Optical Control Plane – *Management Included*

Asian-Pacific Network Operations and Management Symposium
Sapporo, Japan
October 10-12, 2007

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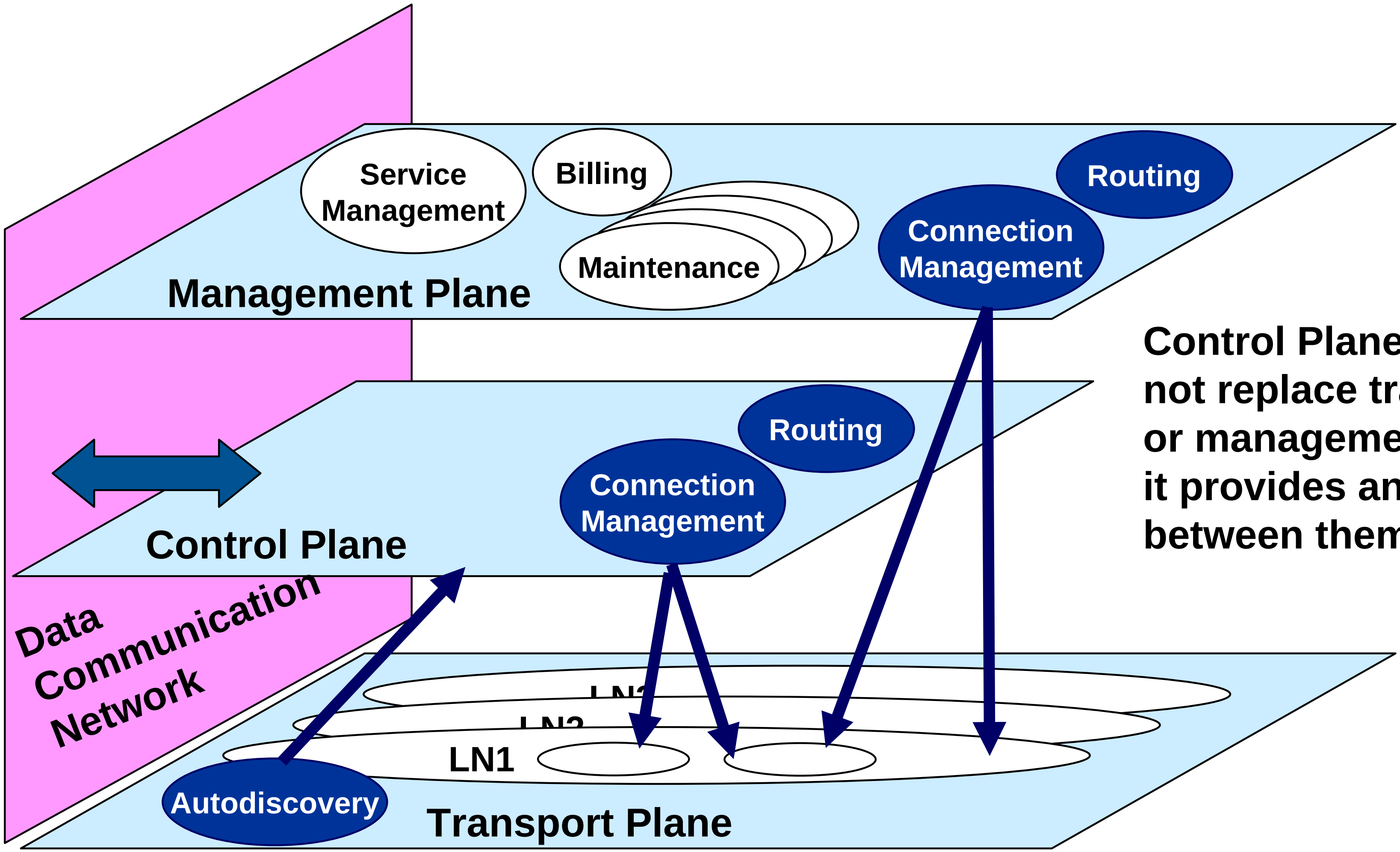
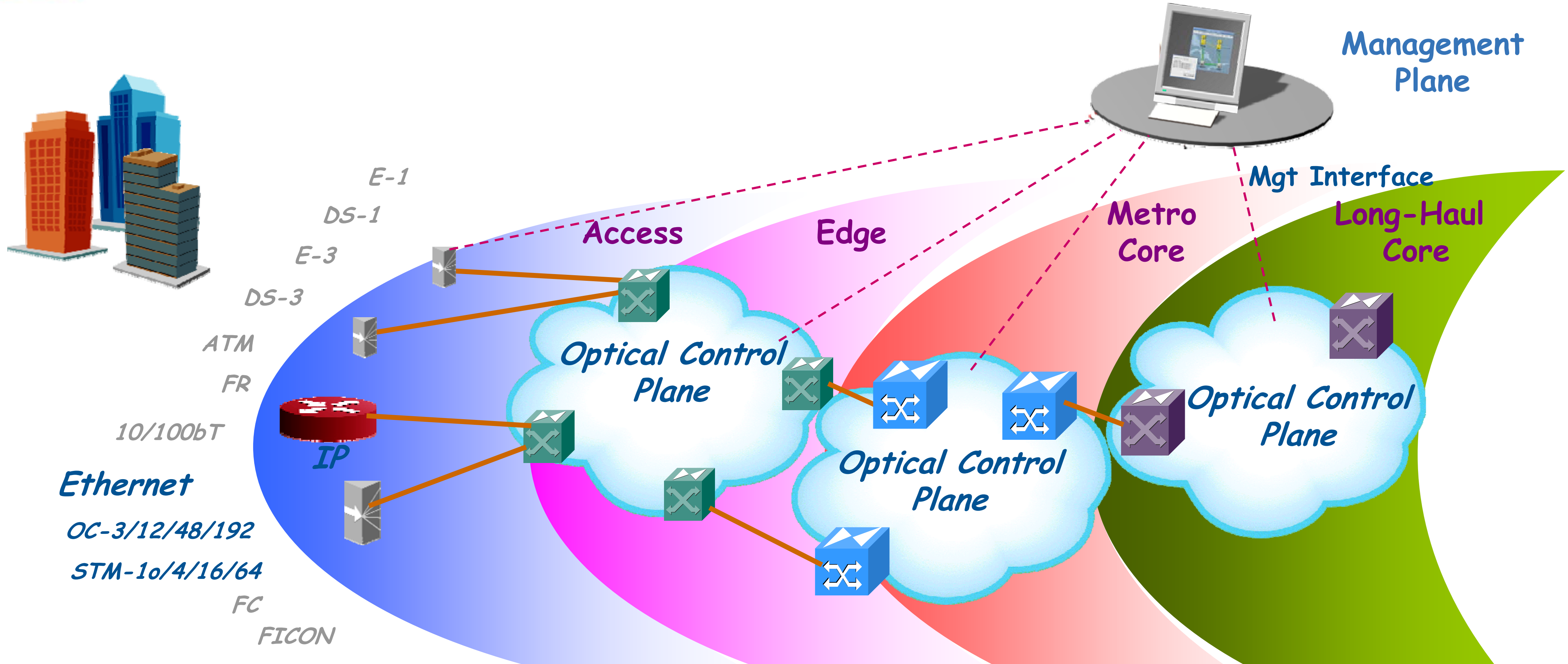
Architectural Planes



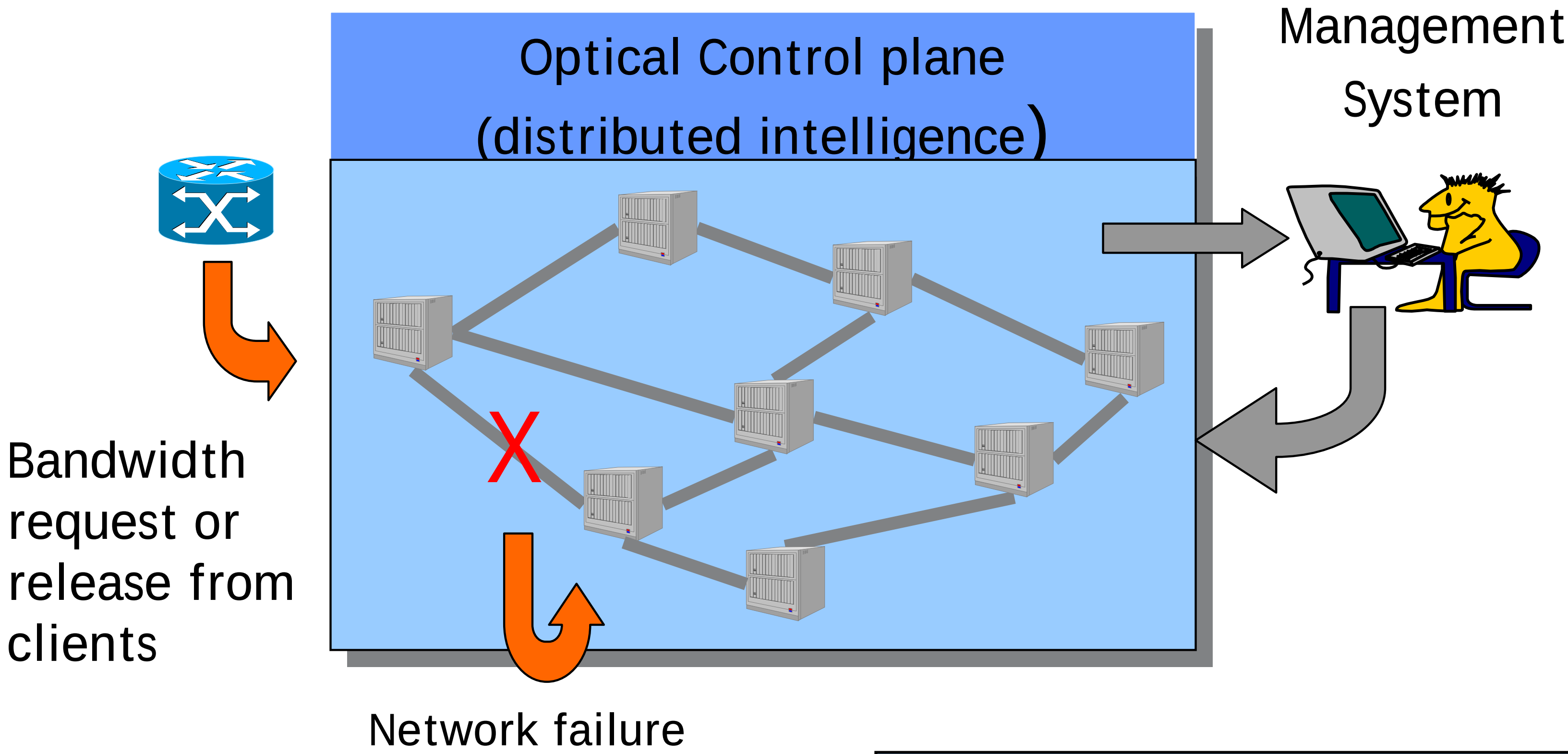
Control Plane does not replace transport or management plane, it provides another layer between them.

Optical Control Plane Goals



- Offer real multi-vendor and inter-domain inter-working
- Enhance service offerings with Ethernet over SONET/SDH or OTN
- Provide end-to-end service activation
- Integrate cross-domain provisioning of switched connection services
- Provide accurate inventory management

Optical Control Plane Value Chain



Control Plane

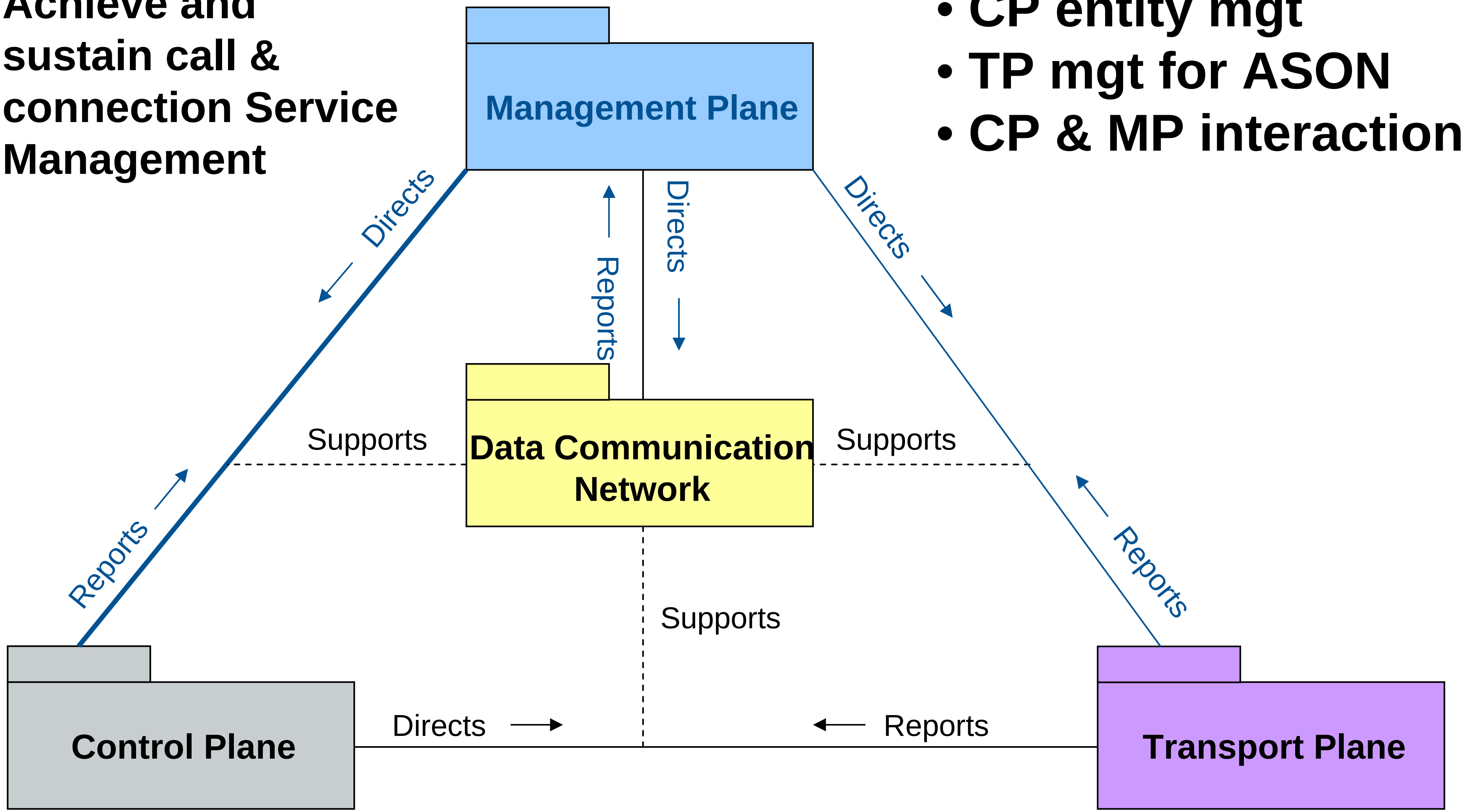
Signaling
Routing
Discovery

Improved bandwidth usage/efficiency
Scheduled/unscheduled Bandwidth on Demand
OSS simplification
Auto-discovery

Control Plane Management & Interactions

Achieve and sustain call & connection Service Management

- **CP entity mgt**
- **TP mgt for ASON**
- **CP & MP interaction**



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Challenges of Control Plane Management

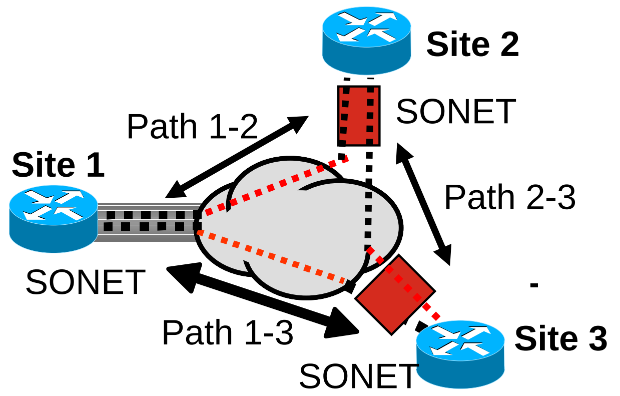
- **Ensure consistent management policy across multi-domain environment, e.g.,**
  - Network wide consistency for CP configuration, such as addressing schema (e.g., TNA)
- **Balance between delegation (to CP) and ultimate control (by MP) (i.e., centralized vs. distributed) e.g.,**
  - Minimize duplication of data & process
  - Maintain consistency between MP and CP database
  - Restore consistency without affecting active services
- **Smooth migration from MP-driven service management (Call/Connection mgmt) to hybrid or CP-driven Service Management**
- **Accurate and cost-effective fault analysis for TP failures using CP capabilities**

Application 1: CP for Bandwidth Efficiency

- Scenario

  After running the NG-SONET/SDH network for a while, available time slots over SONET/SDH links become fragmented (I.e., many discontinuous, small size clusters of bandwidth). Network Operations can invoke the control plane on a regular basis to (1) identify the clusters for each span in the network, and (2) run a defragmentation algorithm to pack in-use time slots into a contiguous space.

- Core Technologies
  - NG-SONET/SDH –Defragmentation over a single vendor domain
  - Optical Control Plane (Auto-Discovery & Self Inventory)
  - Optical Mgmt Plane (EMS/NMS update)



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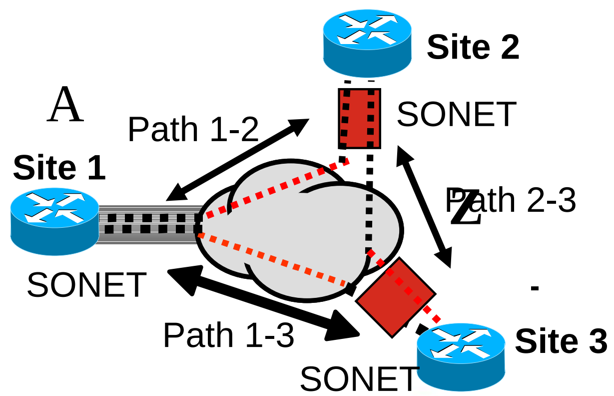
Application 2: A-Z Provisioning via EMS/NMS and Control Plane

- Scenario

  NMS/EMS receives a service order for SONET STS /SDH VC from an enterprise customer that has three sites in the region. The order specifies points A & Z (e.g., from Site 1 to Site 2), payload rate, transparency, protection class, and other constraints.

  The NMS/EMS issues a command to the source node (attached to Site 1), which then triggers the control plane to setup the SONET/SDH path to Site 3 according to the requirements specified in the order. Similarly, when the customer terminates the service, NMS/EMS will invoke the control plane to tear down the path.

- Core Technologies
  - Optical Control Plane (E-NNI, I-NNI)
  - Optical Mgmt Plane (EMS/NMS SPC support)



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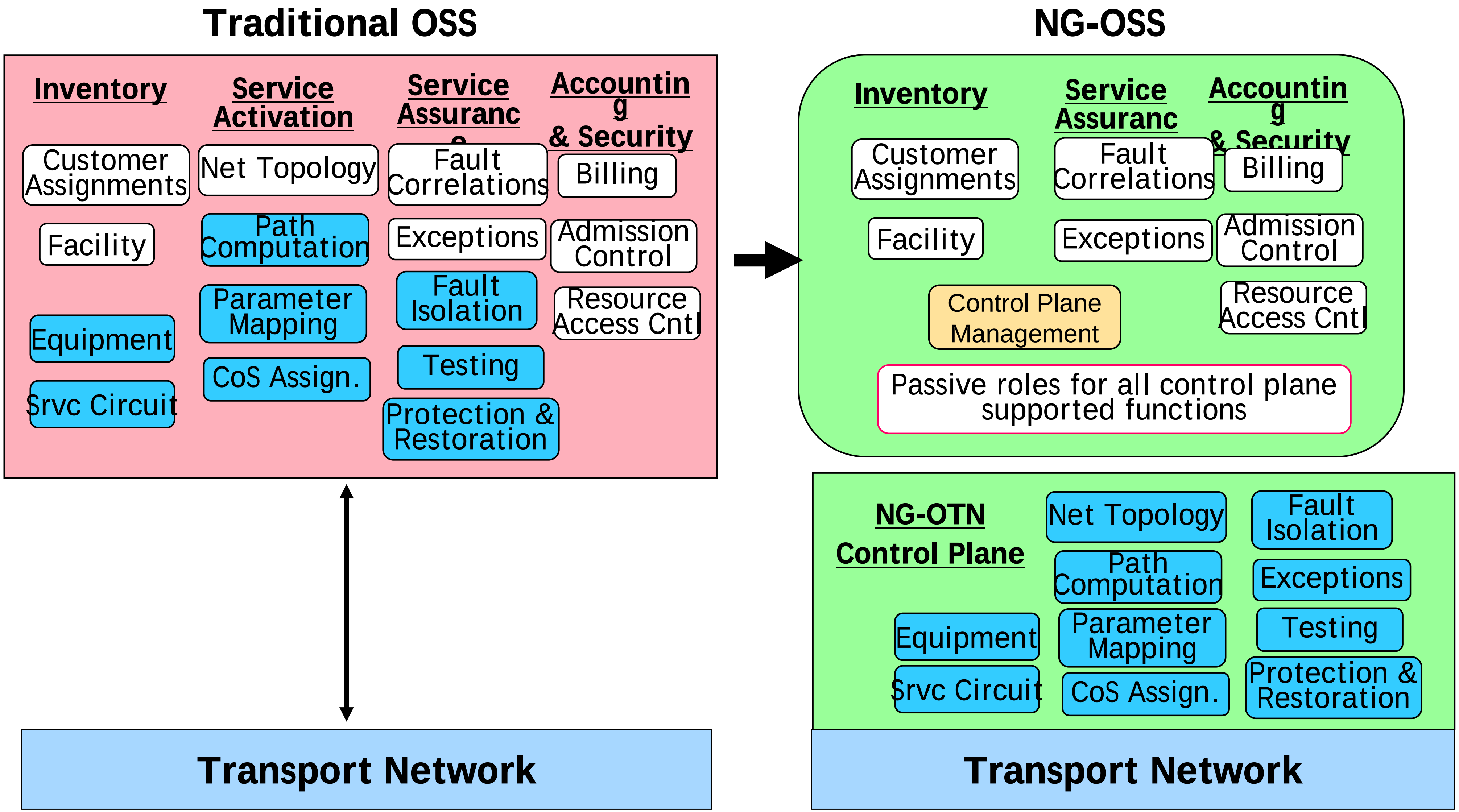
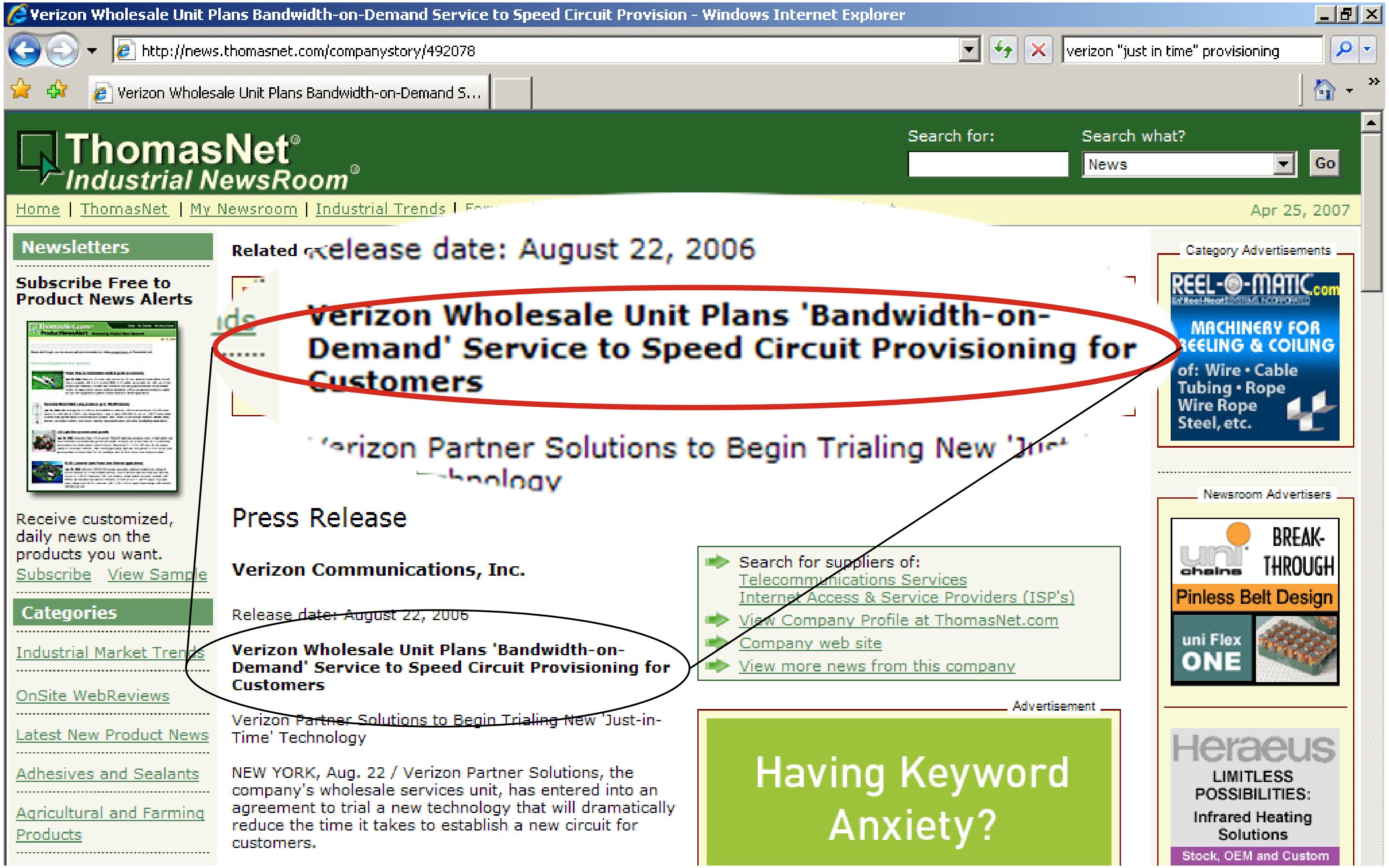
Application 3: OSS Simplification (Green Field)



Integrating Control Plane Networks
Operational Issues

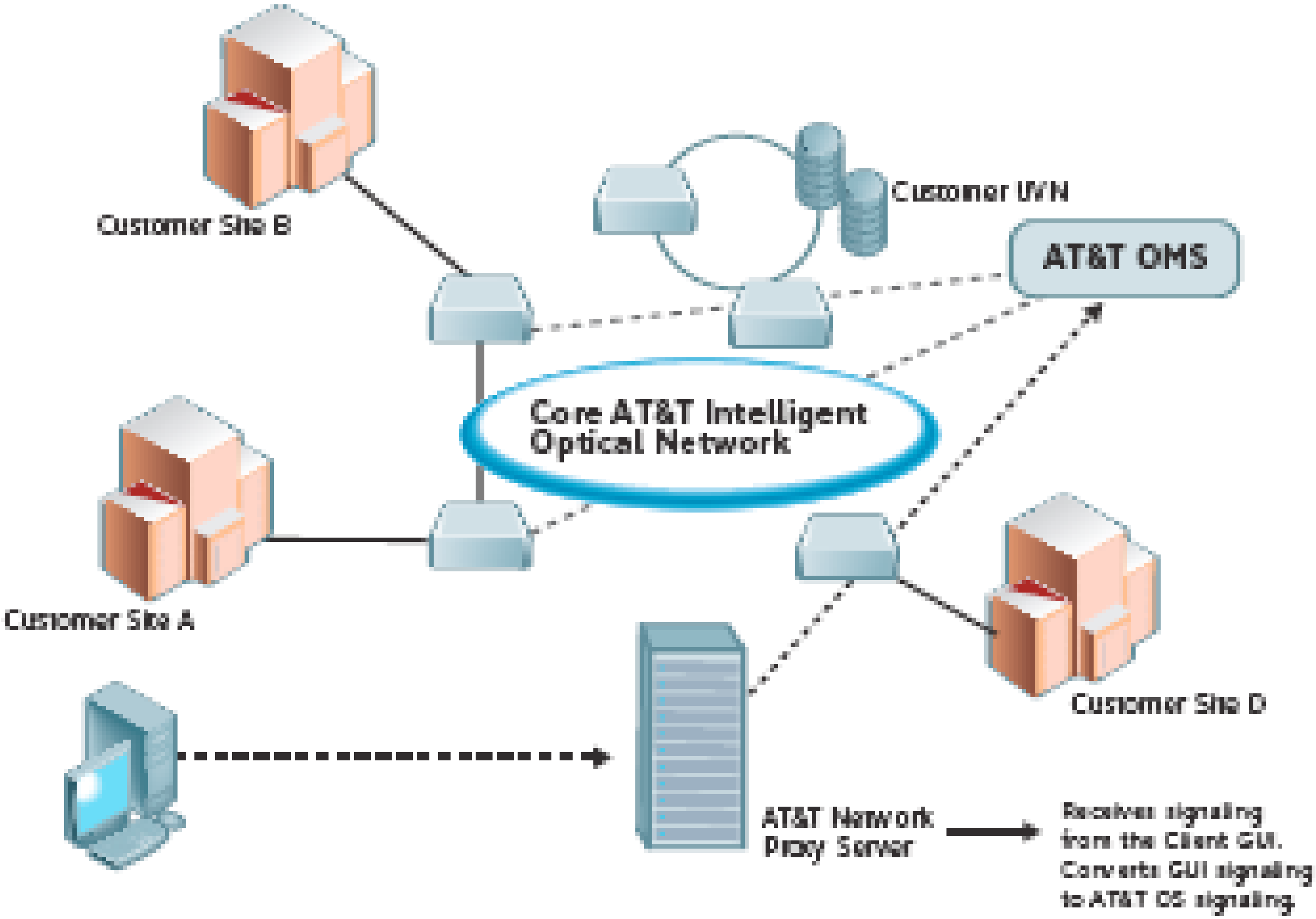
- **Integrate the control plane with operations**
  - Bridge the current world to a control plane enabled network
  - "Operationalize" the new capabilities to ensure value of the new integrated network is realized
- **Streamline processes and operations**
  - Maintain flow through
  - Reduce provisioning processes
  - Improve accuracy of records (e.g., for operations, trouble shooting, capacity planning)
  - Maintain single, multi-vendor connection to control plane
  - Maintain single federated of view of control plane and non-control plane networks
- **Enable fast turn-up of services and new technologies**
  - Provide full functional OSS support for control plane network technology and related services
  - Align OSS support with network deployments
- **Control Plane Management**
  - Failures should not impact service
  - Administer addresses for signaling and routing
  - Assure security for control plane, network elements and OSS

Verizon's "Just in Time" Service



Speedy bandwidth adjustments
Split second traffic rerouting around problems
Better network utilization

AT&T's Optical Mesh Service



Benefits

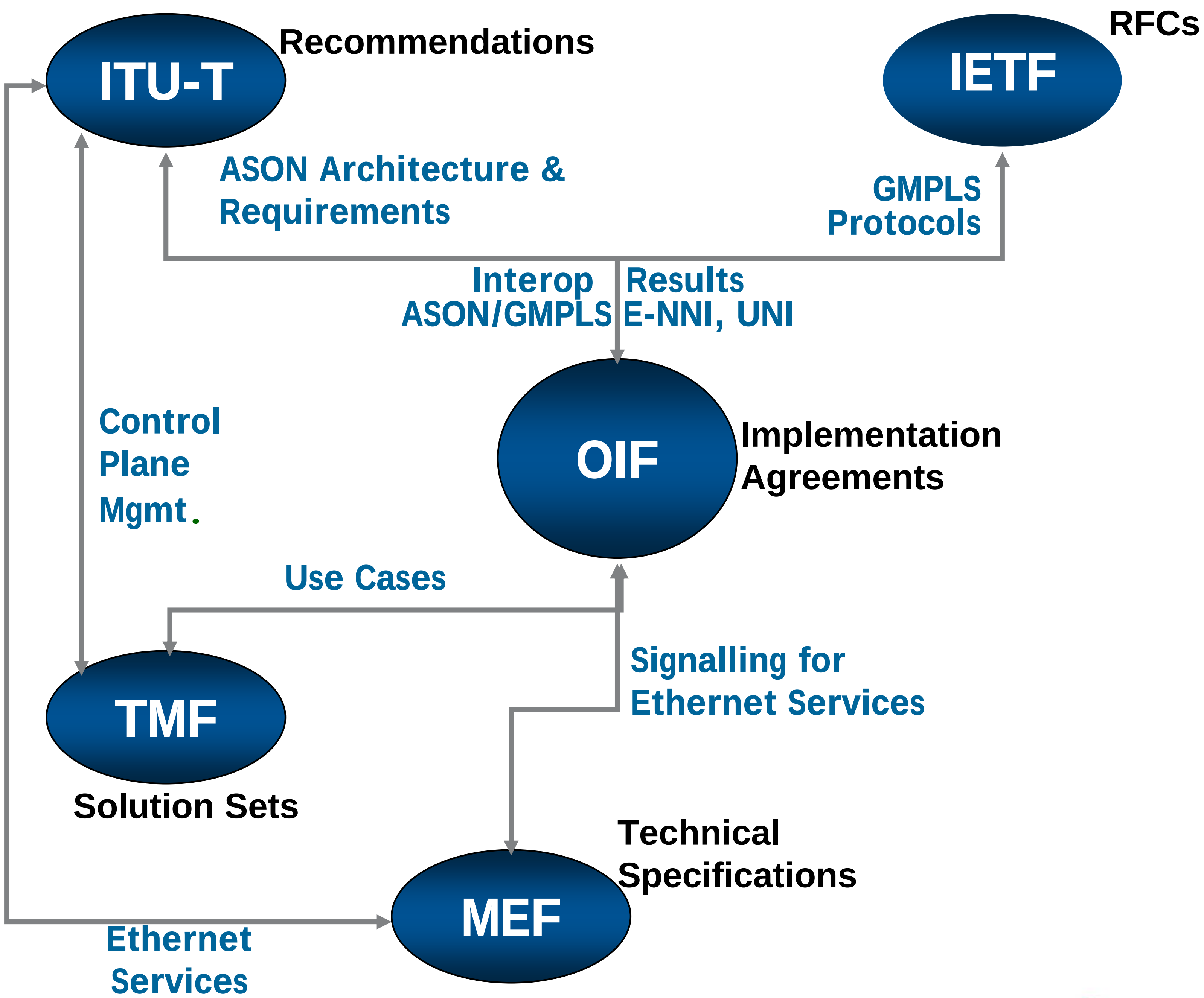
- Network provisioning in minutes
- Bandwidth on Demand capability
- Simplified billing structure
- No change in billing for distance or connection time

Features

- Ability to build a dynamic layer 1 network
- No circuit level provisioning required
- Access to the AT&T network is predefined and static
- Port Rates: OC3, OC12, OC48
- Connection rates: STS1, STS3c, STS12c
- Based on Optical Internetworking Forum Standards (OMS)
- Fixed monthly charge, not usage sensitive
- 24/7 Support Capability - Optical Mesh Control Center

http://www.business.att.com/content/productbrochures/PB-OMS_13970_V04.pdf

Related Standards Development Organizations



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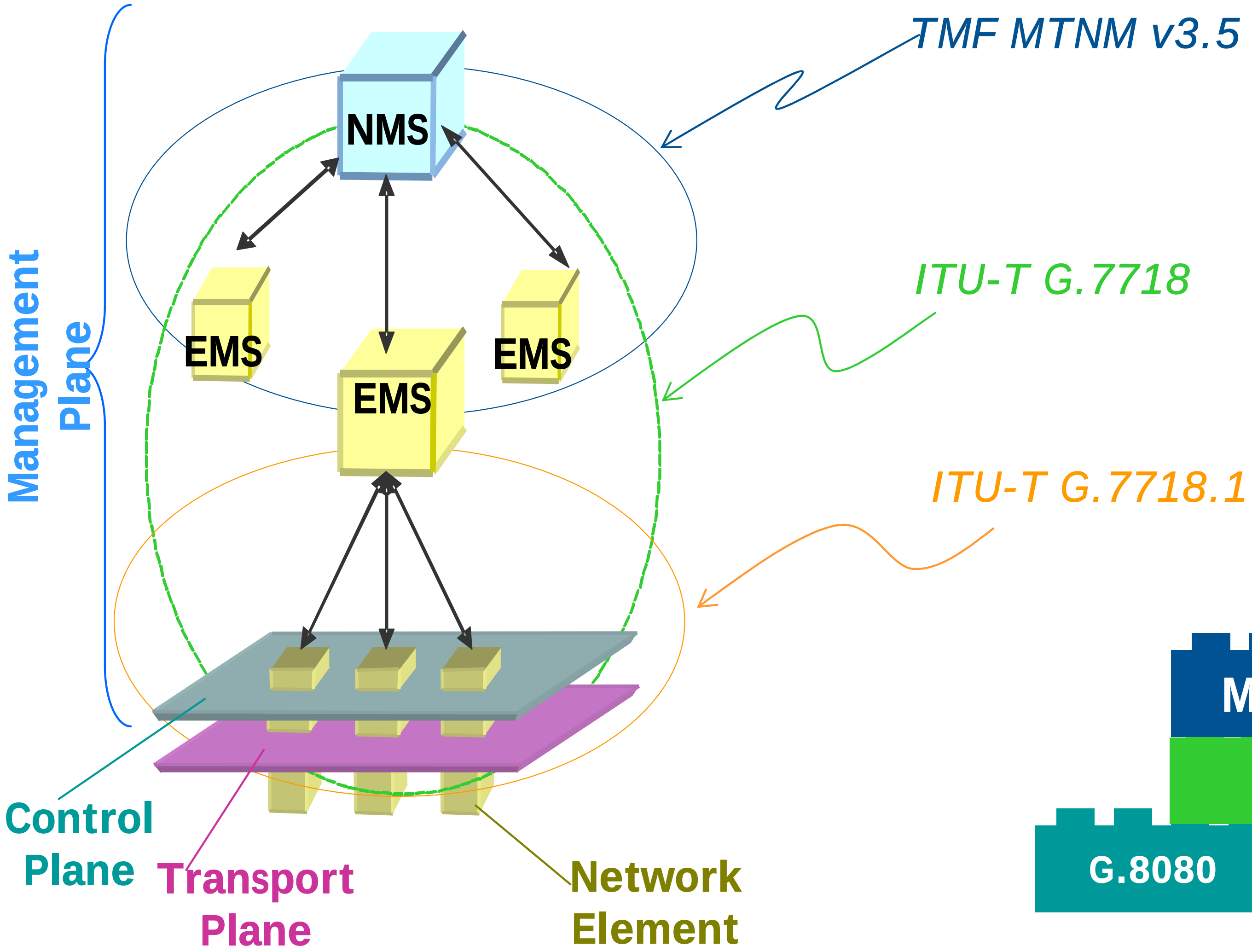
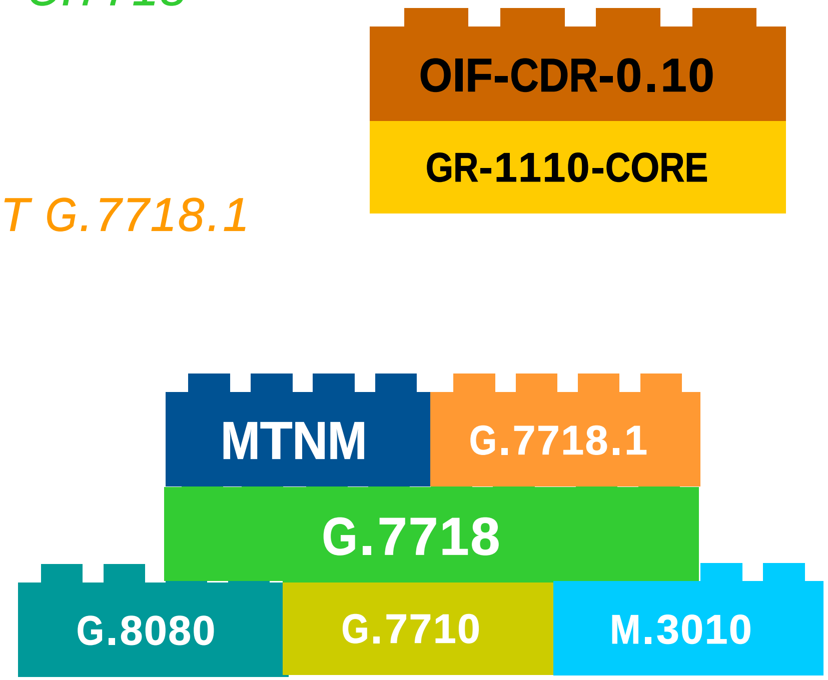
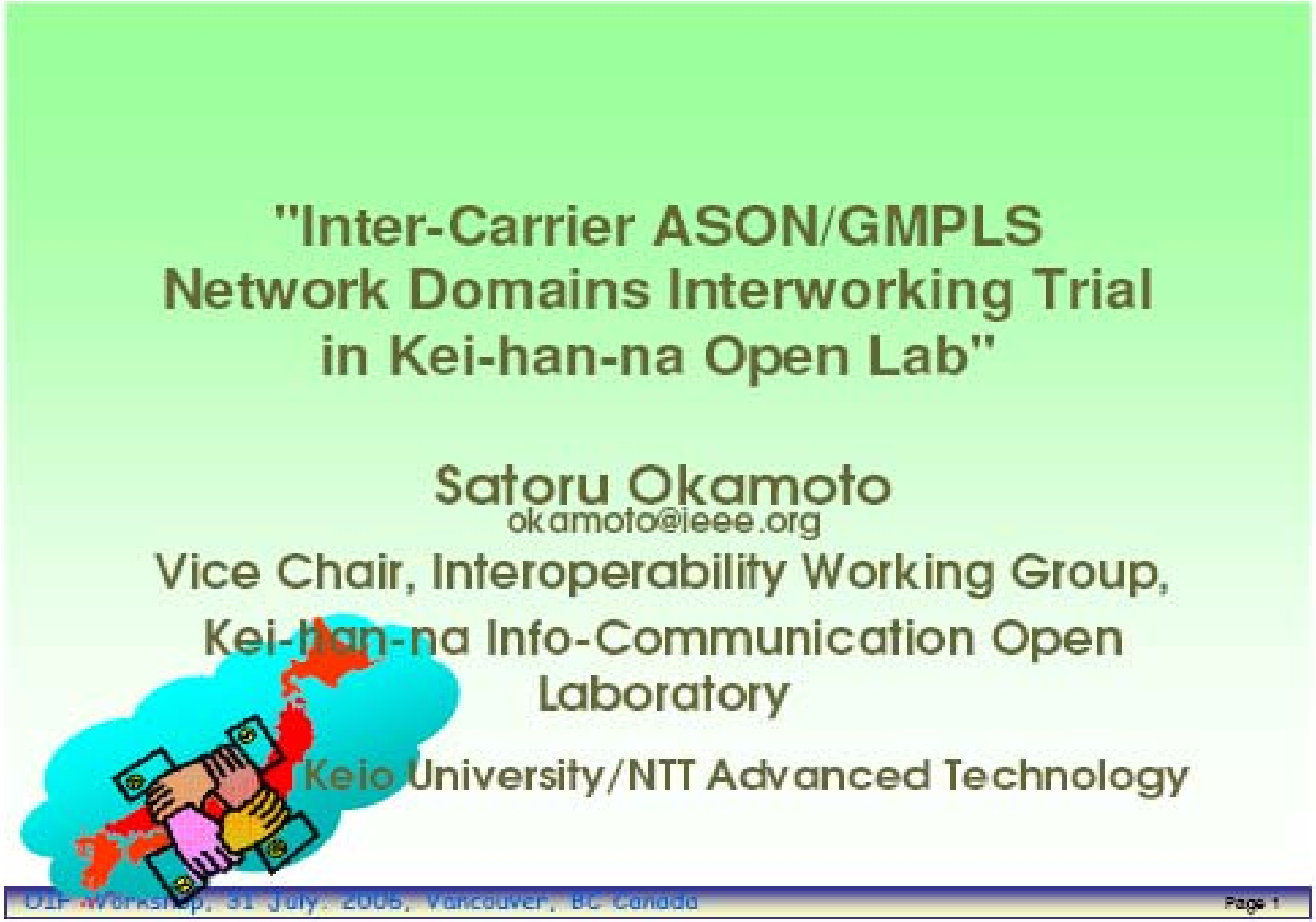
Standards for Control Plane Management





Testbeds - Asia



- Nationwide ASON/GMPLS interworking "green field" trial
- Multi-carrier domain seamless call set up for >1,000 km
- Provides interoperable GMPLS model for carriers
- More work needed to accelerate deployment

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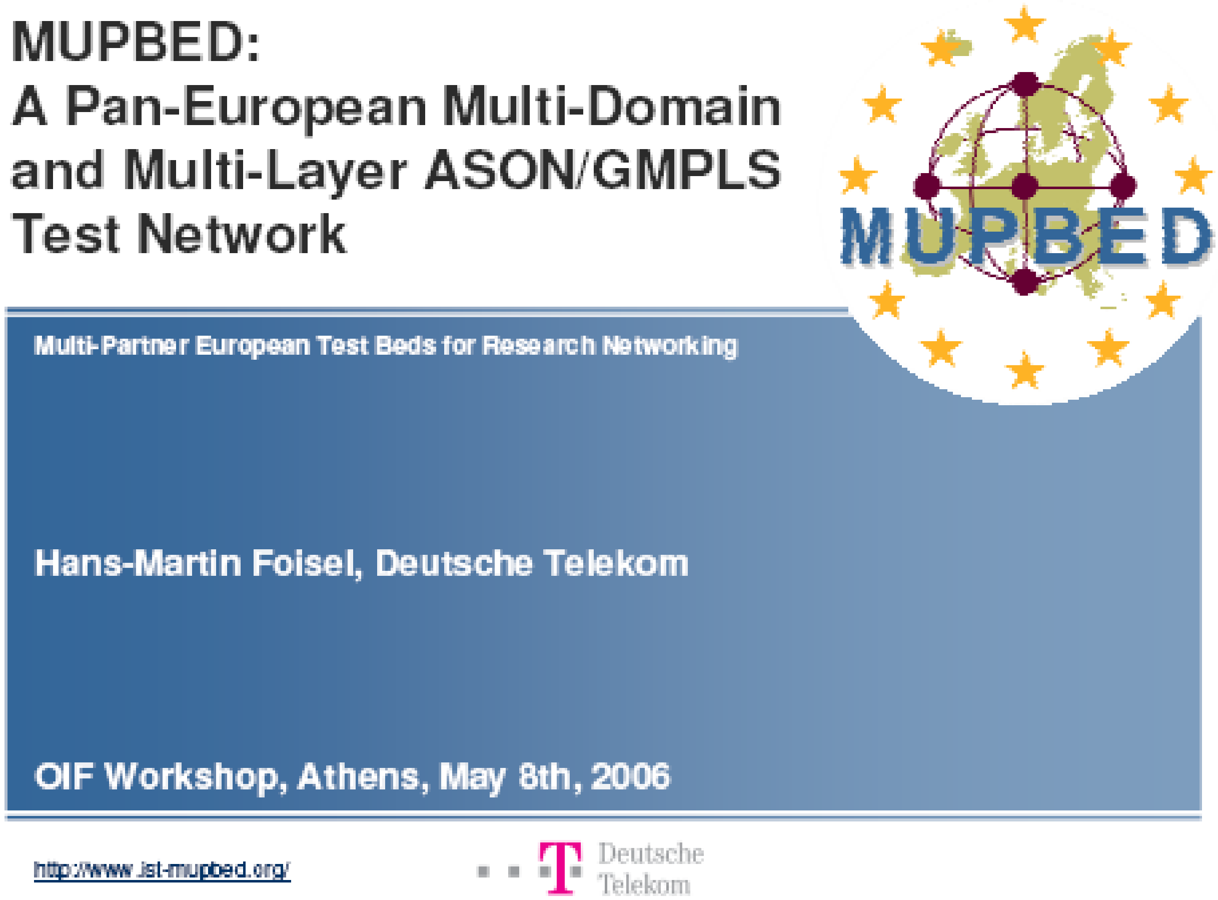
Testbeds - Europe



E-NNI

- Most powerful inter-domain interface
- Supports seamless networking in heterogeneous multi-domain network environment, which will be present for long time (for ever?) in research and carrier's networks
- Is today a high priority (hot) topic in research networks and field tests / demonstrators worldwide

UNI 2.0 Ethernet

- Very powerful interface to client networks and applications (integrated in API implementations)
- Supports on-demand services
- Is today a high priority (hot) topic in research networks and field tests / demonstrators worldwide

Testbeds – North America

- Supports science users on multiple testbeds
- Important goal is full compliance with ASON/GMPLS standards
- Major challenges for AAA and scheduling & interoperation with other control planes (robust, multilevel, multivendor operation)

OIF Implementation Agreements and Interoperability Demos

OIF Implementation Agreements

- 2001: UNI 1.0 signaling
- 2003/2004: UNI 1.0r2 signaling; E-NNI 1.0 signaling
- 2006/2007: E-NNI 1.0 routing
- Beyond 2007: UNI 2.0 signaling; E-NNI 2.0 signaling

2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007

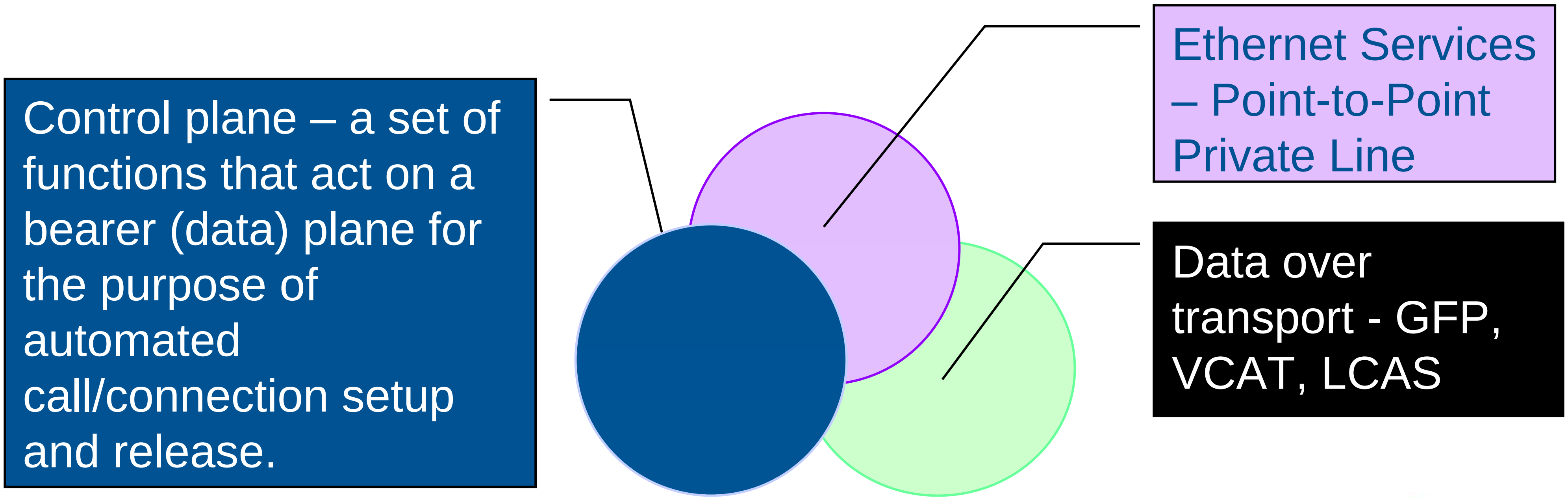
	2001	2002/2003	2004	2005	2007
Lab Location	UNH	UNH	Global - 7 carriers	Global - 7 carriers	Global - 7 carriers
Trade Show	SuperComm	OFC	SuperComm	SuperComm	ECOC
New Capabilities Tested	Draft UNI 1.0	Draft E-NNI signaling and routing	CP-enabled SONET/ SDH data plane Ethernet over SONET/SDH data plane-only test (GFP/VCAT/LCAS)	Draft extensions for control plane-enabled EPL Data plane-only test of EVPL and ELAN	Pre-IA UNI 2.0 and E-NNI 2.0 signaling Control plane failure recovery BW modification Control plane neighbor discovery

OIF Networking Interoperability Demonstrations

OIF Interop Control Plane Demo

- Worldwide demo at ECOC 2007 September in Berlin
- The OIF Worldwide Interoperability Demo combined:
  - Ethernet Services
  - Control plane
  - Flexible Transport Bandwidth functions

To provide on-demand Ethernet services over a bandwidth efficient transport network enabled by OIF UNI and E-NNI



OIF Worldwide Interoperability Demonstration

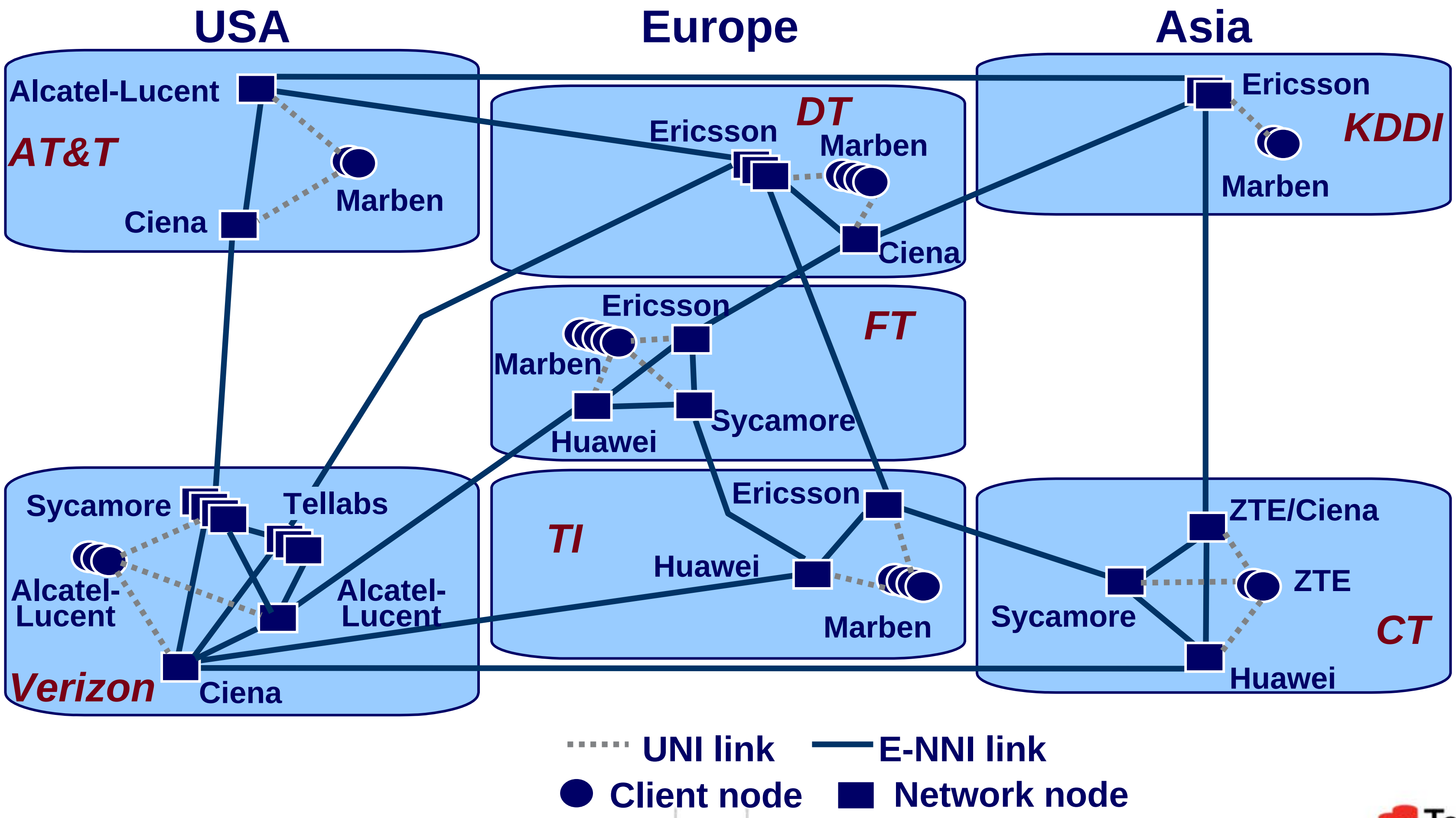
- End-to-end provisioning of dynamic switched Ethernet services
  - Over multiple control plane-enabled intelligent optical core networks
  - Using OIF UNI 2.0 and OIF E-NNI 2.0 Implementation Agreements
- Supported by 7 major Carriers and 8 leading equipment vendors from Asia, Europe and the USA
- Testing has been underway in Carrier labs since the end of June 2007
  - Test network progressed from intra-lab to regional to global network scope

On-Demand Ethernet Services across Global Networks

Demo Set-Up and Topology

Heterogeneous multi-vendor and multi-domain networks with ASON/GMPLS-enabled nodes and domains

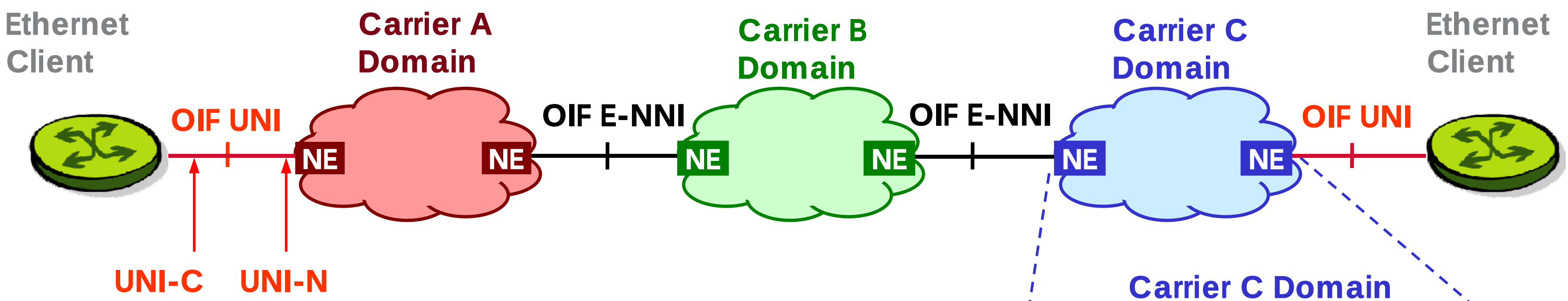
Interconnected via an OIF control plane with inter-domain links and supported by a global SCN

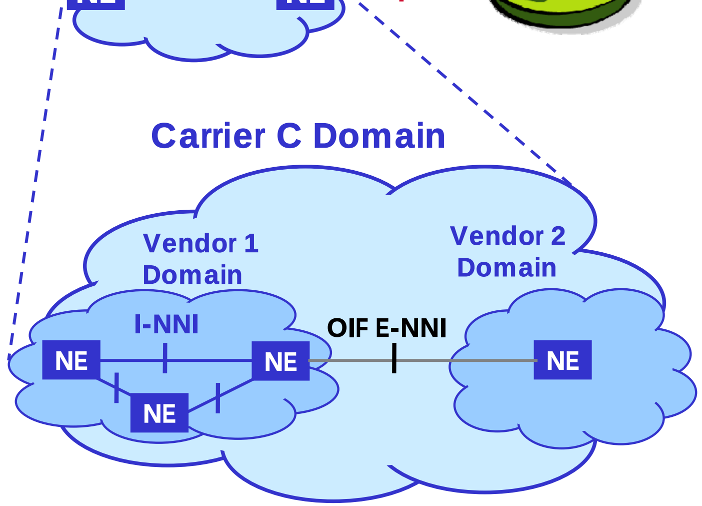


Key Aspects of the Demo

- Standards-based solutions – to ease transition from the lab to network deployment
- Interconnected and interoperable heterogeneous network equipment – from leading vendors
  - At the data plane level between MSPPs, routers, Ethernet switches, cross-connects and OADMs
  - At the control plane between embedded and proxy controllers
- Involvement of major global carriers – shows their commitment and vision

OIF Control Plane Architecture Model

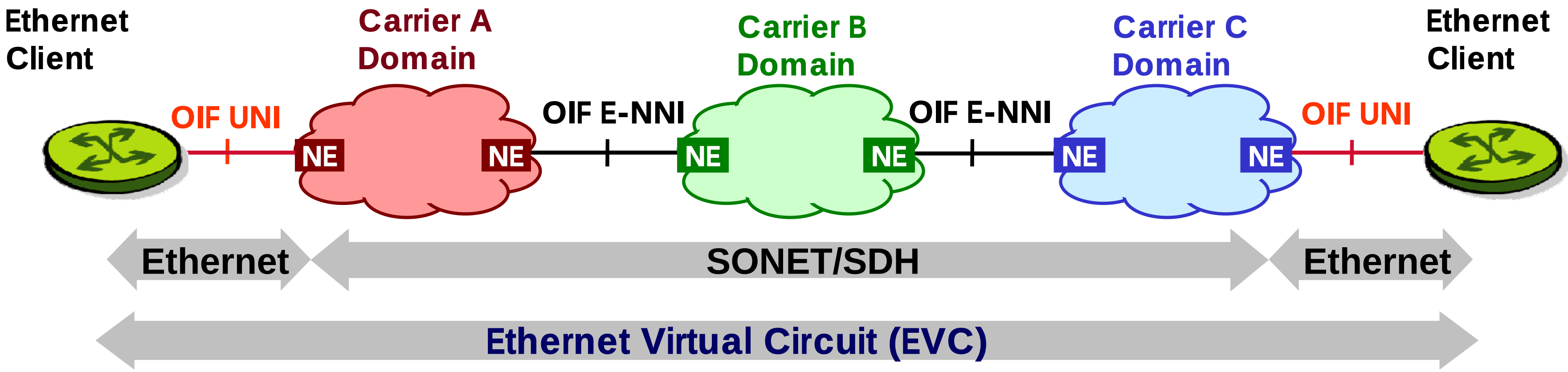




- User-Network Interface (UNI): signaling interface for clients to request services from optical network
- External Network-Network Interface (E-NNI): signaling and routing interface providing call/connection control and topology
- Domain edges provide interworking between vendor-specific Internal NNI (I-NNI) and OIF UNI-N/E-NNI protocols

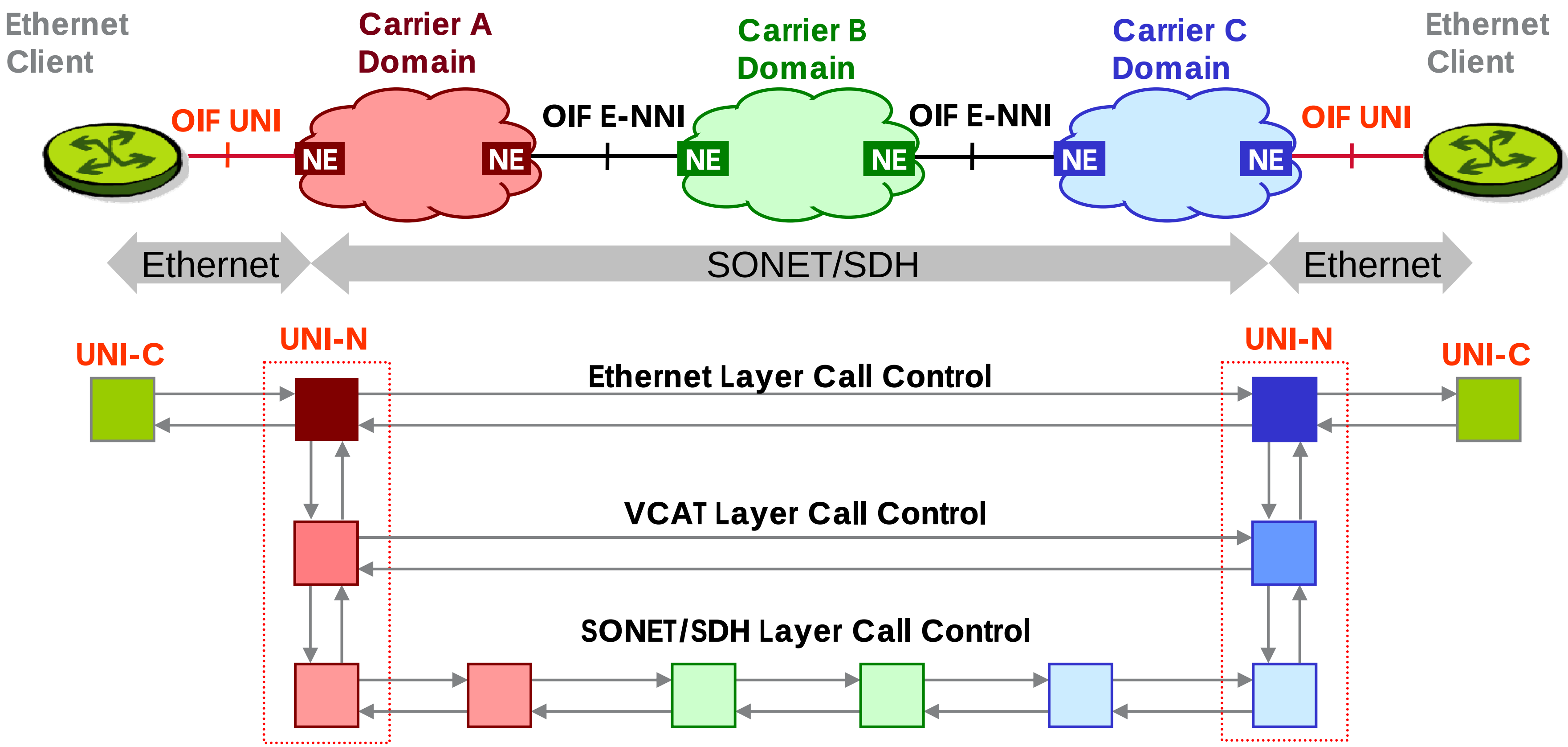
- Domains can be advertised as
  - Multiple exposed border nodes with virtual intra-domain links (vendor 1) or
  - Single abstract node (vendor 2)

Ethernet Services



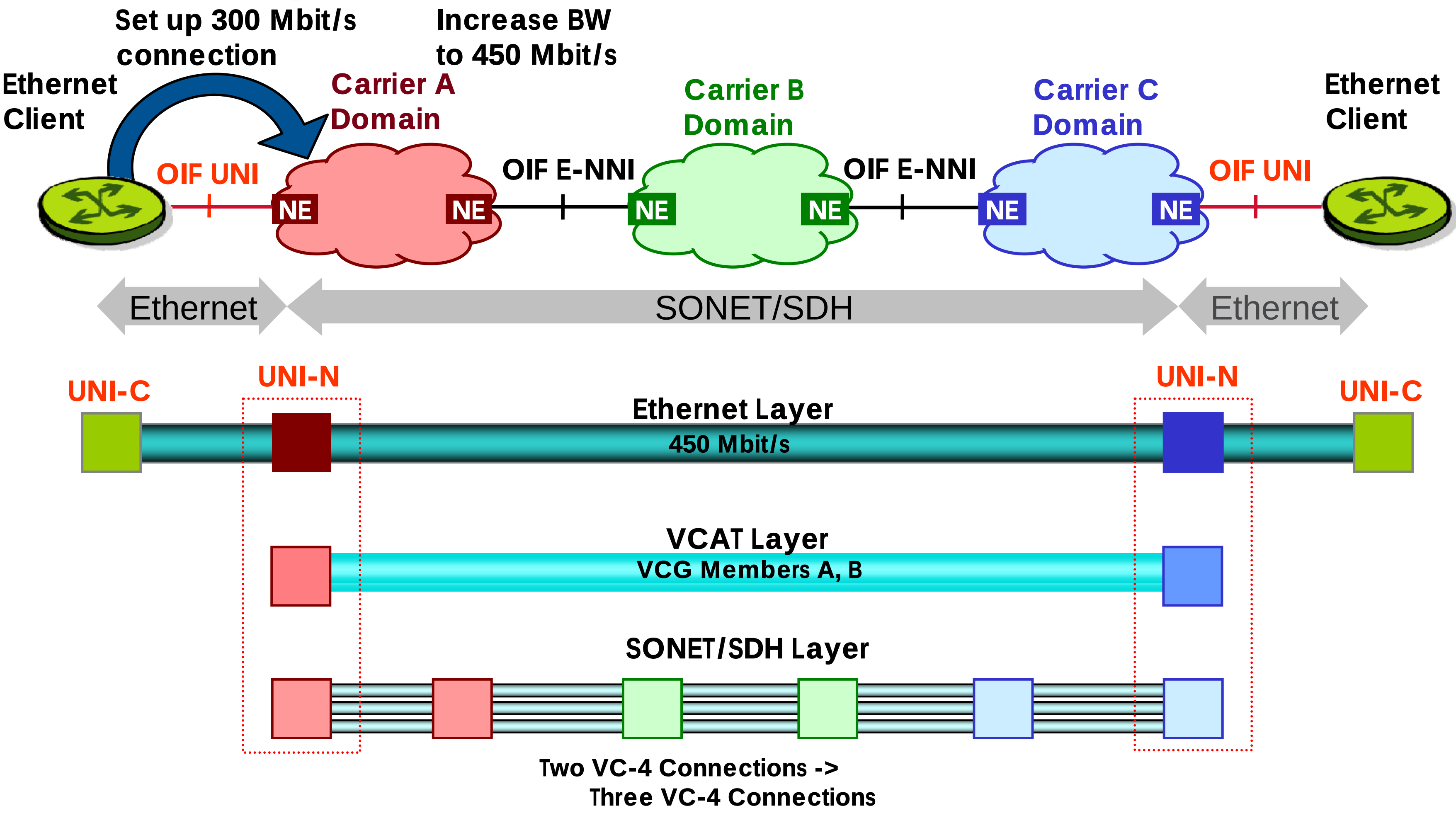
- The Metro Ethernet Forum (MEF) classifies Ethernet services as E-Line (point to point) and E-LAN (multipoint to multipoint). E-Line can be further divided into:
  - Ethernet Private Line (EPL), where an Ethernet port has dedicated bandwidth across a provider network (no service multiplexing)
  - Ethernet Virtual Private Line (EVPL), where multiple Ethernet ports share bandwidth across a provider network (service multiplexing)
- OIF UNI 2.0 supports both EPL and EVPL services
- The demonstration focuses on interoperable on-demand Ethernet Services, offered under the ITU-T Recommendation G.8011.1 EPL model.

OIF Multi-Layer Call Control



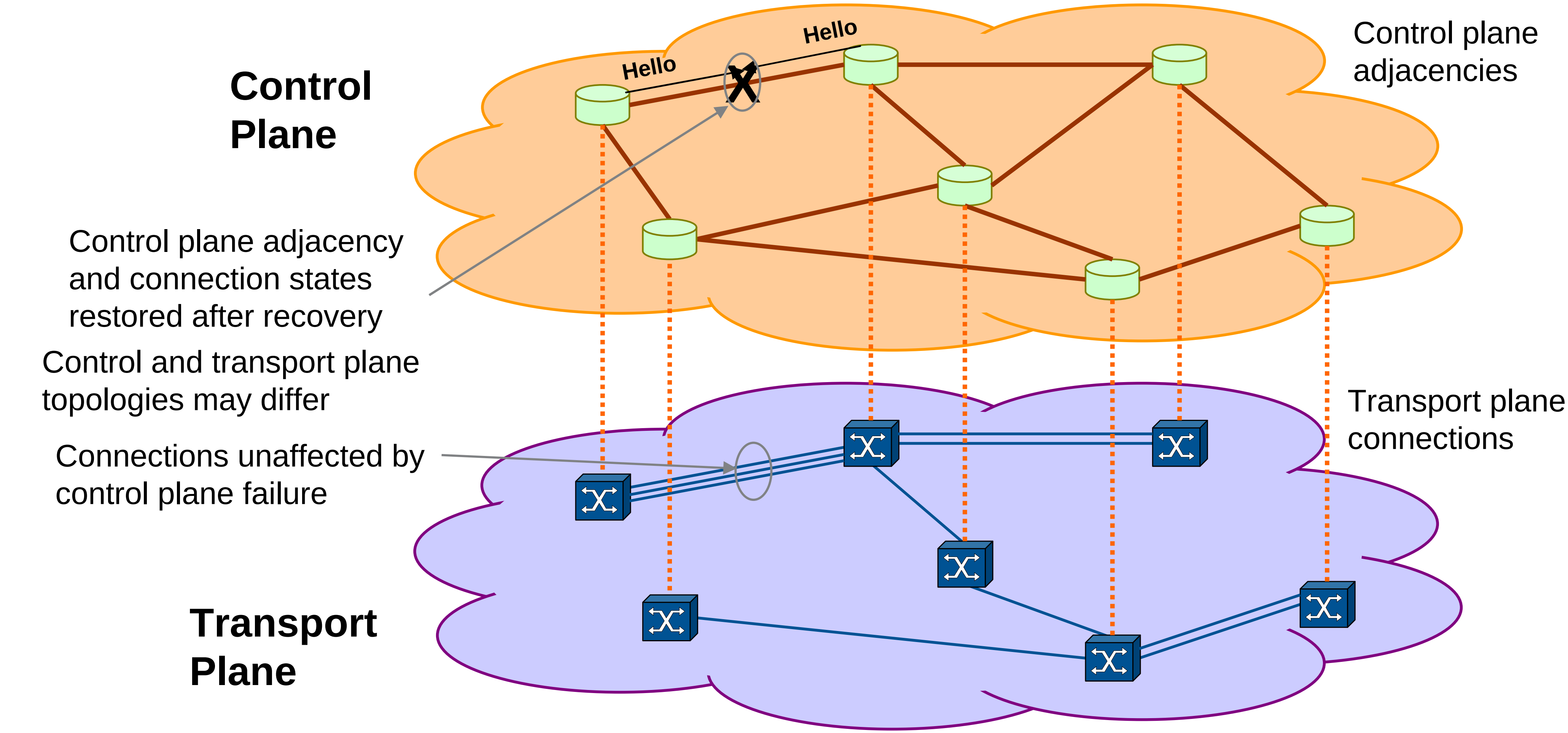
- Actions are coordinated between call controllers at each layer
  - VCAT treated as a separate layer, to allow control and sequencing of VCG members
  - Traffic parameters are tailored to each layer
- These techniques can be applied to other layers besides Ethernet/VCAT/SONET-SDH

Non-Disruptive Bandwidth Modification



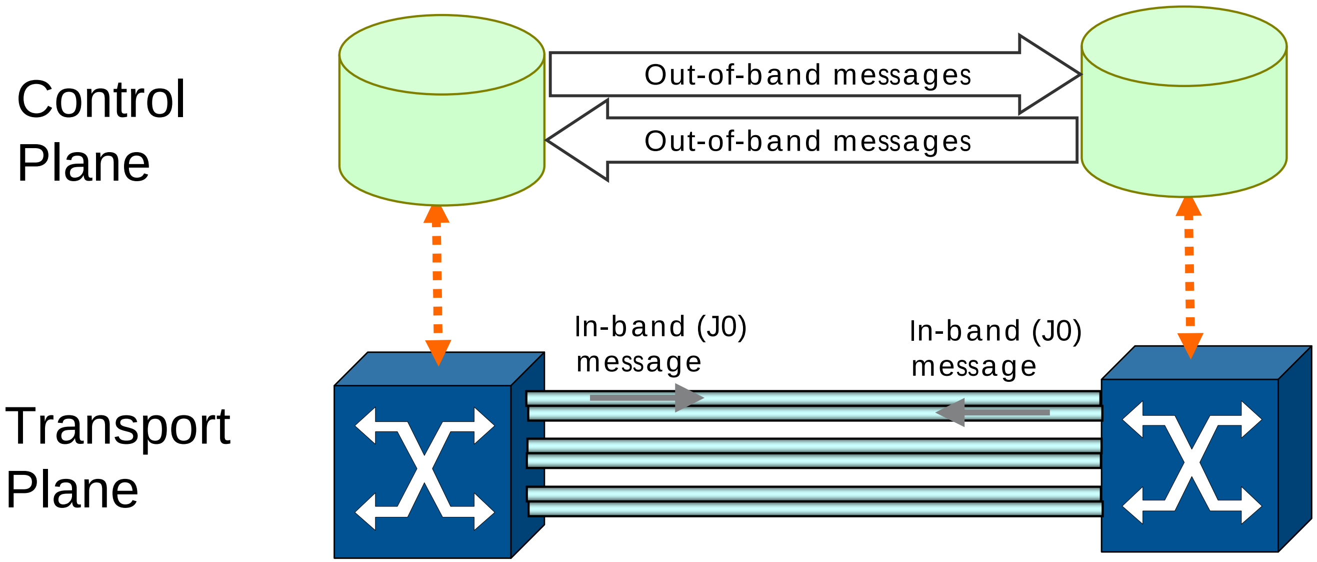
- Bandwidth modification adjusts connection capacity to meet elastic demand
  - Enables carrier to “right-size” client Ethernet BW using legacy SONET/SDH network
  - Clients use/billed for only what they need
  - Network utilization is optimized

Recovery From Control Plane Failure



- **Control plane failure recovery is a key carrier-class resiliency feature**
  - **Existing connections not affected by control plane failure (ASON requirement)**
  - **Applies to control plane link or node failure**

Control Plane Neighbor Discovery



- **Discovery is a dynamic exchange of information for links brought into service – replacing manual configuration with automated "plug and play"**
  - **In-band overhead bytes (J0) describe local transport and control plane resources**
  - **Control plane entity correlates local and remote node information**
- **In-band message formats (such as Layer Adjacency) have been defined in ITU-T.**
  - **The OIF demo extended this capability with out-of-band messages for exchanging discovered information (a Layer Adjacency Discovery response message)**
  - **Discovery was also extended to exchange control plane information, such as identifiers of control plane and transport plane entities, and routing area information**
  - **Results of demo should assist future discovery standards development**

Demo Implications from Participants

Delivering Ethernet services over intelligent optical transport networks may:

- ☑ Enable cost-effective end-to-end transport of high-speed data
- ☑ Leverage embedded transport infrastructure
- ☑ Allow Carriers to selectively upgrade their networks to enable dynamic bandwidth services
- ☑ Accelerate time-to-market, service provisioning, and revenue generation
- ☑ Maintain carrier-grade reliability and customer satisfaction

Network of the Future – Green Field

- Well funded activities worldwide (e.g., NWGN, FIRE, FIND/GENI) for
  - Future Internet
  - Underlying infrastructure
- Customer-focused paradigms that
  - Support consumers and businesses
  - Service-centric design of architecture, protocols, networks
  - Ease of use – significant automation
- Fundamental technical changes impacting
  - Network versus OSS functionality
  - Management and control paradigms
  - Quality and performance
  - Availability and security
  - Scalability

NREN 2006 Workshop

Three Forums in Asia

OIFC

KOIF

PIF

PIF (Photonic Internet Forum) , **OIFC** (Optical Internet Forum of China) and **KOIF** (Korea Optical Internet Forum) have just signed the MoU for collaboration on September 1st , 2006 in Beijing

PIF Proposed Projects - Launched

- Photonic node with multi-granularity switching capability (2005～2009)
- λ Access (2006～2010)
- λ Utility (2005～2009)
- Photonic RAM (2005～2009)

http://www.nren.nasa.gov/workshops/pdfs9/Plenary_Aoyama.pdf

The FIRE Future Internet Research and Experimentation Initiative

- Experimentally-driven long-term research, related to the Future Internet
  - Advanced networking approaches to architectures and protocols
  - starting from the running FET SAC projects, to include the new IPs which will be selected in call 2
  - Open to fresh bottom-up ideas, no backwards-compatibility constraints
- Setting up large-scale testing environments:
  - Creating a European Laboratory for testing potentially disruptive internet concepts
    - Possibly building on ONELAB and on the advanced testbeds parts of SAC projects
  - Federating existing and planned testbeds for emerging technologies
    - exploiting synergies between pre-commercial technologies and services testbeds, e.g. in line with the framework provided by PANLAB

Definition of a European identity based on EU needs and strengths

Possible synergies with FIND/GENI (US) and related initiatives worldwide

Future Internet Network Design (FIND)

FUTURE INTERNET NETWORK DESIGN MEETING
December 5, 2005
Hilton Washington Dulles Airport
Herndon, VA

FIND (Future Internet Network Design) is a major new long-term initiative of the NSF NETS research program. FIND asks two broad questions:

- What are the requirements for the global network of 15 years from now - what should that network look like and do? and
- How would we re-conceive tomorrow's global network today, if we could design it from scratch?

The FIND program solicits "clean slate process" research proposals in the broad area of network architecture, principles, and design, aimed at answering these questions. The philosophy of the program is to help conceive the future by momentarily letting go of the present - freeing our collective minds from the constraints of the current.

The intellectual scope of the FIND program is wide. FIND research might address questions such as:

- What will the edge of the network look like in 15 years? How might the network architecture of 15 years hence best accommodate sensors, embedded systems, and the like?
- How might the network of 15 years from now support what users really do (and care about)? How might such functions as information access, location management or identity management best fit into a new overall network architecture?
- What will the core of the network look like in 15 years? How might the changing economics of optical systems affect the overall design of the larger network?

Mega Challenges (and Opportunities) for Network Operations and Management

- Include network management from the start for new technologies
- Consider operations impacts on business needs for future networks
- Evolve seamlessly from today's deployed network and operations support infrastructure

→ **Actively participate in key forums (such as PIF, OIFC, KOIF - and OIF) to address those challenges!**

Acknowledgment

- The author thanks colleagues from
  - **OIF** - for their work as the basis for this keynote
  - **Telcordia** – for ongoing support of optical control plane activities
- The responsibility for the content of this keynote is with the author

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OIF OAM&P Working Group Chair

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