GEC-3
Control Framework

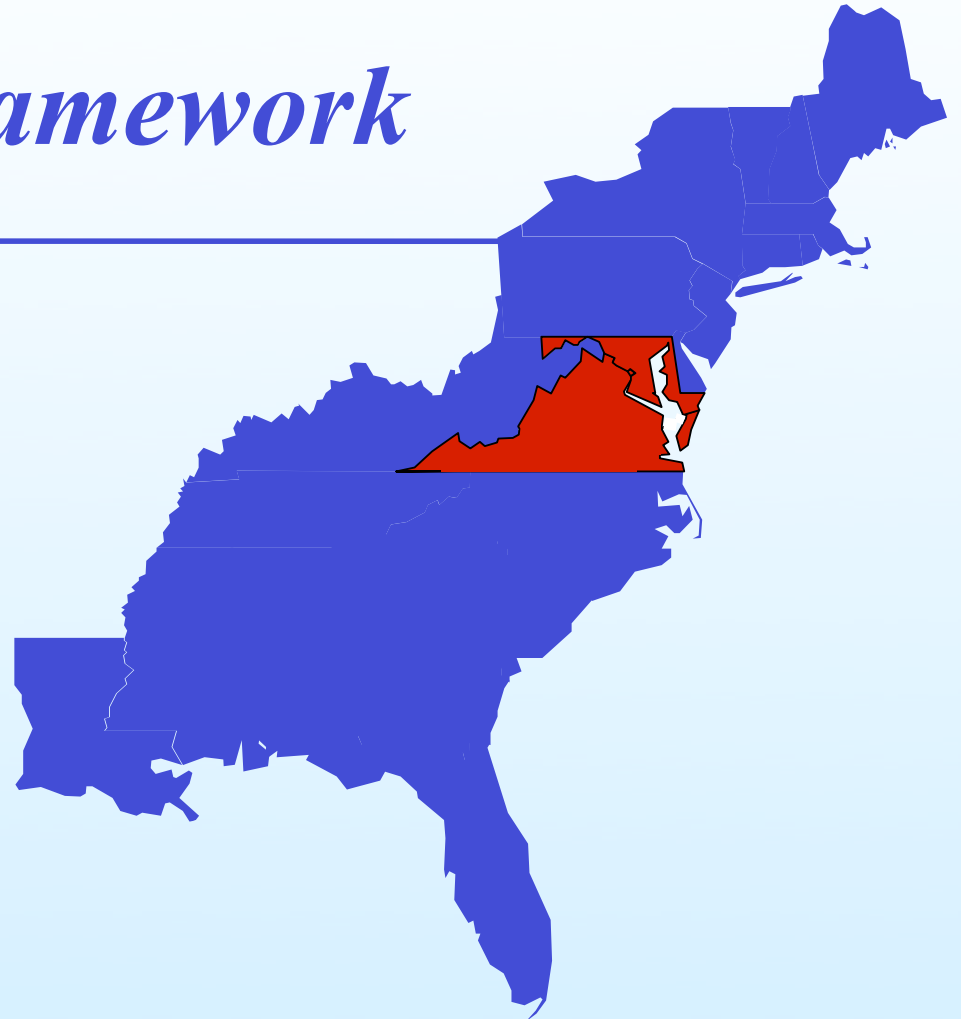**Peter O'Neil**
Chris Tracy
Jarda Flidr
Cluster B Participant
October 29, 2008

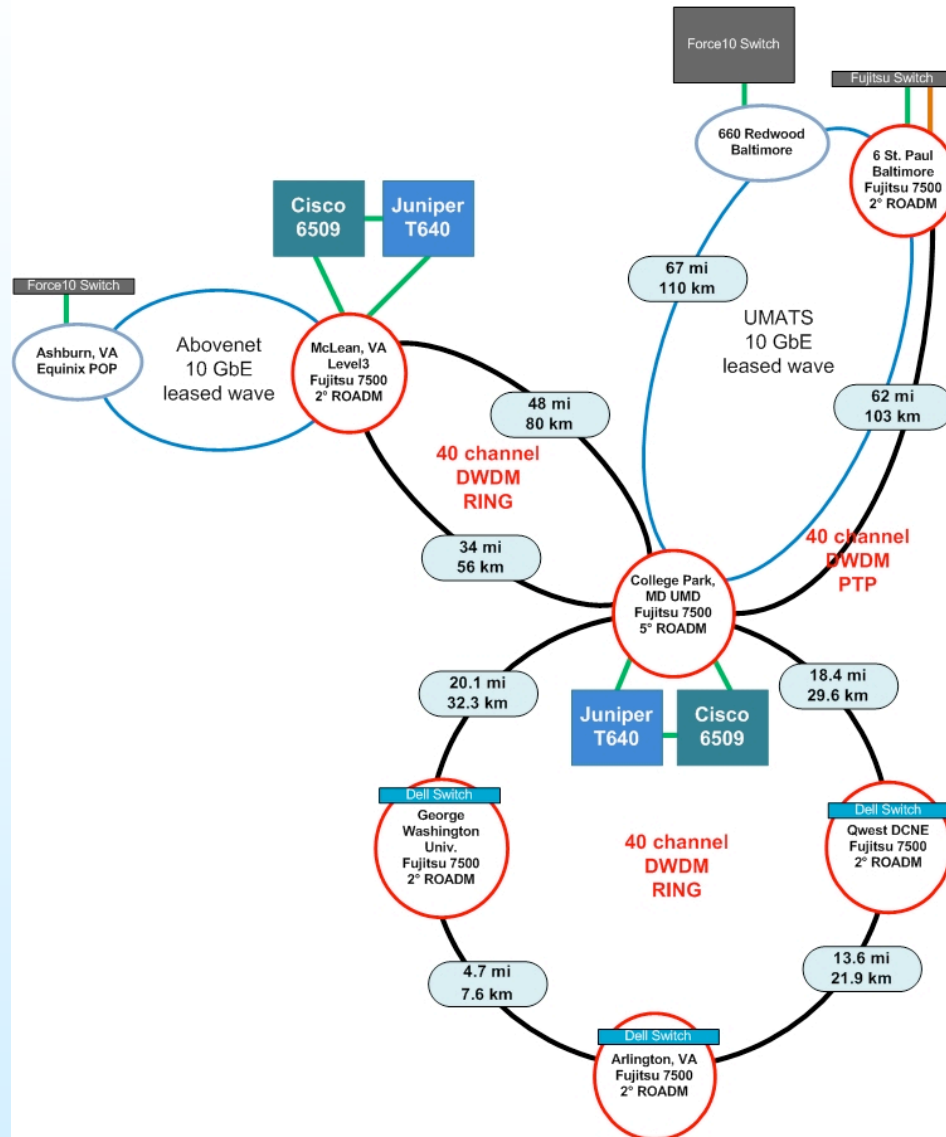*MAX* *Mid-Atlantic Crossroads*

Outline

- MAX Overview

- Offered GENI Capabilities

- GENI Deliverables

- DRAGON API - Jarda Flidr

- DRAGON Overview - Chris Tracy

- Circuit Provisioning Demonstration

MAX Overview

- Regional Optical Network
- Founded 1999 by Georgetown University, George Washington University, University of Maryland, and Virginia Tech
  - Administrative home is University of Maryland
- Production Network Service Offerings
  - Layer 1 Waves over multiple protected fiber rings
  - Layer 2 MPLS Tunnels, VRFs, and VLANs
  - Layer 3 Routed IP
  - Interconnections to NLR at 10G for Layers 1, 2, and 3
  - Interconnections to Internet2 at 2.5G Layers 2 & 3

Mid Atlantic Crossroads Network

Force10 Switch

Fujitsu Switch

660 Redwood
Baltimore

6 St. Paul
Baltimore
Fujitsu 7500
2° ROADM

Cisco
6509

Juniper
T640

67 mi
110 km

UMATS
10 GbE
leased wave

Force10 Switch

Ashburn, VA
Equinix POP

Abovenet
10 GbE
leased wave

McLean, VA
Level3
Fujitsu 7500
2° ROADM

48 mi
80 km

62 mi
103 km

40 channel
DWDM
RING

34 mi
56 km

College Park,
MD UMD
Fujitsu 7500
5° ROADM

40 channel
DWDM
PTP

20.1 mi
32.3 km

18.4 mi
29.6 km

Juniper
T640

Cisco
6509

Dell Switch

George
Washington
Univ.
Fujitsu 7500
2° ROADM

Dell Switch

Qwest DCNE
Fujitsu 7500
2° ROADM

40 channel
DWDM
RING

4.7 mi
7.6 km

13.6 mi
21.9 km

Dell Switch

Arlington, VA
Fujitsu 7500
2° ROADM

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Participants

Federal Labs and Agencies:

- ATDnet – NRL, LTS, DISA
- D.C. Government
- Energy Sciences Network (ESnet)
- Laboratory for Telecommunications Sciences (LTS)
- Library of Congress
- NASA / GSFC
- National Archives and Records Administration (NARA)
- National Institutes of Health (NIH)
- National Institute of Standards and Technology (NIST)
- National Library of Medicine (NLM)
- National Oceanic and Atmospheric Administration (NOAA)
- National Science Foundation (NSF)
- USDA, Beltsville Agricultural Research Center
- U.S. Department of Health and Human Services (HHS)
- U.S. Department of State (through GWU)
- U.S. Geological Survey
- U.S. Holocaust Memorial Museum
- U.S. Veterans Administration

Corporate and Non-profit:

- Columbia Telecommunications Corporation (CTC)
- Howard Hughes Med. Institute
- Fujitsu Labs of America
- Inter-American Development Bank (IADB)
- Northrop Grumman Corporation
- The Institute for Genomic Research
- Windber Professional Services, Inc
- World Bank
- The Venter Institute

Higher Education:

- American University
- Baltimore Education & Research Network (BERnet)
- Catholic University
- GEANT
- Georgetown University
- George Mason University
- George Washington University
- Johns Hopkins University
- Johns Hopkins University – Applied Physics Laboratory (JHU-APL)
- Montgomery College
- National Consortium for Supercomputing Applications / ACCESS
- Network Virginia (aggregating the State of Virginia)
- Smithsonian Institution
- Southern Universities Research Association (SURA)
- University of California, D.C. campus
- University Consortium for Advanced Internet Development (UCAID / Internet2)
- University of Maryland, College Park
- University of Maryland, Baltimore
- University of Maryland, Baltimore Co.
- Univ. System of Maryland Network (aggregating 11 campuses)
- University of Southern California, Information Sciences Institute / East
- Washington Research Library Consortium

Research Infrastructure
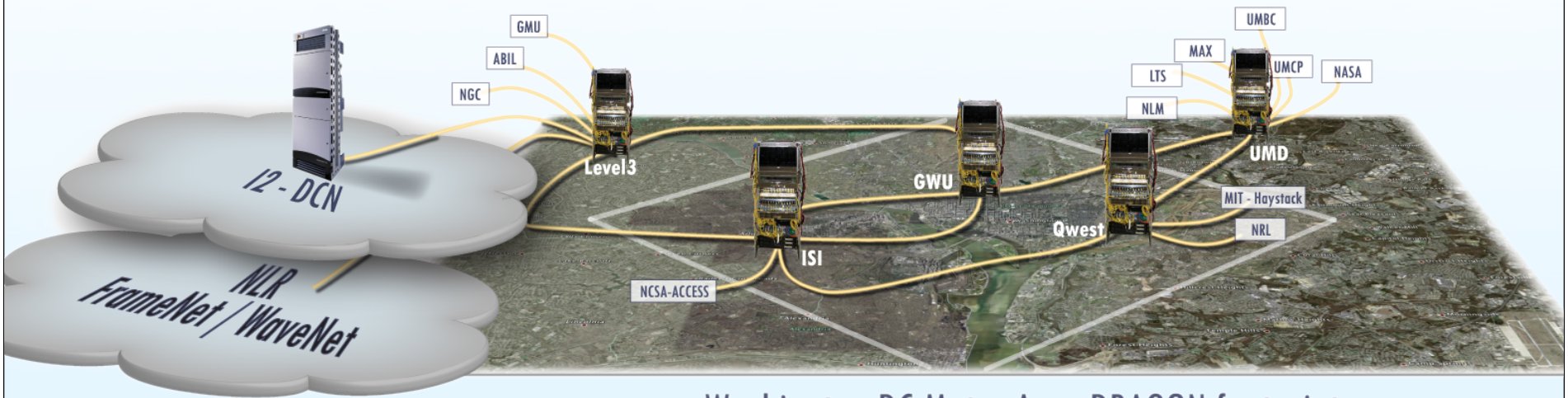
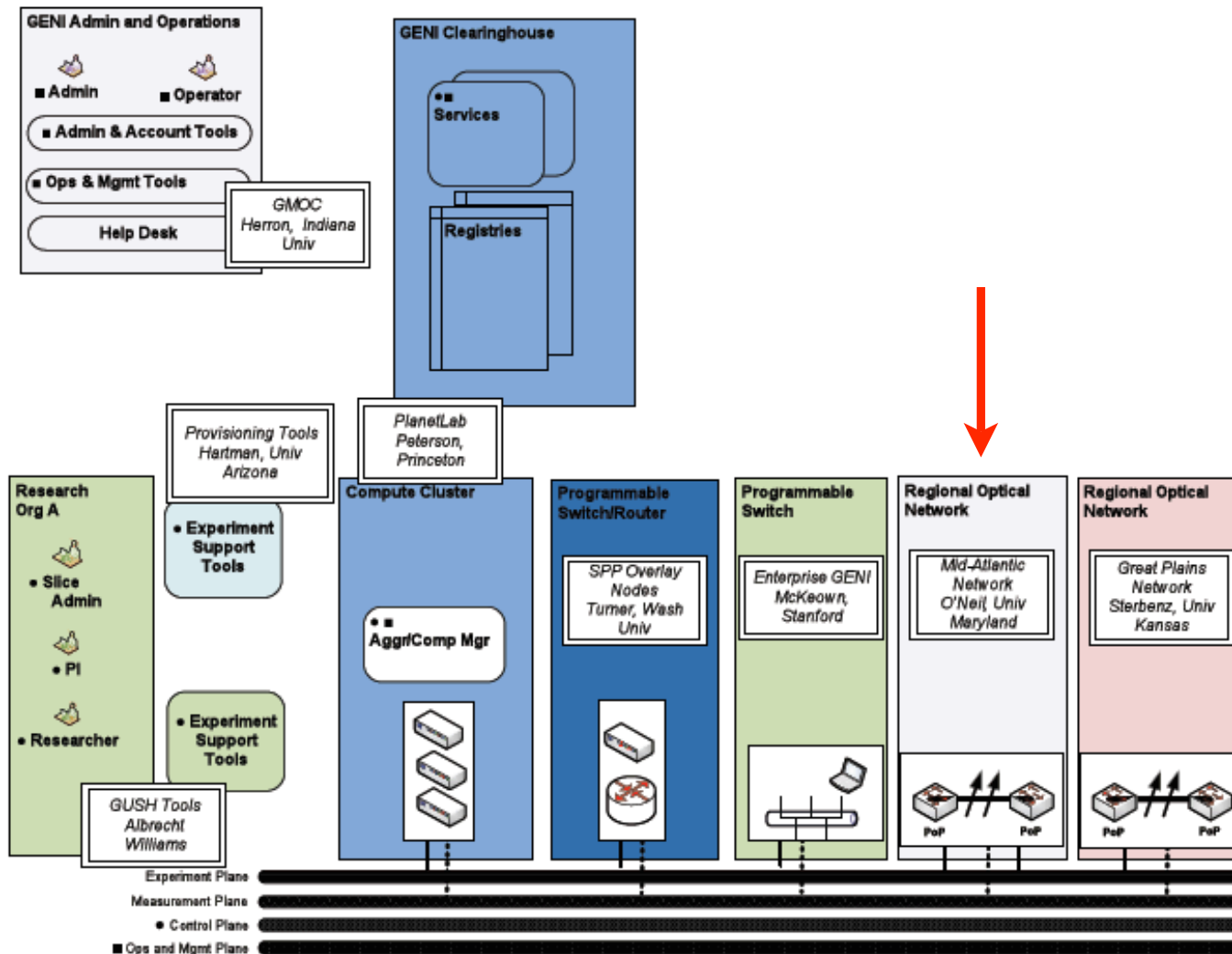Washington DC Metro Area DRAGON footprint

MAX In-Kind Facilities for GENI

- Use of multiple waves on research infrastructure
- DRAGON control plane functionality
- 2 PlanetLab servers (with ~1TB RAID storage)
- Ethernet Switch (if necessary)
- Tie fibers and cross connects to Internet2 and NLR

Cluster B Participant

GENI Deliverables

- Extend DRAGON's open-source GMPLS-based control plane implementation to include edge compute resources and support network virtualization;

- Lead the integration of PlanetLab control framework within Cluster B onto the DRAGON test-bed and the deployment of that control plane software over other networks;

- Enable backbone connections to resources of substrate components in Cluster B participants across Internet2 in support of end-to-end VLAN connections into the DRAGON test-bed;

- Make integrated (VLAN connections and control framework) DRAGON infrastructure available to external researchers by the end of Spiral 1;

- Representing/ offering developed DRAGON technology to the various control frameworks selected in Spiral 1 through active participation in GECs
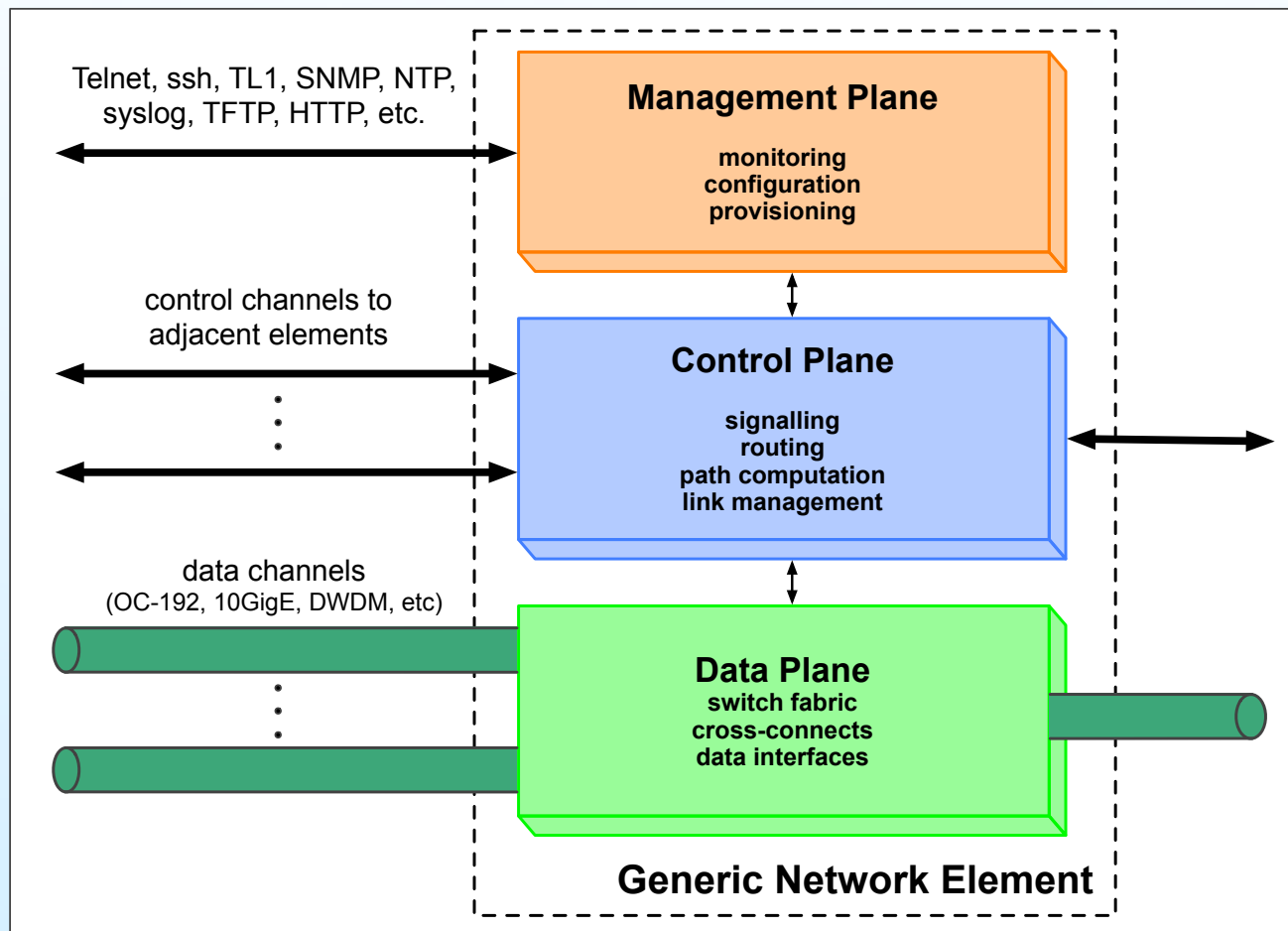
DRAGON API Overview
by Jaroslav Flidr

Dynamic Resource Allocation via GMPLS Optical Network (DRAGON)

- Funded by NSF as part of the Experimental Infrastructure Network (EIN) program
- <u>Optical Network Testbed</u>
  - MEMS-based wavelength selectable switches
  - Optical Add/Drop Multiplexors (OADMs)
  - 10Gbps capable Ethernet switches
  - Connects research facilities within the DC metro area in support of e-Science applications and development of optical control plane technologies
- <u>Control Plane Software</u>
  - Open-source implementation of GMPLS protocols
  - Extended existing implementations of OSPF and RSVP to support GMPLS & TE
  - Developed inter-domain methodologies for topology distribution and multi-layer path computation
  - Currently deployed in several semi-production environments
- More information available at: **http://dragon.maxgigapop.net/**

Generic Network Element

– Consider the major components inside a typical network element:

Telnet, ssh, TL1, SNMP, NTP,
syslog, TFTP, HTTP, etc.

Management Plane

monitoring
configuration
provisioning

control channels to
adjacent elements

Control Plane

signalling
routing
path computation
link management

data channels
(OC-192, 10GigE, DWDM, etc)

Data Plane
switch fabric
cross-connects
data interfaces

Generic Network Element

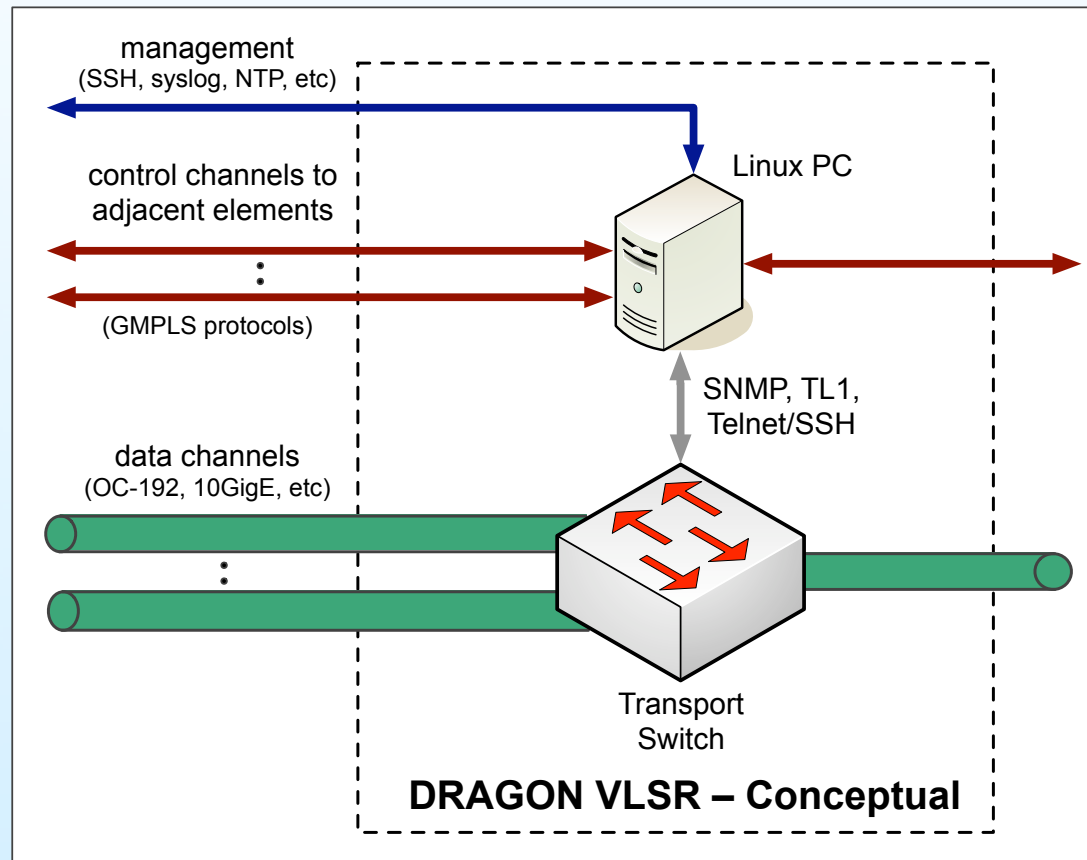# *DRAGON Virtual Label Switching Router (VLSR)*

- Open-source implementation of GMPLS RSVP signaling and OSPF routing with Traffing Engineering (TE) extensions

- Manages and provisions transport elements which do not support GMPLS, such as:
  - Ethernet switches
  - SONET/SDH digital cross-connects

- Supported equipment currently includes:
  - Cisco Catalyst 3750/65xx, HP ProCurve 5406, Raptor ER-1010, Dell PowerConnect 5224/5324/6024/6024F, Extreme Summit 5i/7i, Force10 EthernetScale E300/E600/E1200, Intel Express 530T, SMC 8708L2/8848, Ciena CoreDirector

- Potential for interoperability with other GMPLS-speaking network elements
  - demonstrated interoperability with Adva Optical lambda switches and Calient DiamondWave fiber switches
  - interoperability with other vendors may require code changes due to vendor proprietary Link State Advertisements (LSAs)

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DRAGON Virtual Label Switching Router (VLSR)

– Unix PC implements GMPLS control plane protocols (open-source package)
– Provides GMPLS protocol support for devices which do not support GMPLS

Control channels may be provisioned **in-band** or **out-of-band**

(e.g. GRE/IPsec tunnel over out-of-band Layer 3 network or in-band control VLAN over Ethernet data channel)

management
(SSH, syslog, NTP, etc)

control channels to adjacent elements

:

(GMPLS protocols)

Linux PC

SNMP, TL1,
Telnet/SSH

data channels
(OC-192, 10GigE, etc)

:

Transport
Switch

DRAGON VLSR – Conceptual

Signalling RFCs:
RFC 2205
RFC 3209
RFC 3471
RFC 3473
RFC 3477
(GMPLS-RSVP-TE)

Routing RFCs:
RFC 2328
RFC 2370
RFC 3630
RFC 4202
RFC 4203
(GMPLS-OSPF-TE)

DRAGON Network Aware Resource Broker (NARB)

- Open-source implementation of path computation engine (PCE)
  - NARB is an agent that represents a domain
  - Provides Constrained Shortest Path First (CSPF) path computation service
    - With OSPF-TE, reachability is no longer the only criteria for deciding next-hop
  - Pluggable path computation algorithms
    - Constrained Breadth First Search (C-BFS)
    - Channel Graph Transformation Search
    - K-Shortest Path (KSP) Heuristic Search
  - Intra-domain listener
    - Listens to OSPF-TE to acquire intra-domain topology
    - Builds an abstracted view of internal domain topology
  - Inter-domain routing / topology exchange
    - Based on OIF E-NNI implementation agreement

On-demand Secure Circuits and Advance Reservation System (OSCARS)

- OSCARS (IDC)
  - Web service layer
  - InterDomain messaging
  - AAA
  - Book-ahead scheduling of circuits
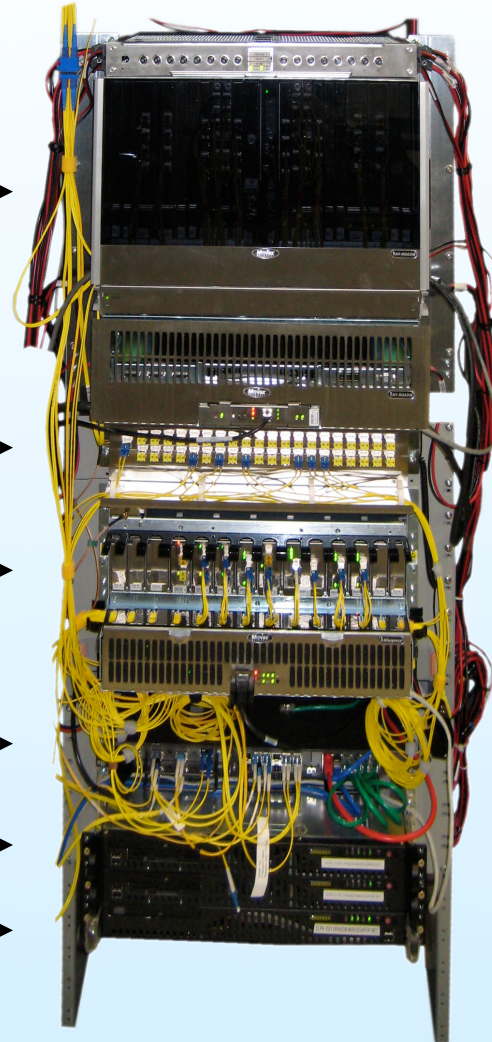- Version 0.3.1 of DCNSS released April, 2008
  - https://wiki.internet2.edu/confluence/display/DCNSS

Inter-domain Provisioning Example
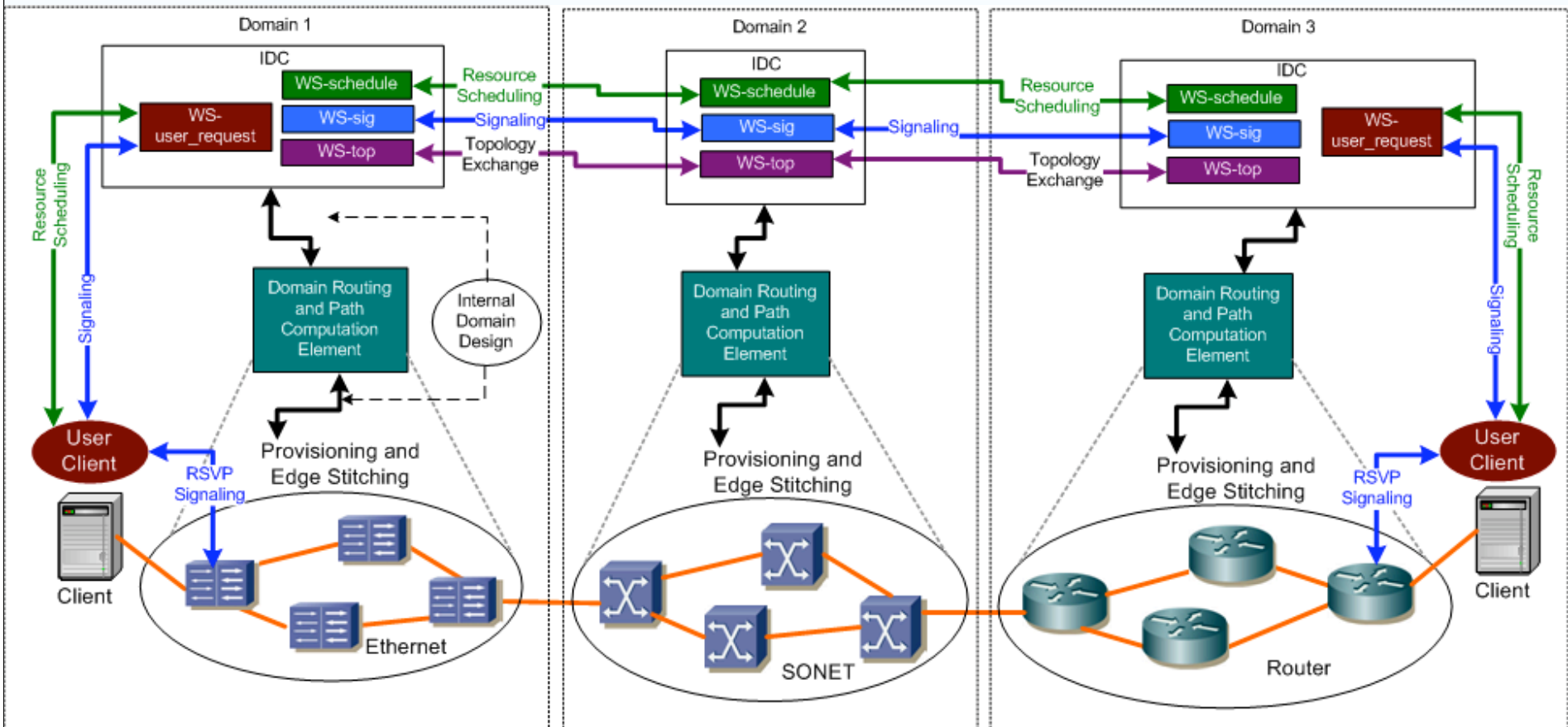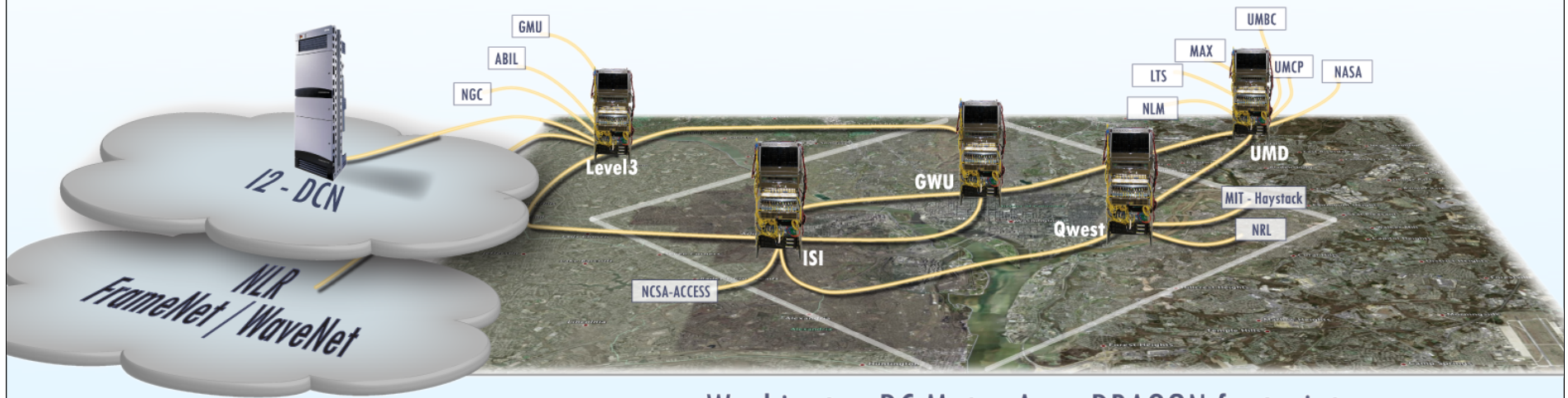
Typical DRAGON core node

Adva Optical Multi-degree ROADM ⟶

Adva Optical 40 λ mux/demux ⟶

Adva Optical RayExpressII OADM ⟶

Raptor ER-1010 Ethernet switch ⟶

Virtual Label Switching Router (VLSR) ⟶

Perf PCs, virtualization nodes, etc. ⟶

DRAGON deployment in DC Metro Area

MAX — Mid-Atlantic Crossroads

Washington DC Metro Area DRAGON footprint

- Over 150 miles of dark fiber
- 5 multi-degree ROADMs (four 4-degree, one 3-degree)
- 12 OADMs (up to 40 channels, some transponders are tunable)
- 10 Ethernet switches (10GigE, GigE)
- Lambdas and Ethernet VLANs provisioned exclusively using GMPLS
- Interconnects to national backbones and many regional campuses
- Control PCs, performance and virtualization nodes, compute clusters

Circuit Provisioning Demonstration

- Two example of circuit provisioning across the DRAGON testbed
  - (1) using web-based user interface
  - (2) using Java client API

- Demonstration illustrates:
  - enforcement of bandwidth policy on sub-rate circuits
  - slicing of network resources using Ethernet VLANs and bandwidth policing
  - interoperability with Ethernet switches from 4 vendors:
    » Cisco Catalyst 6509
    » Raptor ER-1010
    » Force10 EtherScale E600
    » Dell PowerConnect 6024F