandwidth services.

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 identified as the right platform for supporting existing Service Level Agreements (SLAs) due to their built-in resiliency and manageability. 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 carrier-grade reliability.

2.1 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 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 (QoS) 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 Generic Framing Procedure (GFP), Virtual Concatenation (VCAT) and Link Capacity Adjustment Scheme (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 sufficient to support the customer throughput request. Use of LCAS further increases network flexibility by enabling carriers to hitlessly adjust network usage in response to changing customer requests. LCAS also minimizes the impact of network failures on customer service by mapping the data stream to unaffected units; thus adjusting the service transport.

2.2 Carriers' Use of Optical Control Plane

An optical control plane is the key to realizing transport networks' full potential 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.

GFP, VCAT, and LCAS interoperability was first demonstrated by OIF in 2004, as a necessary stepping stone towards achieving interoperable end-to-end Ethernet services over SONET/SDH networks. At SUPERCOMM 2005, OIF extends this functionality by demonstrating dynamic client-to-client Ethernet-over-SONET/SDH signaling using UNI and E-NNI advances, and integrating transport and control plane functions in an effective way. Clients are thus able to dynamically signal for bandwidth, without having to be aware of the underlying server layer network.

2.3 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 (ROADMs). Ethernet over optical transport networks is a further step that will enable cost-effective transport of high-speed data, using control plane functionality.

The 2005 OIF Worldwide Interoperability Demonstration proves the effective coexistence of Ethernet Services over intelligent optical networks. It confirms the long established rule in the carrier market that services are the primary drivers for technology adoption and network build-out.

3. Related Standards Activities

ITU-T SG 15 is specifying the ASON and Ethernet over Transport framework of Recommendations upon which the OIF 2005 Worldwide Interoperability Demonstration is based. Foundation Recommendations are enumerated in Table 1.

G.807/Y.1302	Requirements for automatic switched transport networks (ASTN)
G.8080/Y.1304	Architecture for the automatically switched optical network (ASON)
G.7713/Y.1704	Distributed Call and Connection Management (DCM)
G.7713.1/Y.1704.1	Distributed call and connection management (DCM) based on PNNI
G.7713.2/Y.1704.2	Distributed call and connection management (DCM): Signaling mechanism using GMPLS RSVP-TE

G.7713.3/Y.1704.3	Distributed call and connection management (DCM): Signaling mechanism using GMPLS CR-LDP
G.7715/Y.1706	Architecture and Requirements for Routing in the ASON
G.7715.1/Y.1706.1	ASON Routing Architecture and Requirements for Link State Protocols
G.7718/Y.1709	Framework for ASON Management
G.8010/Y.1306	Architecture of Ethernet Layer Networks
G.8012/Y.1308	Ethernet UNI and Ethernet NNI
G.8021/Y.1341	Characteristics of Ethernet transport network equipment functional blocks
G.8011/Y.1307	Ethernet over Transport – Ethernet Services Framework
G8011.1/Y.1307.1	Ethernet private line service
G.8011.2/Y.1307.2	Ethernet virtual private line service
G.7041/ /Y.1303	Generic Framing Procedure (GFP)
G.7042/Y.1305	Link Capacity Adjustment Scheme (LCAS)

Table 1 Foundation ITU-T Recommendations for ASON and Ethernet Transport

This year's interoperability testing focuses on support of the OIF UNI 2.0 Ethernet Services and Ethernet Virtual Services, defined in ITU-T G.8011.x series. The OIF UNI 2.0 work is also tracking the Ethernet service descriptions defined by the Metro Ethernet Forum (MEF) in their Ethernet Service Document. The OIF works cooperatively with the ITU-T, MEF and IETF sharing work in progress and approved documents via liaisons.

4. Technology of the Demonstration

4.1 OIF Control Plane Testing

OIF has defined and tested Implementation Agreements for the optical UNI and the optical E-NNI that are aligned with the ITU-T ASON Recommendations. The optical UNI enables clients of optical networks to dynamically establish connections using signaling, while the E-NNI automates the establishment of these connections between optical networks. Together, UNI and E-NNI permit dynamic A-to-Z provisioning of services across an optical network in real time without manual intervention, resulting in faster and more efficient operation than traditional optical networks. The link state routing protocol is used for automated network topology distribution and link status updates inside the network.

4.2 Control Plane Enhancements for Ethernet Services

For the 2005 OIF Worldwide Interoperability Demonstration, the network consists of multiple technology layers, the client interface being Ethernet and the underlying core network being SONET/SDH. Architecturally, connections are established by the control plane at both the Ethernet layer and the SONET/SDH layer (see Figure 3). Multiple stages of signaling are used to establish the supporting SONET/SDH layer connection(s) and to carry the Ethernet client layer call request, making the control plane processing significantly more complex than previous years' demonstrations.

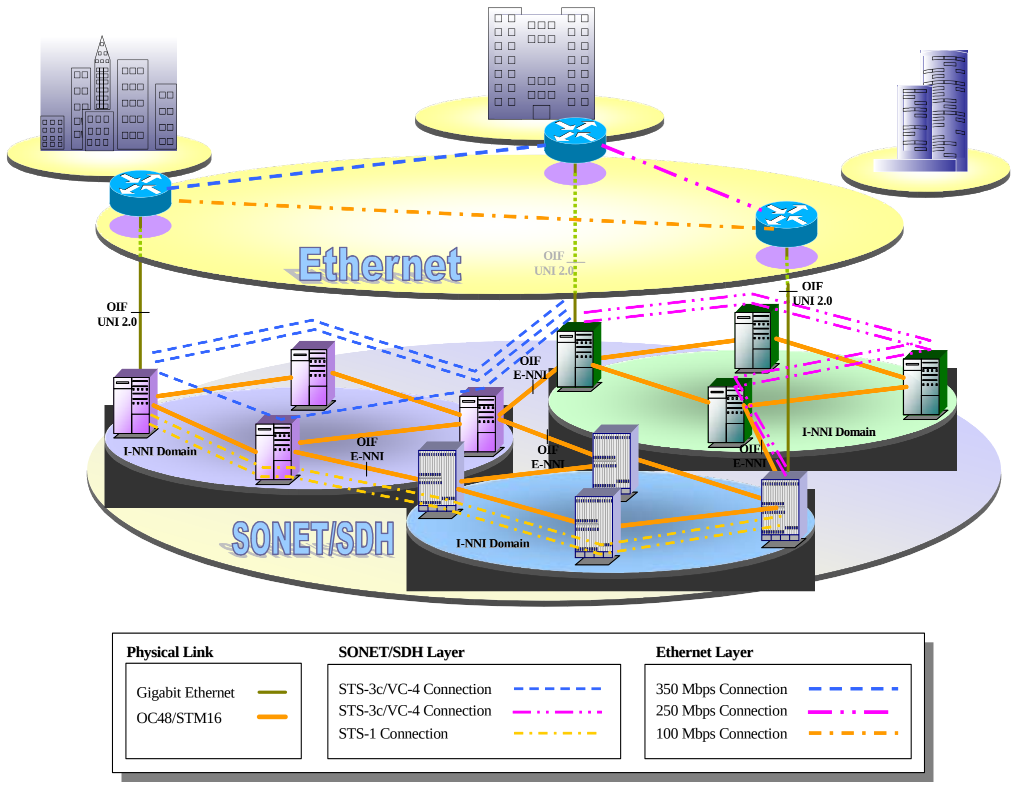

Figure 3: Multi-layer Intelligent Optical Transport Network

A key extension of this demonstration is the ability to dynamically trigger the creation of the supporting server layer connection upon detecting that new optical capacity is required. When the ingress optical switch receives the UNI 2.0 call request, it determines that an optical connection is required, computes the path across the optical core and creates the connection, which is then used to carry GFP-encapsulated Ethernet frames. In the future, the switch may also reuse existing optical connections where spare bandwidth may be available. The network will be able to respond dynamically to new demands, either creating a new optical connection or reusing existing optical connections.

A number of important technical extensions are used in the UNI and E-NNI for support of Ethernet connections, including the following:

- Correlation of signaling at client and server layers using label switched paths (LSP) Hierarchy mechanisms.
- Correlation of multiple server layer call/connections with the associated client layer call/connection (discussed further in the VCAT section below)
- Mapping of Ethernet signaling components to SONET/SDH components, including

the Transport Network Assigned (TNA) addresses for Ethernet clients and the Ethernet layer Traffic Specification (Tspec).

4.3 Control Plane Support of Virtual Concatenation

VCAT is an inverse multiplexing capability defined in ITU-T that allows multiple SONET/SDH channels to be bound into a single higher rate VCAT group (VCG). For the demonstration, separate connections are set up for each component of the group, in order to create higher survivability for the group as a whole. LCAS allows failure of individual connections to be treated as reduced bandwidth in the group without actually causing failure of the entire group.

Multiple VCAT connections in the server layer are achieved by creating multiple calls and therefore allowing each connection to follow different routes. An example of call setup for VCAT is shown in Figure 4 below. A coordination mechanism is supported to synchronize the establishment of the supporting VCAT connections and the client layer call. Both parallel and sequential strategies of setting up VCAT connections are possible.

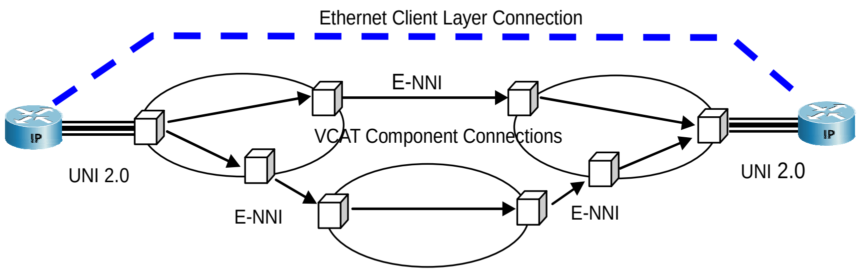

Figure 4: Setup of Diverse VCAT Connections

4.4 Additional Data Plane Testing

As shown at SUPERCOMM 2004, some additional data plane-only Ethernet testing is being done, based on Ethernet service specifications developed in ITU-T and the Metro Ethernet Forum (MEF). These tests demonstrate interoperability in the data plane for Ethernet Virtual Services, where multiple Ethernet services are transported using the same SONET/SDH VCGs. The virtual services demonstrated include: Ethernet Virtual Private Line, Ethernet Virtual Private LAN and Internet Access/Virtual Trunk. These provide a complementary aspect to the control plane testing, which focuses on Ethernet Private Line. Figure 5 shows an example of the Ethernet Virtual Private Line service, where individual client flows are aggregated into a single transport link and separated at the destination based on the VLAN tags. VLAN tags as defined in IEEE 802.1Q are used to identify an individual service.

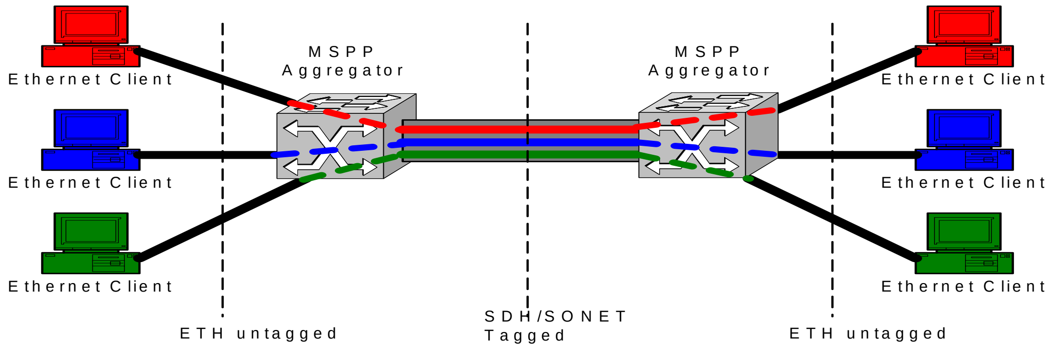

Figure 5: Ethernet Virtual Services Tested at the SUPERCOMM 2005 Demonstration

5. Conclusion

The 2005 OIF Worldwide Interoperability Demonstration is designed to maximize the carriers' involvement. Multiple vendors have equipment installed in carriers' labs to achieve interoperability within a lab, and to then connect multiple carriers' labs together in order to achieve interoperability across carrier sites. This a stepping stone towards real world carrier environments. By the cooperative work of carriers and vendors across the globe, OIF provides a truly worldwide test bed for carriers and vendors around the globe to interoperate with each other via the optical control plane. The OIF's successful interoperability testing proves that the automatically switched optical network will become reality in the near future.

About the OIF

Launched in April of 1998, the OIF is a non-profit organization with a unique and diverse member base, including many of the world's leading carriers, component manufacturers and system vendors. As the only industry group uniting representatives from data and optical networks, the OIF helps advance the standards and methods of optical networks. The purpose of the OIF is to accelerate the deployment of interoperable, cost-effective and robust optical networks and their associated technologies. Optical internetworks are data networks composed of routers and data switches interconnected by optical networking elements.

The OIF actively supports and extends the work of national and international standards bodies with the goal of promoting worldwide compatibility of optical internetworking products. Liaisons have been established with The ATM Forum, IEEE 802.3, IETF, ITU-T Study Group 13, ITU-T Study Group 15, MEF, NPF, OPTXS, Rapid I/O, TMF MTNM group, TMOC, UXPi and the XFP MSA Group. More information on the OIF can be found at www.oiforum.com.

Glossary

ASON:	Automatically Switched Optical Network
E-NNI:	External Network-to-Network Interface
GFP:	Generic Framing Procedure
GRE:	Generic Routing Encapsulation
LCAS:	Link Capacity Adjustment Scheme
MSPP:	Multi-Service Provisioning Platform
OSS:	Operations Support System
RSVP:	Resource ReSerVation Protocol
SCN:	Signaling Control Network
SLA	Service Level Agreement
UNI:	User-to-Network Interface
VCAT:	Virtual Concatenation
VCG:	Virtual Concatenation Group

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