Major Networking Research Themes, US Testbeds, and the GENI Initiative

Joe Mambretti, Director, (j-mambretti@northwestern.edu)
International Center for Advanced Internet Research (www.icair.org)
Director, Metropolitan Research and Education Network (www.mren.org)
Partner, StarLight/STAR TAP, PI-OMNINet (www.icair.org/omninet)

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Tokyo, Japan

May 31, 2007

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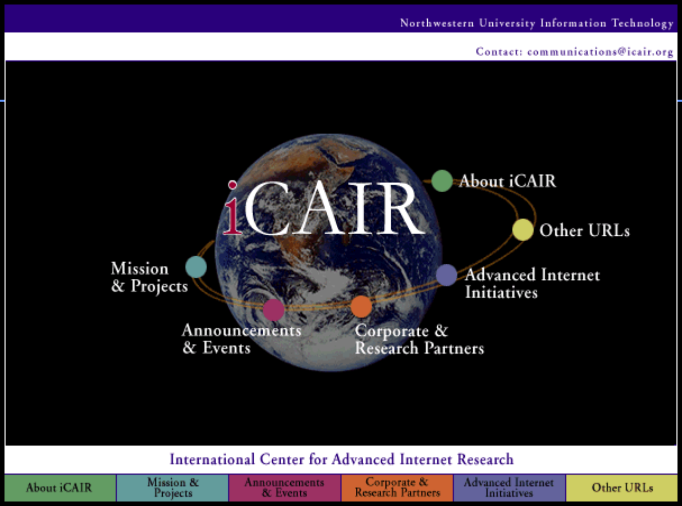
Introduction to iCAIR:



Accelerating Leading Edge Innovation and Enhanced Global Communications through Advanced Internet Technologies, in Partnership with the Global Community

- **Creation and Early Implementation of Advanced Networking Technologies - The Next Generation Internet All Optical Networks, Terascale Networks**
- **Advanced Applications, Middleware, Large-Scale Infrastructure, NG Optical Networks and Testbeds, Public Policy Studies and Forums Related to NG Networks**
- **Three Major Areas of Activity: a) Basic Research b) Design and Implementation of Prototypes c) Operations of Specialized Communication Facilities (e.g., StarLight)**

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Advanced Communications Research Topics

- Many Current Topics Could Be Considered "Grand Challenges" In Communications
- Scaling the Internet from 1 Billion (Current) to 3 Billion (Future)
- Improving the Current Internet (Removing Limitations, Adding Capabilities)
- Migrating Services from Layer 3 Only to Multi-Layer Services, Including L2.5, L2, L1, e.g., Lightpaths
- Creating a New Architecture
- Migrating Architecture from "Network Centric" Models to "Facilities Centric" Models
- The New Architecture Is Not a "Network" Design But Instead is A Highly Distributed Facility That Can Change Instantaneously – Ultimately In Picosecs
  - Discoverable Resources
  - Programmable
  - Reconfigurable
  - Segmented
  - Deterministic
  - Etc

Motivation for New Communications Architecture

- Traditional Networking Architecture and Technology Are Oriented to Supporting A Relatively Few Communications Modalities e.g., Voice, Video, Common Data, for a Very Long Time (Many Years...).
- Traditional Networking Infrastructure Is Too Rigid Too Accommodate Change Quickly
- Current Infrastructure Cannot Meet Many Emerging Requirements for 21st Century Services
- A Fundamentally New Architecture is Required
- A New Architecture Will Replace The Traditional Network With a New Communication Services Foundation – a Highly Distributed Facility That Can Support Multiple Networks With Different Characteristics Each Supporting Multiple Highly Differentiated Services

Related To Macro Trends in IT Architecture

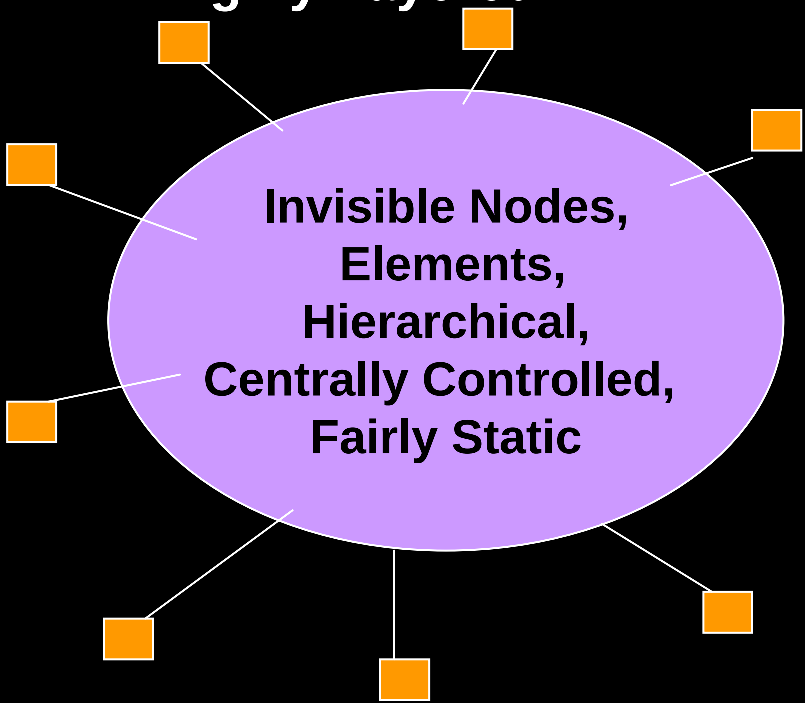
- Services Oriented Architecture (SOA)
- Services As Platform
- Web 2.0
- BPEL Processes (Service Creation, Integration)
- Highly Distributed Systems
- Enabling Customization At Distributed System Edge
- Discovery, Configuration, and Integration of Advertised Services, Middleware, and Other Resources, Including Core Resources
- Network 2.0 => Communications Infrastructure 2.0

Next Generation Communications

- A Key Resource = “Intelligent” Processes
  - Next Generation Distributed Facilities Will Support Multiple, Simultaneous Differentiated Data Streams That Can Be
    - Individually addressed as separate traffic flows
    - Individually characterized (deterministic)
    - Dynamically recharacterized
    - Scaled to include many large volume streams without negative consequences to other traffic
    - Optimized to enable significantly more use of bandwidth capacity than is possible with traditional methods
    - Characterized to support extremely low latency and minimal delay
    - Provided with enhanced security

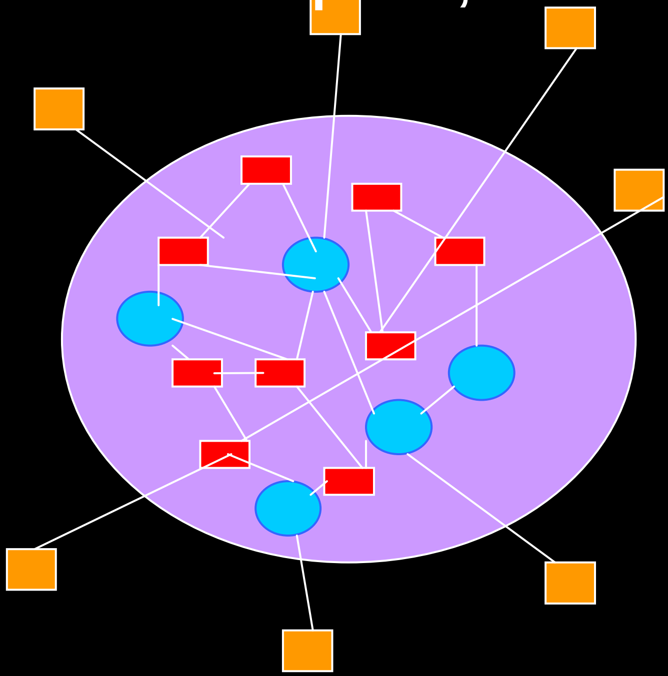
Paradigm Shift – Large Scale Distributed Facility vs Separate Component Resources – Communication Services View

Traditional Communication Services:
Invisible, Static Resources, Centralized Management, Highly Layered



Limited Services, Functionality, Flexibility

Distributed Resources, Dynamic Services,
Visible & Accessible Resources, Integrated As Required, Non-Layered



Unlimited Services, Functionality, Flexibility

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A Next Generation Architecture: *Distributed Facility* Enabling Many Types Network/Services

Environment: VO

Environment: Real Org1

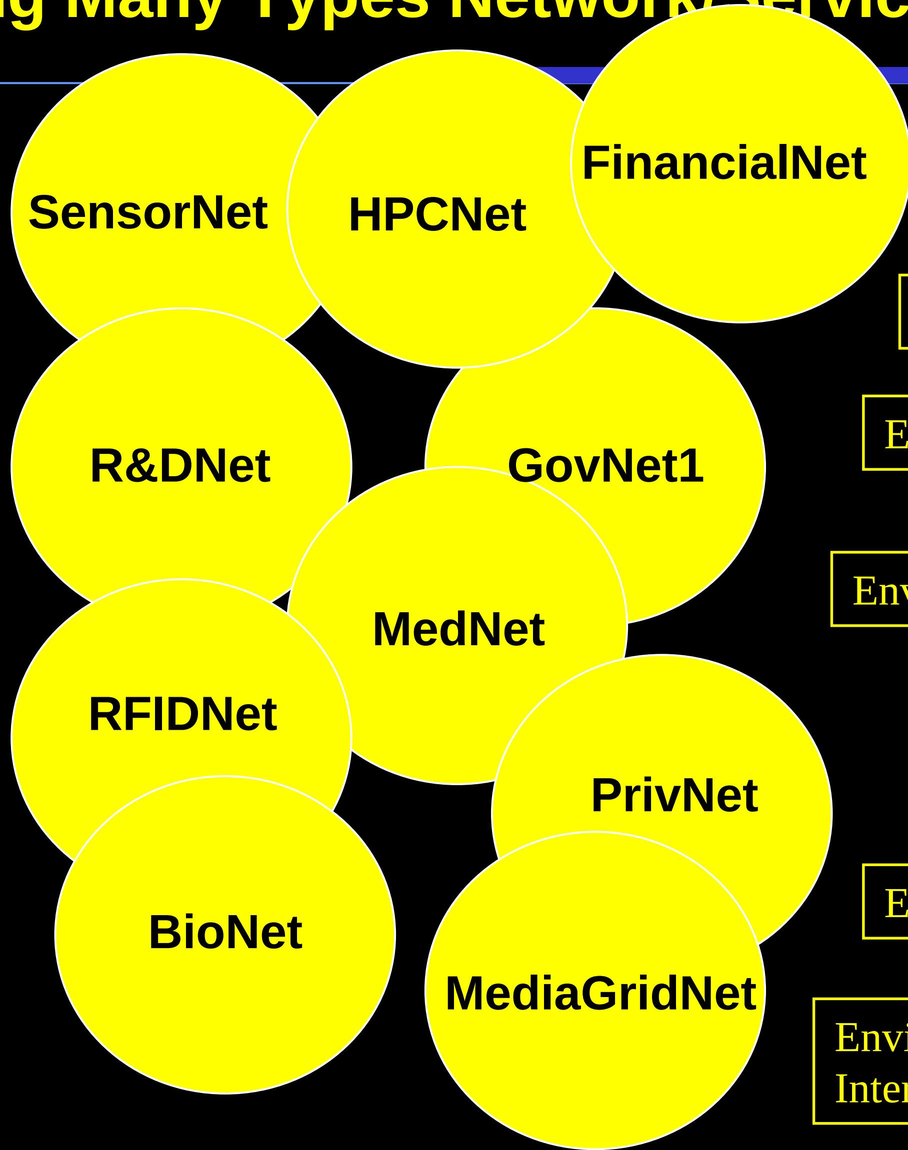
Environment: Intelligent Power Grid Control

Environment: RFIDNet

Environment: Bio Org

Environment: Large Scale System Control

Environment: Global App



Environment: Sensors

Environment: Real Org

Environment: Real Org2

Environment: Gov Agency

Environment: Control Plane

Environment: Lab

Environment: International Gaming Fabric

Environment: Financial Org

HP Communication Challenges and Opportunities
Part 1: Challenges

- HP Communication Challenges
  - Currently, High Performance Service Requirements Do Not Integrate Well With Existing Architecture and Technology
  - A New Architectural Design Is Required - Based on Existing and Emerging Primitives/ Components, Including:
    - New Control and Management Planes
    - Enhanced Dynamic Provisioning
    - Paths and Edge Points Addressing
    - State Information Services
    - Performance Assurance and Monitoring
    - Optimizing Finite Network Resources
    - New Services, e.g., L1/L2 “Multicast”

HP Communications Challenges and Opportunities Part 2: Opportunities

- **HP Communications Opportunities**
  - New Architectural Design - Based on Existing and Emerging Primitives/Components With Additional Considerations
  - Today Prototypes Can Be Created
    - No Compromising Requirements To Conform to the Restrictions of Traditional Infrastructure
    - Utilizing Existing, Emerging, and New Technologies and Techniques
    - Many Existing and Emerging Primitives/Components Can Be Integrated Into Powerful Capabilities Today To Design and Implement Specialized Networks
    - Many Traditional Barriers To Designing and Implementing This Type of New Service Can Be Addressed Including Issues Related to:
      - Existing Services
      - Existing Infrastructure
      - Economics

Many Building Blocks Exist Today

- Dynamic L2 and L1 (Lightpath) Allocation and Adjustment
- Advertisement of Persistent and Dynamic Large Scale L1/L2 Resources, Discovered (via Discovery Mechanisms), Provisioned, Configured Reconfigured In Real time, In Response To Changing Requirements
- Edge Device Addressing, Path Addressing
- “MAC DNS”
- “L1 (Optical) DNS”
- Integration of WAN and LAN Paths
- Application APIs for Path Control
- Policy Based Access Mechanisms
- L1 New Control Plans (eg, GMPLS Based)
- L2 Multicast of Large Scale Streams – eg, By Parameters Established Through Device Control Systems
- L2 Techniques for Network Segmentation

Key Standards Organization Activities

- **IEEE Developing Hierarchical Architecture**
  - Ethernet Architecture = Current Lack of Hierarchy
  - Network Partitioning (802.1q, vLAN tagging)
  - Multiple Spanning Trees (802.1s)
  - Segmentation (802.1ad, “Provider Bridges”)
  - Enables Subnets To be Characterized Differently Than Core
- **IETF – Architecture for Closer Integration With Ethernet**
  - GMPLS As Uniform Control Plane
  - Generalized UNI for Subnets (GMPLS UNI)
  - Link State Routing In Control Plane
  - TTL Capability to Data Plane
  - Pseudo – Wire Capabilities
  - Major Implications for Recovery/Restoration
- **ITU**
  - ITU-T SG Generic VPN Architecture (Y.1311)
  - Service Requirements (Y.1312)
  - L1 VPN Architecture (Y.1313)

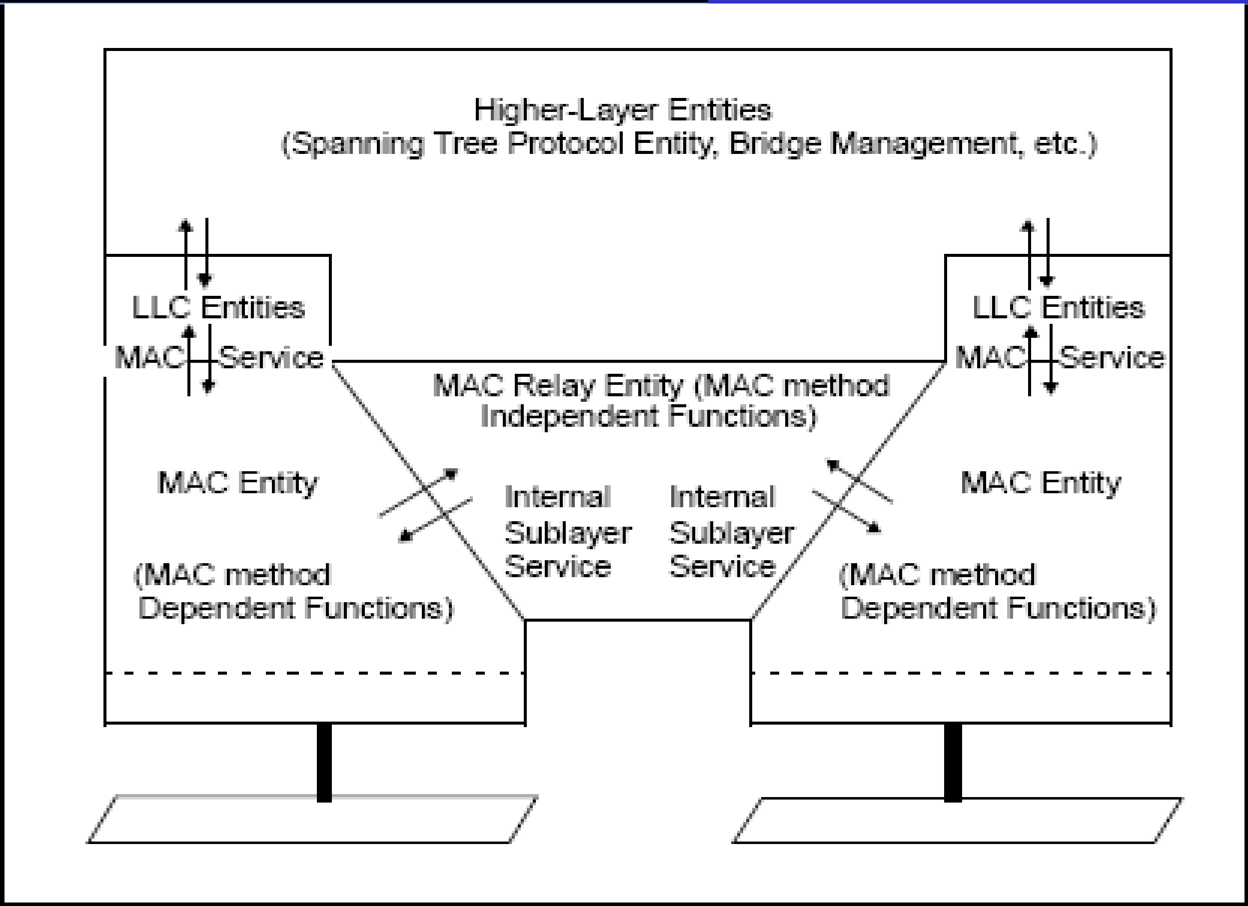
IEEE L2 Scaling Enhancements

- IEEE Developing Hierarchical Architecture for Ethernet
- This Architecture Enables Differentiations in Segments (Including Subnets) To Allow Characterization Separate From Core and Enhanced Virtualization
- Key IEEE Standards Include:
  - Network Partitioning (802.1q, vLAN tagging)
  - Multiple Spanning Trees (802.1s)
  - Segmentation (802.1ad, "Provider Bridges")
  - MAC-in-MAC (802.1ah "Provider Bridges")
  - MAC Bridges (802.1d)
- MEF Ethernet NNI (ITU G.8021/Y.1341)
- New Capabilities Include Direct Ethernet ⇔ Optical Transport Integration – As Well As Integration With External Signaling and Control

MAC Bridges

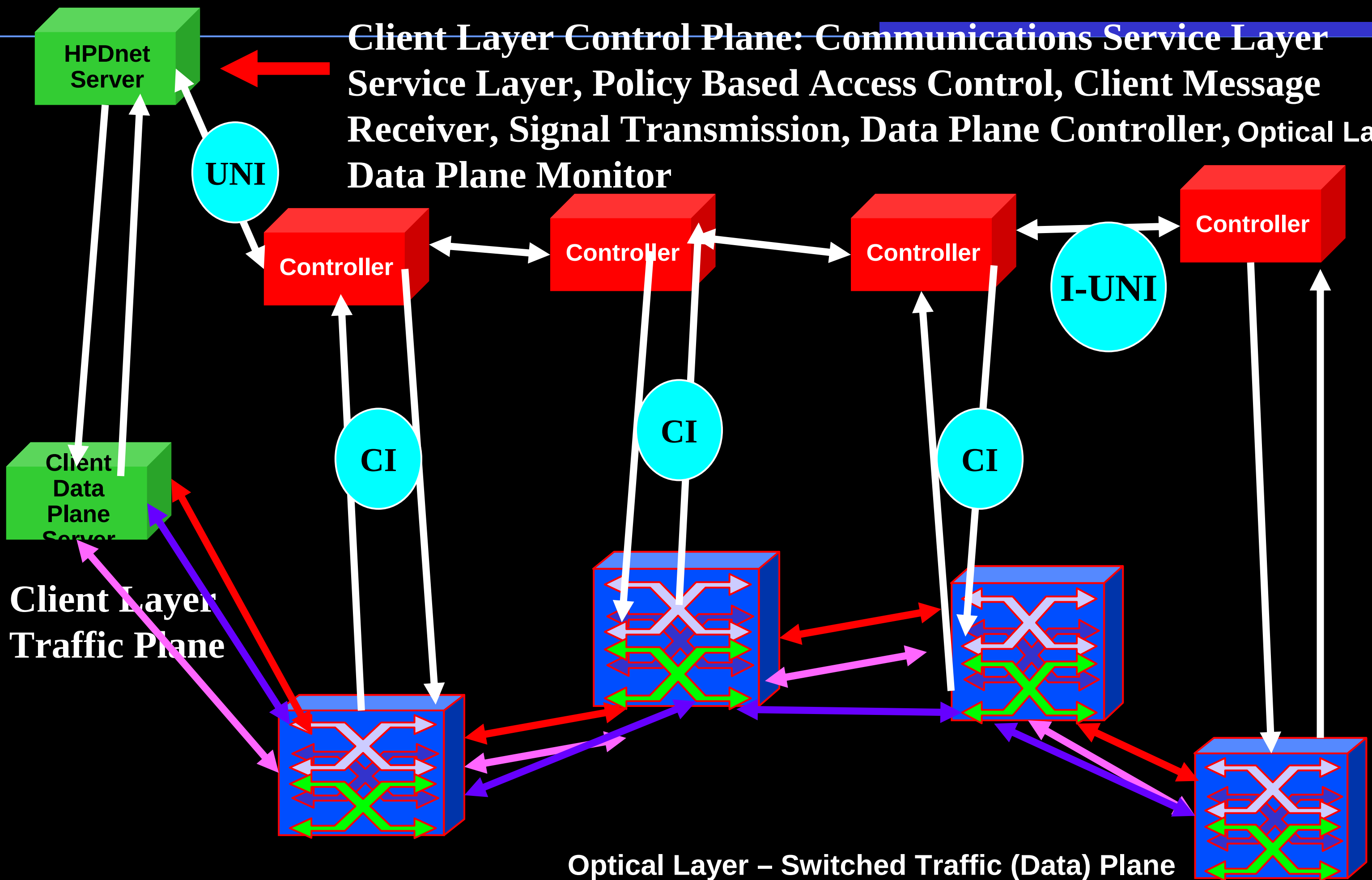
- MAC Bridges
  - Provide Enhanced Virtualization
  - Enable Interconnected Edges Points To Appear As If They Are on the Same LAN
  - Operate Below MAC Service Boundary
  - Are Transparent To Protocols Operating Above the MSB
  - Allow for:
    - Interconnections of Multiple Edge Devices at Multiple Sites
    - Scalability With Regard to Number of Devices
    - Partitioning
    - Policy Based Access Control (Security)
    - Redundancy
    - Etc.

Ref: IEEE 802.1d, p. 32



PBs Enable SubFabrics Under Standard Protocols and Management Plane

New Optical Control Planes



Client Layer Control Plane: Communications Service Layer Service Layer, Policy Based Access Control, Client Message Receiver, Signal Transmission, Data Plane Controller, Optical Layer Control Plane Data Plane Monitor

Optical Layer – Switched Traffic (Data) Plane Multiiservice: Unicast, BiDirectional, Multicast, Burst Switching

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*** Also Control Signaling, et al**

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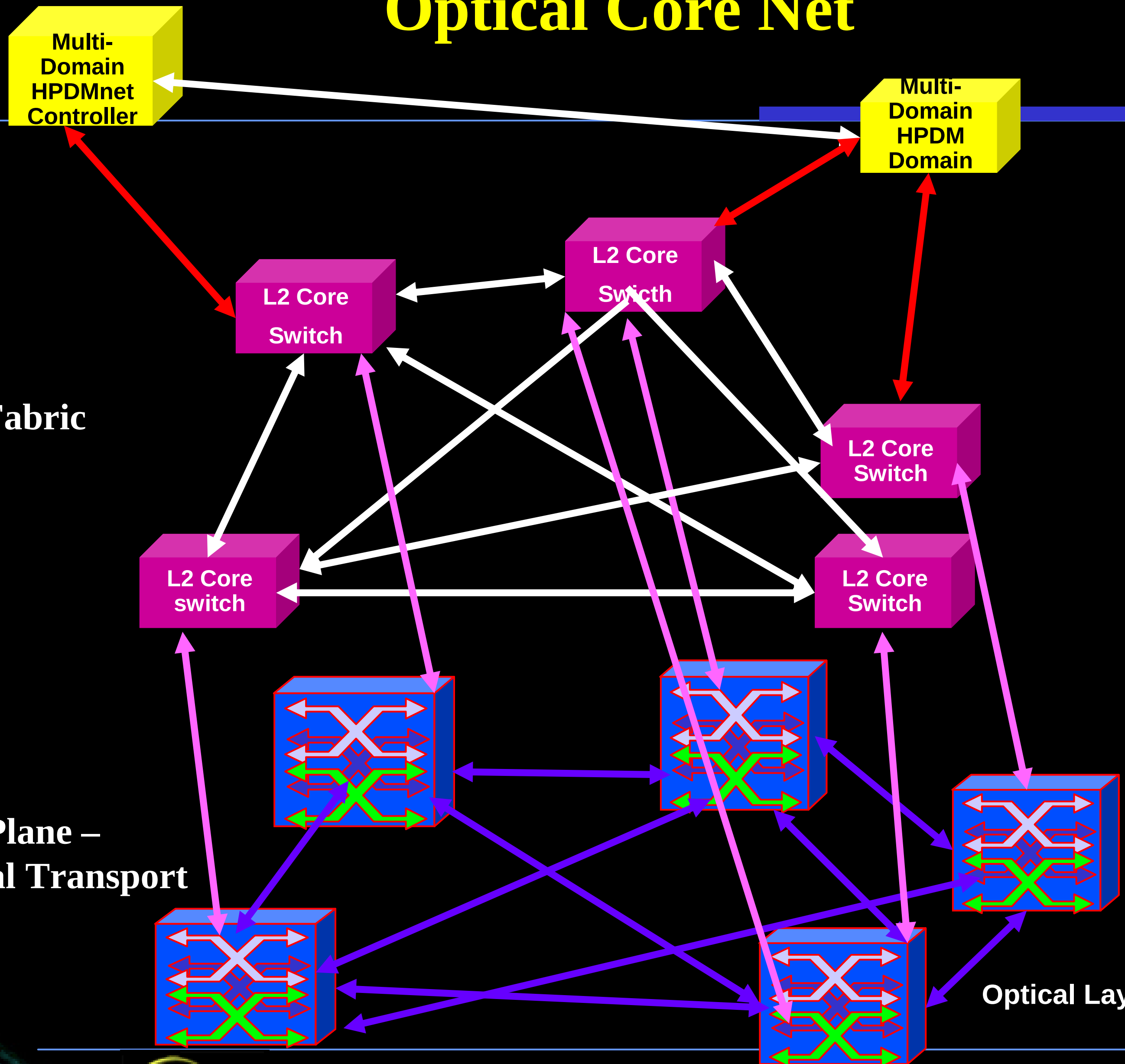
Optical Core Net

L2 Fabric

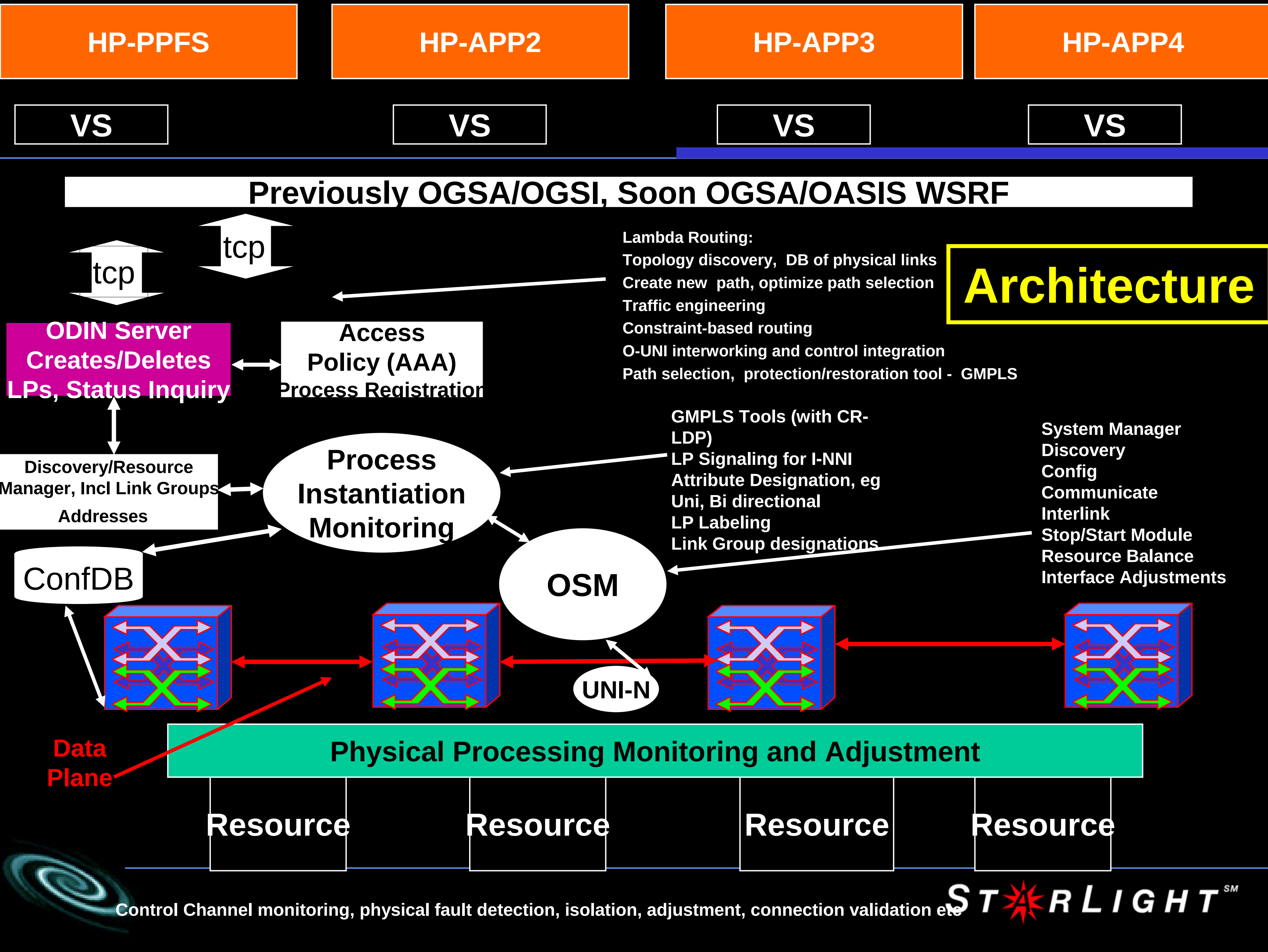


Data Plane –
Optical Transport

Optical Layer – Switched Lightpaths

Management Plane:
Access
Engineering
Restoration
Performance
Resource Use
Audits

Control Plane
Provisioning
L1/L2 Path Assignments
Stream
“Routing”


HP-PPFS
HP-APP2
HP-APP3
HP-APP4
VS
VS
VS
VS
Previously OGSA/OGSI, Soon OGSA/OASIS WSRF
tcp
tcp
Lambda Routing:
Topology discovery, DB of physical links
Create new path, optimize path selection
Traffic engineering
Constraint-based routing
O-UNI interworking and control integration
Path selection, protection/restoration tool - GMPLS
Architecture
ODIN Server Creates/Deletes LPs, Status Inquiry
Access Policy (AAA) Process Registration
GMPLS Tools (with CR-LDP)
LP Signaling for I-NNI
Attribute Designation, eg
Uni, Bi directional
LP Labeling
Link Group designations
System Manager
Discovery
Config
Communicate
Interlink
Stop/Start Module
Resource Balance
Interface Adjustments
Discovery/Resource Manager, Incl Link Groups Addresses
Process Instantiation Monitoring
ConfDB
OSM
UNI-N
Data Plane
Physical Processing Monitoring and Adjustment
Resource
Resource
Resource
Resource
Control Channel monitoring, physical fault detection, isolation, adjustment, connection validation etc
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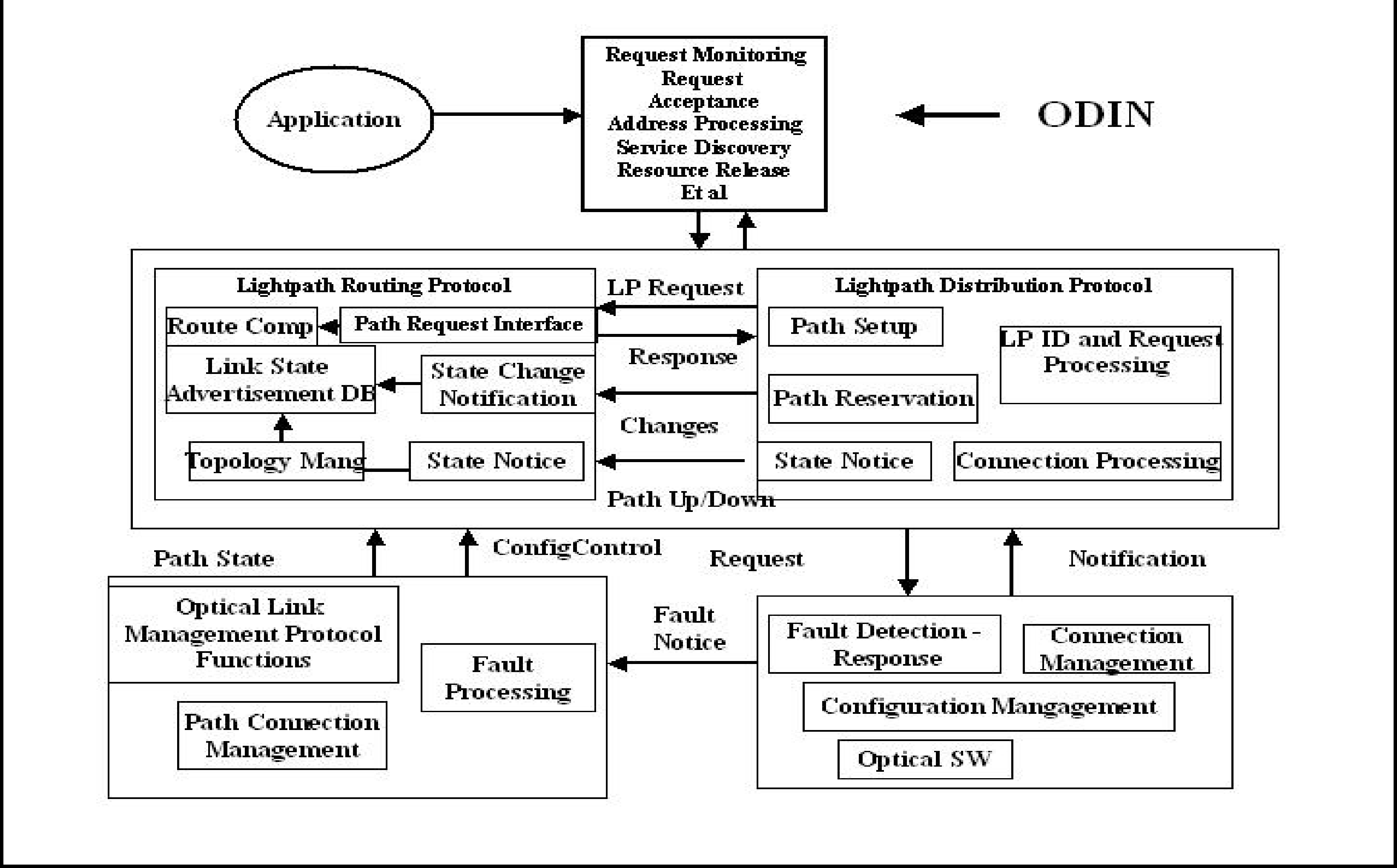
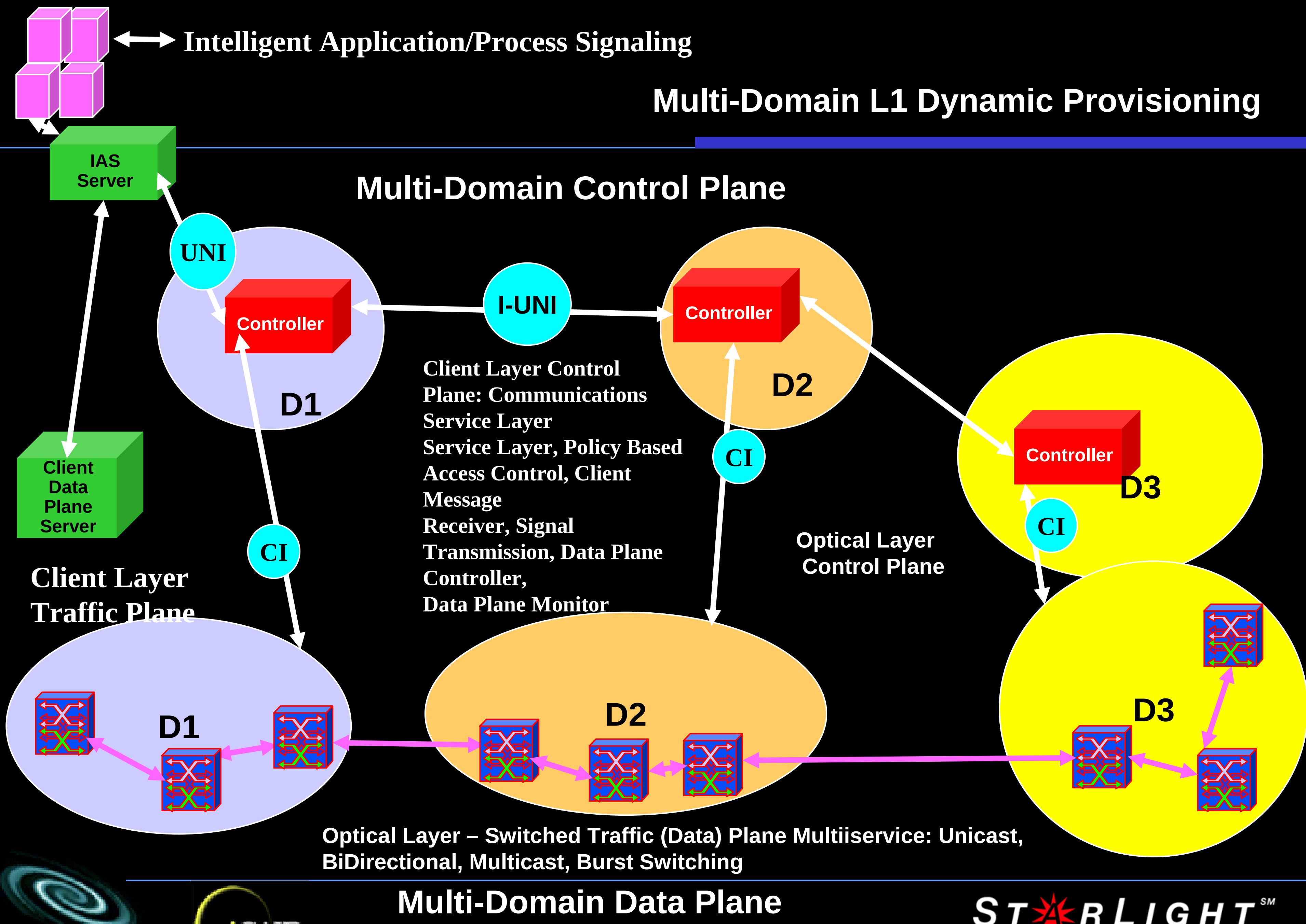
Optical Dynamic Intelligent Network (ODIN)




Intelligent Application/Process Signaling
Multi-Domain L1 Dynamic Provisioning
IAS Server
Multi-Domain Control Plane
UNI
Controller
I-UNI
Controller
D1
D2
Client Layer Control Plane: Communications Service Layer
Service Layer, Policy Based Access Control, Client Message
Receiver, Signal Transmission, Data Plane Controller,
Data Plane Monitor
Client Data Plane Server
CI
CI
Controller
D3
CI
Optical Layer Control Plane
Client Layer Traffic Plane
D1
D2
D3
Optical Layer – Switched Traffic (Data) Plane Multiiservice: Unicast, BiDirectional, Multicast, Burst Switching
Multi-Domain Data Plane

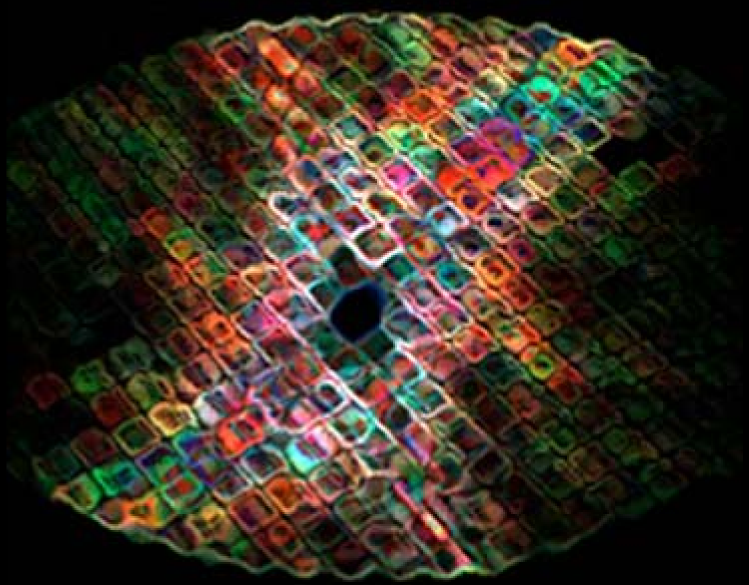
One Example Consequence of New Model

- New Architecture and Related Technology Will Provide for New Services and Capabilities That Are Not Possible Today
- One Example is Next Generation Ubiquitous Digital Media and High Performance Digital Media
- Services Will Include Services for Media Objects That Do Not Exist Today, e.g.,
  - "Digital Media Mail,"
  - Virtual Instruments Integrated with Media Services
  - Extremely High Performance Digital Media
  - 4k Digital Media
  - "8k" Digital Media

Digital Media 2000 – L3 Based IETF DiffServ QoS (iGrid 2000
USA, Canada, Japan, Singapore, Netherlands, Sweden, CERN, Spain, Mexico, Korea) iGRID 2000 Yokohama

GiDVN: Global Internet Digital Video Network

- Digital Video Working Group, Coordinating Committee for International Research Networks
- CERN, Switzerland
- APAN, Japan; KDD, Japan
- APAN-KR, Korea; Seoul National University, Korea
- SURFnet, The Netherlands
- DFSCA-UNAM, Mexico
- SingAREN, Singapore
- Universitat Politecnica de Catalunya, Spain
- Royal Institute of Technology, Sweden
- Int’l Center for Advanced Internet Research (iCAIR), Northwestern, USA



GiDVN projects have been enhancing media capabilities for the next-generation Internet, enabling new applications to interoperate throughout the world.

www.icair.org/inet2000

High Performance Digital Media

- Today Digital Media Is Special, Uncommon
- In the Future, It Will Be Ubiquitous
- 3D, Full Color Interactive Digital Media Objects, Not Simply Embedded in Apps, But Comprising App Objects, e.g., Media Wikis, Personal Digital Media Communications
- Implication => Network As Digital Media Platform
- Multiple Sites World-Wide Streaming Large Scale HD Media
- Various Scenarios (One to Many, Many to One, Many to Many - Simultaneously Among All Locations, etc.)

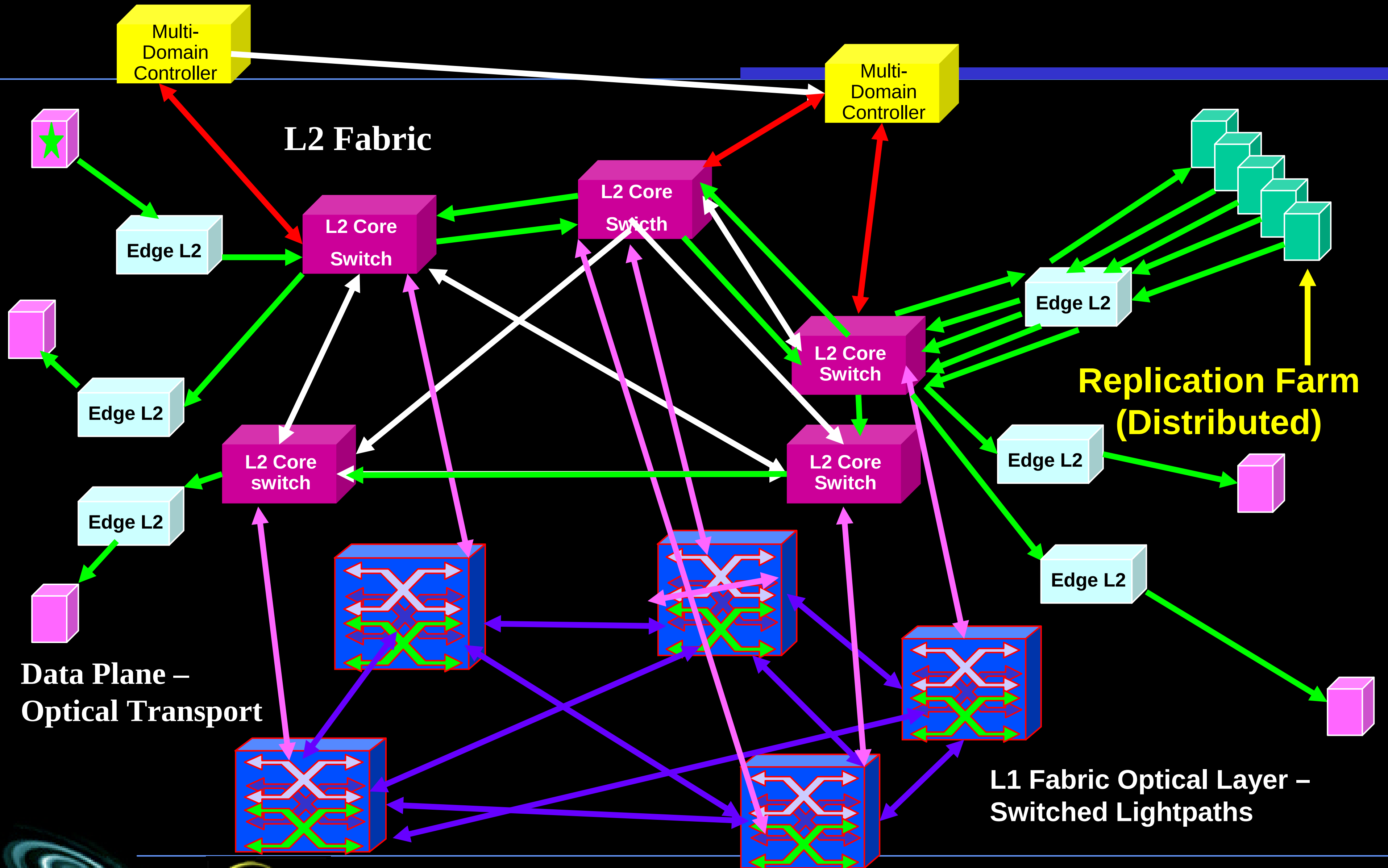
High Performance Digital Media

- **For Many Classes of Media Streams, Common L3 Techniques Are Not Sufficient**
- **L1/L2 Techniques Have Been Shown to Be Key Enablers for Such Media Streams**
- **L1/L2 Capabilities Can Be Used As Primitives to Design Infrastructure that Will Support HPDM Services**
- **Emerging Potentials Also for New L3 Techniques**
- **Requirements: Architecture, Technology, Integrated Service Model**

L1/L2 Multicast

- L2 Frame Duplication in Software
- Optical Multicast
- L1 Unidirectional Capability for Obtaining a 1 Gigabit Ethernet Stream and Duplicating It To Several (1:N)
- Technique Can Be Used With SONET/SDH Contiguous or Virtual concatenation
  - At a Single Node
  - Using a Continuing Series of Nodes
  - Nodes Can be Remote, Local, or Local and Remote
- Techniques Can Be Extended Through Processes Using MAC Addressing

HPDMnet With L2 Multicast (Simple Case, One to Many)



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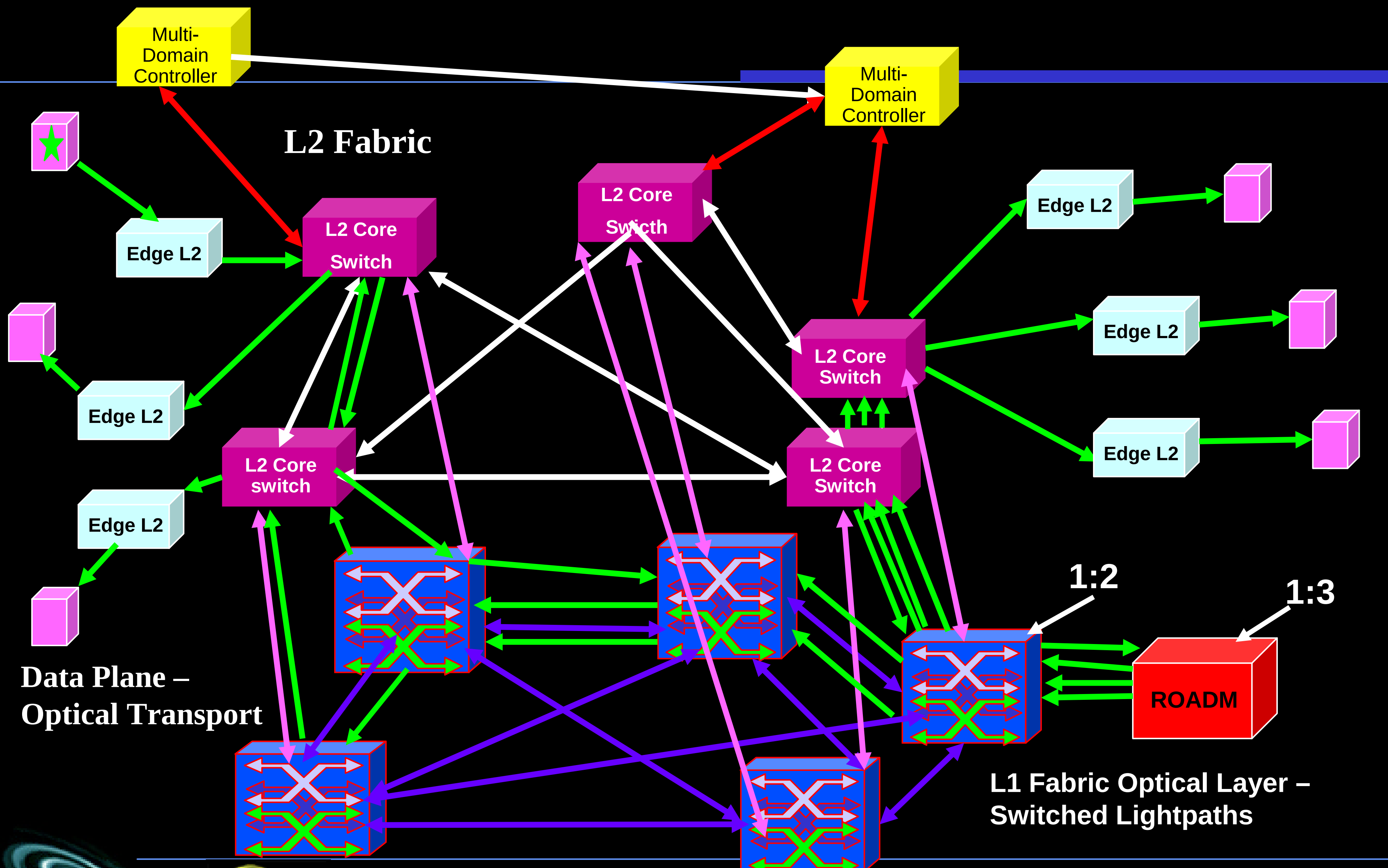
HPDMnet With L1 Multicast (Simple Case, One to Many)



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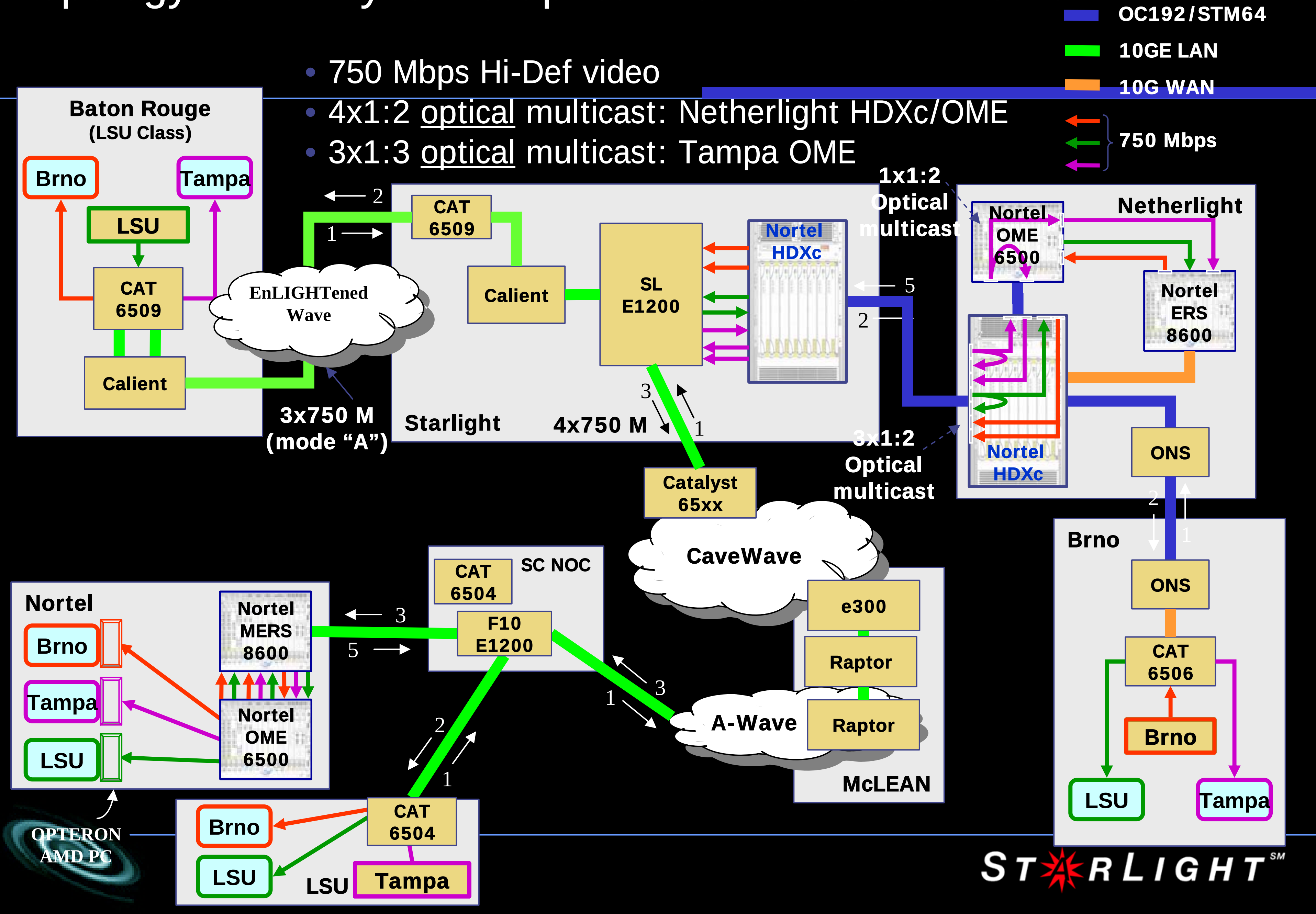
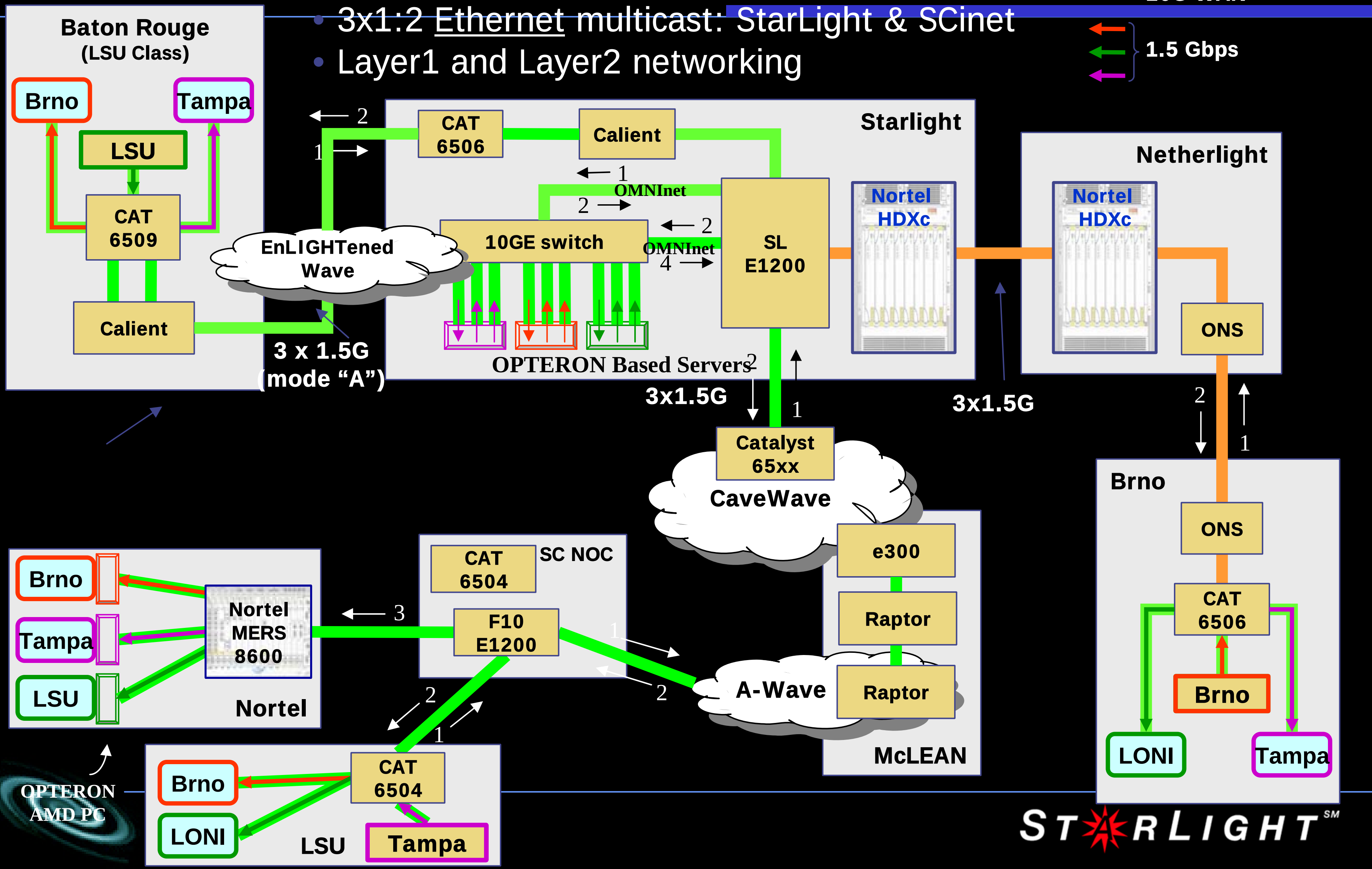
Topology for L1 Dynamic Optical Multicast SC06 Demo

- 750 Mbps Hi-Def video
- 4x1:2 optical multicast: Netherlight HDXc/OME
- 3x1:3 optical multicast: Tampa OME



Topology for L2 Multicast SC06 Demo (L2 Stream Duplication)

- 1.5 Gbps Hi-Def video
- 3x1:2 Ethernet multicast: StarLight & SCinet
- Layer1 and Layer2 networking



HPDM Demos at SC06

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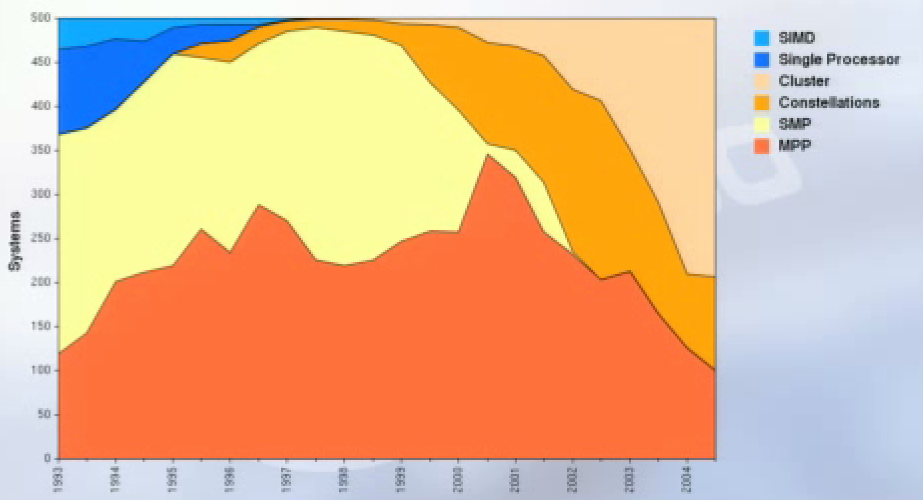
Edit View Favorites Tools Help

Back Search Favorites

https://www.cct.lsu.edu/csc7600/media/ncast/20070116-163021-001.mp4 Go Links Google Settings

TOP500

Architectures / Systems

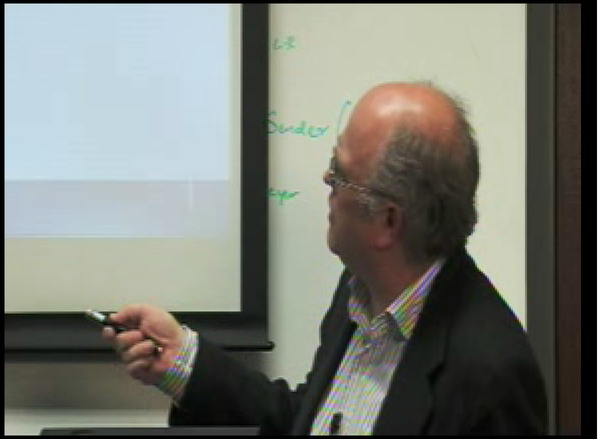


24th List / November 2004 http://www.top500.org/

Introduction to
High Performance
Computing

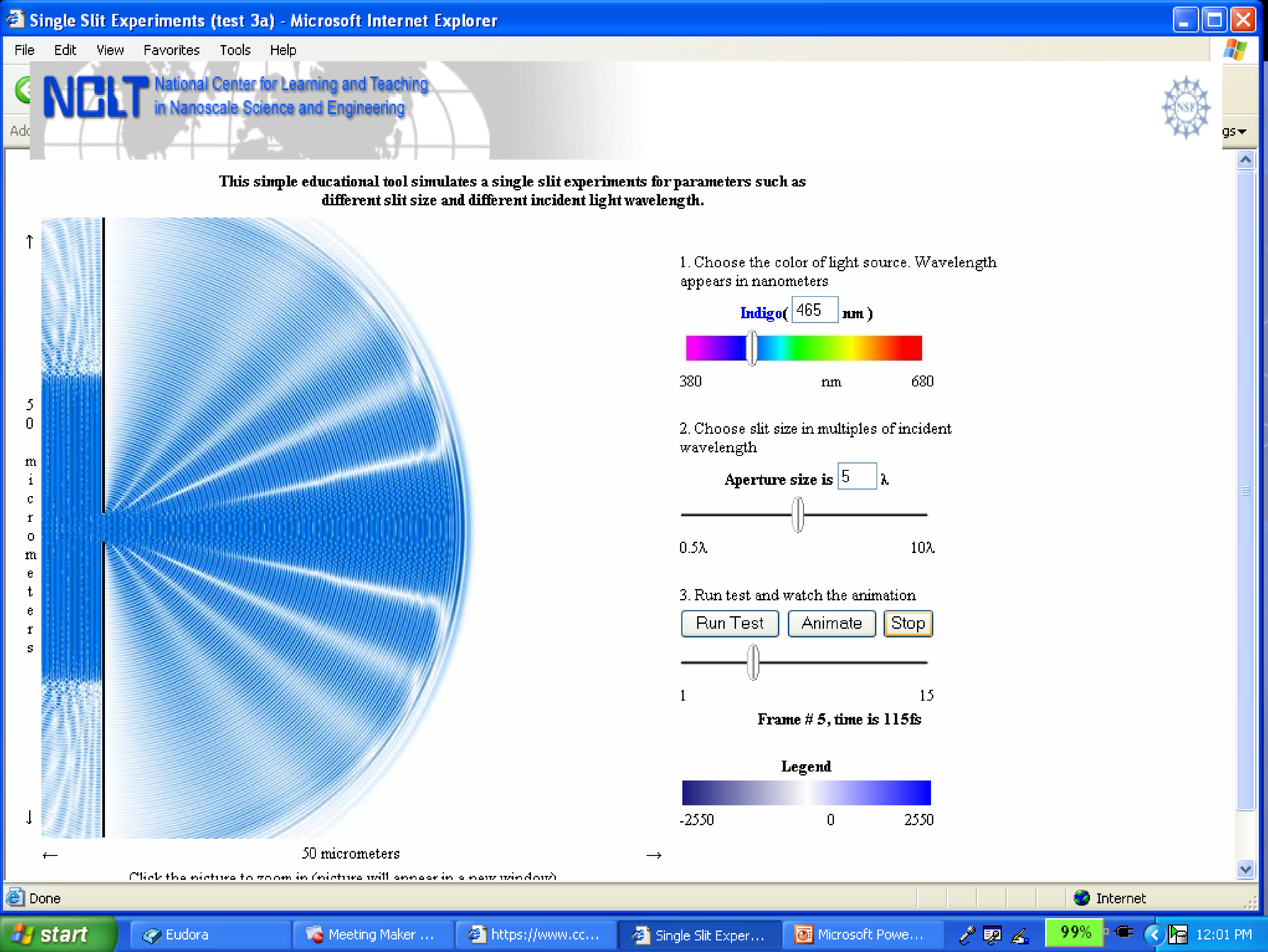
Dr. Thomas Sterling
January 16, 2007

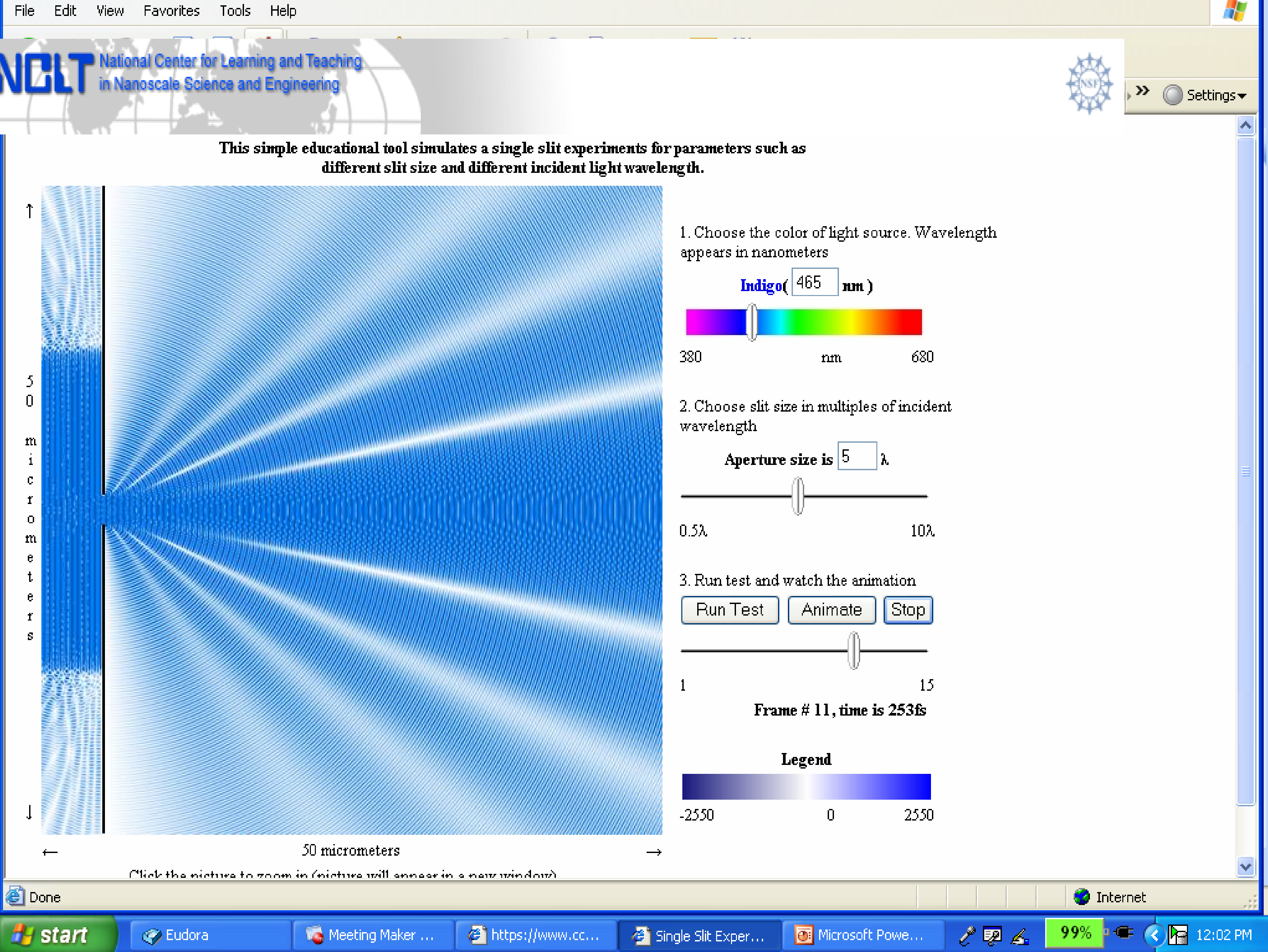
Week One: Class One
Introduction



LSU Center for Computation & Technology
http://www.cct.lsu.edu/

one Internet


Single Slit Experiments (test 3a) - Microsoft Internet Explorer
File Edit View Favorites Tools Help
NCLT National Center for Learning and Teaching in Nanoscale Science and Engineering
This simple educational tool simulates a single slit experiments for parameters such as different slit size and different incident light wavelength.
50 micrometers
50 micrometers
Click the picture to zoom in (picture will appear in a new window)
1. Choose the color of light source. Wavelength appears in nanometers
Indigo(465 nm)
380 nm 680
2. Choose slit size in multiples of incident wavelength
Aperture size is 5 λ
0.5λ 10λ
3. Run test and watch the animation
Run Test Animate Stop
1 15
Frame # 5, time is 115fs
Legend
-2550 0 2550
Done
Internet
start Eudora Meeting Maker ... https://www.cc... Single Slit Exper... Microsoft Powe...
99%
12:01 PM


File Edit View Favorites Tools Help
NCLT National Center for Learning and Teaching in Nanoscale Science and Engineering
Settings
This simple educational tool simulates a single slit experiments for parameters such as different slit size and different incident light wavelength.
50 micrometers
50 micrometers
1. Choose the color of light source. Wavelength appears in nanometers
Indigo(465 nm)
380 nm 680
2. Choose slit size in multiples of incident wavelength
Aperture size is 5 λ
0.5λ 10λ
3. Run test and watch the animation
Run Test Animate Stop
1 15
Frame # 11, time is 253fs
Legend
-2550 0 2550
Click the picture to zoom in (picture will appear in a new window)
Done
Internet
start Eudora Meeting Maker ... https://www.cc... Single Slit Exper... Microsoft Powe...
99%
12:02 PM

The Future Internet (NSF Perspective)

- Reliable
- Trustworthy
- Secure
- Capable of
  - Enabling New Services and Applications
  - Being Integrated with Pervasive Computing
  - Being Improved Dramatically
  - Providing Create New Opportunities for Social Improvements

"New Internet" Research Topics

- Theoretical Foundations
- New Basic Concepts for Architecture, Protocols Methods
- New Core Functionalities
- New Technology (Through Other NeTS Programs and ENG)
- Security
- Reliability
- Privacy
- Accountability
- Manageability
- Usability
- Net Economics

FIND Concepts

- NSF NeTS Program: Future INternet Design
- In 3 Years the Internet Will Be 40 Years Mature
- By All Major Measures, It Has Been an Outstanding Success
- Yet, There Are Problems, Related To
  - Flaws in Existing Architecture and Technology
  - Limitations
  - Deterioration of Basic Protocols
  - “Calcification”
  - Enhancing Existing Architecture and Technology
  - Migrating to New Services and Capabilities
  - Taking Advantage of New Innovation, e.g., Sensor Nets, Software Radios, Mobile Nets, Ad Noc Nets, Virtual Nets, Optical Net, Highly Secure Nets, Lightpath Switching, Optical Packet Switching, Photonics, etc.

FIND Challenge: Migrating The Internet Forward

- The Future Internet Here is Broadly Defined, Includes e-2-e, Highly Distributed Systems, Edge, Access, Core, etc.
- Must Incorporate Best of Existing Concepts Plus New Innovation
- The Inertia Caused By the Current Installed Base Presents a Major Problem for Innovation
- Question: How To Create a “New Internet,” When the Existing Internet Is a Barrier To Innovation
- A “Clean Slate” Approach Is Required – No Preconceptions
- New Paradigms, Architecture, Protocols, Technologies
- Migration of Highly Disruptive Technologies from Labs
- New Research Approach and Processes
  - Allowing Major Innovation, Not Only Incremental Improvement
  - Providing Major Large Scale Experimental Facilities (Ref: GENI)

FIND - New Process

- **Traditional = Not “Goal Oriented”**
- **FIND = “Goal Oriented” (i.e., Creating a Future Internet)**
- **Traditional Short Term**
- **FIND = Long Term**
- **Traditional One-Time Funding**
- **FIND = Sustained Funding**
- **Traditional = Single Phase**
- **FIND = Multiphase (Architecture Exploration, Convergence, Simulation, Emulation, Large Scale Experimentation, ref: GENI)**
- **Traditional = Competition, Best of Class**
- **FIND = “Competitive Cooperation” (Partnership to Create the Future Internet**
- **The FIND Program Requires an Experimental Instrument (GENI)**

GENI Concepts

- NSF GENI Program: Global Environment for Network Innovation
- "GENI Is An Open, Large Scale, Realistic Experimental Facility That Will Revolutionize Research in Global Communication Networks."
- "A Central Goal of GENI is To Change the Nature of Networked and Distributed Systems Design To Integrate Rigorous Theoretical Understanding with Compelling and Thorough Experimental Validation."
- GENI = An Experimental Instrument, Like a Synchrotron for High Energy Physics

Source: Guru Parulkar NSF

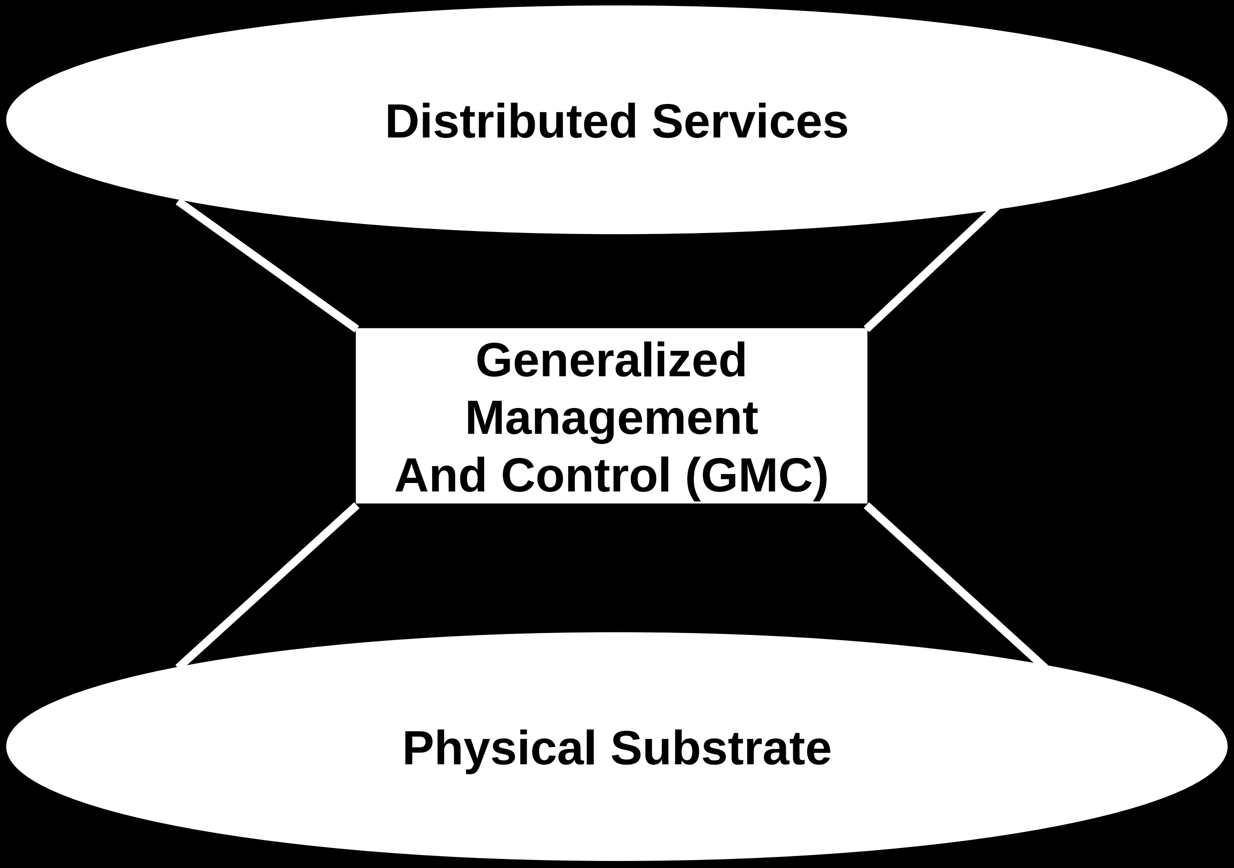
New GENI Processes

- Theoretical Conceptual Innovation
- Analysis =>
  - Simulation
  - Emulation
  - Analysis =>
- Large Scale Experimentation
- Analysis
- Migration to Internet at Large
- First Class Software Development Methods
  - Open, Well Designed Architecture
  - Open Protocols
  - Open Source

GENI Stages

- Science Plan
- Requirements Definition
- Facilities Design
- Facilities Implementation
- Facilities Operation
- Facilities Technology Refresh
- Very Much Like Other Large Scale Science Instruments, Telescopes, Synchrotrons, Supercomputers, etc.

GENI Facility



GMC = name space for users, slices, resources, interfaces, access channels etc

GENI Vocabulary

- Physical Substrate: Accessible Hardware Resources
- Slice: Virtualized or Partitioned Resources
- Embedding: Slices are Embedded in Substrate
- Building Blocks: Nodes, Links, Subnets
- Software Management Framework: Enables Embedding in Substrate
- Generality: Programmability
- Fidelity: Exposure of The Appropriate Level of Abstraction (e.g., via APIs)
- User Access: Ability To Use Real User Traffic as Part of Experimentation
- Controlled Isolation: Ability to Access Legacy Internet
- Diversity and Extensibility: Ability To Experiment With Many Technologies None Exclusive
- Wide Deployment: Hundreds of PoPs
- Observability: Substantially Instrumented
- Sustainability: Partnership Federations
- Backbone Facilities, VMs, Net Prog Processor, Blades, Programmable Routers, Reconfigurable Virtual and real circuits, Dynamic Lightpaths

Source: Guru Parulkar

StarLight – “By Researchers For Researchers”

StarLight is an experimental optical infrastructure and **proving ground for network services** optimized for high-performance applications

GE+2.5+10GE Exchange

Soon:

Multiple 10GEs Over Optics – World’s “Largest” 10GE Exchange

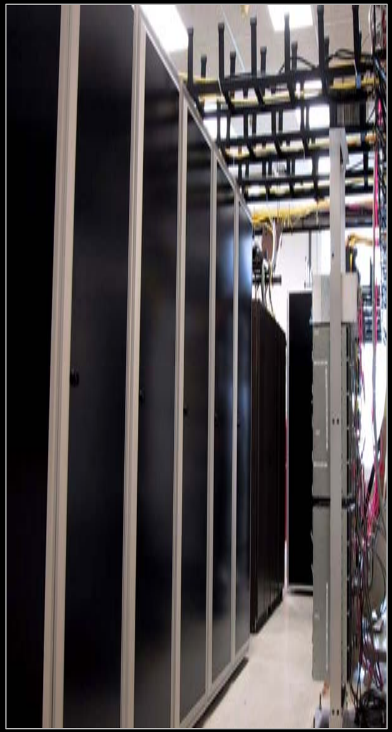
First of a Kind Enabling Interoperability At L1, L2, L3

View from StarLight

Abbott Hall, Northwestern University’s Chicago downtown campus

StarLight Infrastructure

StarLight is *a large research-friendly co-location facility* with space, power and fiber that is being made available to university and national/international network collaborators as a *point* of presence in Chicago



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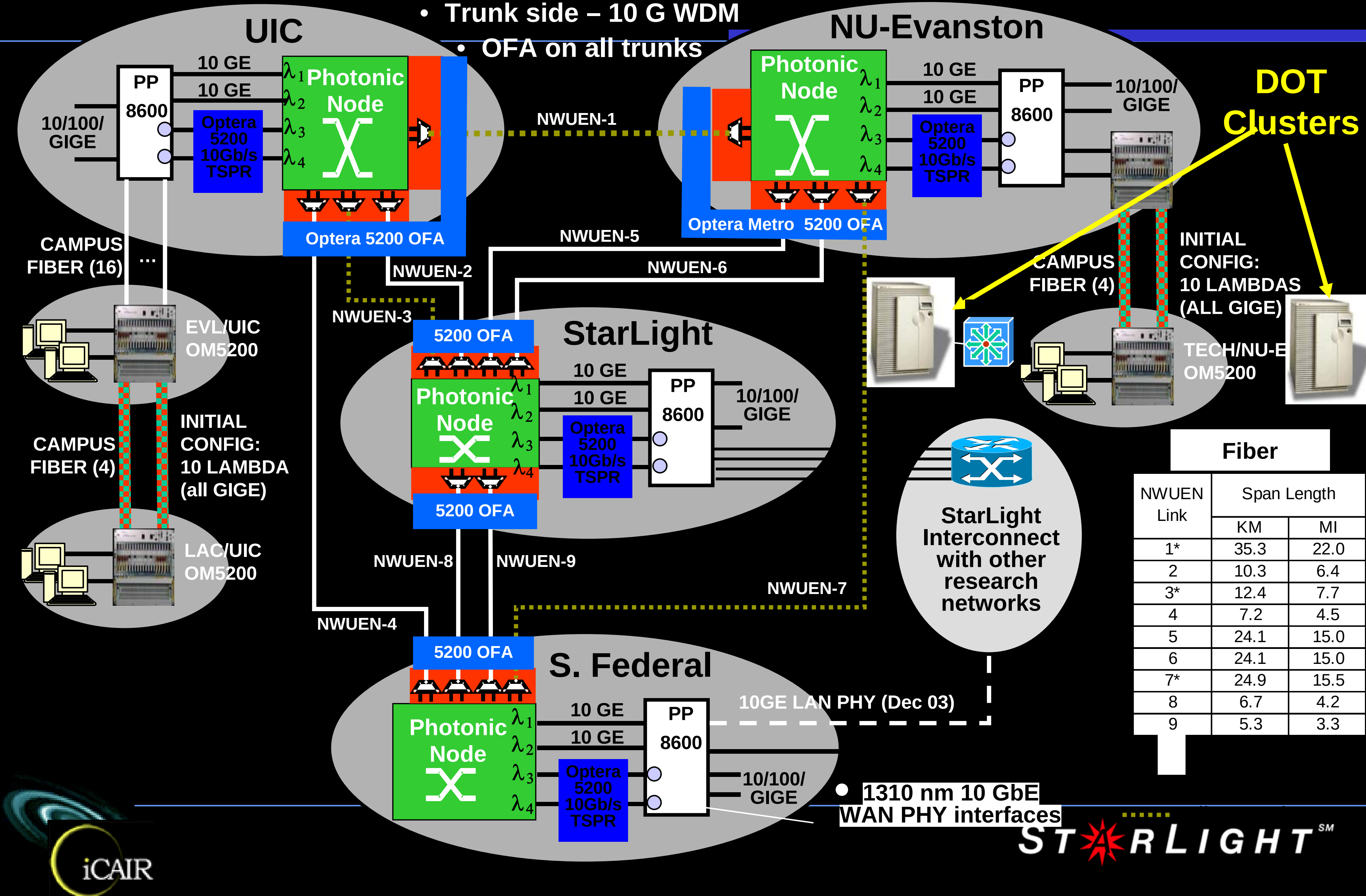
StarLight Supports All Major National and International Networking Testbeds

- StarLight Was Designed To Support Advanced Networking Communications Innovation
- StarLight Has Introduced Multiple Architecture, Services and Technology Innovations
- StarLight Supports 12 Major Local, National and International Experimental Communications Testbeds
- Several Additional Testbeds Will Be Announced Soon
  - Extensions to the TeraFlow Testbed
  - TeraFlow Network
  - Flow Stream Testbed
  - C(ON)2
  - HPDM Testbed

OMNInet Network Configuration Phase 2 (Extended Via Demonstrations Nationally and Internationally)

- 8x8x8λ Scalable photonic switch
  - Trunk side – 10 G WDM
    - OFA on all trunks



Fiber

NWUEN Link	Span Length KM	Span Length MI
1*	35.3	22.0
2	10.3	6.4
3*	12.4	7.7
4	7.2	4.5
5	24.1	15.0
6	24.1	15.0
7*	24.9	15.5
8	6.7	4.2
9	5.3	3.3

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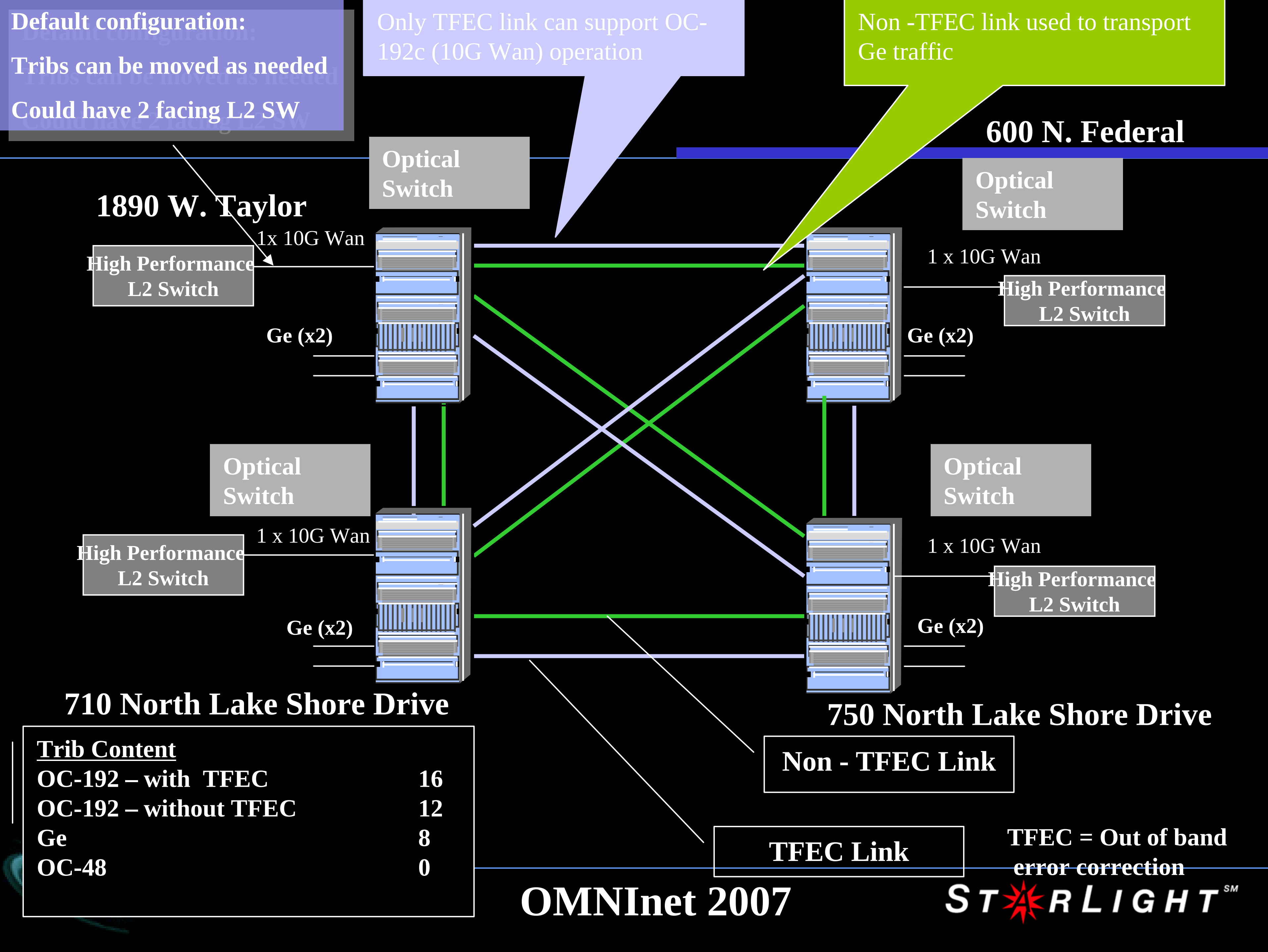
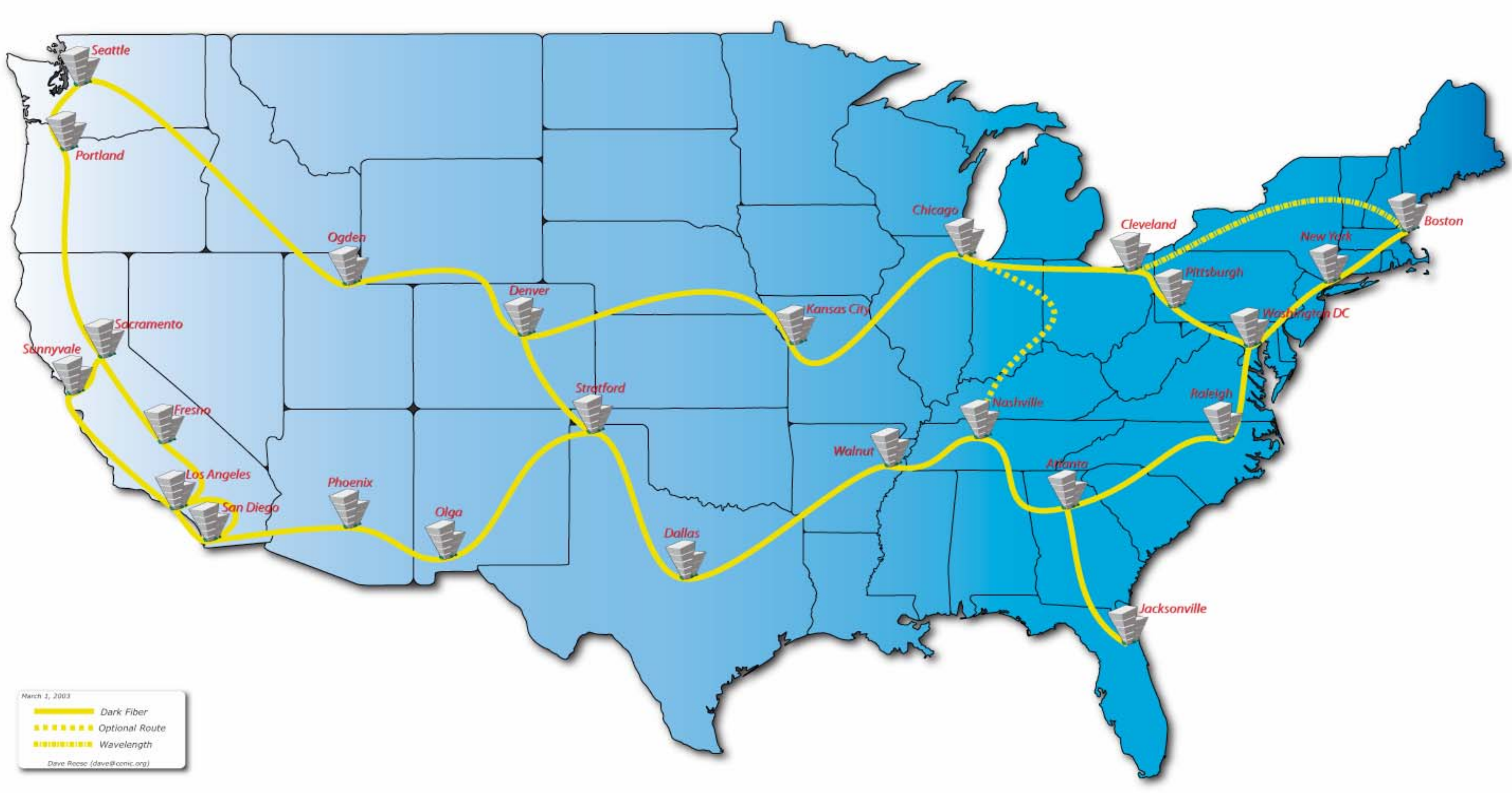


Default configuration:
Tribs can be moved as needed
Could have 2 facing L2 SW
Only TFEC link can support OC-192c (10G Wan) operation
Non -TFEC link used to transport Ge traffic
600 N. Federal
Optical Switch
1890 W. Taylor
1x 10G Wan
High Performance L2 Switch
Ge (x2)
Optical Switch
1 x 10G Wan
High Performance L2 Switch
Ge (x2)
Optical Switch
1 x 10G Wan
High Performance L2 Switch
Ge (x2)
Optical Switch
1 x 10G Wan
High Performance L2 Switch
Ge (x2)
710 North Lake Shore Drive
750 North Lake Shore Drive
Trib Content
OC-192 – with TFEC 16
OC-192 – without TFEC 12
Ge 8
OC-48 0
Non - TFEC Link
TFEC Link
TFEC = Out of band error correction
OMNInet 2007
STARLIGHT SM

National Lambda Rail



Source: John Silvester, Dave Reese, Tom West, CENIC

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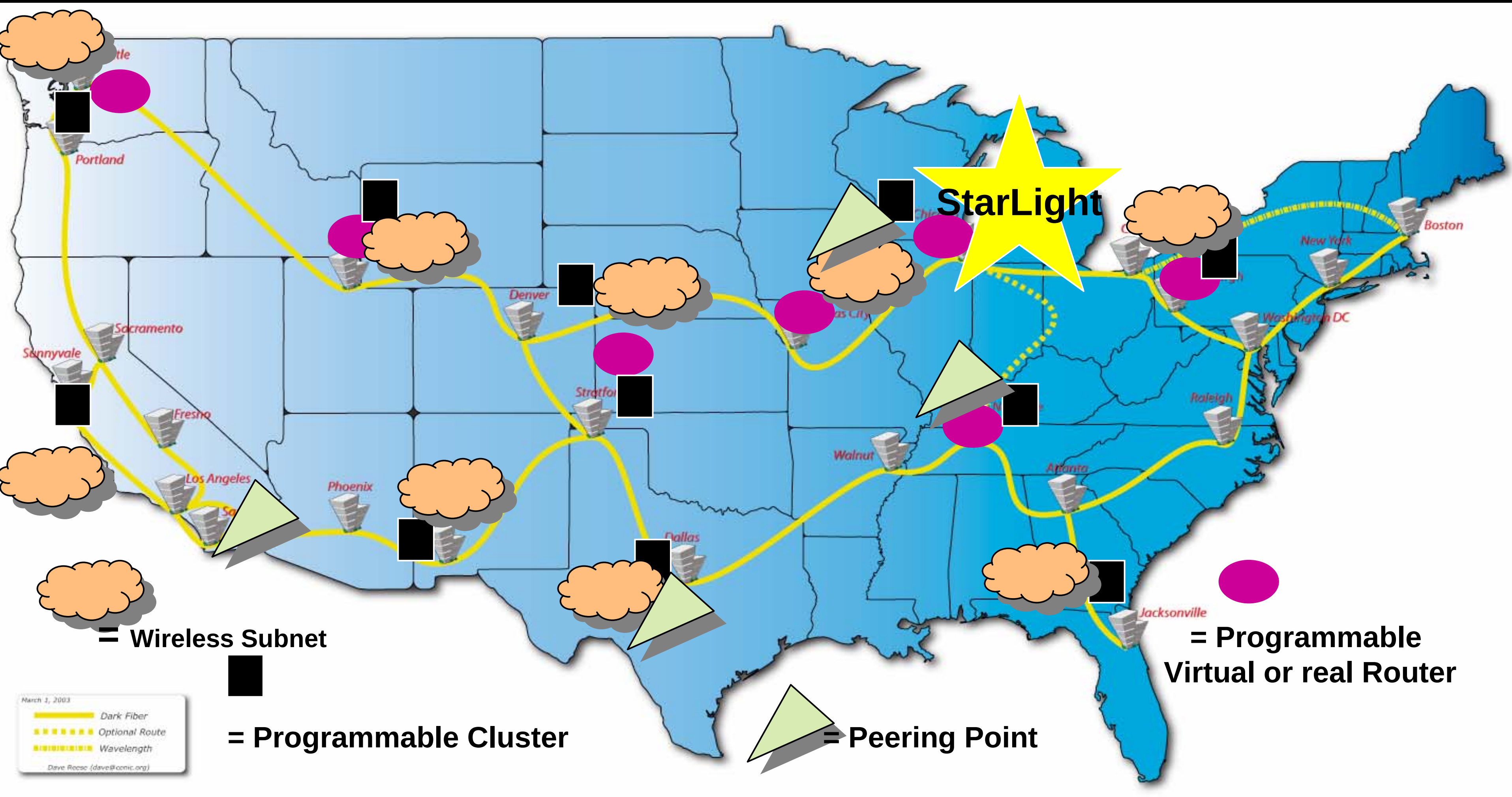
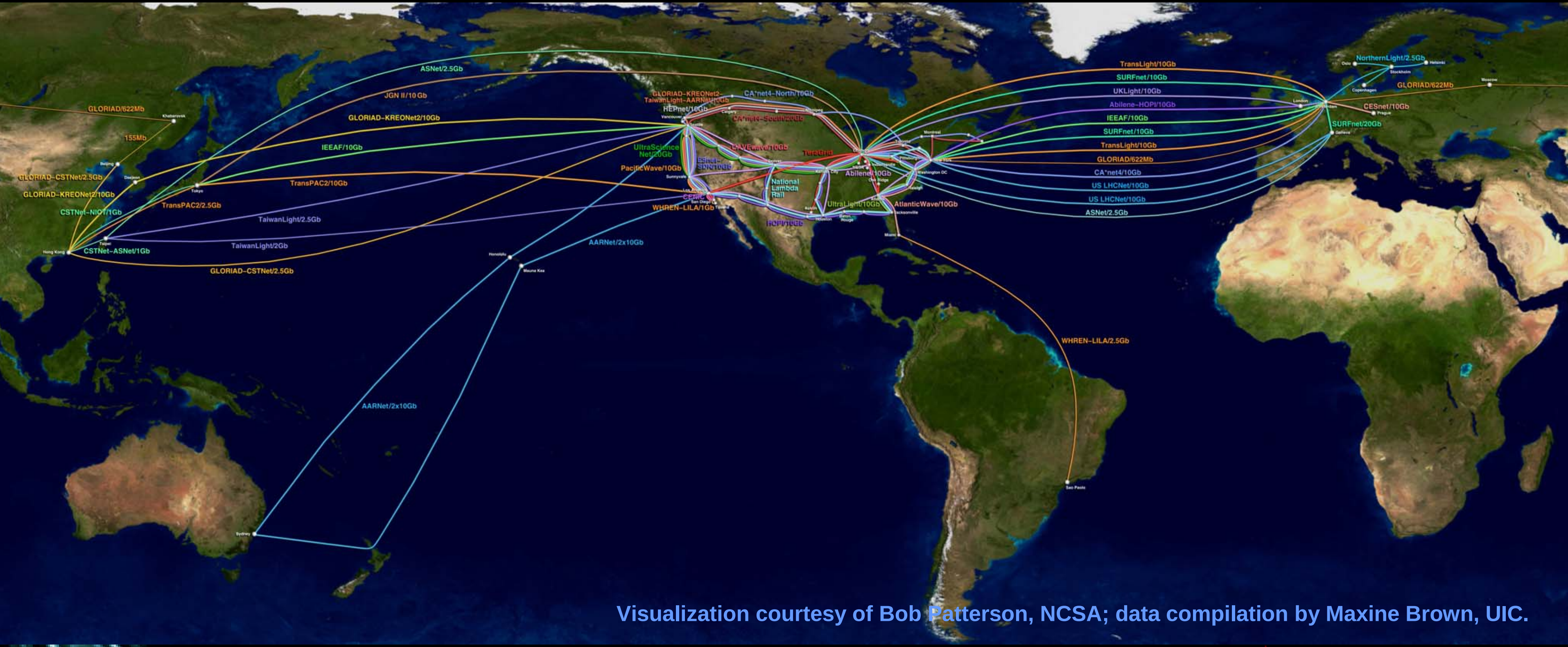
National Lambda Rail



iCAIR: Founding Partner of the Global Lambda Integrated Facility Available Advanced Network Resources

GLIF is a consortium of institutions, organizations, consortia and country National Research & Education Networks who voluntarily share optical networking resources and expertise to develop the *Global LambdaGrid* for the advancement of scientific collaboration and discovery.



Visualization courtesy of Bob Patterson, NCSA; data compilation by Maxine Brown, UIC.

www.glif.is

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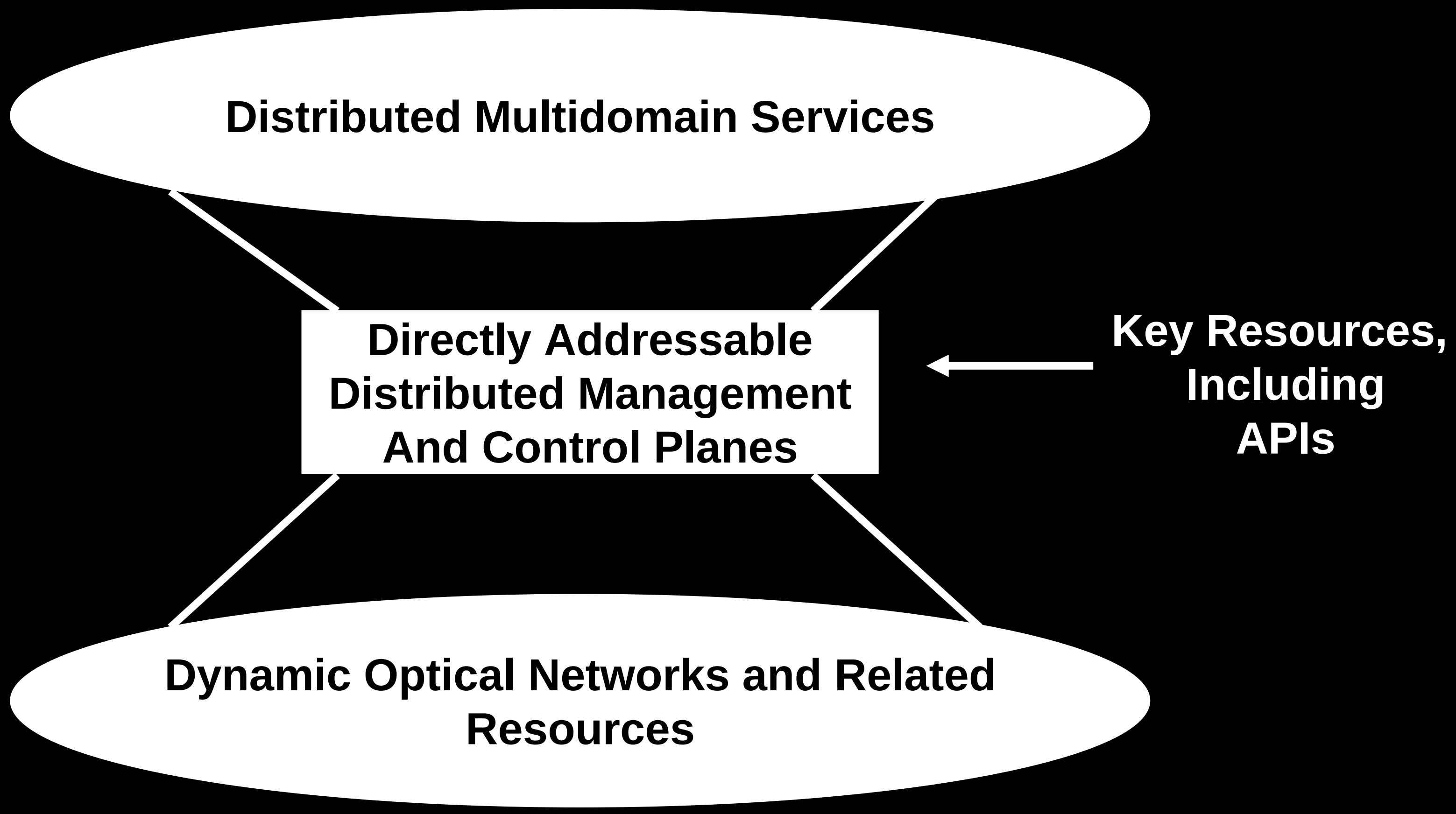
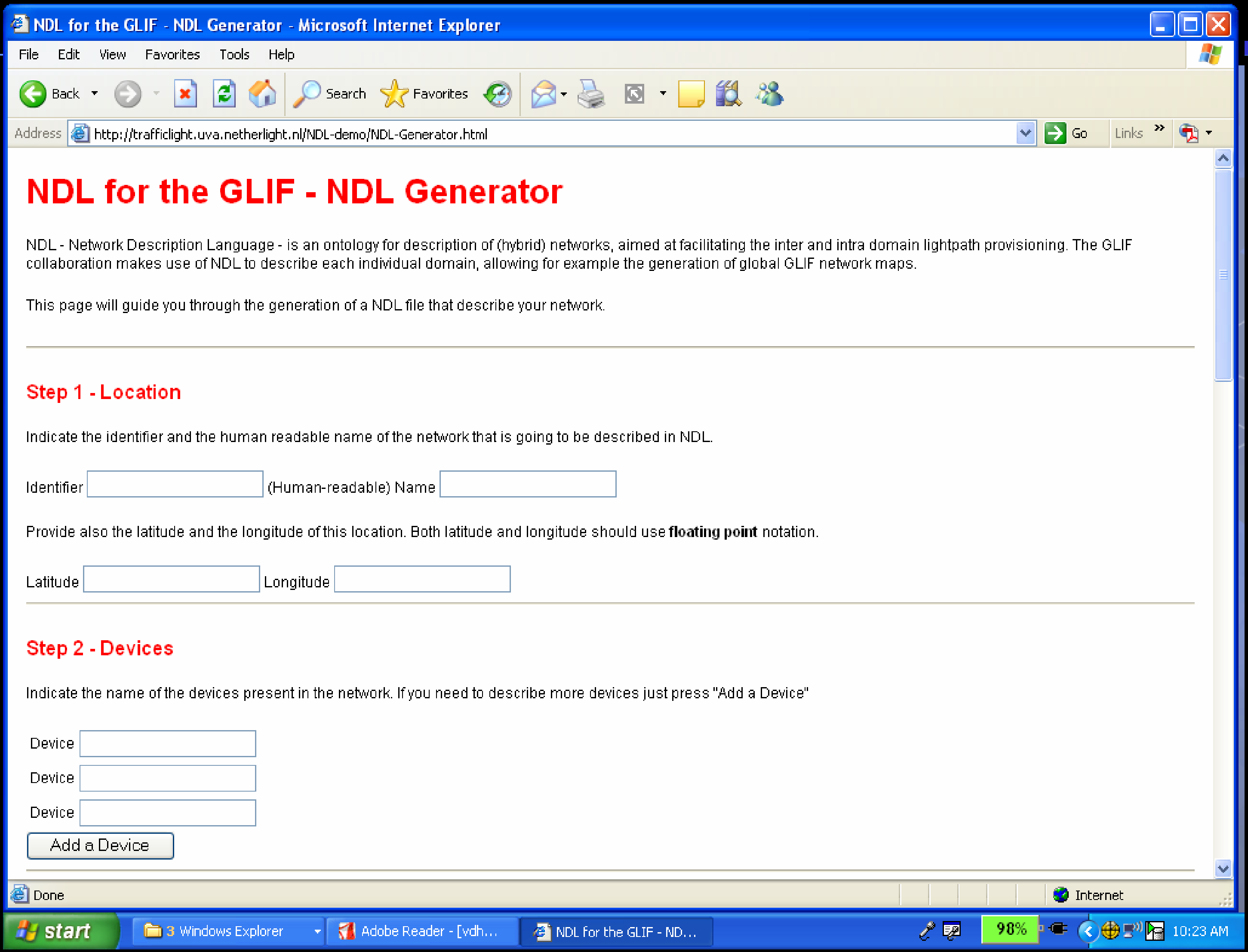
Global Lambda Integrated Facility (GLIF)



DMCP = “Facility Intelligence”

Network Description Language for the GLIF



Source: GLIF/SURFnet/GigaPORT

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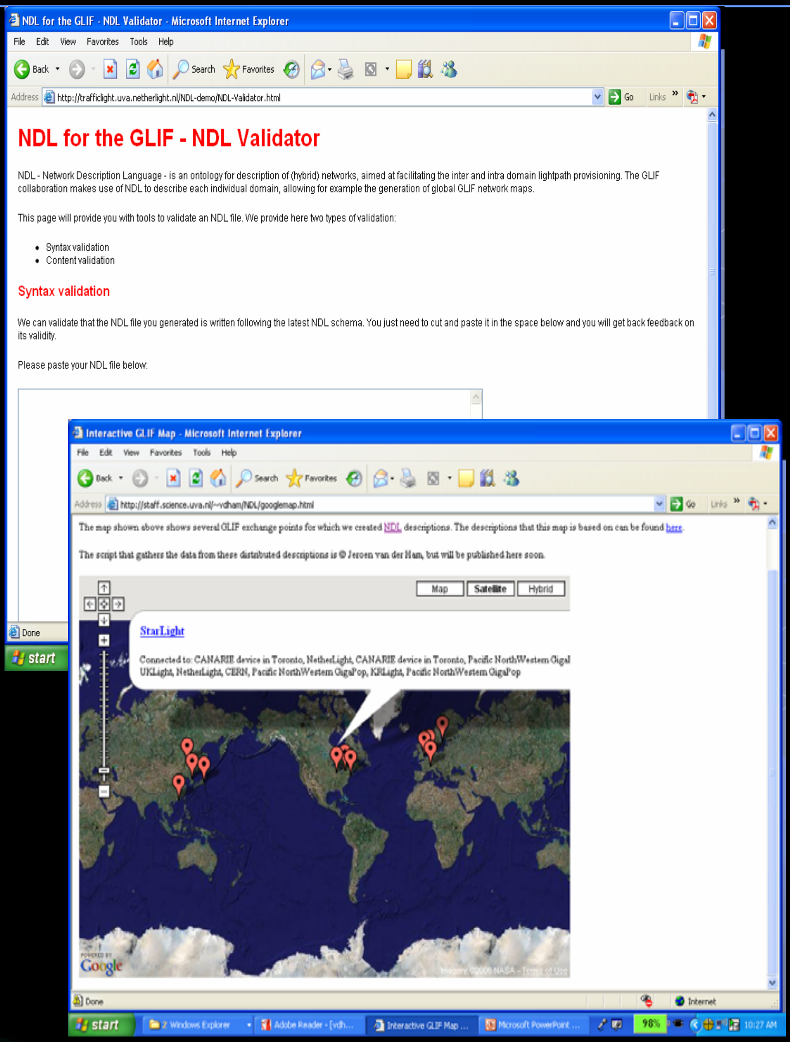
NDL WS, Validator, Maps, GOLE Description



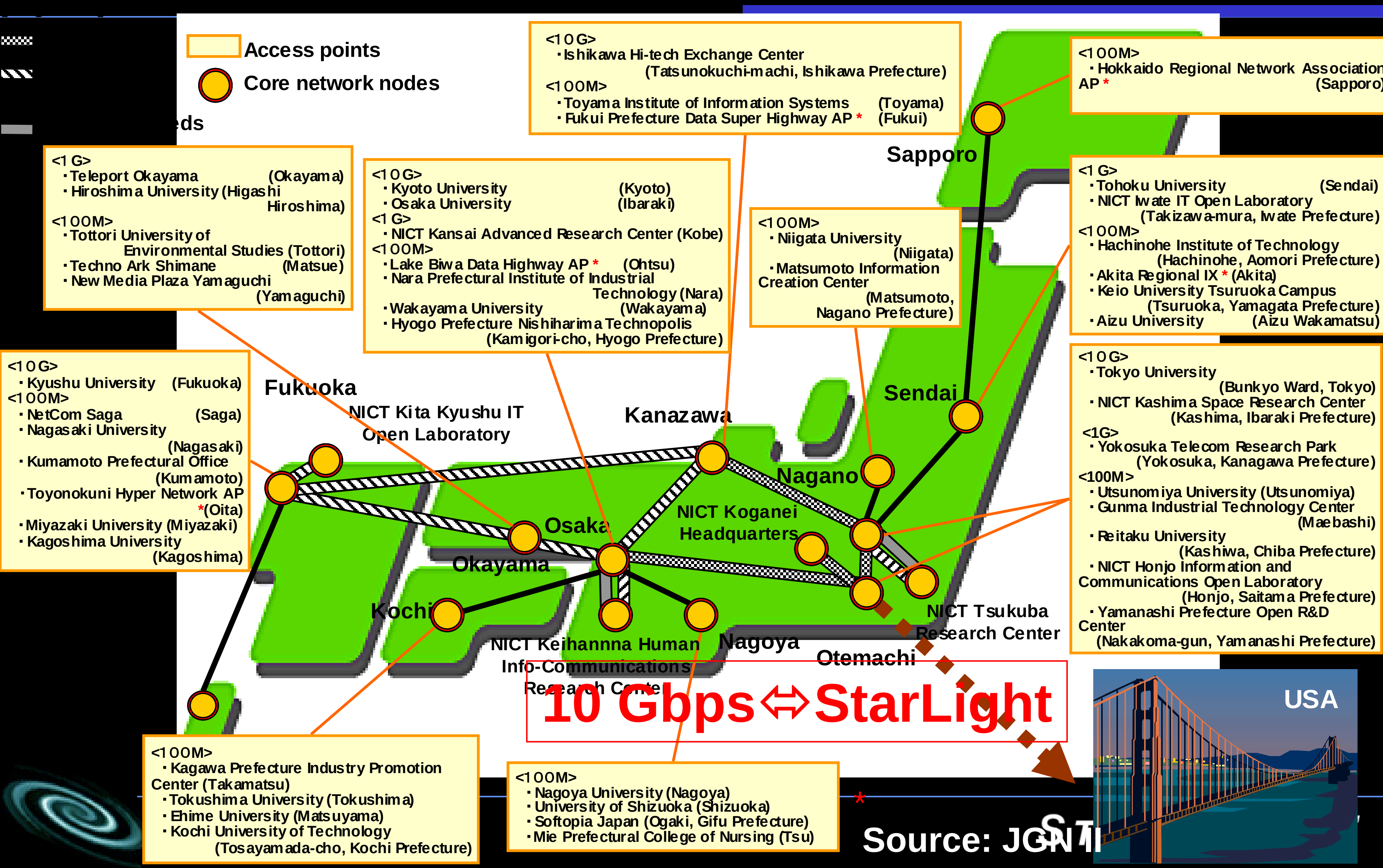

```
<ndl:Interface rdf:about="#netherlight:if5">
    <ndl:name>netherlight:if5</ndl:name>
    <ndl:connectedTo
rdf:resource="http://trafficlight.uva.netherlight.nl/JointDemo/GOLEs/starlight
/starlight.rdf#starlight:if3"/>
</ndl:Interface>

<!--http://trafficlight.uva.netherlight.nl/JointDemo/GOLEs/starlight/starlight
.rdf#starlight:if3-->
<ndl:Interface
rdf:about="http://trafficlight.uva.netherlight.nl/JointDemo/GOLEs/starlight/st
arlight.rdf#starlight:if3">
    <rdfs:seeAlso
rdf:resource="http://trafficlight.uva.netherlight.nl/JointDemo/GOLEs/starlight
/starlight.rdf"/>
</ndl:Interface>

<!--netherlight:if6-->
<ndl:Interface rdf:about="#netherlight:if6">
    <ndl:name>netherlight:if6</ndl:name>
    <ndl:connectedTo
rdf:resource="http://trafficlight.uva.netherlight.nl/JointDemo/GOLEs/starlight
/starlight.rdf#starlight:if4"/>
</ndl:Interface>
```

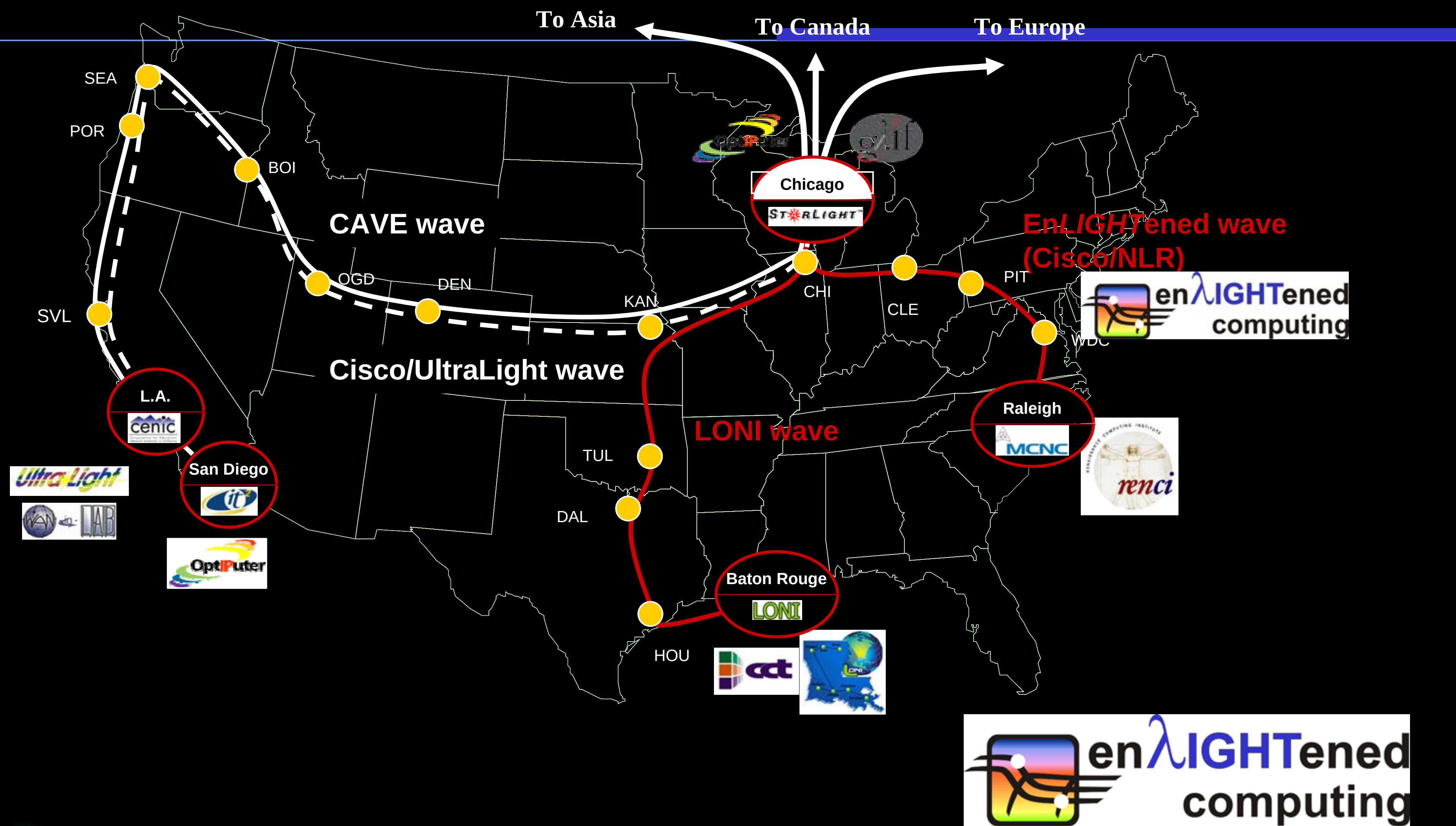
Source: GLIF/SURFnet/GigaPORT

JGN II Network Topology Map
National Institute for Information Communication Technology (NICT)



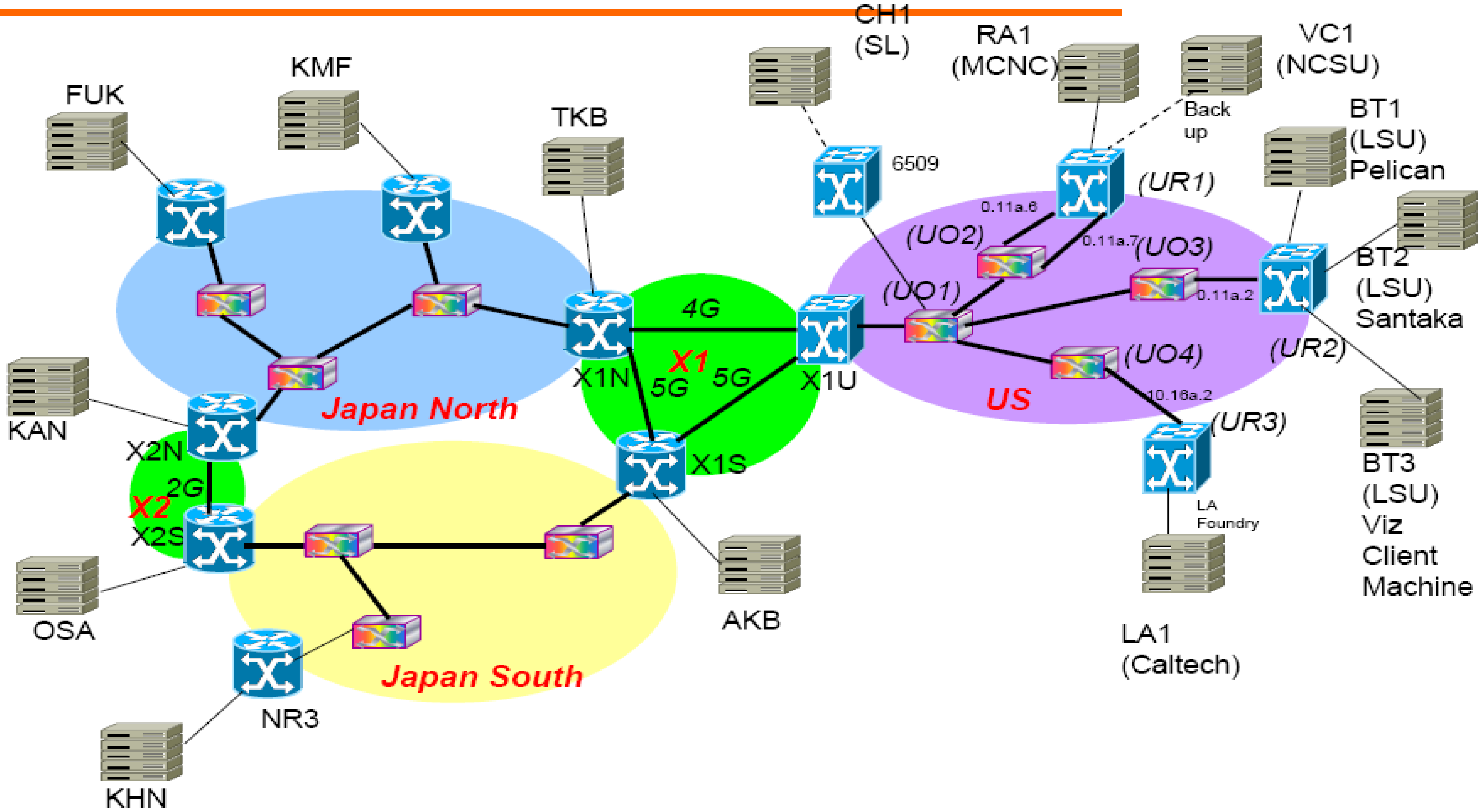
Source: JGN II

Early Testbed Diagram

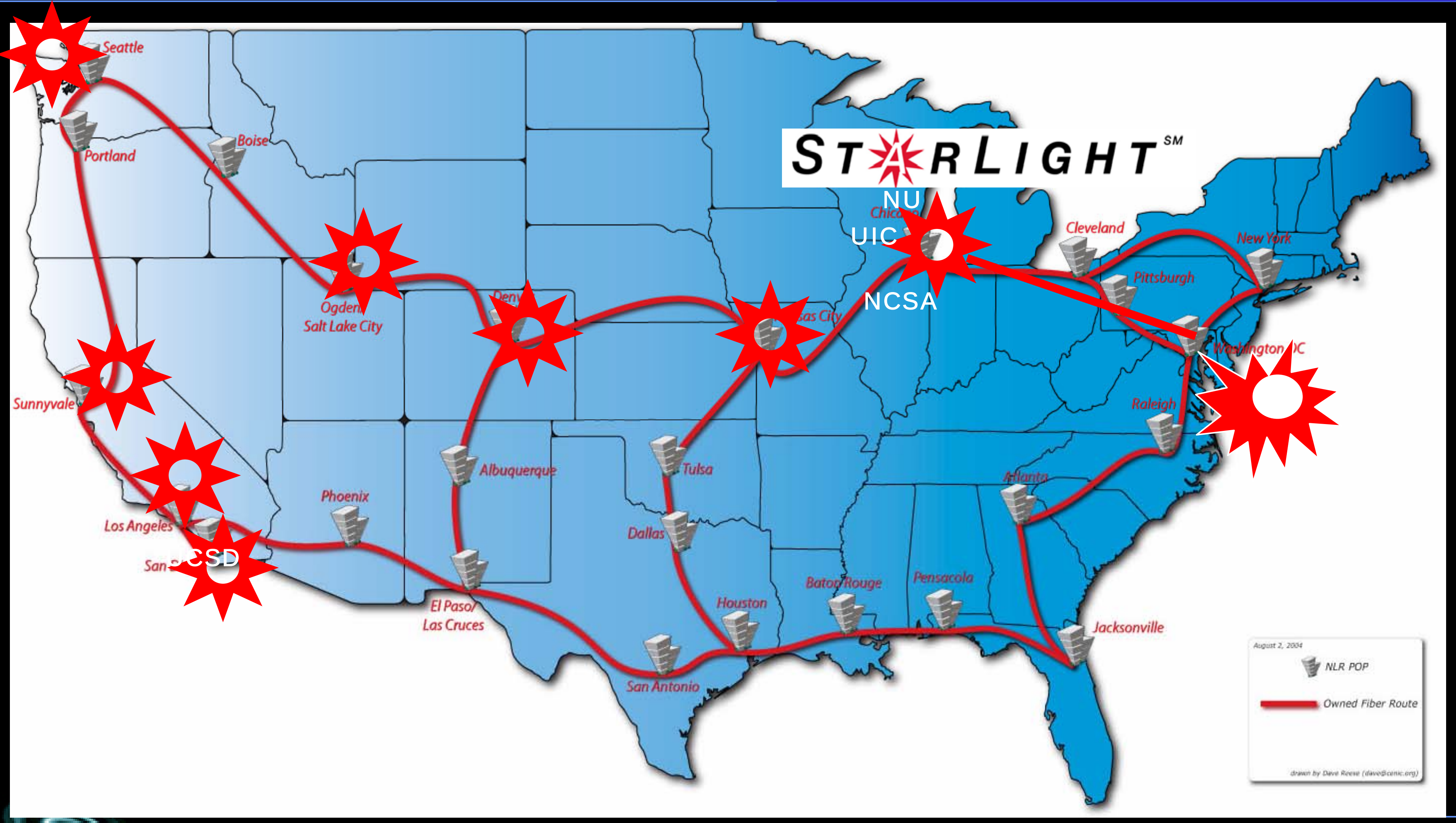


EnLightened/G-Lambda Demo at GLIF

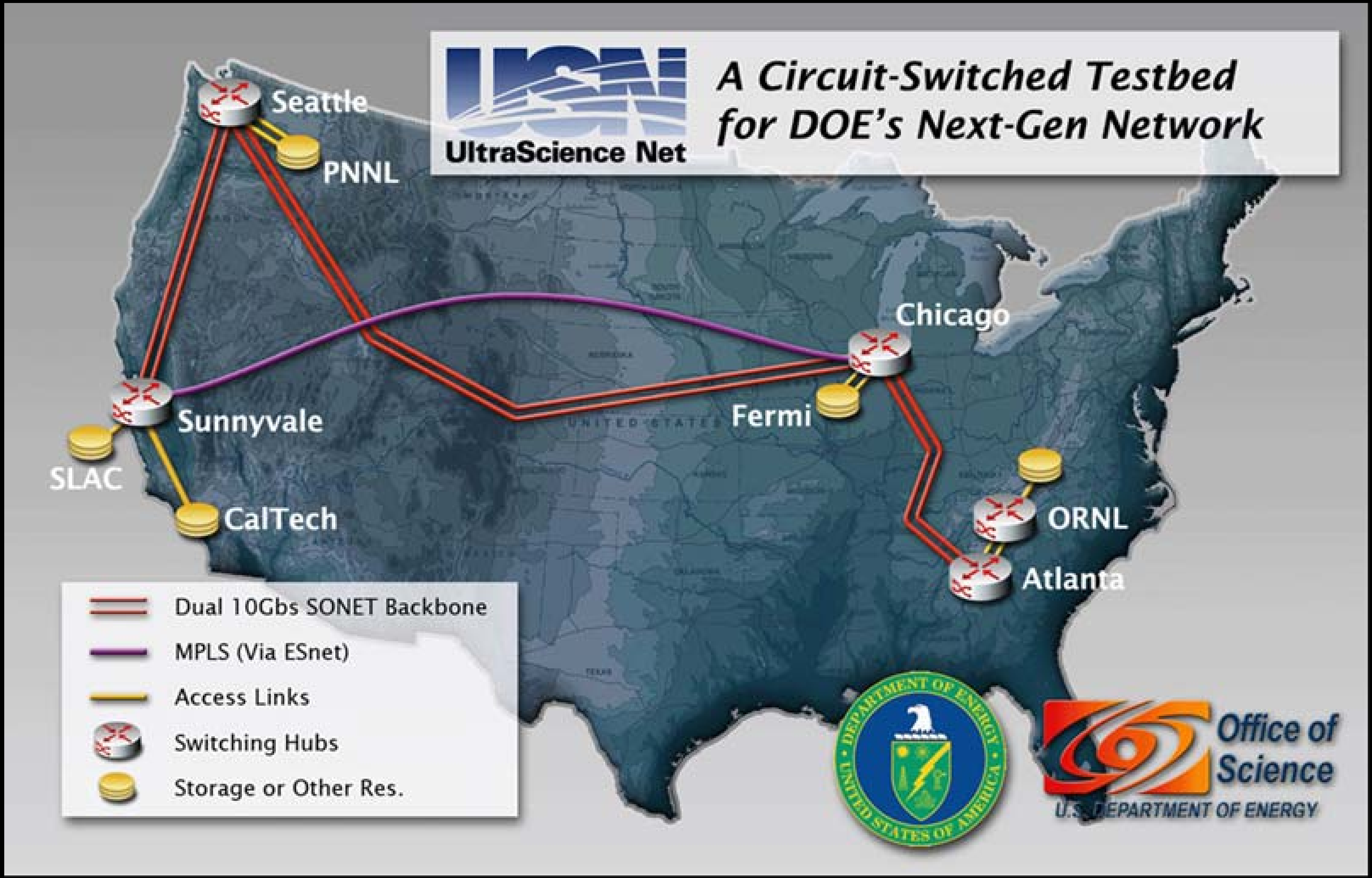
Resource map of the demo



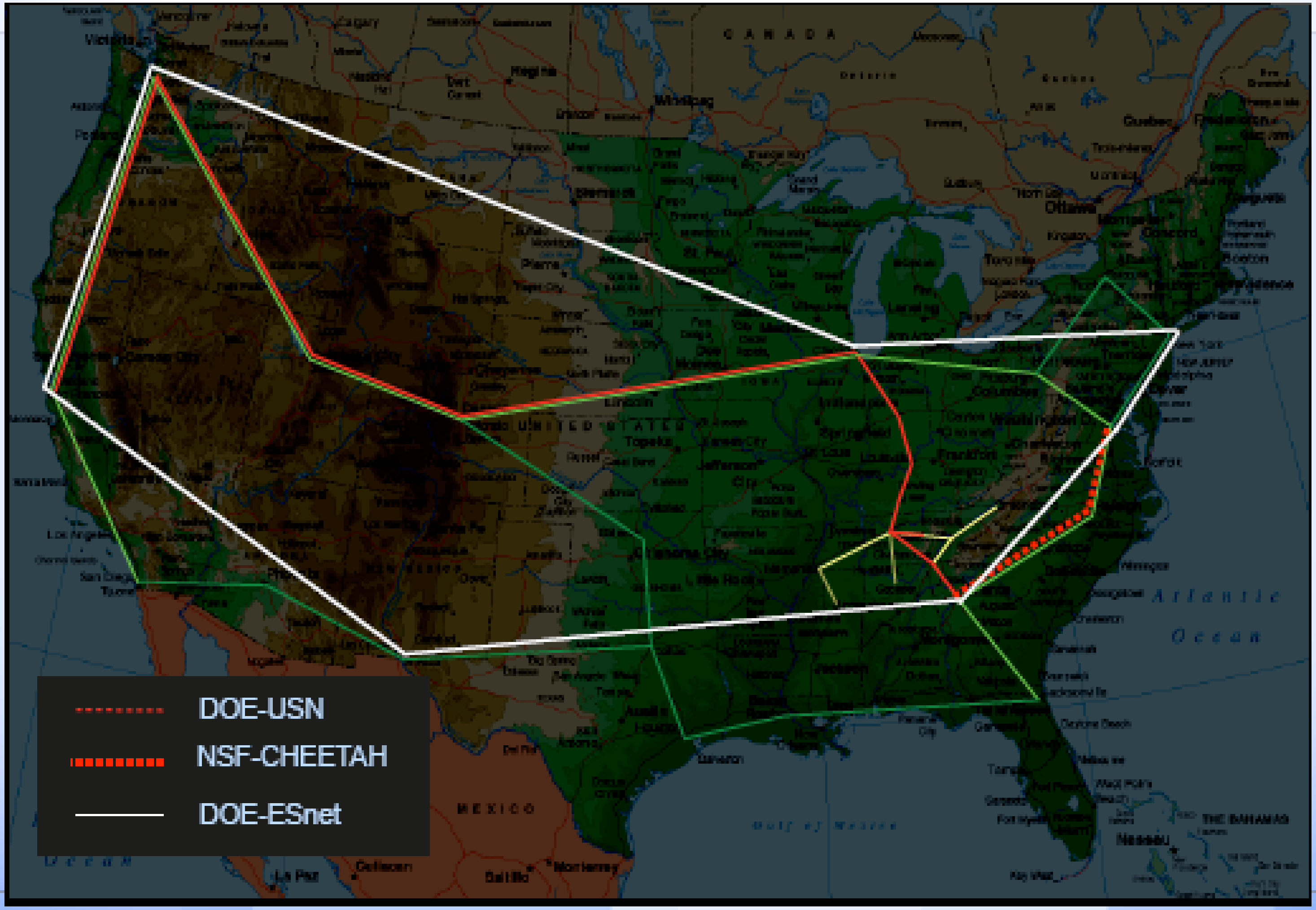
10GE *CAVEwave* on the National LambdaRail



DOE's UltraScience Net is at StarLight



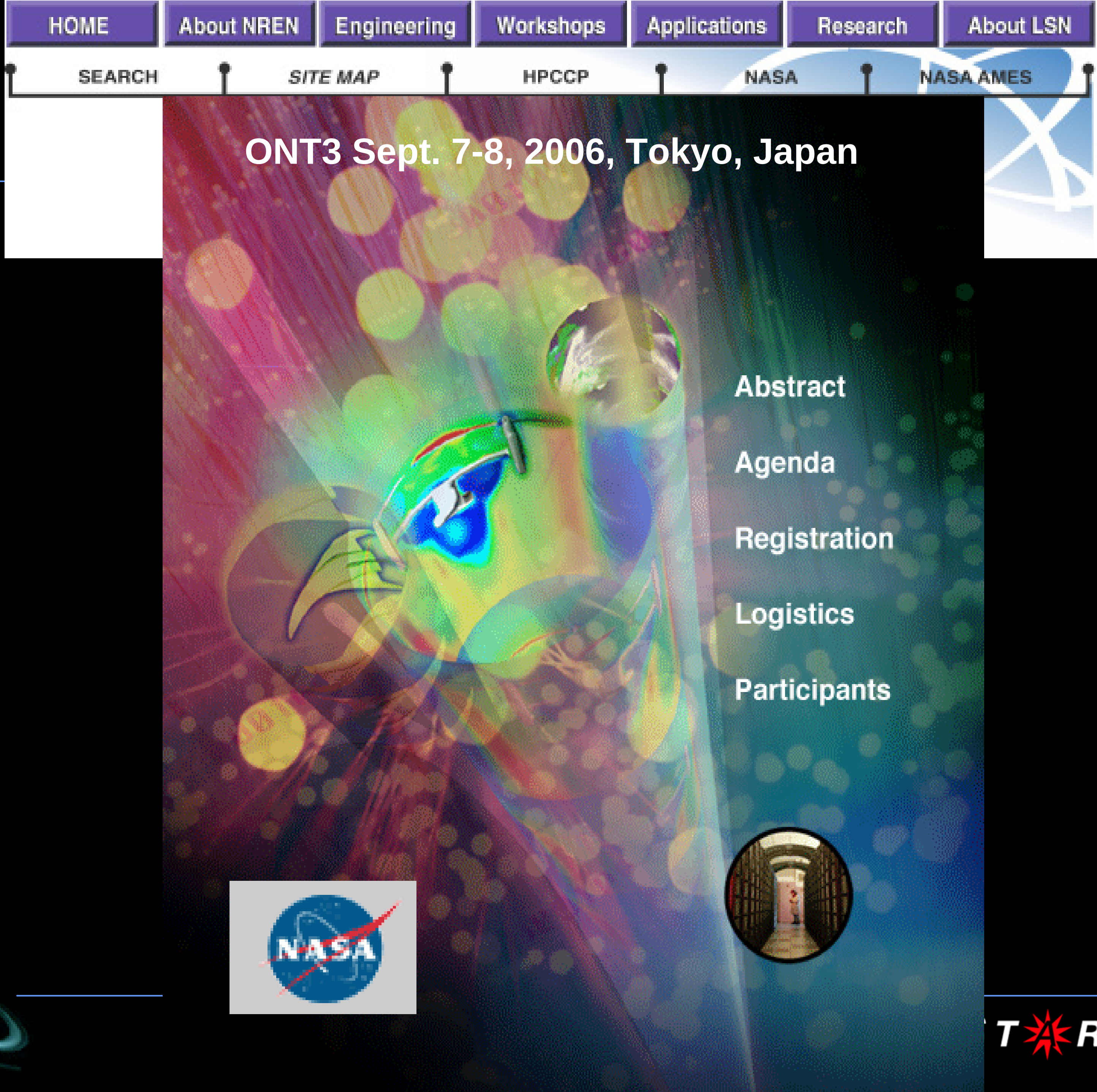
USN, ESnet, and CHEETAH



Source: DOE ESnet

Multiple Relevant ITU SIG 15 Standards

- Requirements for Automatic Switched Transport Networks (G.807/Y.1302)
- Architecture for Automatically Switched Optical Networks (G.8080/Y.1304)
- Architecture and Requirements for Routing in the ASON (G.7715.1/Y.1706)
- ASON Architecture and Requirements for Link State Protocols (G.7715.1/Y.1706.1)
- Architecture of Ethernet Layer Networks (G.8010/Y.1306)
- Ethernet UNI and Ethernet NNI (G.8012/Y.1308)
- Characteristics of Ethernet Transport Network Equipment Functional Blocks (G.8021/Y1341)
- Ethernet Over Transport – Ethernet Service Framework (G.8011/Y.1307)
- Ethernet Private Line Service (G.8011.1/Y.1307.1)
- Ethernet Virtual Private Line Service (G.8011.2/Y.1307.2)
- Generic Framing Procedure (GFP) (G.7041/Y.1303)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Report of the Interagency

Optical Networking Testbed Workshop 3

September 7 – 8, 2006
Tokyo, Japan

Jointly Sponsored by the

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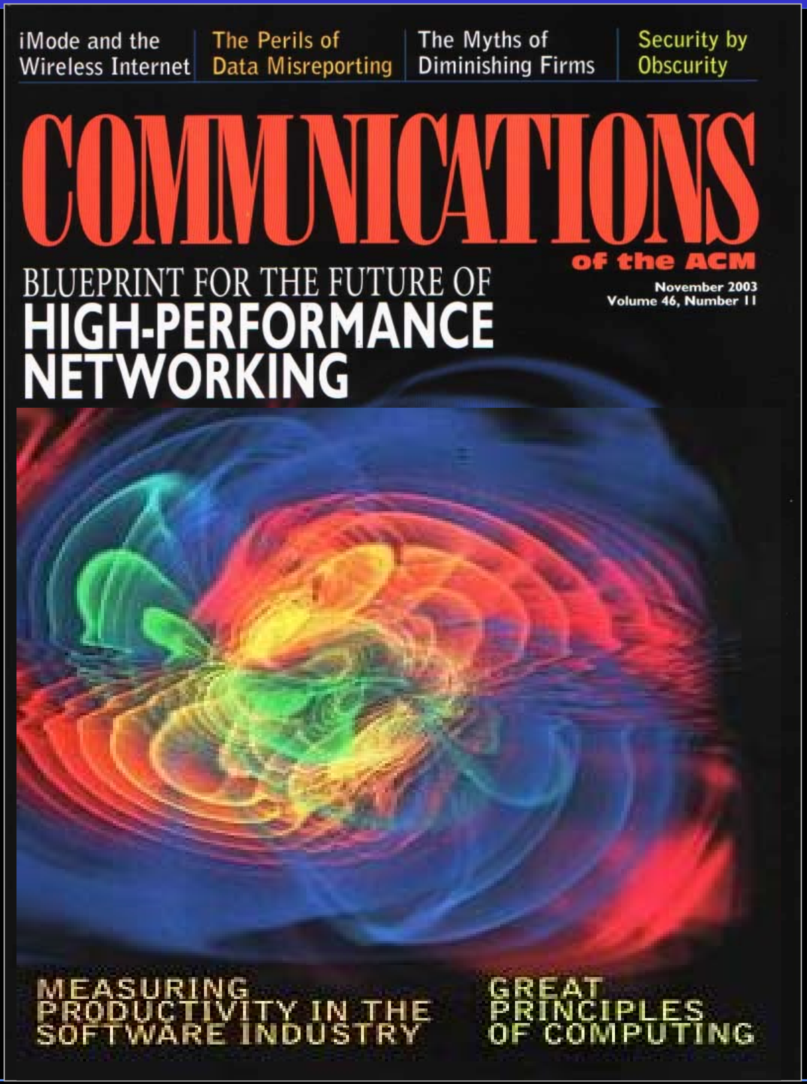
Joint Engineering Team
of the Networking and Information Technology
R&E Program's
Large Scale Networking Coordination Group

Communications of the ACM (CACM)

Volume 46, Number 11
November 2003

Special issue: Blueprint for the Future of High-Performance Networking

- ***Introduction,*** **Maxine Brown (guest editor)**
- ***TransLight: a global-scale LambdaGrid for e-science,*** **Tom DeFanti, Cees de Laat, Joe Mambretti, Kees Neggers, Bill St. Arnaud**
- ***Transport protocols for high performance,*** **Aaron Falk, Ted Faber, Joseph Bannister, Andrew Chien, Bob Grossman, Jason Leigh**
- ***Data integration in a bandwidth-rich world,*** **Ian Foster, Robert Grossman**
- ***The OptIPuter,*** **Larry Smarr, Andrew Chien, Tom DeFanti, Jason Leigh, Philip Papadopoulos**
- ***Data-intensive e-science frontier research,*** **Harvey Newman, Mark Ellisman, John Orcutt**



www.acm.org/cacm

IEEE Communications March 2006 Special Issue on “An Optical Control Plane for the Grid Community”

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iGrid 2005 Proceedings Available!

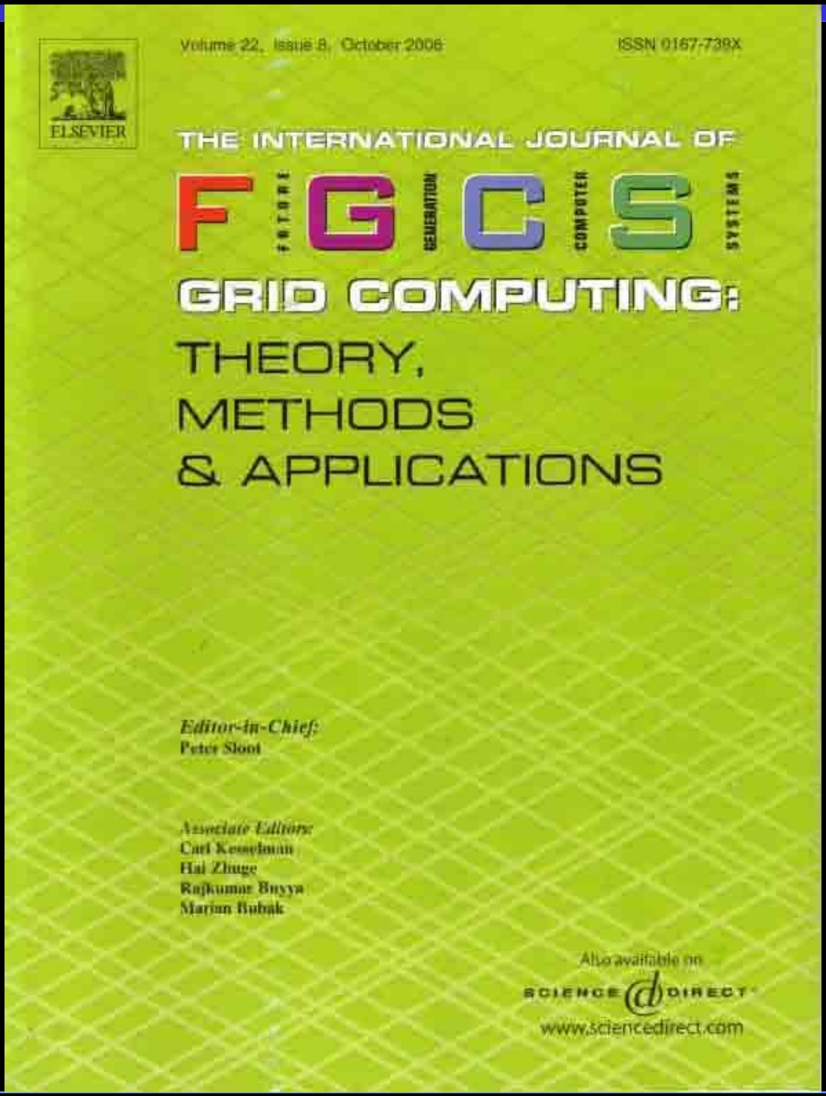
Special issue on iGrid 2005: The Global Lambda Integrated Facility

27 referred papers!

Smarr, Larry, Maxine Brown, Tom DeFanti and Cees de Laat (guest editors)

Future Generation Computer Systems, Volume 22, Issue 8, Elsevier, October 2006, pp. 849-1054

“Computational Astrophysics Enabled By Dynamic Lambda Switching,” iCAIR



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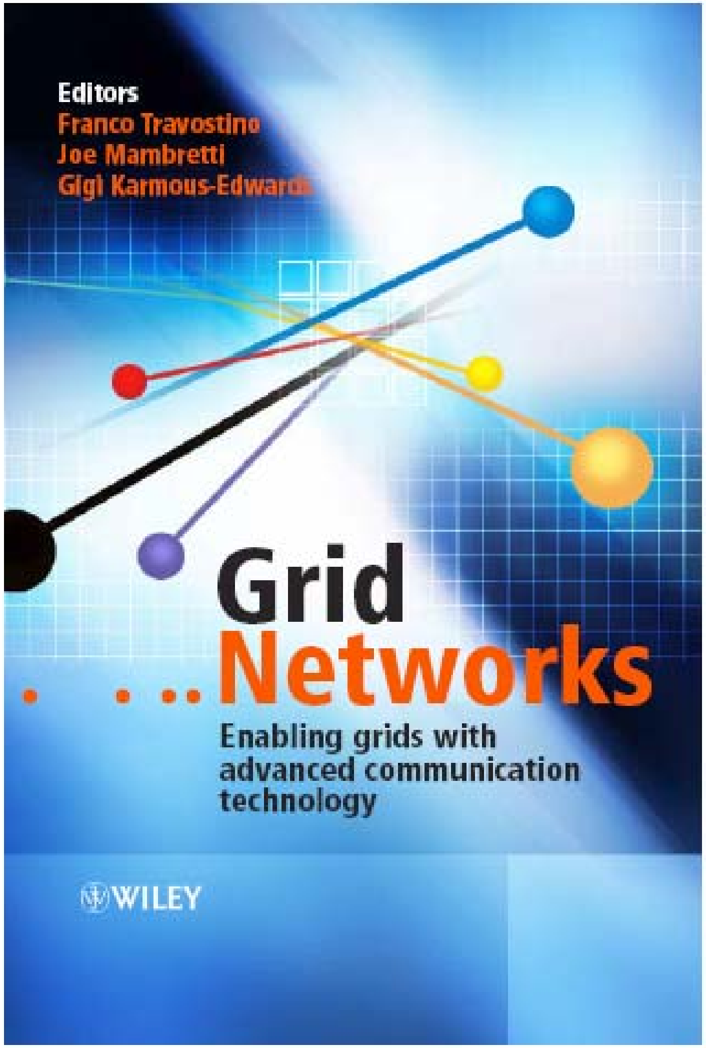
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Franco Travostino
Joe Mambretti
Gigi Karmous-Edwards
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Enabling grids with
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