Network Convergence Looking Forward

Networking Research Challenges Workshop

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Seattle, Washington

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Overview

- Next Generation and Emerging Network Architectures - Hybrid Networks
- Hybrid Networks - Where are today?
- Relationship/Differences between R&E and Commercial network spaces
- Vision for R&E network research and development moving forward

Emerging Network Architectures

- There has been significant activity and progress in development and deployment of hybrid network architectures over the last couple of years
- Network technologies, elements, features continue to evolve
- R&E communities use and deployment of these capabilities continues to evolve

Multi-Domain, Multi-Layer Hybrid Networks

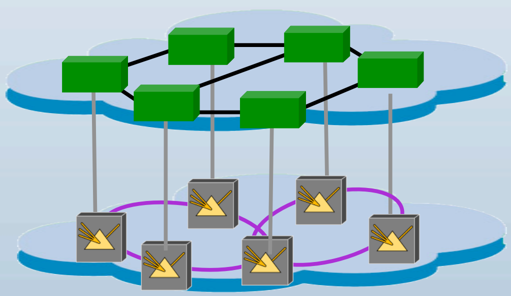
- Hybrid networks are intended to provide a flexible mix of IP routed service and dedicated capacity "circuits"
- The "**Multi-Layer**" is meant to identify several items regarding how hybrid networks may be built. In this context it includes the following:
  - **Multi-Technology** - MPLS, Ethernet, Ethernet PBB-TE, SONET, NG-SONET, T-MPLS, WDM
  - **Multi-Level** - domains or network regions may operate in different routing areas/regions, and maybe be presented in an abstracted manner across area/region boundaries
- **Multi-Domain** indicates that we want to allow hybrid network service instantiation across multiple domains
- But there are other "**Multi-**" parameters as well

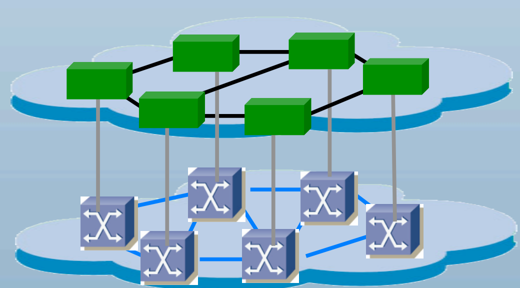
Multi-Domain, Multi-Layer Hybrid Networks

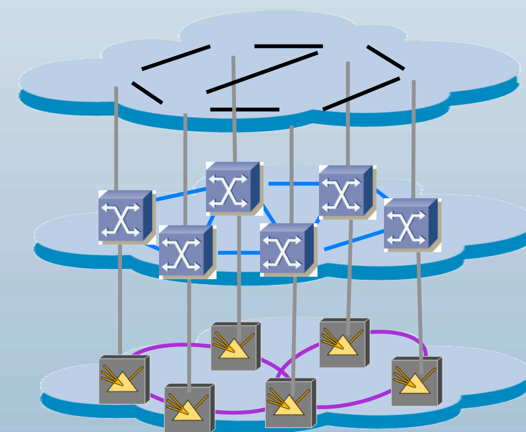
- **Multi-Service**: This refers to the client experience when they connect to the edge of a dynamic network. Typical service definitions are characterized by the combination of the physical port type (e.g. Ethernet, SONET/SDH, Fibre Channel, etc), the network transport instance (e.g. IP Routed, Ethernet VLAN, SONET), and performance characteristics (e.g. bandwidth, QoS specifications).
- **Multi-Vendor**: This is a reflection that advanced networks will be constructed based on technologies from multiple vendors. A key challenge will be to develop technologies and mechanisms which allow integrated control and service provisioning in this multi-vendor environment.
- **Multi-Policy**: Access to and use of various network components, regions, or topologies may vary by user and/or community due to provider policies.
- **Multi-X** environment

Multi-Level, Multi-Technology, Multi-Vendor Infrastructures

- Multiple Options, most will have vendor proprietary control and management mechanisms which only work across single vendor regions

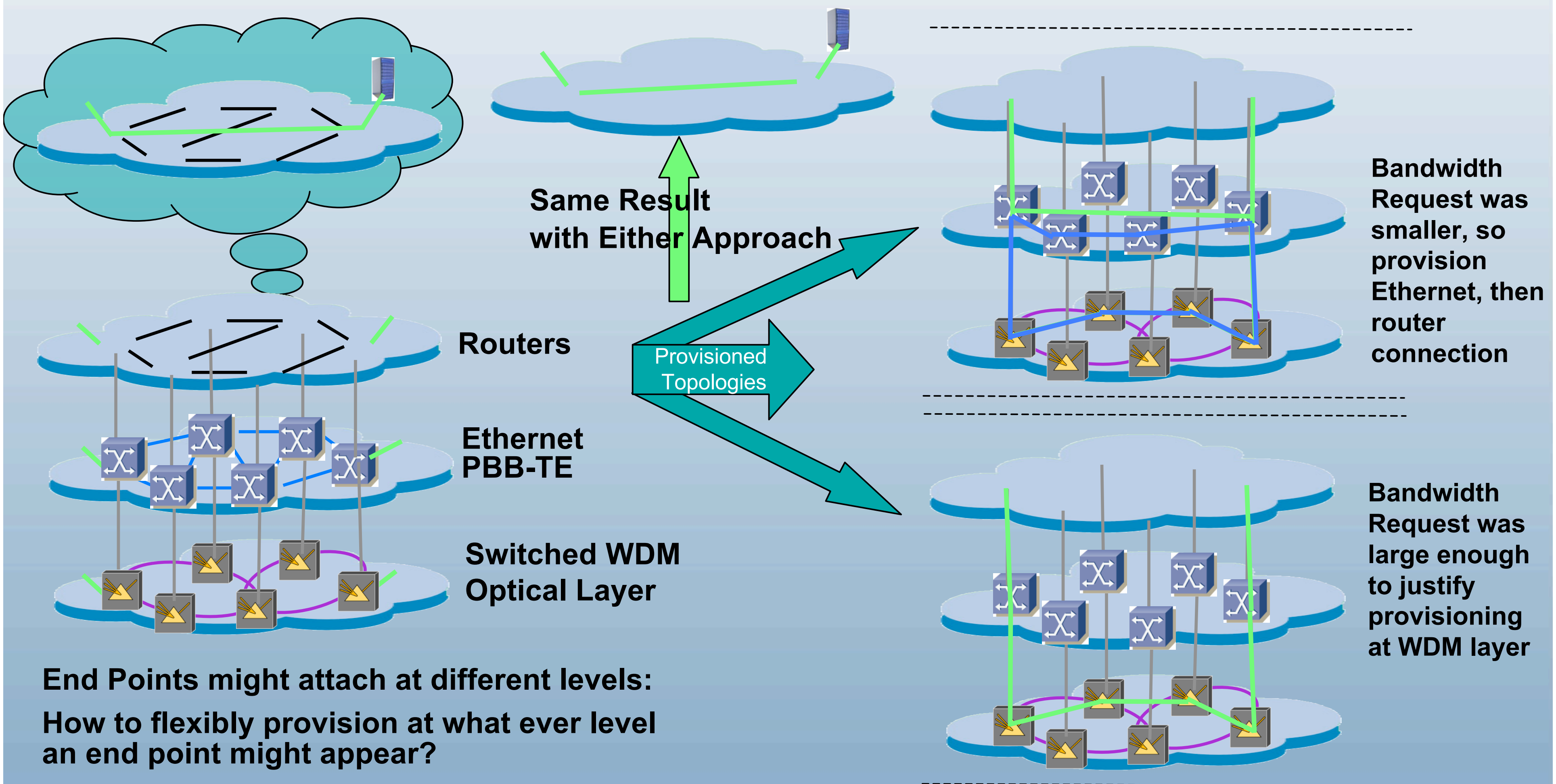






Multi-Level, Multi-Technology, Multi-Vendor – Network Virtualization

- **Network Virtualization and Topology Building in Multi-Level, Multi-Technology, Multi-Vendor Infrastructures**



End Points might attach at different levels:

How to flexibly provision at what ever level an end point might appear?

Multi-Level, Multi-Technology, Multi-Vendor Infrastructures

- Current dynamic provisioning environment can be described as:

  - **Static Topology, Dynamic Provisioning**

- Next we want to enable:

  - **Dynamic Topology, Dynamic Provisioning**

Multi-X, Multi-Domain Control Plane
What can we do today?

- Dynamic provision of end to end (circuits) across multiple domains.
- Specify a few basic parameters regarding a single circuit request: edge technology/configuration, bandwidth, end points, domain sequence, specific start/stop times
- There are multiple projects/efforts/activities around the world working on these types of issues from a multi-domain perspective

InterDomain Messaging Agreements in place

- Web Service Definitions
- Originally developed in DICE
  - Dante, Internet2, CANARIE, ESNet
  - now includes other organizations as well
- wsdl - web service definition of message types and formats
- xsd – definition of schemas used for network topology descriptions and path definitions

InterDomain Protocol Standardization Activities

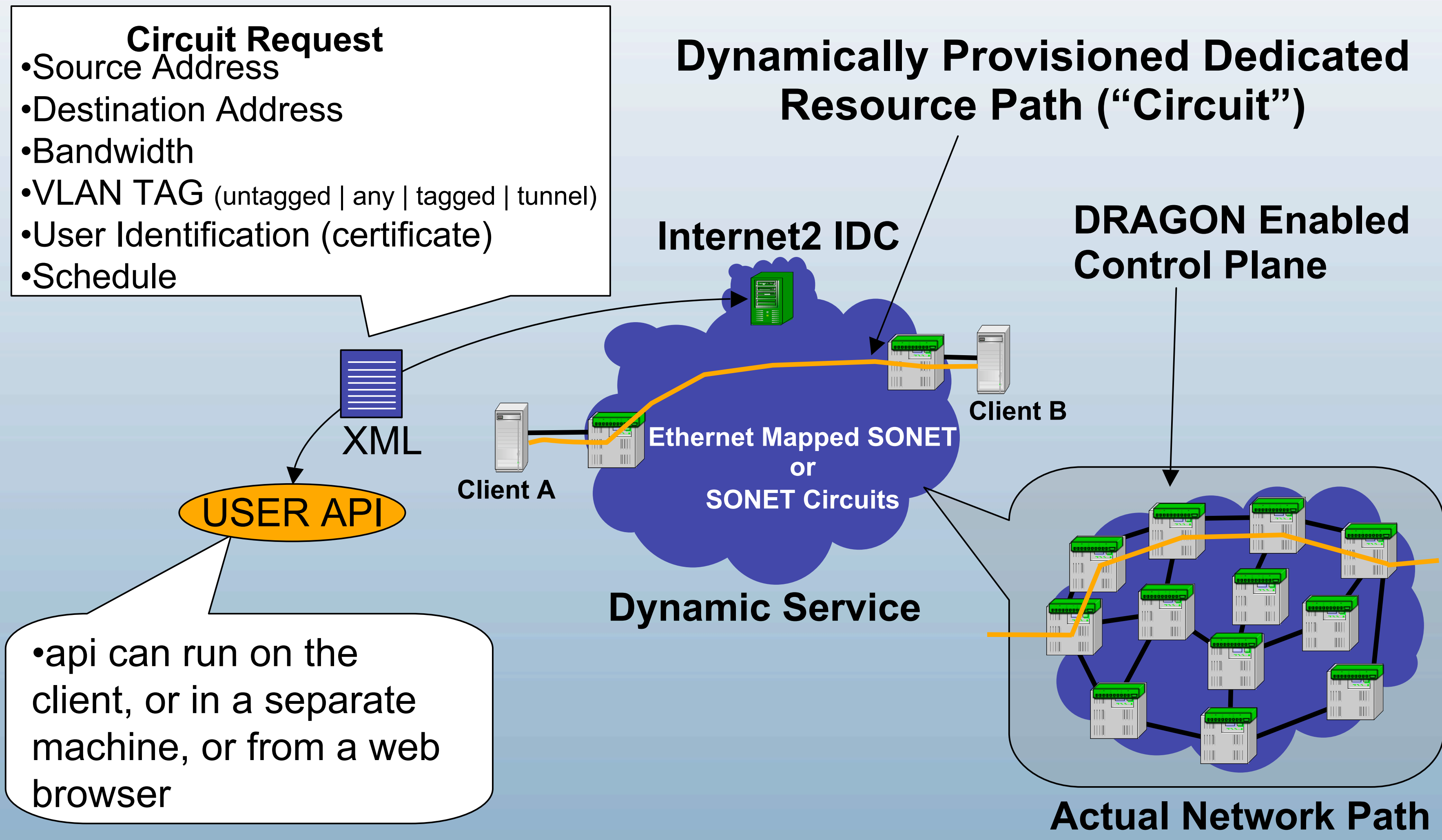
- Standardization process and increasing community involvement continues
- GLIF
  - Control Plane Subgroup working on normalizing between various interdomain protocols (IDCP, G-Lambda GNS-WSI, Phosphorus API)
- Open Grid Forum (OGF)
  - Network Service Interface Working Group (NSI-WG)
    - Co-chairs:

      Tomohiro Kudoh

      Guy Roberts

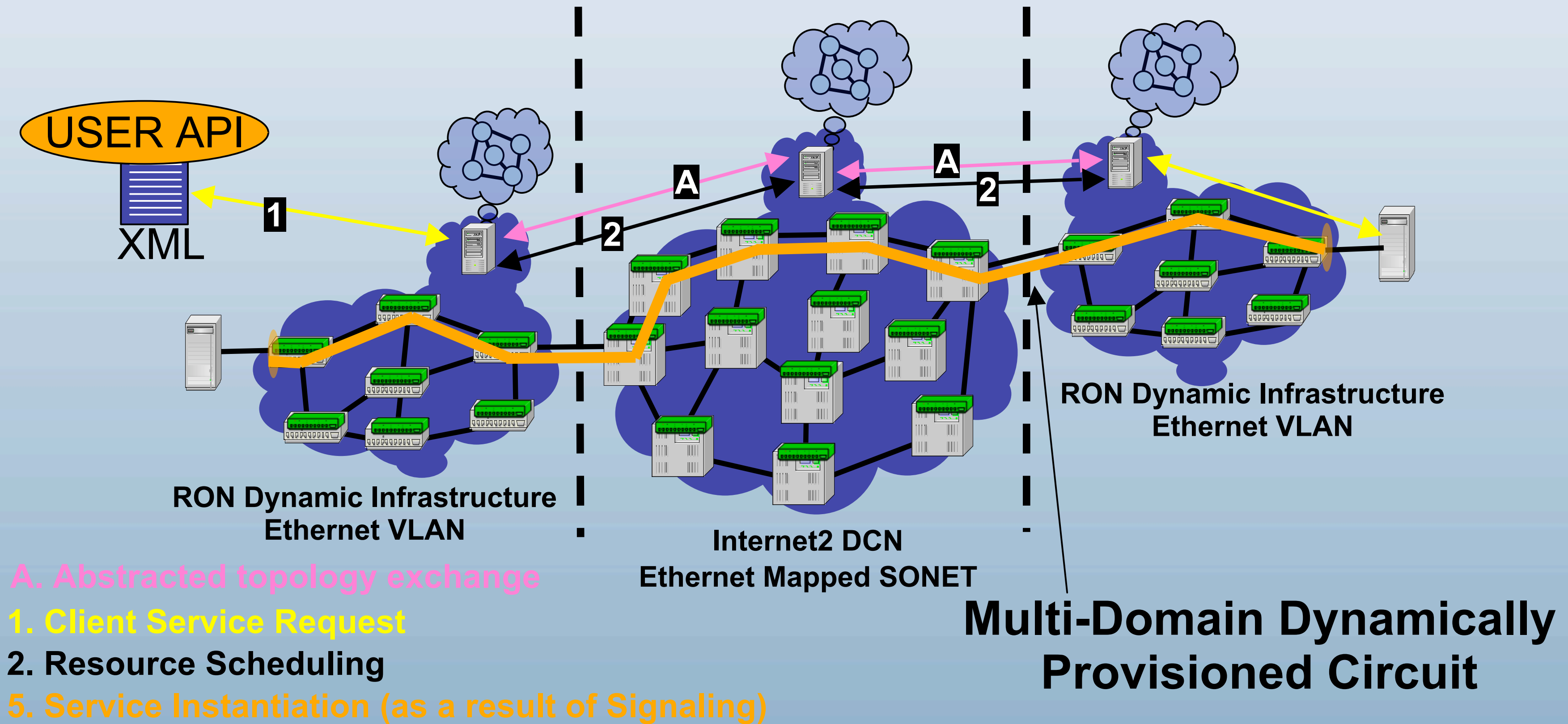
      Inder Monga

Dynamic Provisioning IntraDomain

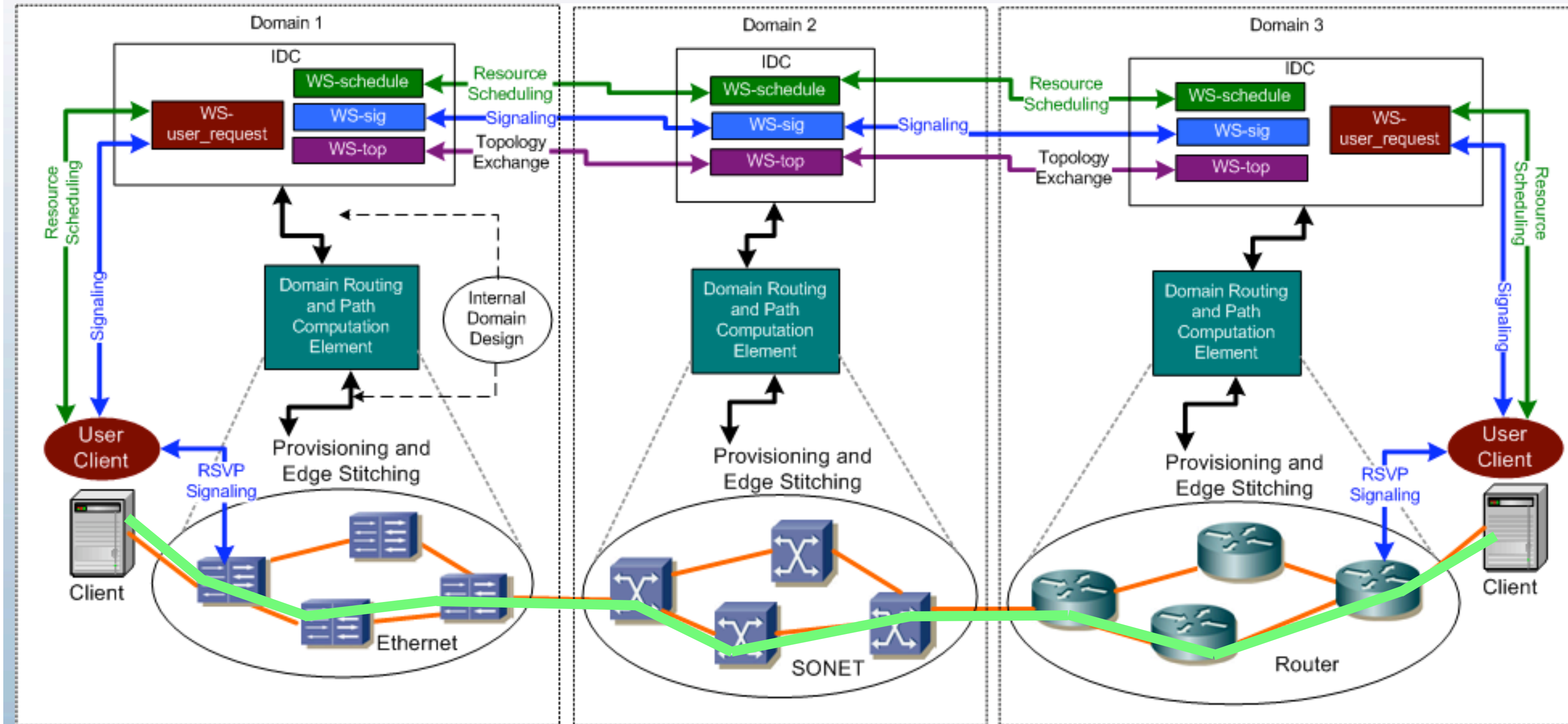


Dynamic Provisioning InterDomain

- No difference from a client (user) perspective for InterDomain vs IntraDomain

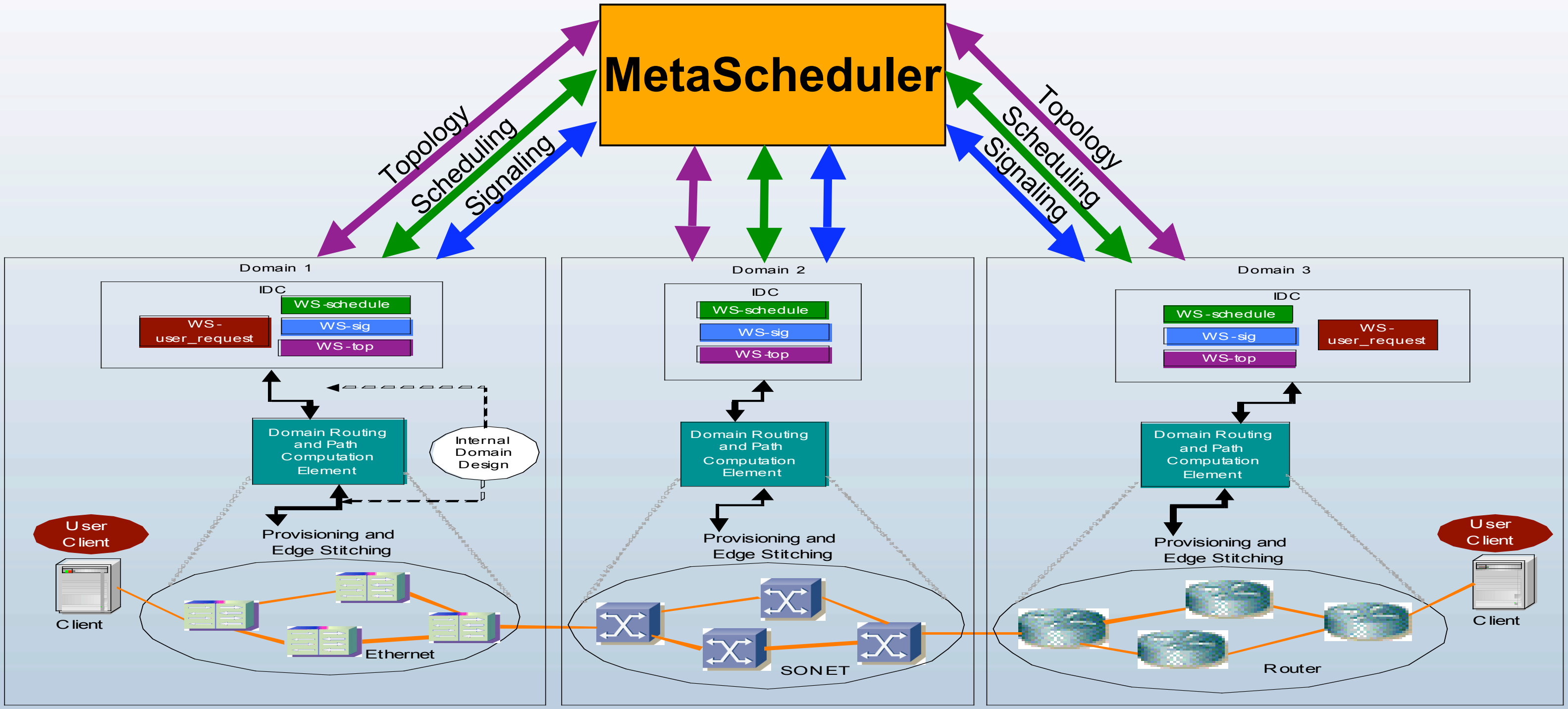


IDC - Web Service Based Definition



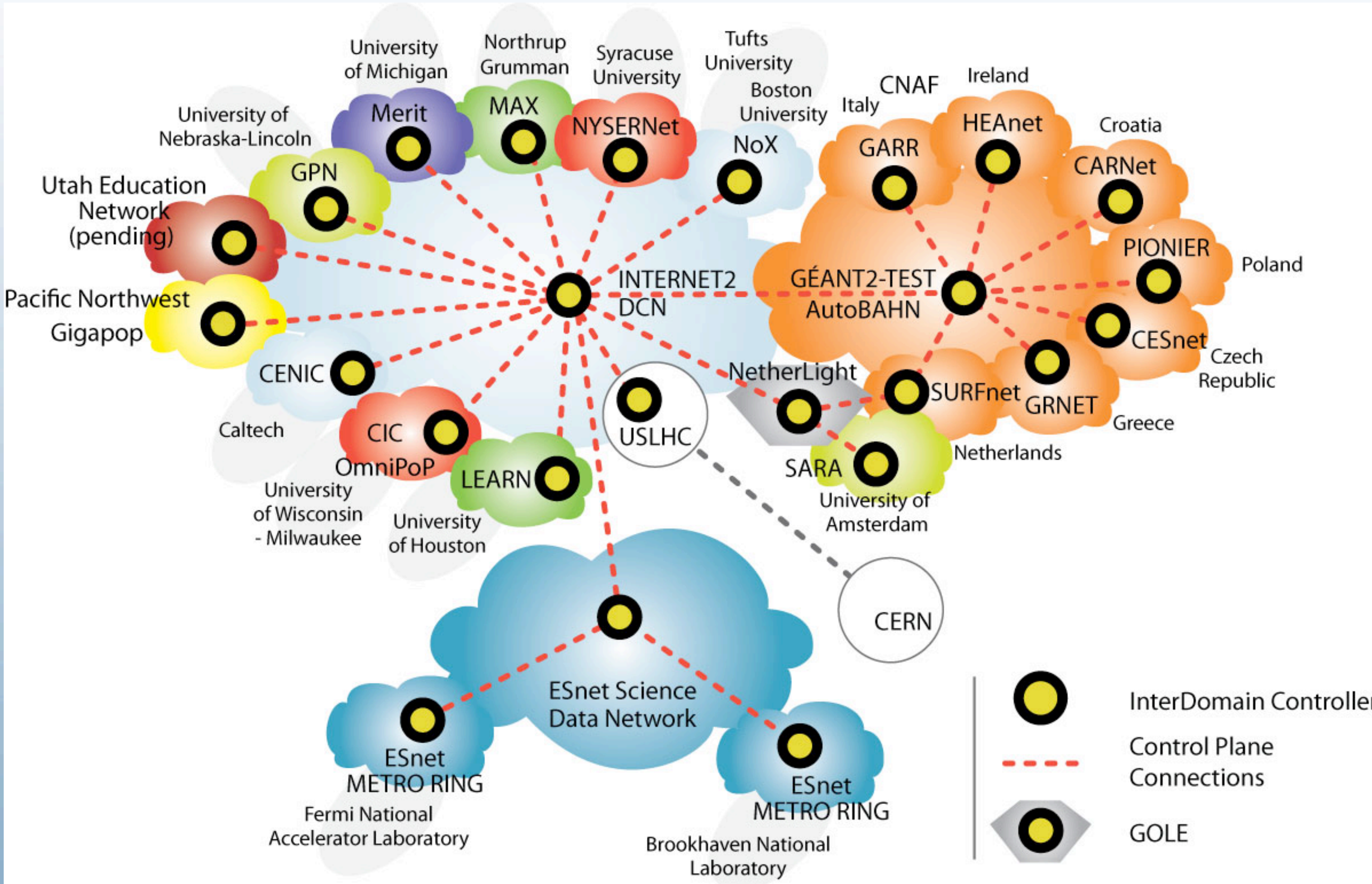
- Four Primary Web Services Areas:
  - Topology Exchange, Resource Scheduling, Signaling, User Request

Other AAA Models Possible



- Meta-Scheduler Approach
- Same set of Web Services used for linear instantiation model can be used by a high level process to build services:
  - Topology Exchange, Resource Scheduling, Signaling, User Request
- A key issue is that this requires a trust relationship between the “meta-scheduler” and all the domains with which it needs to talk

Global Dynamic Circuit Network



InterDomain Controller (IDC) Protocol (IDCP)

- The following organizations have implemented/deployed systems which are compatible with this IDCP
  - Internet2 Dynamic Circuit Network (DCN)
  - ESNet Science Data Network (SDN)
  - GÉANT2 AutoBahn System
  - Nortel (via a wrapper on top of their commercial DRAC System)
  - Surfnet (via use of above Nortel solution)
  - LHCNet (use of I2 DCN Software Suite)
  - Nysernet (use of I2 DCN Software Suite)
  - LEARN (use of I2 DCN Software Suite)
  - LONI (use of I2 DCN Software Suite)
  - Northrop Grumman (use of I2 DCN Software Suite)
  - University of Amsterdam (use of I2 DCN Software Suite)
  - DRAGON Network
- The following "higher level service applications" have adapted their existing systems to communicate via the user request side of the IDCP:
  - LambdaStation (FermiLab)
  - TeraPaths (Brookhaven)
  - Phoebus

Open Source DCN Software Suite

- OSCARS (IDC)
  - Open source project maintained by ESNet and Internet2
- DRAGON (DC)
  - NSF-funded
  - Open source project maintained by USC ISI EAST and MAX
- Version 0.3.1 of DCNSS current deployed release
  - https://wiki.internet2.edu/confluence/display/DCNSS

Architecture Definition
Key Control Plane Features

- Routing
  - distribution of "data" between networks. The data that needs to be distributed includes reachability information, resource usages, etc
- Path computation
  - the processing of information received via routing data to determine how to provision an end-to-end path.
- Signaling
  - the exchange of messages to instantiate specific provisioning requests based upon the above routing and path computation functions.
- Architecture definition document under development
  - Addresses tradeoffs and decisions with respect to these issues and others.

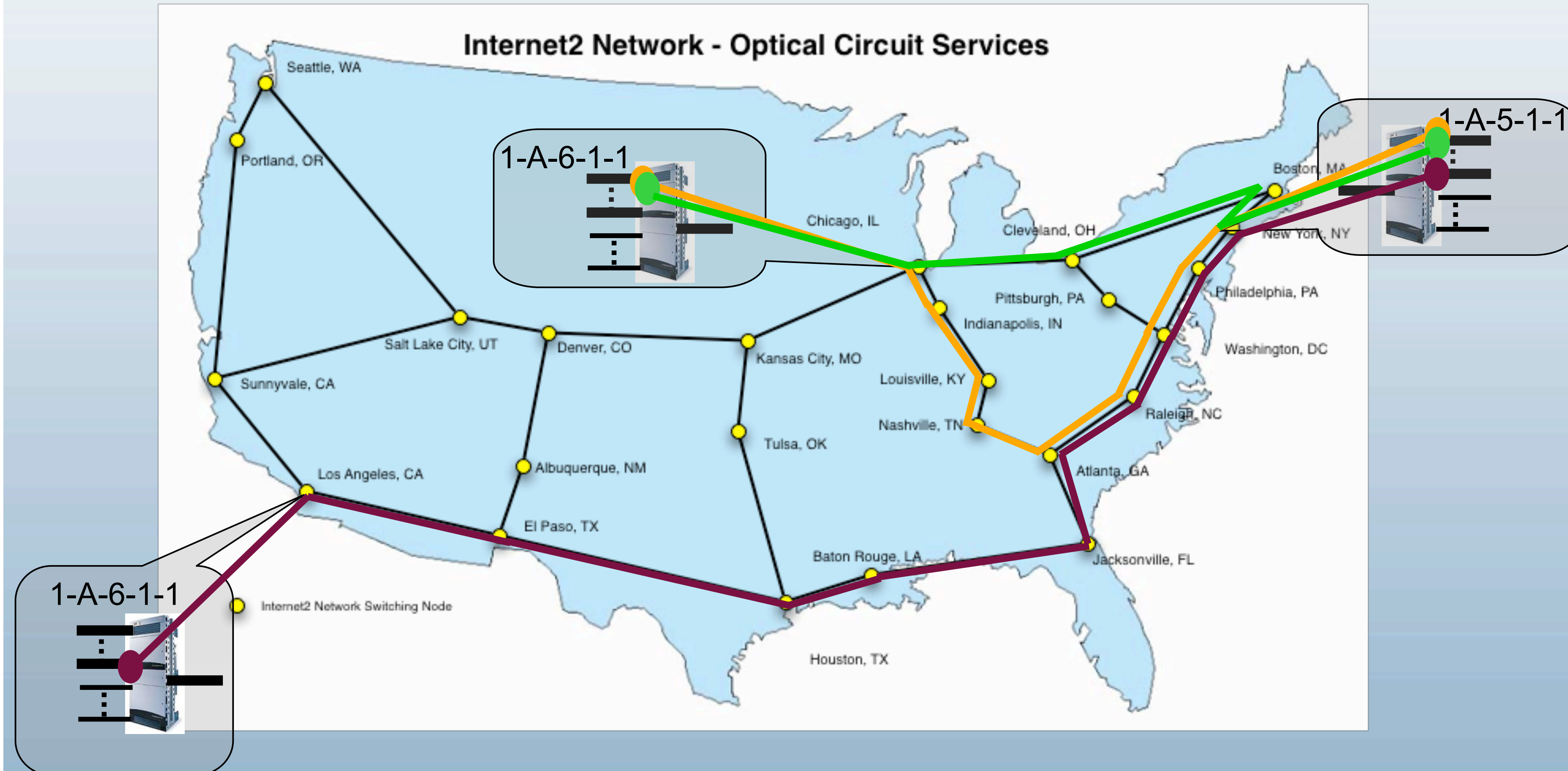
Architecture Definition
Key Control Plane Features

- Routing
  - Topology Exchange, Domain Abstraction
  - Link State based with varying levels of dynamic information (practically no dynamic information shared in initial implementations/deployments)
- Path Computation
  - Multi-Domain, multi-stage path computation techniques (includes a Scheduling and AAA components)
- Signaling
  - path setup, service instantiation
- Architecture would allow for web service or traditional protocol types of exchanges
  - web service mechanisms are the current choice
  - future may see a mix of both

Key Control Plane Key Capabilities IntraDomain

- InterDomain Architecture Definition and Agreements are the most important issue to be resolved amongst external organizations.
- However, there are many important IntraDomain issues as well
  - multi-layer, multi-vendor, multi-technology path computation control and provisioning
  - use of control plane protocols, management systems, or a combination of both
  - path computation and resource management which includes AAA and scheduling information
  - developing abstract view of your network for sharing with external domains
  - use of hierarchical techniques. Provision a circuit at one layer, then treat it as a resource at another layer. (i.e., Forward Adjacency concept)
- These are individual domain design decisions, but best practices and architectures will emerge

Circuit Provisioning or Network Virtualization?



OSCARS Project

- On-demand Secure Circuits and Advance Reservation System (OSCARS)
- DOE Office of Science and ESnet project
- Co-development with Internet2
- Web Service based provisioning infrastructure, which includes scheduling, AAA architecture using X.509 certificates
- Extended to include the DICE IDCP
- http://www.es.net/oscars/index.html

DOE

Office of Science

DRAGON Project

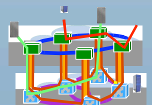
- Dynamic Resource Allocation via GMPLS Optical Networks (DRAGON)
- Developed control plane for multi-technology hybrid networks
- Deployed on Internet2 HOPI and DCN
- NSF Funded Project
  - originally funded by CISE/ANIR
  - Program Manager, Kevin Thompson, OCI
- Collaborative project: USC/ISI, UMD/MAX, GMU
- http://dragon.east.isi.edu

Hybrid Multi-Layer Network Control Project (Hybrid-MLN)

- Investigating issues associated with Multi-Layer, Multi-Domain Hybrid Networks from an architecture, data plane, and control plane perspective
  - Architecture Development
  - Design, analysis, modeling, simulation
  - Experimentation and data collection
- USC/ISI, UNM, ESNet, ORNL, Internet2
- Funded by DOE Office of Science
  - Dr. Thomas D. Ndousse, Program Manager
- http://hybrid.east.isi.edu

DOE

Office of Science



Hybrid MLN

DRAGON

The University of New Mexico

ISI Information Sciences Institute USC Viterbi School of Engineering

ESnet

INTERNET2

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

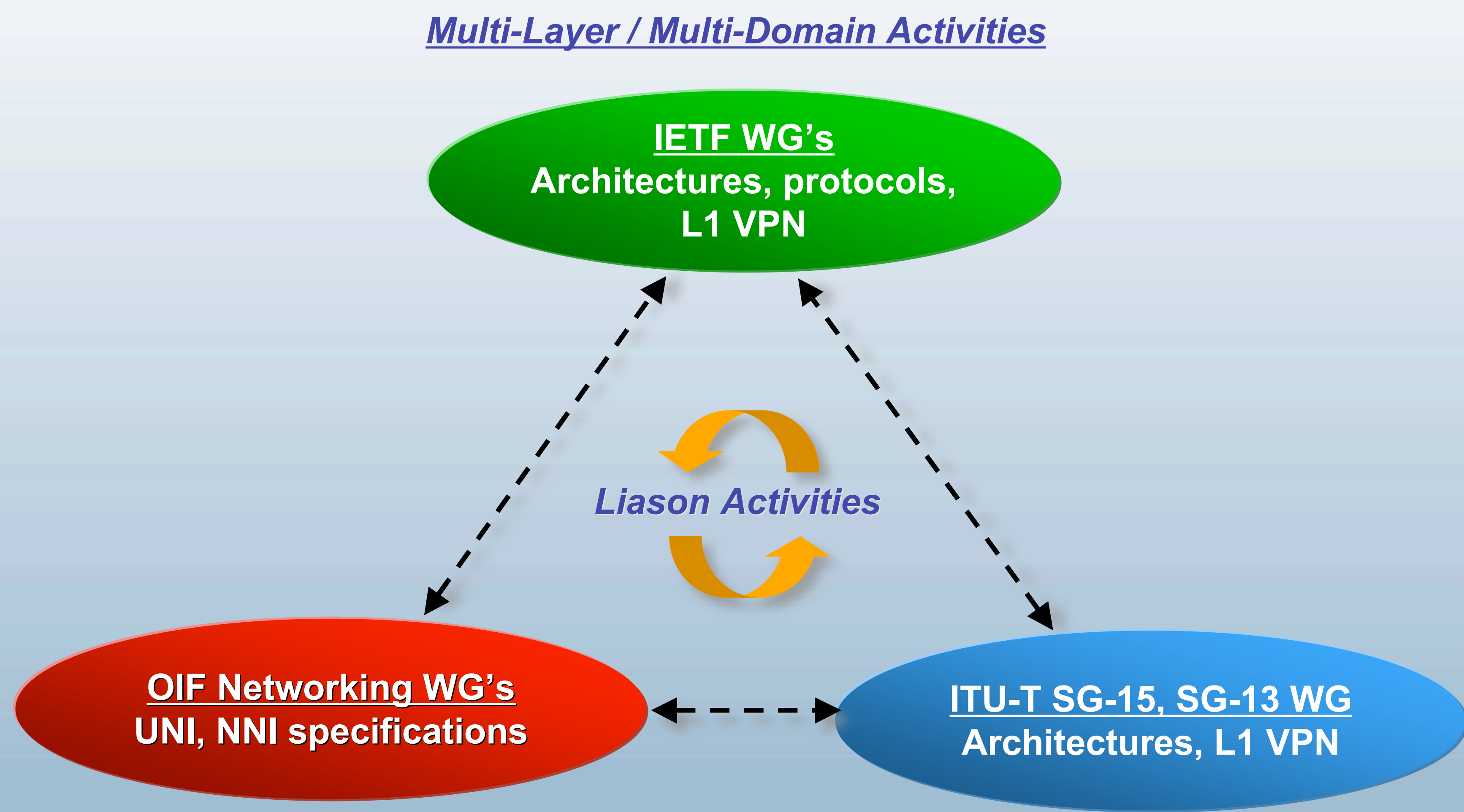
Commercial multi-layer network activities

- Standards bodies, vendors, commercial network deployments are working on multi-layer networks
- How do the R&E activities relate to Commercial multi-layer activities?

Standards Bodies Progress and Status

- Several standards bodies working in this space:
  - ITU-T ASON
  - OIF
  - IETF (CCAMP, L1VPN, L2VPN)
  - MEF
- UNI, I-NNI, E-NNI, BGP Extensions are some the key topics of discussion in these groups
- Vendor implementations are also following
- The work that the R&E community needs to leverage this work, but it needs to go further (and faster) then what is occurring in these standards bodies and associated vendor implementations. In particular, the standards bodies:
  - Have not converged on Inter-AS interdomain E-NNI routing or signaling protocols
  - Not working on multi-layer path computation details
  - Completed very little work on application of an Authentication, Authorization, Accounting (AAA) model to the control plane
  - Completed very little work on scheduling of provisioned services
  - Not addressing scalability and security to the degree required for the R&E community
- This is an opportunity for the R&E community to lead via early research, design, deployment of advanced multi-layer, multi-domain networks which provide real benefits to real users

Current Overview



R&E Network Research and Development Moving Forward

Emerging Network Architectures

- I believe we are in the middle of a major evolution/transformation/revolution of network architectures
- This revolves around viewing the network as “multi-layer, multi-technology” construct
  - with different switching types like PSC, L2SC, TDM, LSC, FSC,
  - reflected in new technologies ethernet PBB-TE, NG-SONET, OTN, NG WDM

Emerging Network Architectures
Some Key Questions

- how do we use these layers to build the IP routed network?
- how do we use these layers to traffic engineer the IP routed network? with some humans in the loop and a couple of days of planning? in real time by “management” computers? or by the network itself?
- how do we use these layers to build totally new “network services”

Emerging Network Architectures
Some Key Questions

- the first two applications are most obvious and will provide immediate benefits
- the last item is where a new network paradigm is waiting to be developed
- Service Oriented Networks
  - networks go beyond just providing IP routed service to also providing lower layer services directly to “applications”
  - networks provide “value added service embedded in the network itself” such as high performance data backup, content distribution systems, providing virtual network topologies with flexible levels of isolation, deterministic performance, dedicated resources, user perceived performance.

Emerging Network Architectures
Some Key Questions

- Network operators of the future may need to use the power of their networks to provide value added services that can only be constructed by tight coupling with network infrastructure and capabilities.
- So the future may not be so much “network convergence” as it will be “network services convergence”
- so we will find a way to use a very heterogeneous set of network technologies to provide a rich set of network services

R&E Community Network Research

- The R&E community is uniquely positioned to make contributions in the development of future network architectures
- Commercial networks are built to support the applications (profiles) they want their customers will use
  - hope the users do not disturb the network in unexpected ways with unexpected applications
  - they have a much bigger scale dimension to address

R&E Community Network Research

- R&E community is building networks to encourage/enable domain experts to develop the applications they can imagine.
  - design networks to allow application communities to innovate, and subsequently drive the network design and requirements
- R&E networks should really view as their mission to enable/encourage application domain experts to be able to create and innovate in their domain space.

R&E Community Network Research

- This is difficult, because innovating and creating is always hard, and it is not realistic to just ask the application domain experts to tell us what they want from a next generation network. They are not network experts
- The network community needs to take responsibility for integrating deep enough into the domain areas to allow innovation to happen, and build networks to support that innovation

Summary

- Future Network architectures are likely to be based on exploiting the multi-layer topology of networks
- Networks should evolve to providing services
- Exploit and encourage the natural feedback loop between vendors, standards bodies, commercial users, commercial networks, R&E networks, R&E user.
- The future may not be so much “network convergence” as it will be “network services convergence"

Thank You

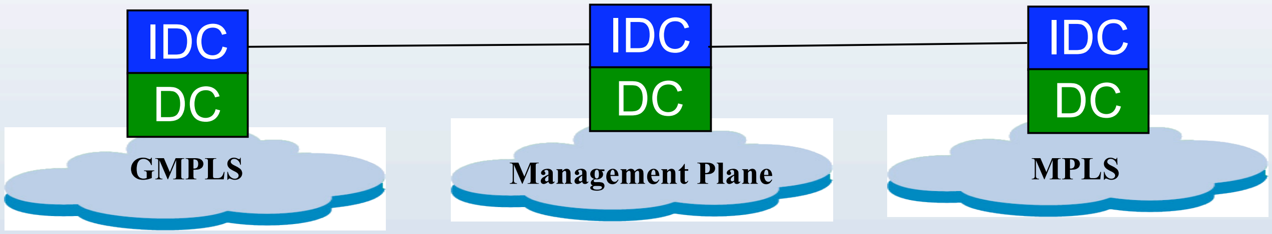
- Questions,Comments?
- Tom Lehman
  - tlehman at east.isi.edu

Extra Slides

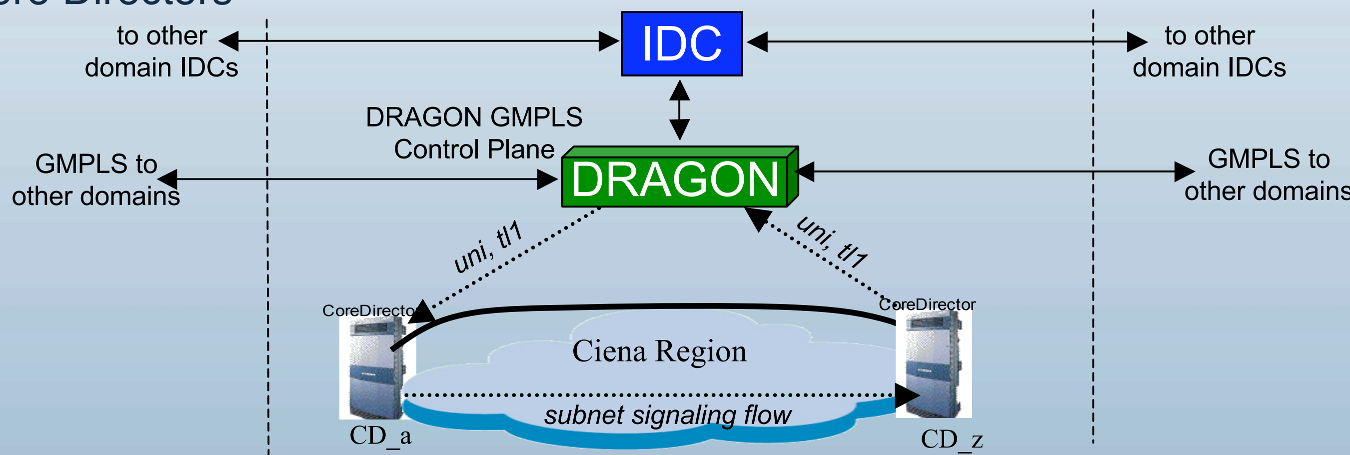
IntraDomain Network Control

- A key requirement for the architecture is to be able to handle the reality that the underlying networks will be very heterogeneous in terms of technology, control mechanisms, and vendors.
- In the current architecture this is abstracted out by the DC to IDC interface.
- Four types of underlying domain types have been identified in terms of how the DC interacts with them:
  - GMPLS (I2 DCN is an example, regional networks based on ethernet switch dynamic provisioning is another example)
  - MPLS (ESNet SDN is an example)
  - Management Plane Controlled (USN is an example)
  - Vendor Control Plane (I2 DCN also has a component of this)

Dealing with Heterogeneous Network Technologies and Vendor Equipment



- As an Example, DRAGON is used as the DOMAIN Controller for I2 DCN Ciena Core Directors

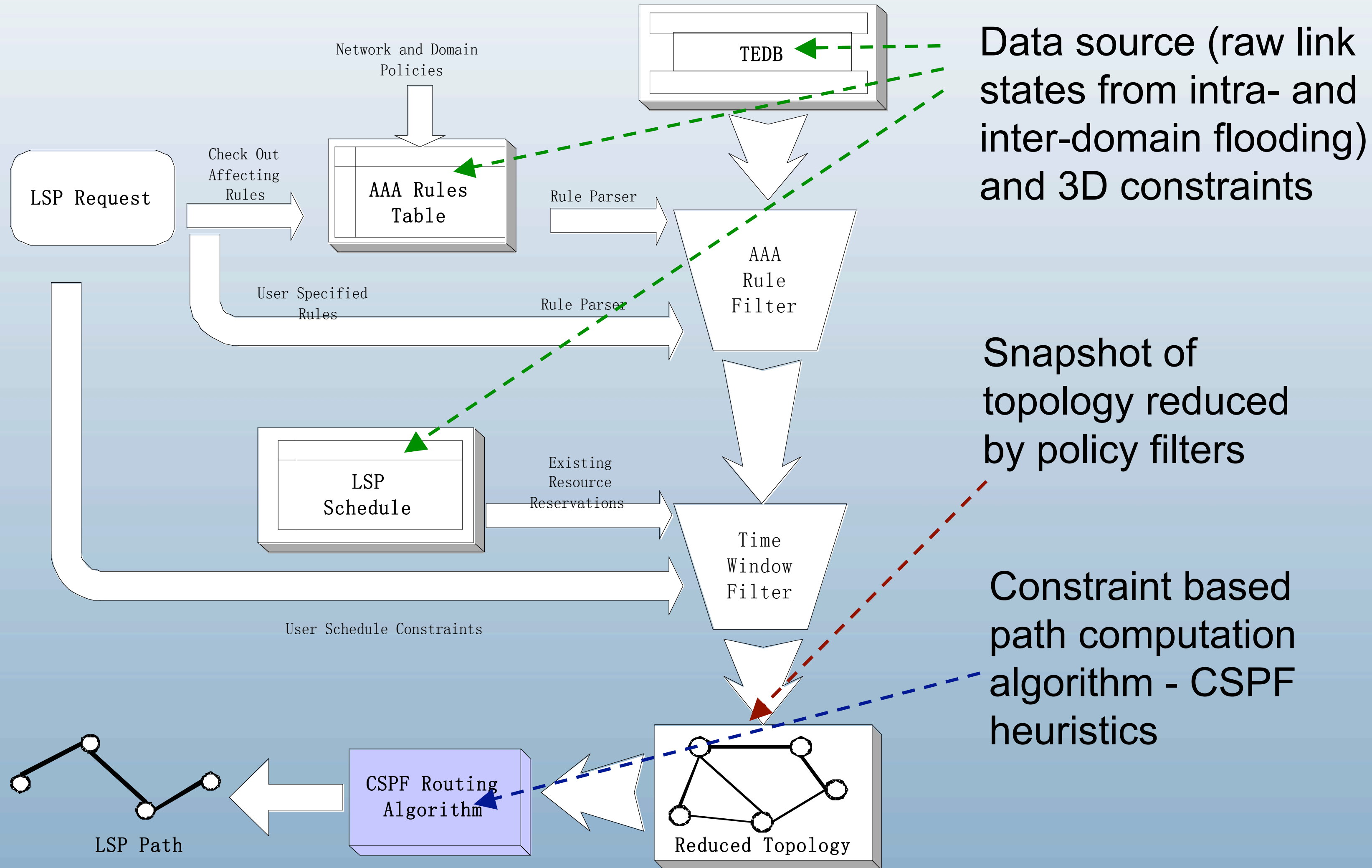


- Adding regions of new technologies and vendors is not too difficult from the provisioning perspective
- The difficult issue is in terms of the routing exchange between/from the technology/vendor regions and path computation (intra and multi-domain) with multiple constraints.

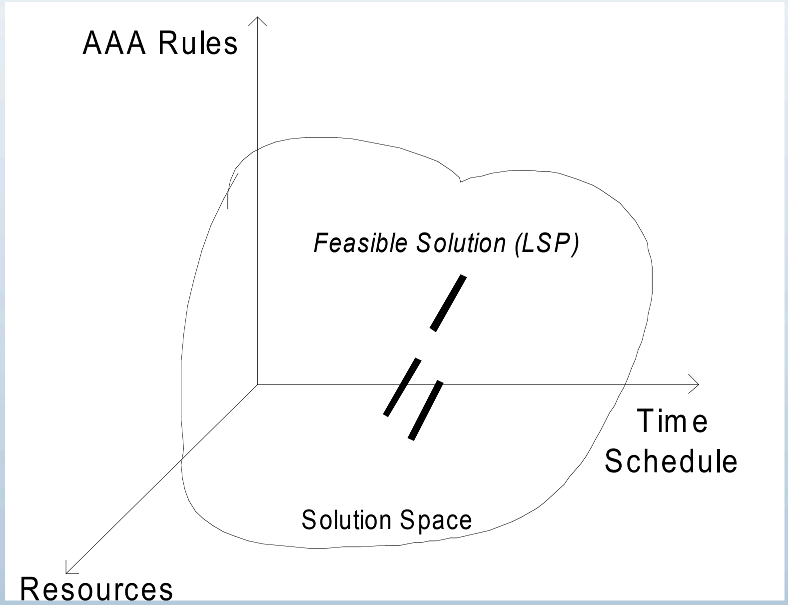
Multi-Constraint Path Computation

- IntraDomain provisioning requires a path computation process to determine a path across the local network
- If the domain consists of multiple technologies, multiple levels, and multiple vendors this problem can be complex
- In order to realize the advanced control plane features multi-domain path computation needs to be augmented to operate in these environments. This will likely include addition of the following constraints to the path computation process:
  - time domain
  - flexible set of AAA and other user defined constraints
  - Ability to look for paths as a group in the context of a entire topology build.
  - These scheduling and flexible policy processing mechanisms will need to be tightly integrated/coupled with path computation and selection processes

Flexible and Policy Based Multiple Constraint Path Computation with Filtering/Pruning Processes



Path Computation with Multiple Dimensions



- Resource dimension
  - Link availability, bandwidth capability & resource interdependence
  - TE constraints, e.g. switching cap.
- AAA policy dimension
  - User privileges
  - App. specific requirements (SLA)
  - Administration policies
- Time schedule dimension

- Integrate and translate network resource states and policies into shared control plane intelligence.
- Synergize AAA policy decision with TE based provisioning decision, resulting in fast, precise and simplified control process.

Optical Transport Network (OTN)

- ITU Standard G.709, Optical Transport Network (OTN), or digital wrapper technology.
- OTU1, 2.7 Gbit/s, transport a SONET OC-48 SDH STM-16 signal.
- OTU2, 10.7 Gbit/s, transport an OC-192, STM-64 or 10Gbit/s WAN. Overclocked to carry signals faster than STM64/OC192 (9.953Gbit/s) like 10 GiGE LAN PHY
- OTU3, 43Gbit/s, transport an OC-768 or STM256 signal

Provide BackBone Bridging Traffic Engineering (PBB-TE)

- 802.1q, VLANS
- 802.1ad, Provider Bridges, QinQ
- 802.1ah, PBB
  - connection oriented operation enabled by disabling flooding, learning, spanning tree
  - use a control plane to establish paths thru network
  - 24 bit service ID, eliminates scaling issue within the PBB domain
  - only switches at the edge of the PBB network need this capability, rest can be provider bridges

Internet Engineering Taskforce

CCAMP working group (GMPLS)

- GMPLS control for SONET/SDH (RFC 4257)
- GFP/LCAS interface discovery (OSPF-TE, RSVP-TE implications)
- *Multi-layer/multi-region (MRN) networks drafts*:
  Interface switching capability (ISC), unified TE database
- Drafts on multi-domain routing (OSPF-TE, O-BGP), no temporal state
- Other drafts on multi-domain/AS signaling & recovery:
  Crankback, inter-AS exclude routes, etc

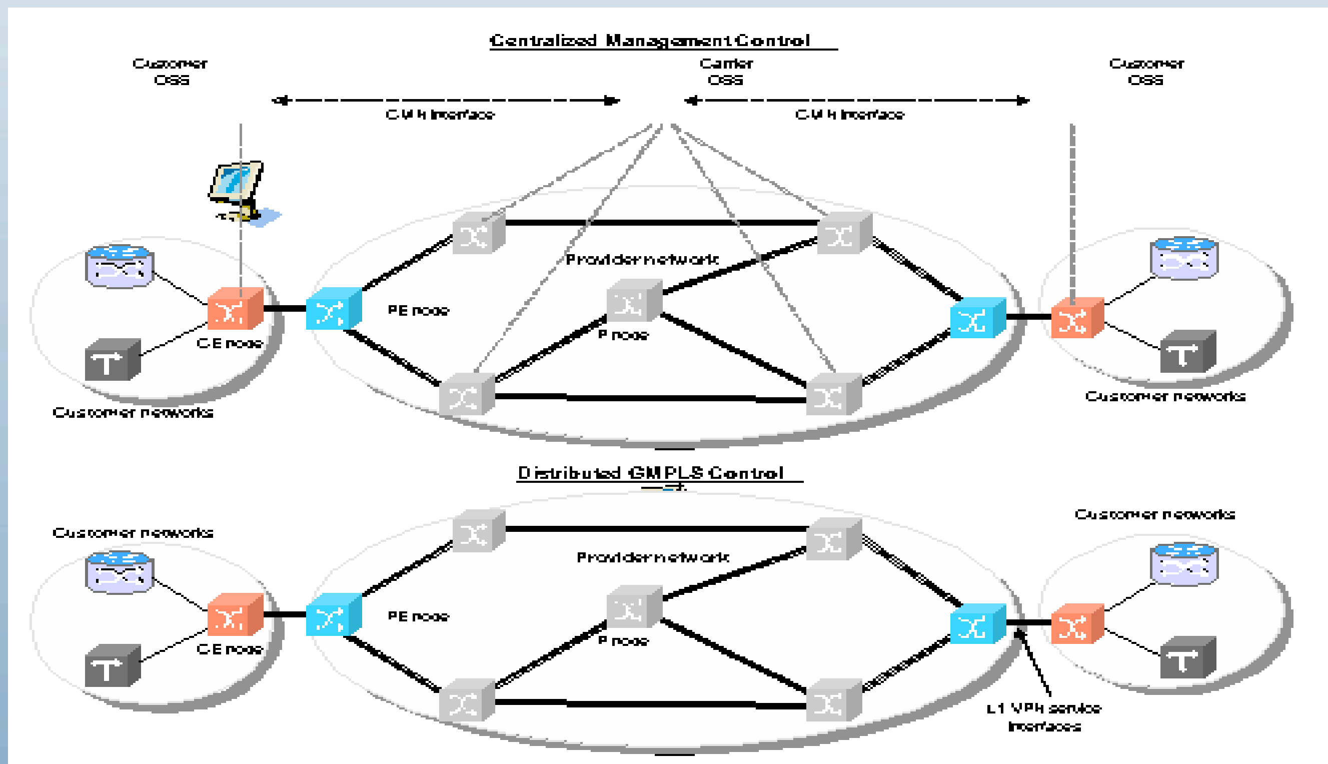
Path computation element (PCE) working group (TE)

- Path composition for TE-LSP paths:
  Centralized / distributed, loose-domain / hop-by-hop
- Inter-area / AS / layer considerations (virtual topology management)
- New PCEP signaling protocol, possibly one for PCE discovery
- No PCE considerations for advance scheduling
- Various requirements drafts (2004-5), no RFC yet

IETF L1 VPN Framework

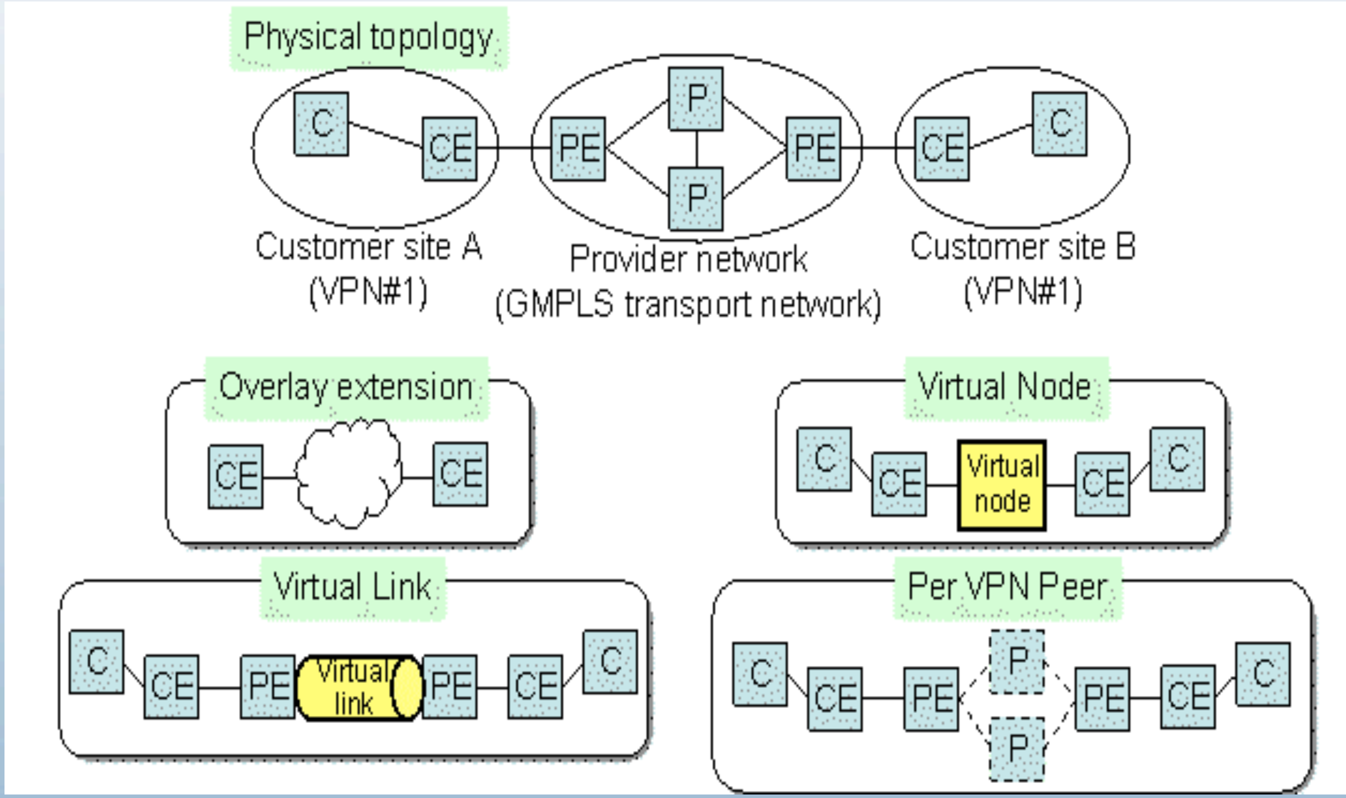
Layer 1 VPN working group

- “Infrastructure virtualization”: DWDM lighpath, SONET circuit
- Basic and enhanced modes: signaling only vs. dist^{d} signaling & routing
- Drafts on BGP & OSPF PE discovery (opaque LSA), single AS focus for now
- Proposal to extend RSVP-TE signaling (per VPN instances)
- provide layer-1 VPN services (establishment of layer-1 connections between CE devices) over a GMPLS-enabled transport service-provider network.



IETF L1 VPN Service Models

Differing Levels of CE-PE Functionality / Exchange



Optical Internetworking Forum

User Network Interface (UNI) 2.0

- Multi-vendor interoperable client provisioning
  Automated end-pt & service discovery, signaling (parameters)
- Improved resiliency, control security, Eth support (IETF, ITU-T inputs)
- UNI-N side supports multi-layer call/connections (VCAT)

Network to Node Interface (Internal – NNI, External - NNI)

- Decouple intra & inter-domain mechanisms (protocols, algorithms)
- Signaling protocol: parameter negotiation, protection/diversity
- Hierarchical routing: topology / resource discovery (DDRP mixed review)
- Generally lacks provisions for advance scheduling

IEC Supercomm interoperability trials

- <u>Interim UNI 1.0 (2001):</u> End-pt discovery, setup/teardown, full λrates
- <u>UNI 2.0, E-NNI 1.0 (2005):</u>
  13 vendors, 7 service providers (focus on EoS services)

International Telecom Union (ITU-T)

Automatically-Switched Optical Network (SG - 15, G.8080)

- Multi-level hierarchical link-state routing (G.7715.x):

  Horizontal (areas), vertical (leaders), inter-level state exchange
- Dist^{d} call / connection management (G.7713.x, SN controllers):

  Recently addressing protection/restoration, no crankback yet

Layer 1 VPN (SG - 13)

- Req & architecture documents (Y.1312 / 2003, Y.1313 / 2004)
- Close liason w. IETF (routing area) on suitability of IETF protocols

Other liason activities to evolve "ASON compliant" protocols

- Signaling:

  IETF RSVP-TE drafts for ASON, OIF UNI 2.0 & NNI 1.0 alignment
- Link-state routing:

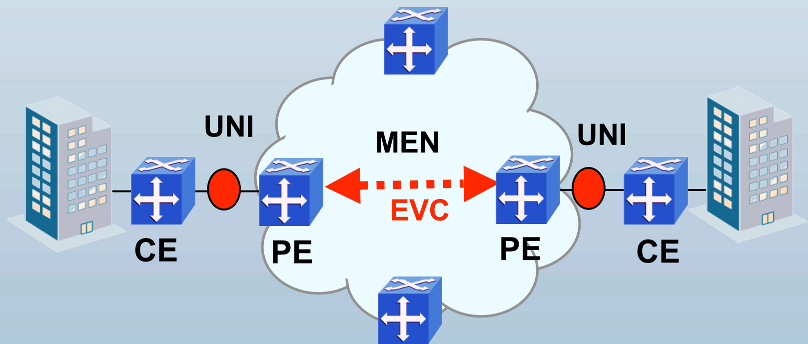
  - Reqs RFC 4258, OSPF-TE and IS-IS drafts for ASON (G.7715.1)
  - OIF NNI 1.0 routing

Metro Ethernet Forum

Accelerate "carrier-class" Ethernet

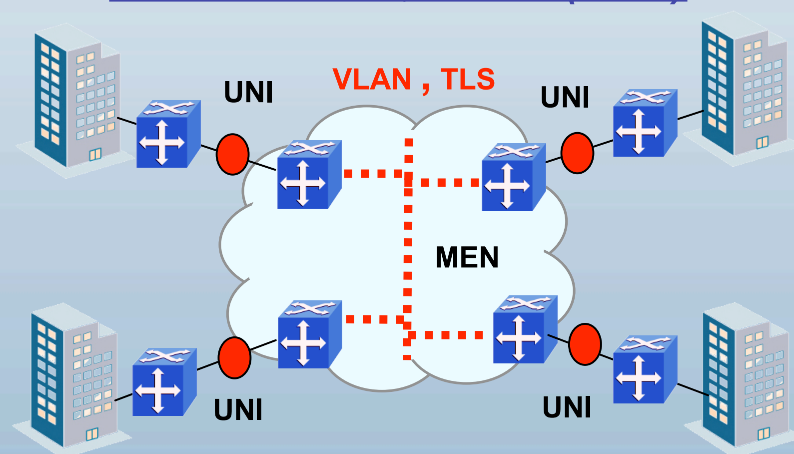
- ***Service focus***, layered network decomposition:
  Applications, Eth services, metro Eth network (MEN)
- Agnostic to MEN technology (SONET, DWDM, MPLS)
- UNI spec for client-MEN boundary (UNI-C, UNI-N), NNI

E-Line Service, MEF 4 (2004)



- Point-to-point (unicast) Ethernet VC (EVC)
- Service attributes (at UNI):
  Interfaces, BW profiles, service performance, frame delivery, service multiplexing, L2 control tunneling/discard, etc
- UNI multiplexing (EVPL service)

E-LAN Service, MEF 4 (2004)



- Multipoint-to-multipoint (broadcast) EVC
  Best-effort or QoS between UNI's
- Similar service attributes
- Support address learning over UNI