Hybrid Optical+Packet Infrastructure
HOPI
Dynamic Provisioning of Light Path Services for Radio Astronomy and Visualization Applications

INTERNET2®

A demonstration of global e-science collaboration leveraging experimental internetworking technologies

SC|05

Seattle, WA
November 14-17, 2005

The Emerging Global Application

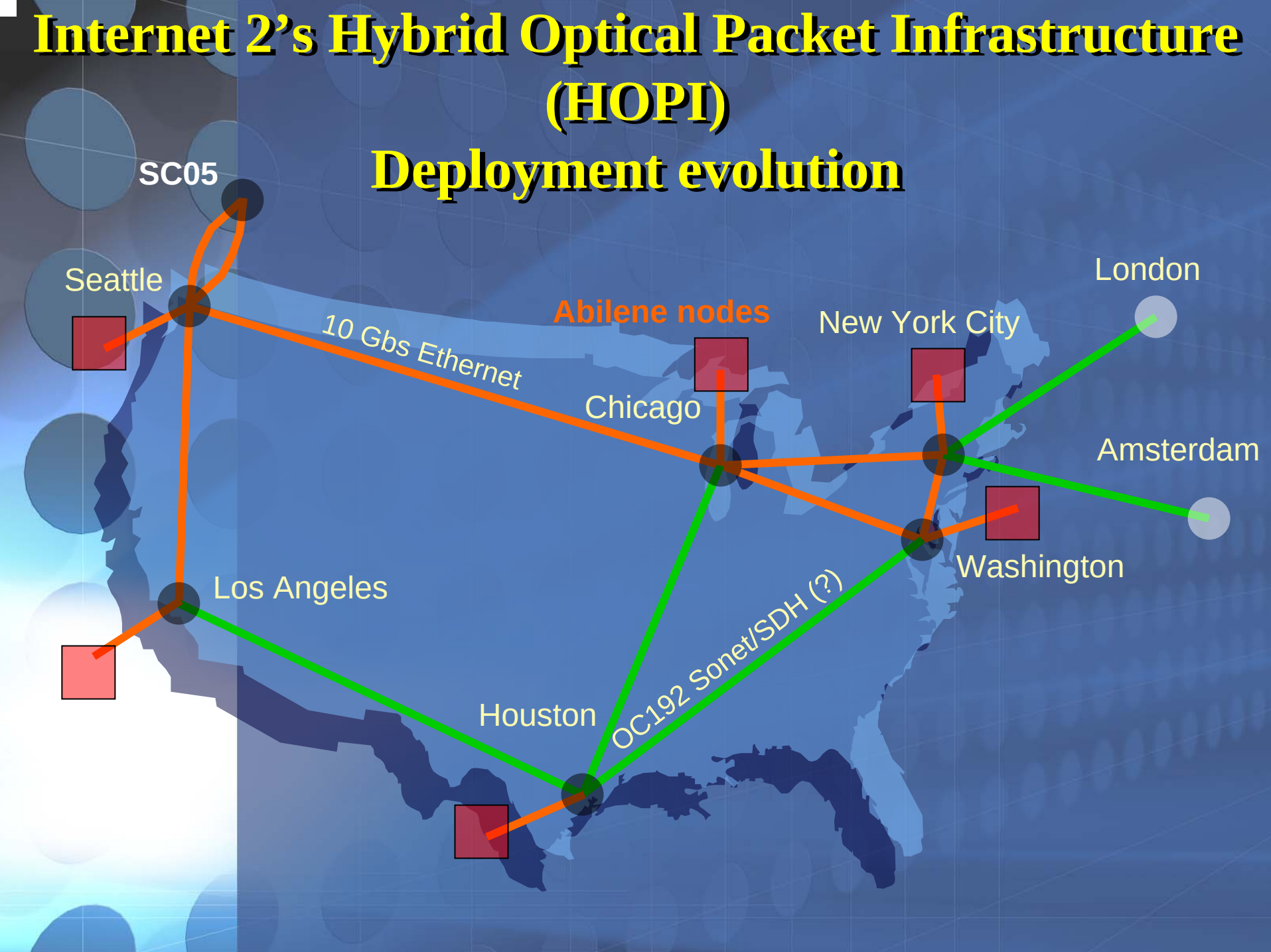
- Emerging large-scale, globally distributed applications require more sophisticated network services than have previously been available:
  - Dedicated network resources
    - An application needn't worry about its impact on other network users, or vice versa
  - Deterministic performance
    - Repeatable and predictable from day to day /year to year
  - Very high performance…
    - Multi-Gbs flows, low latency/loss, minimal jitter, global reach
  - Reservable and schedulable in advance
    - Particularly in conjunction with availability of non-network resources (e.g. radio telescopes, computational clusters, etc.)
  - Flexible and dynamic
    - Able to acquire these dedicated network resources on short notice from many potential service/resource providers

The Internet2 Hybrid Optical+Packet Infrastructure HOPI

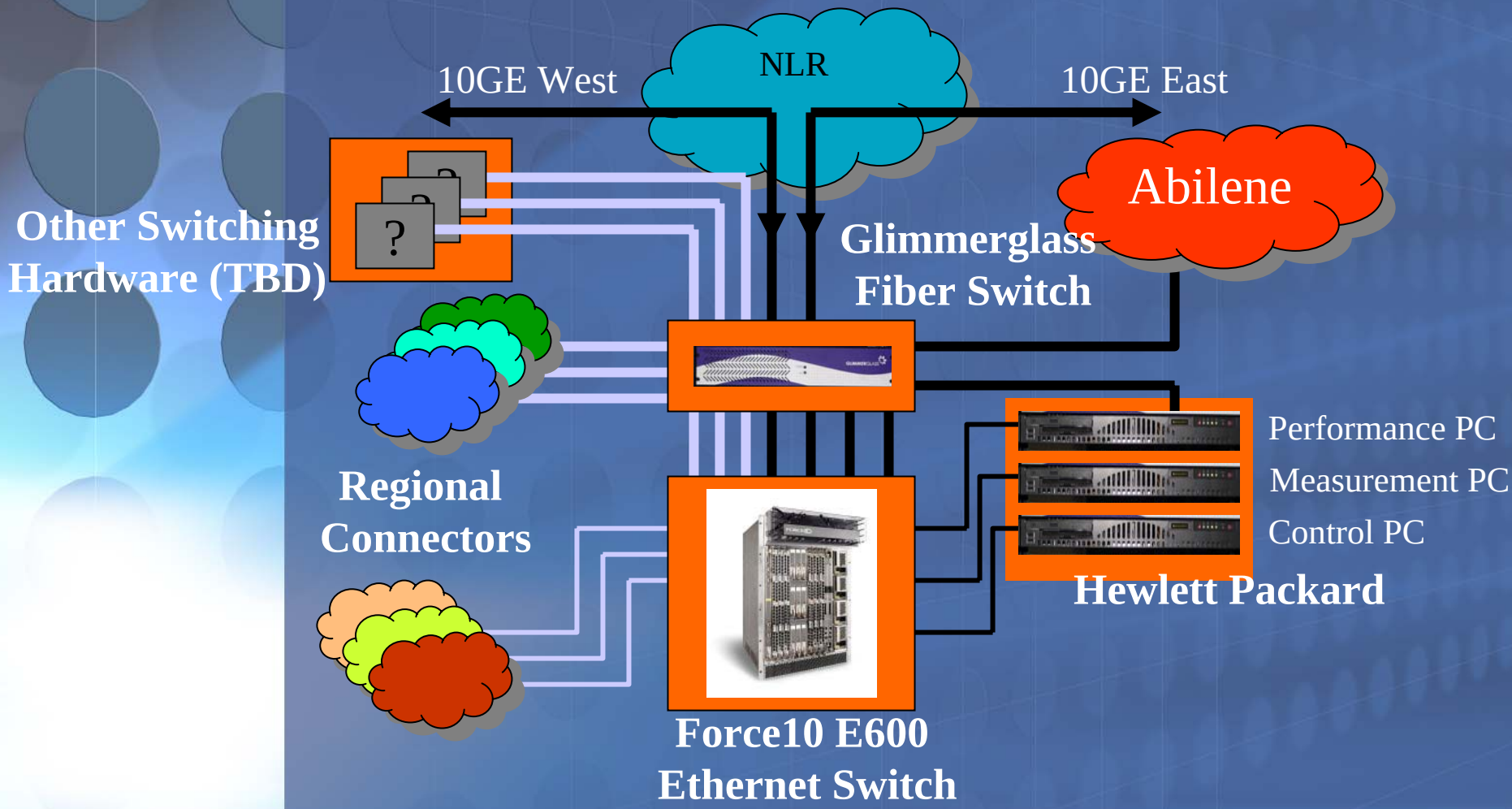
- HOPI is an experimental testbed to deploy, test, evolve, and evaluate new network technologies and architectures to address the needs of emerging global e-science applications.

- HOPI resources:
  - Wavelength transport capabilities from the National Lambda Rail, regional optical networks, and commercial providers
  - High performance IP packet services from the Abilene network, regional R&E networks, and open exchange points such as MANLAN
  - Expertise of the network research and e-science applications communities to provide network architecture, engineering, and middleware development, integration and validation.

Internet 2's Hybrid Optical Packet Infrastructure (HOPI)
Deployment evolution



The HOPI Node Architecture



HOPI Useability

- Enable a wide base of users to connect and experiment with the facility
  - Establish a Testbed Support Center to assist with operations, systems development and testing, engineering and applications
    - Mid-Atlantic Crossroads, North Carolina Research and Education Network, and Indiana University GRNOC
  - Integrate Abilene reach and performance capabilities
  - Incorporate international links and exchange points
    - MANLAN, StarLight, …
- Dynamic – Learn how to allocate dedicated resources by user request
  - Deploy a low level control plane foundation for developing automated middleware to allocate, reserve, and provision higher layer networks services
- Open and [where available] standards based:
  - Open source DRAGON Software Suite:
  - GMPLS protocols for routing, signaling: GMPLS-OSPF-TE and GMPLS-RSVP-TE to control the switching elements (VLSR)
  - Inter-domain Service Routing (NARB)
    - End-to-End Path Computation
    - AAA
    - Advanced scheduling/reservations

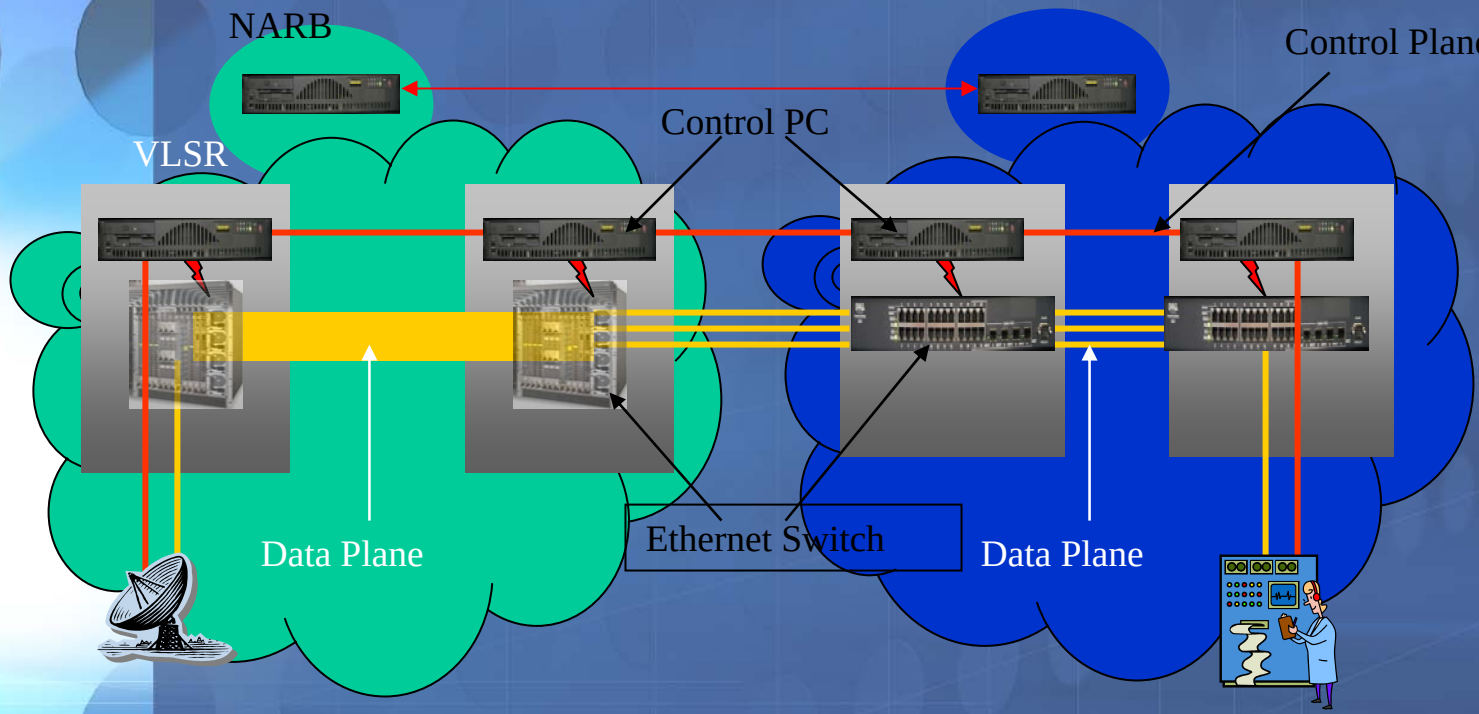
The HOPI Control Plane

- DRAGON Software Suite provides the dynamic routing and provisioning capability in HOPI:
  - Virtual Label Swapping Router (VLSR)
    - Open source implementations of GMPLS-OSPF-TE and GMPLS-RSVP-TE protocols
    - Protocols run under FreeBSD or Linux
    - The VLSR translates network protocol events into SNMP/TL1/CLI transactions to reconfigure the switching elements
  - Network Aware Resource Broker (NARB)
    - Domain specific agent that listens to OSPF for internal link state changes
    - Provides inter-domain service capability announcements and topology summarization
    - Creates loose hop ERO for RSVP 'PATH' requests across multiple domains
    - Performs request authorization and book ahead reservations

DRAGON Control Plane

Virtual Label Switching Router (VLSR)

- Open source protocols running on PC act as GMPLS signaling entity
- Control PCs participate in protocol exchanges and reprovision covered switch according to protocol events (PATH setup, PATH tear down, state query, etc)



SC05 Demonstration Objectives:

- **Deploy and demonstrate the GMPLS control plane for Light Path services**
  - Dynamically allocate and provision dedicated network resources (For SC05, an "etherwire" service will be shown)
  - Across multiple [globally distributed] administrative domains/networks
- **Show how dedicated Light Path services benefit a globally distributed research activity:**
  - Specifically the E-VLBI radio astronomy application/community
  - Link radio telescopes and correlator facilities around the world into a single application specific network facility
- **Début the operational availability and capabilities of the Internet2 HOPI test bed**
  - 10Gbs switched Ethernet experimental backbone, coast to coast across the US (WDC, CHI, SEA, LAX, [soon NYC])
  - Inter-connectivity to Abilene, Starlight, DRAGON, Ultralight, etc
  - Introduce the Testbed Support Center team as part of Supercomputing 2005
- **Deploy and present *persistent* infrastructure capabilities as part of the SC05 demo**
  - These applications capabilities will remain and will continue to serve the E-VLBI community

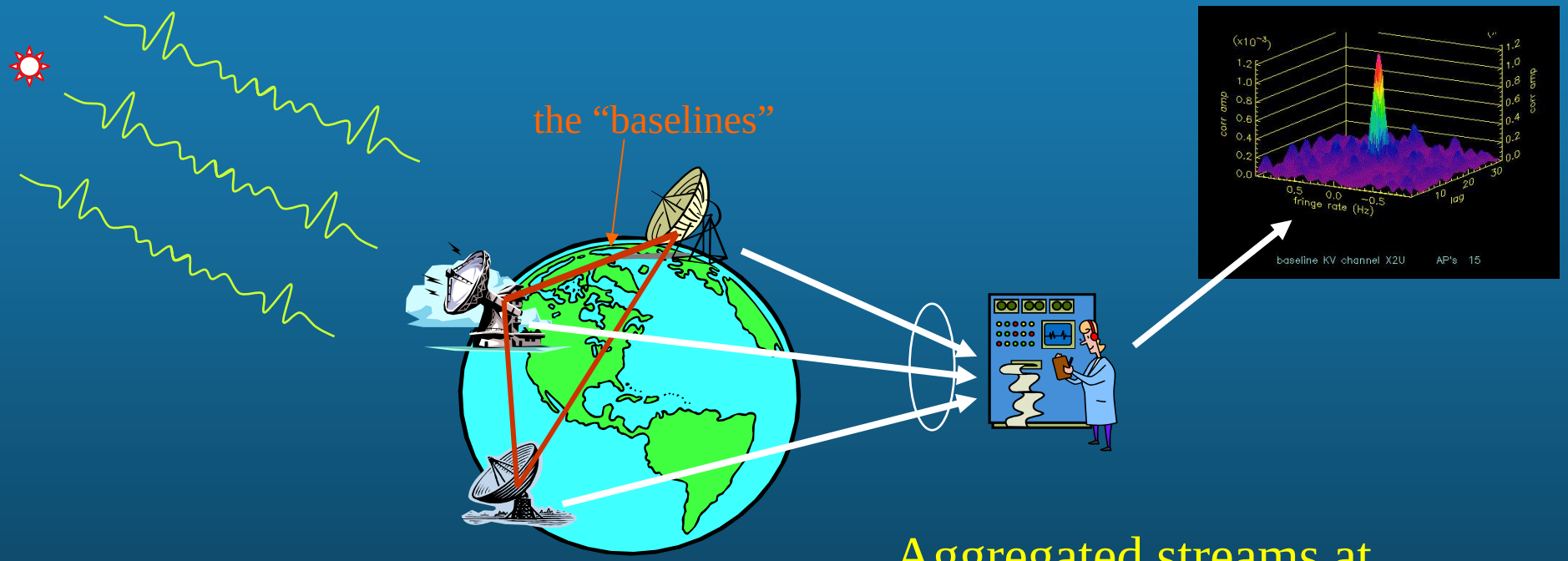
E-VLBI

- **VLBI :=Very Long Baseline Interferometry**
- **Radio telescope arrays separated by large distances offer dramatically improved resolution of celestial objects and events**
  - **Multiple telescopes around the world are trained on a single point in the sky and simultaneously capture the RF noise to tape or removable disk packs**
  - **These recorded streams are then *shipped* to a computational facility for "correlation" which generates a high resolution image of the object**
- **E-VLBI := Electronic VLBI**
  - **Move the sensor streams to the correlators in [near] real time over high performance R&E networks**
- **E-VLBI observations and correlations are also used to study terrestrial geodesy – i.e. the same VLBI techniques used to observe the cosmos can very accurately position the telescopes themselves thereby measuring plate tectonics or the changes in gravitational reference frames of the earth itself**
  - **Important for the Global Positioning System (GPS) satelites to accurately know where they are…**
- **The E-VLBI community is an international community and forms a natural "affinity group" of researchers, collaborative projects and scientific resources that are global in scope.**

Mapping Advanced Global Applications to Advanced Global Network Services

- E-VLBI application resources:
  - Radio telescopes (a small sample)
    - Haystack Observatory (Westford Ma. US)
    - NASA Goddard Geophysical & Astronomical Obs. (Greenbelt, Md. US)
    - Onsala Space Observatory (Onsala, SE)
    - Westerbork Observatory (Amsterdam, NL)
    - Kashima Observatory (Kashima, JP)
    - Jodrell Bank Observatory (Manchester, UK)
  - Correlators (a small subset)
    - Haystack Observatory
    - US Naval Observatory (Washington, DC)
    - Joint Institute for VLBI in Europe - JIVE (Dwingeloo, NL)
  - Data transport between telescope and correlator
    - {tape, disk} + FedEx
    - Global networks: – Abilene + GEANT + UKLight + …

E-science Example:
Electronic-Very Long Baseline Interferometry
"E-VLBI"

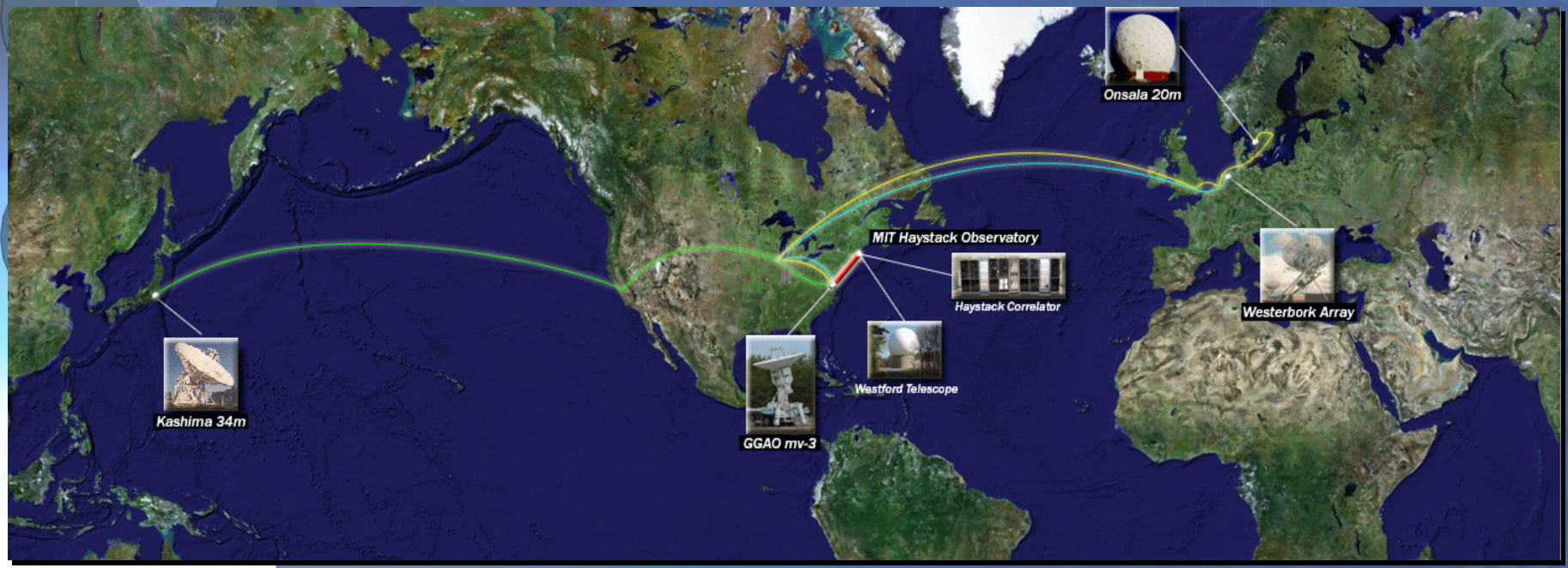


Radio Telescopes
2005 = 512 Mbs
2007 = 2 Gbs
2009 > 4+ Gbs

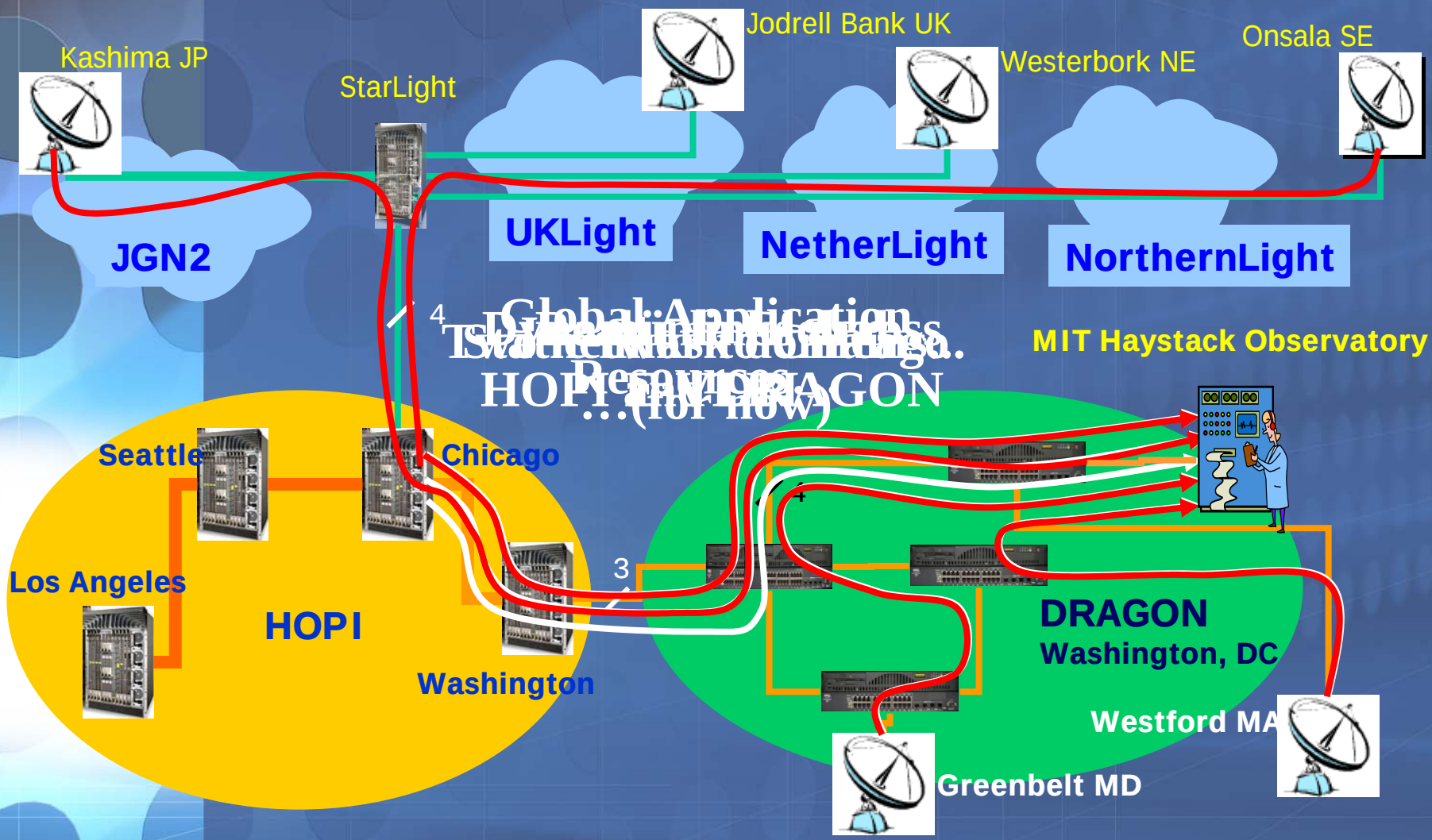
Aggregated streams at correlator:
2005 > 2 Gbs
2007 ~ 10 Gbs to 20+ Gbs
2009 > 20 Gbs to 40+ Gbs

Global e-VLBI

SC05



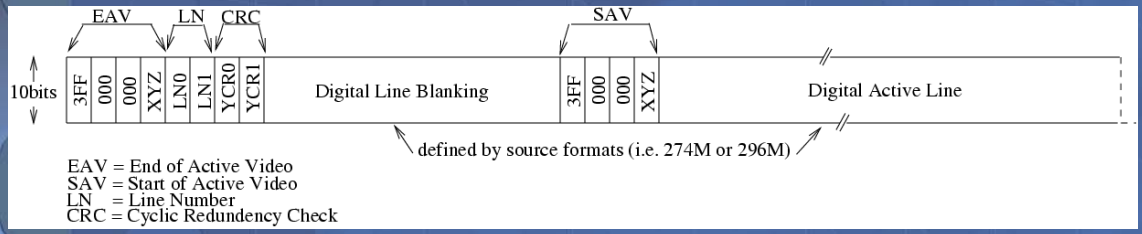
The 30,000 foot view: HOPI SC05 Demo:



High Definition Collaboration and Visual Area Networking (HD-CVAN)

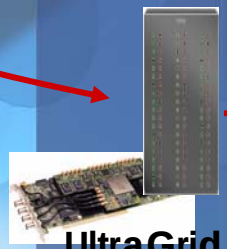
- DRAGON dynamic resource provisioning will be used to instantiate an application specific topology
  - Video directly from HDTV cameras and 3D visualization clusters will be natively distributed across network
- Integration of 3D visualization remote viewing and steering into HD collaboration environments
- HD-CVAN Collaborators
  - UMD VPL
  - NASA GSFC (VAL and SVS)
  - USC/ISI (UltraGrid Multimedia Laboratory)
  - NCSA ACCESS

Uncompressed HDTV-over-IP Current Method



LDK-6000

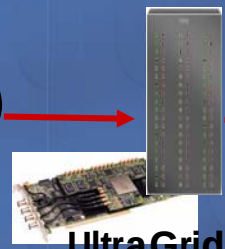
SMPTE-292
HDTV output
1.485 Gbps



UltraGrid
node

850Mbps
RTP/UDP/IP

network



UltraGrid
node

Astro 1602 DAC

PDP-502MX

- Not truly HDTV --> color is subsampled to 8bits
- Performance is at the mercy of best-effort IP network
- UltraGrid processing introduces some latency

Low latency High Definition Collaboration - DRAGON Enabled

LDK-6000

SMPTE-292

proxy

e/o

d/a

o/e

NARB

DRAGON Network

proxy

o/e

d/a

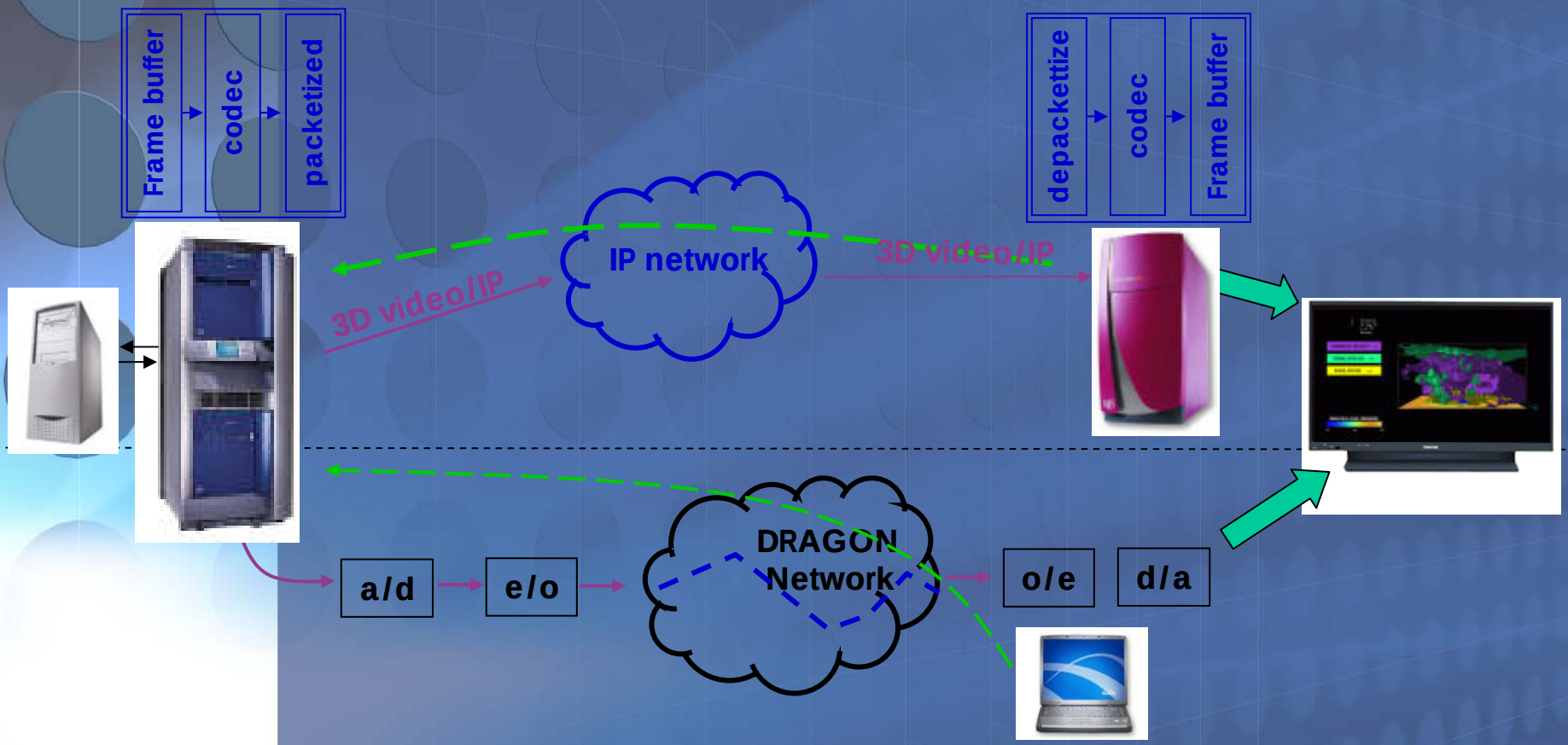
e/o

SMPTE-292

NARB

- End-to-end native SMPTE 292M transport
- Media devices are directly integrated into the DRAGON environment via proxy hosts
  - Register the media device (camera, display, …)
  - Sink and source signaling protocols
  - Provide Authentication, authorization and accounting.

Low Latency Visual Area Networking



- Directly share output of visualization systems across high performance networks.
- DRAGON allows elimination of latencies associated with IP transport.

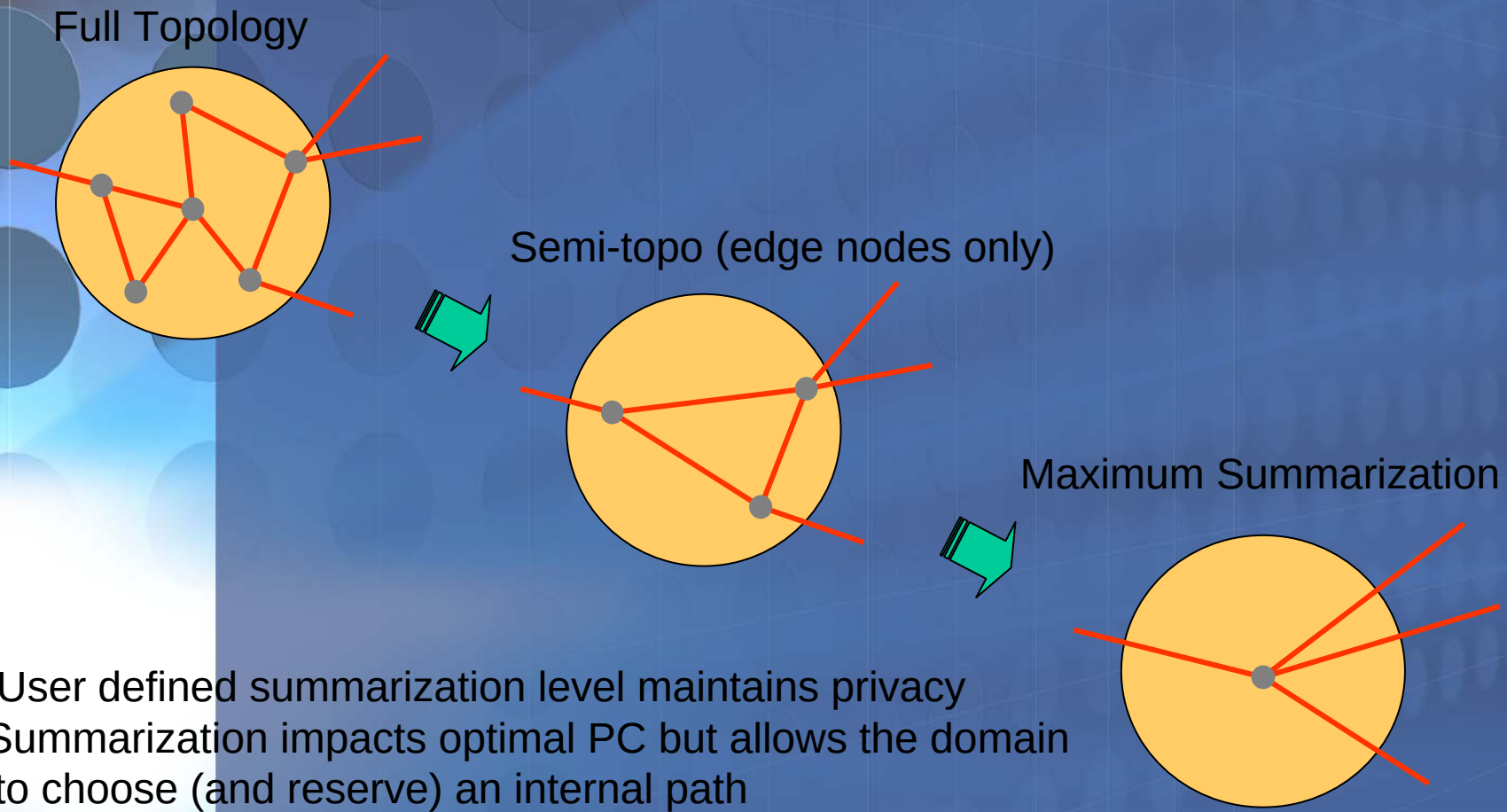
Challenges and Hurdles for Global Real Time E-VLBI

- This demonstrating needs:
  - Better debugging and service verification tools for light paths
  - Dependable automated control plane –With inter-domain service routing capabilities and generic integrated resource brokering
- Issues encountered during preparation
  - VLAN loops during testing
  - Production components in experimental networks
  - Hdw failures in all-optical research segments
  - Transport protocols across big long pipes
  - Scheduling and availability limitations of end-systems
  - Lack of knobs in application to adjust for new dynamic networking capabilites
  - Code porting to new hardware and OS environments

Demo Caveats…

- The E-VLBI application requires extensive tuning at the end systems and between flows before the actual “fringing” can begin..
  - For SC05, we have tuned the end systems in advance of the the presentation in order to show the application running in real time using globally distributed resources over dynamically allocated light paths.

Inter-Domain Topology Summarization



- User defined summarization level maintains privacy
-Summarization impacts optimal PC but allows the domain to choose (and reserve) an internal path