The BRIDGES Project-

Binding Research Infrastructures for the Deployment of Global Experimental Science

Building a Global Cyber-Infrastructure Canvas Supporting Networked Applications Experimentation and Evolution

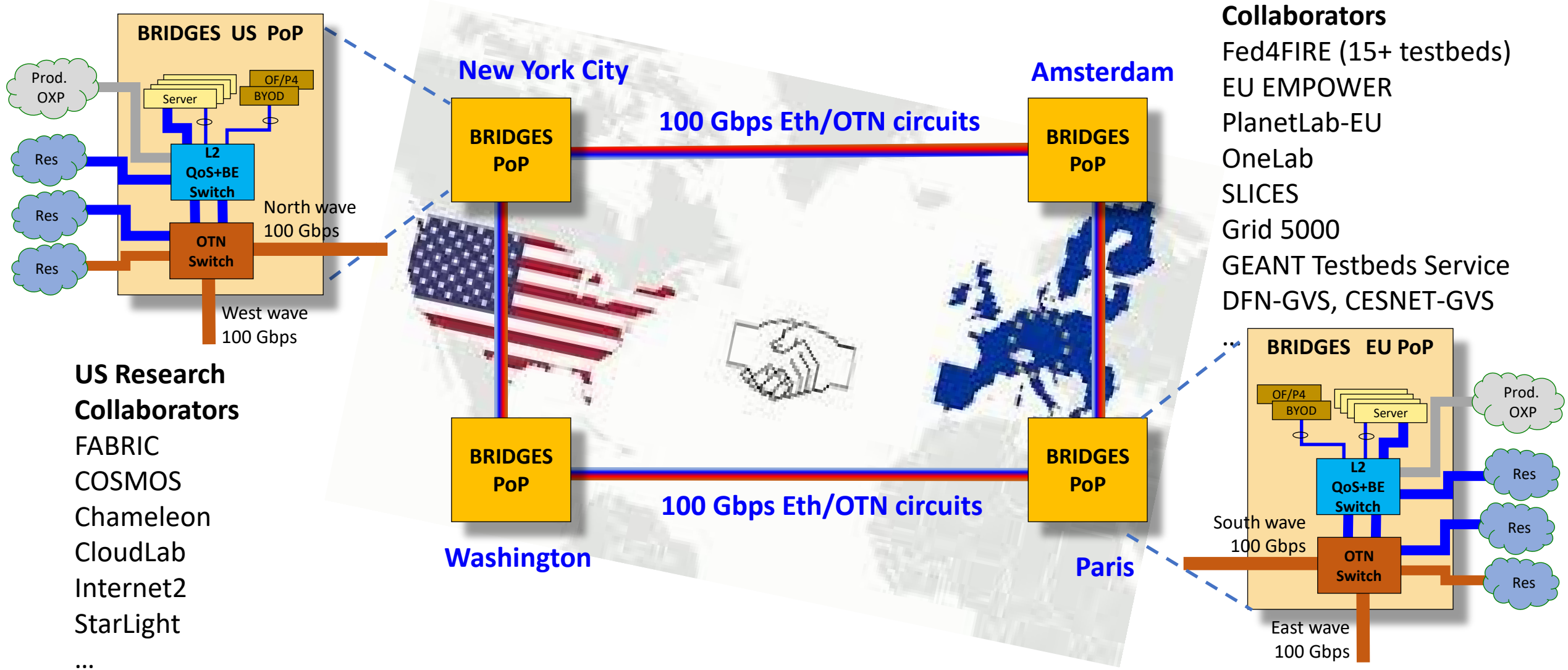
Introduction and Overview of the Project

What is "BRIDGES" ?

- Long acronym: "Binding Research Infrastructures for the Deployment of Global Experimental Science"
- Part of the NSF Int'l Research Network Connections (IRNC) program "Testbeds" platforms
- Funded by the US National Science Foundation (NSF)
  - $2.5M USD, 3 years

- BRIDGES goal is to make customized deterministic cyber-infrastructure resources available to advanced experimental applications globally
  - Predictable, deterministic performance – anywhere/everywhere
  - Agile and customizable to meet changing usage or application requirements
  - Globally scalable and globally secure architecture
- Start with US and European collaborators

BRIDGES- Binding Research Infrastructures for the Deployment of Global Experimental Science



US Research Collaborators

FABRIC
COSMOS
Chameleon
CloudLab
Internet2
StarLight
…

EU Research Collaborators

Fed4FIRE (15+ testbeds)
EU EMPOWER
PlanetLab-EU
OneLab
SLICES
Grid 5000
GEANT Testbeds Service
DFN-GVS, CESNET-GVS
…

Key BRIDGES Project Objectives

- Establish and operate a long term physical infrastructure that supports globalized *experimental* networked and distributed CI applications

- Demonstrate the efficacy of a Generic Virtualization Model to deliver cyber-infrastructure resources on a global scale – dynamically with deterministic performance attributes

- Enable integrated/unified research infrastructures that can span the Atlantic.

BRIDGES Project Team:

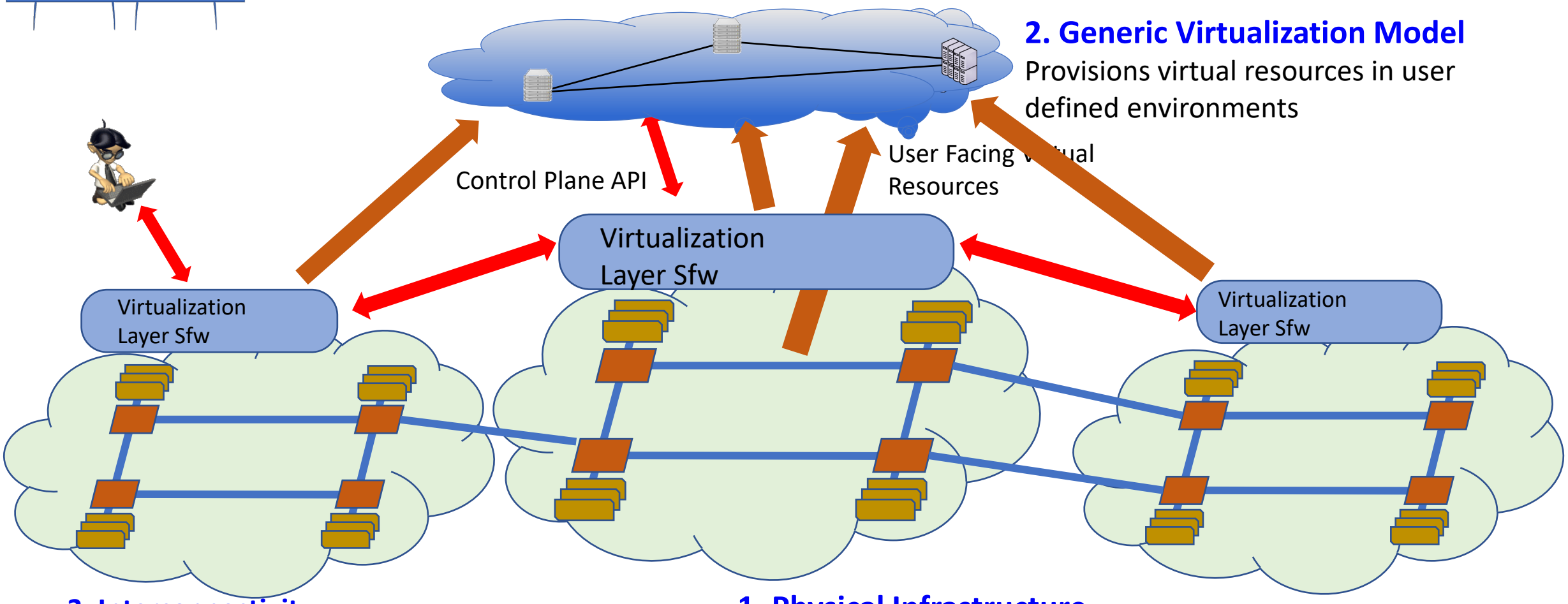
- **George Mason University** (Fairfax, VA)
  - Dr. Bijan Jabbari (Principle Investigator)
  - Jerry Sobieski (Co-PI)
  - GMU leads the infrastructure engineering and software deployment

- **East Carolina University** (Greenville, NC)
  - Dr. Ciprian (Chip) Popoviciu (Co-PI)
  - ECU heads up virtualized operational component, and is key in software development

Project Partners

- Juniper Networks
  - Packet switching equipment
  - PoC: John Jamison (Reston, VA)
- Ciena
  - OTN switching equipment
  - PoC: Marc Lyonnais, Rod Wilson, Lance Williford   (Ottawa, CA)
- Global Cloud Exchange
  - 100Gbps trans-Atlantic waves
  - PoC: Daniel Minns (London, UK)
- SURFnet and Internet2
  - Terrestrial dim-spectrum EU and US respectively

BRIDGES Three Primary Components:



2. Generic Virtualization Model
Provisions virtual resources in user defined environments

3. Interconnectivity
Data plane interconnection, control plane interoperation, mgmt plane federation. Connect other domains, interworking of provisioning mechanisms, and unified policy for federation

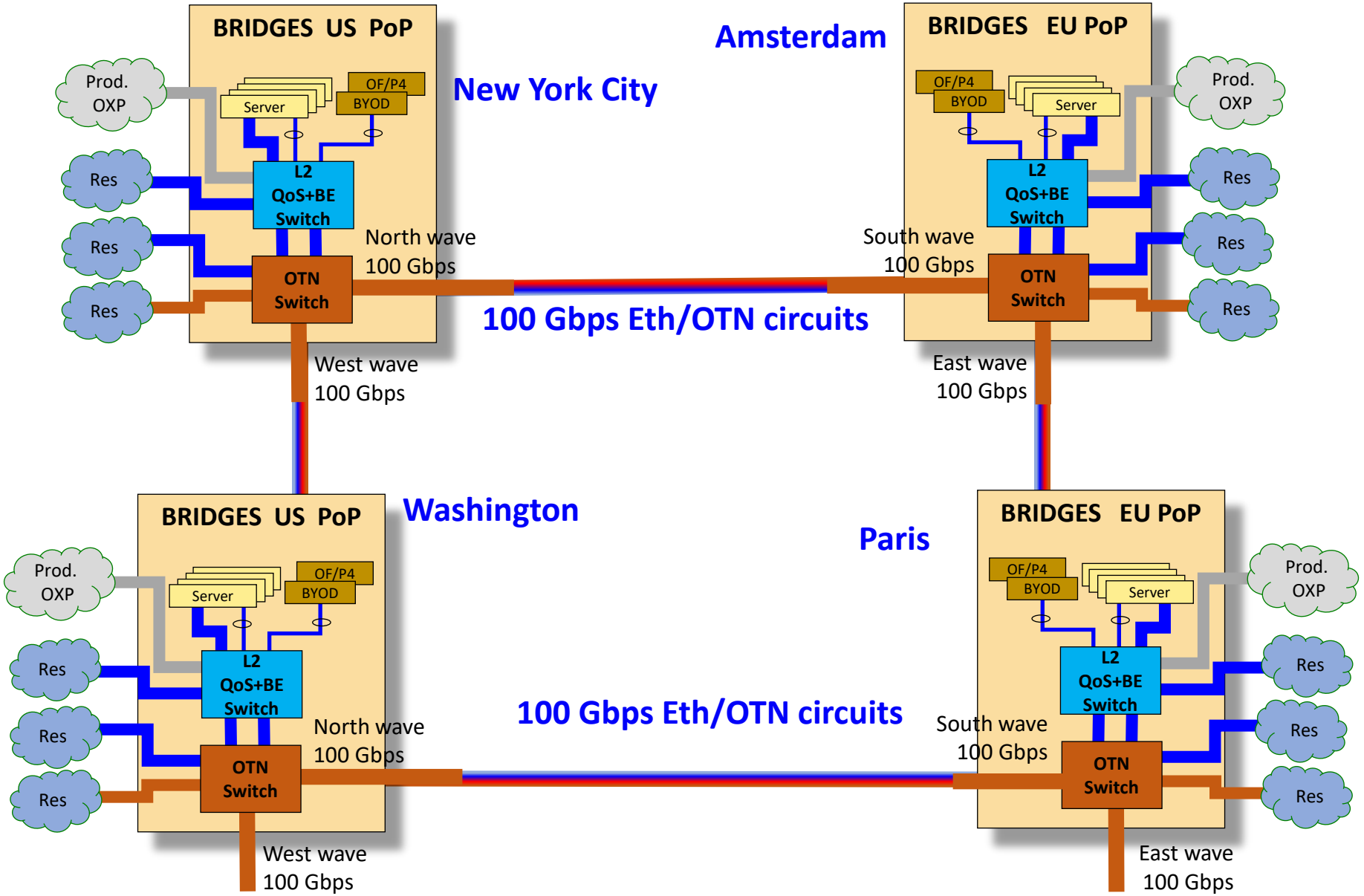
1. Physical Infrastructure
Transport circuits, switching elements, compute platforms, storage systems

Infrastructure: The Ring

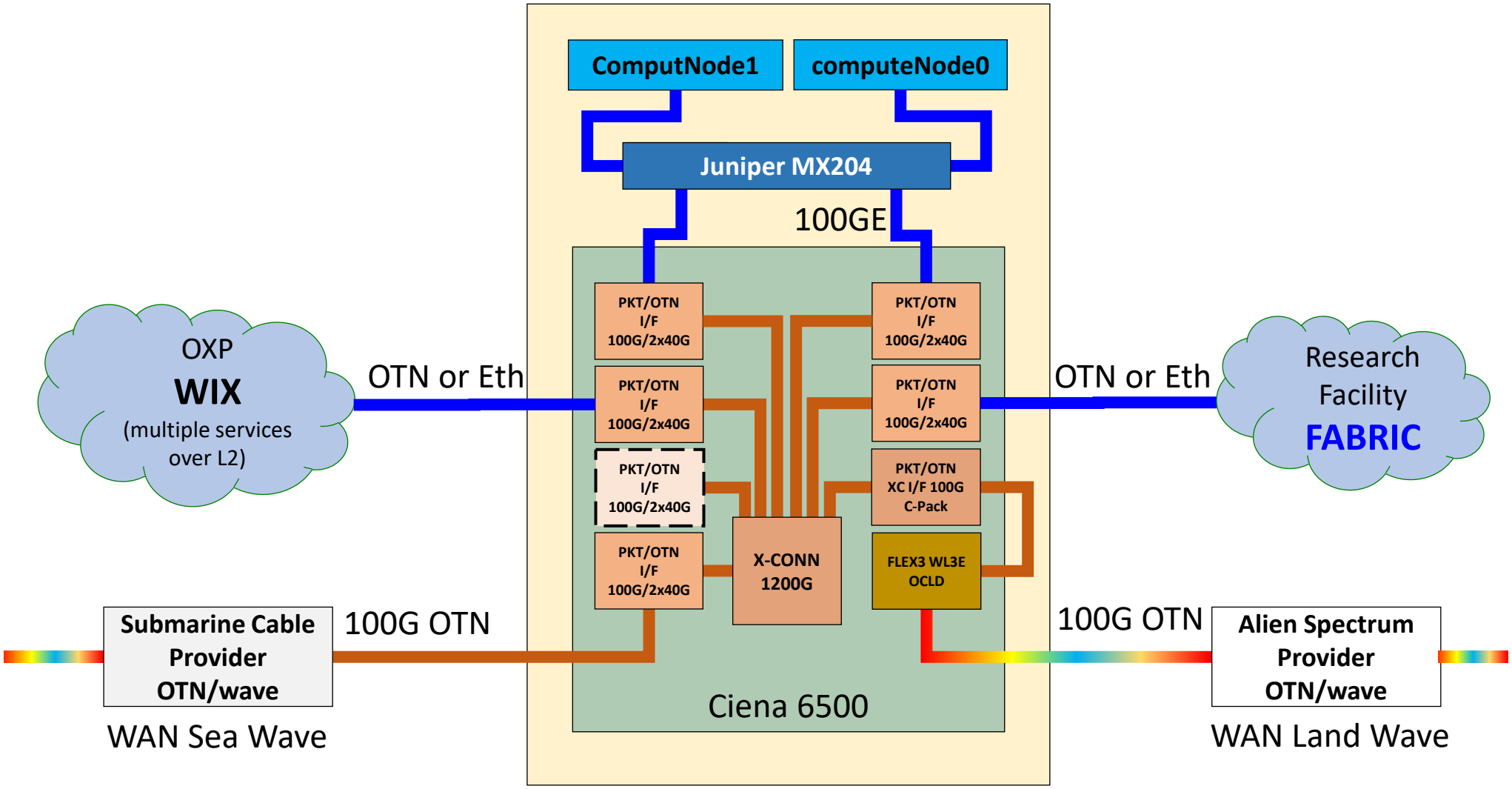
- Four “Nodes” connected by four 100 Gbps waves.
  - Washington, DC US (Equinix Ashburn, VA)
  - Paris, FR (Interaxion)
  - Amsterdam, NL (NetherLight/SURFnet)
  - New York City, NY US (MANLAN)
- Each BRIDGES node occupies its own dedicated rack and is composed of BRIDGES dedicate equipment, completely managed by the BRIDGES project
  - Nodes are collocated with global R&E open exchange points to facilitate physical X-connects when/where needed.
- The Waves are all 100 Gbps ETH/OTN framing.
  - Allows link concatenation up to 200 Gbps and deterministic performance provisioning. Ciena 6500 OTN hdw + Juniper MX204 hdw
  - Trans-Atlantic waves are 10 yr IRU from WDC-PAR, and from NYC-AMS. (GCX provider)
  - Land waves are dim spectrum from WDC-NYC (I2) and AMS-PAR (SURFnet)
- Each node will offer multicore X86 virtual machines with up to 100Gbps network.
- Other hdw can be inserted to support other technologies in the Infrastrcuture (e.g. P4, GPUs, etc.)

- *BRIDGES is an experimental Testbed*
  - How BRIDGES is applied to support science applications and other research is fully under control of the BRIDGES program and BRIDGES users

Infrastructure: The Ring



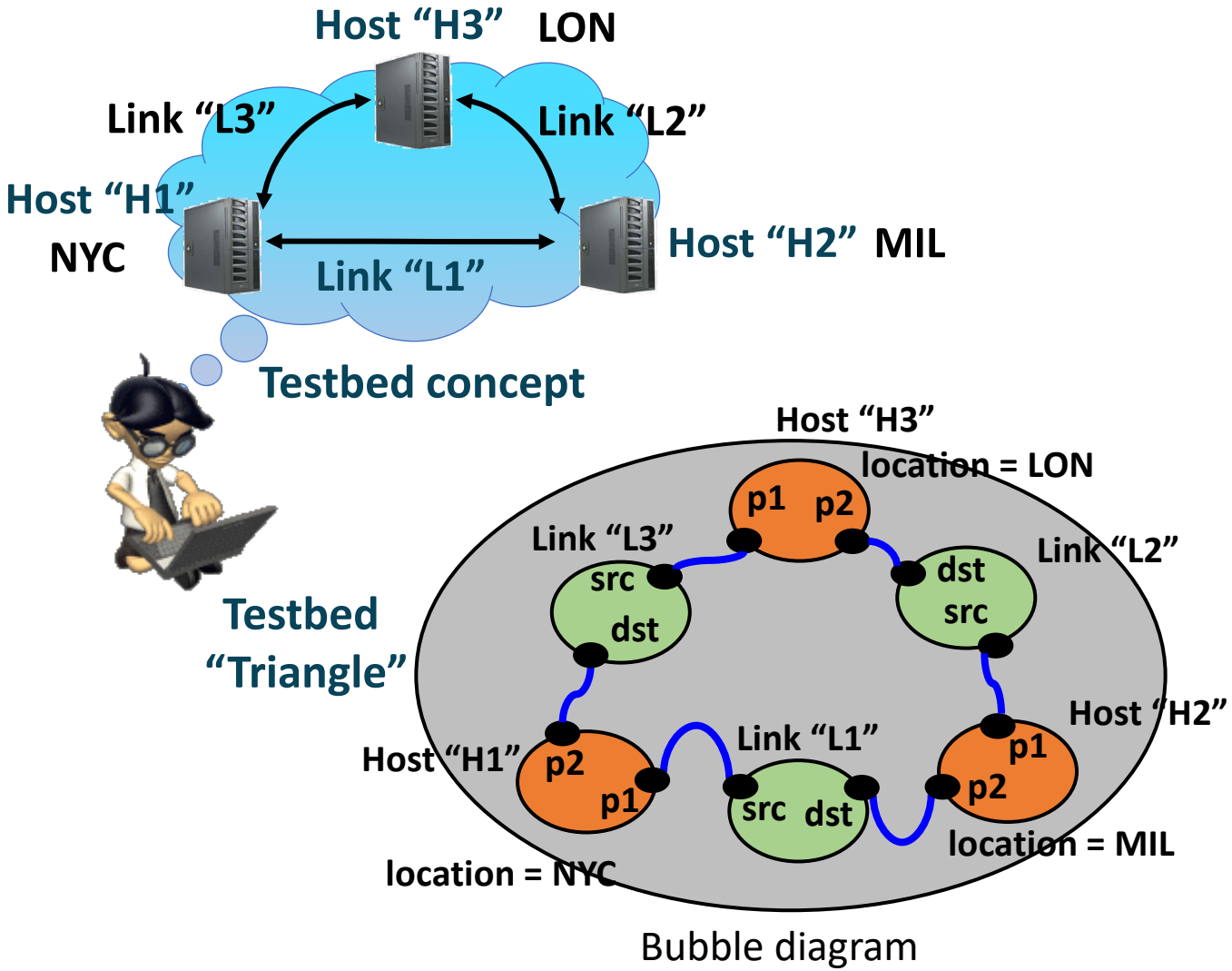
The Infrastructure: The Nodes



Virtualization as an Architecture

- BRIDGES asserts that ”virtualization” is an ***architectural*** concept – not simply a software technique
  - This is not simply a collection of things labeled “virtual”
- BRIDGES promotes a **Generic Virtualization Model**
  - All user facing resources are *virtual* – i.e. each virtual resource is predefined with a closed set of attributes that users can select and tune to their applications’ requirements.
  - A set of commonly used functional resources are defined as base “atomic” resources:
    - Virtual circuits, virtual machines, virtual switches, etc.
  - More complex or specialized virtual resources can be defined through composition.
    - Composite resources can be user defined.
  - Users and applications interact with the BRIDGES virtual services environment either through an interactive web portal or via a programmatic API to enable automation and orchestration.
- BRIDGES operates a “fully virtualized” services environment
- All BRIDGES resources allocated to collaborating projects will be “virtual resources”
  - The GVM control and management does not insert itself between th euser and the virtualized resource… Thus resources can exhibit up to full native hardware performance
  - These resources will look and feel as if they are dedicated physical infrastructure
  - Deterministic, predictable performance, agile, customizable, integrated virtual resource model

The Generic Virtualization Model Constructs

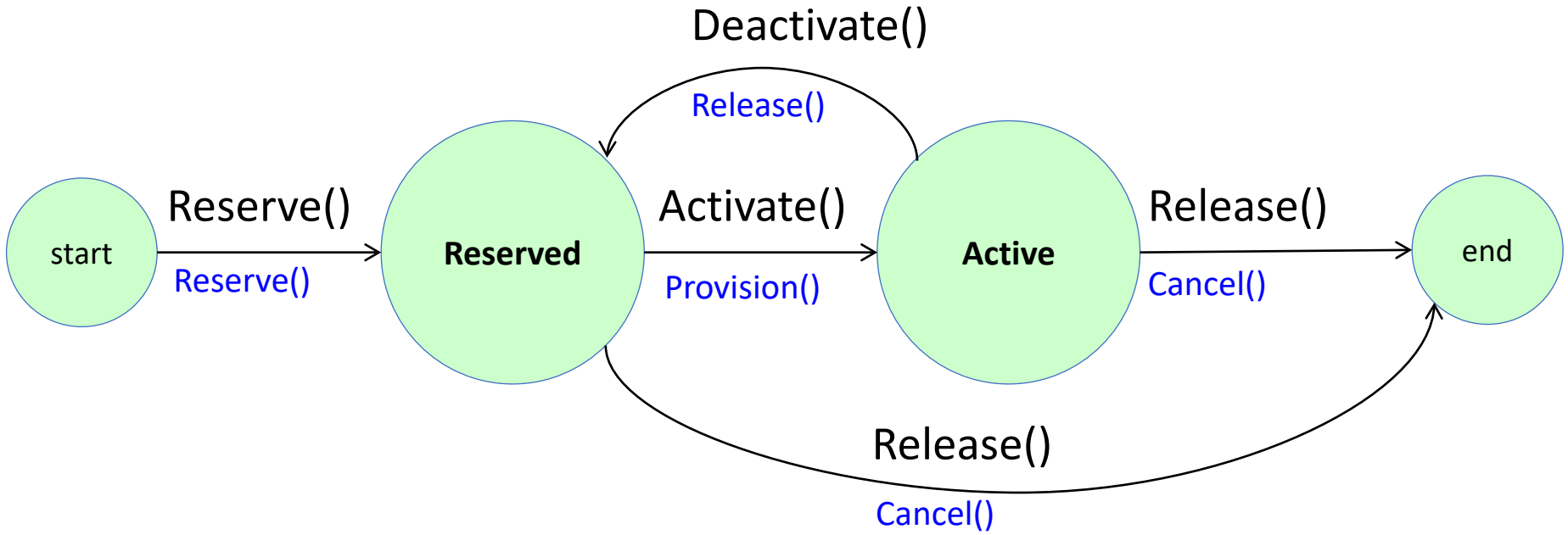


Bubble diagram

```
triangle {
  host {
    id="h1"
    location=”nyc"
    port { id=”p1" }
    port { id=”p2" }
  }
  host {
     id="h2"
     location="mil"
     port { id=”p1" }
     port { id=”p2" }
   }
   host {
     id="h3"
     location="lon"
     port { id=”p1" }
     port { id=”p2" }
  }
  link {
     id="l1"
     port { id="src" }
     port { id="dst" }
   }
 link {
     id="l2"
     port { id="src" }
     port { id="dst" }
   }
  link {
     id="l3"
     port { id="src" }
     port { id="dst" }
   }

   adjacency h1.p1, l1.src
   adjacency h2.p2, l1.dst

   adjacency h2.p1, l2.src
   adjacency h3.p2, l2.dst

   adjacency h3.p1, l3.src
   adjacency h1.p2, l3.dst

}
```

Done.

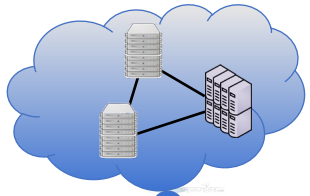
GVM Life Cycle Model



Virtual resource life cycle: **GVM / NSI**

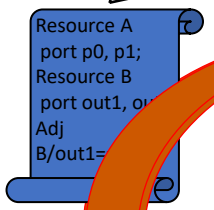
GVM User API primitives:

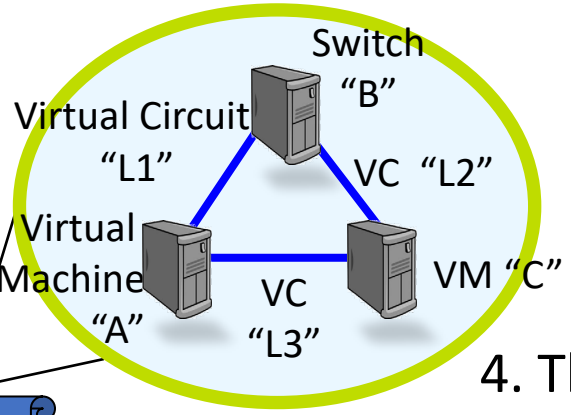
2. Network conceived to test brilliant idea



1. Researcher has a brilliant idea

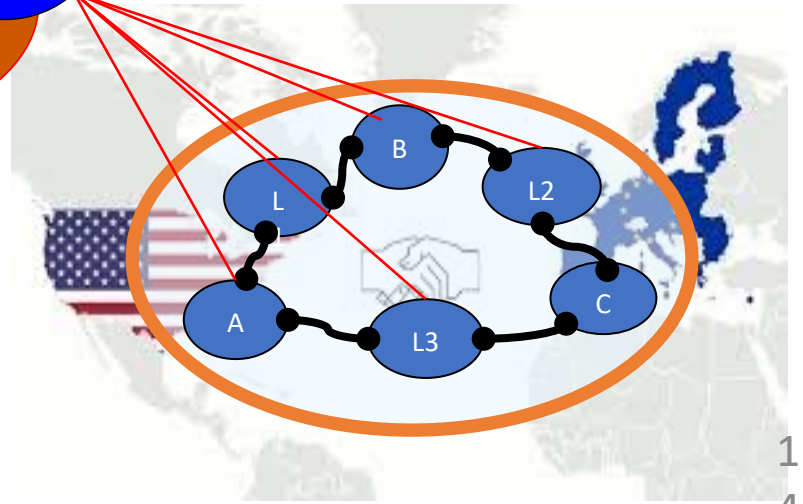
3. Researcher logs in, describes a testbed using a web GUI





4. The User Agent sends the testbed description to GTS using the GTS API

5. The GTS Provider Agent finds and reserves resources for the testbed



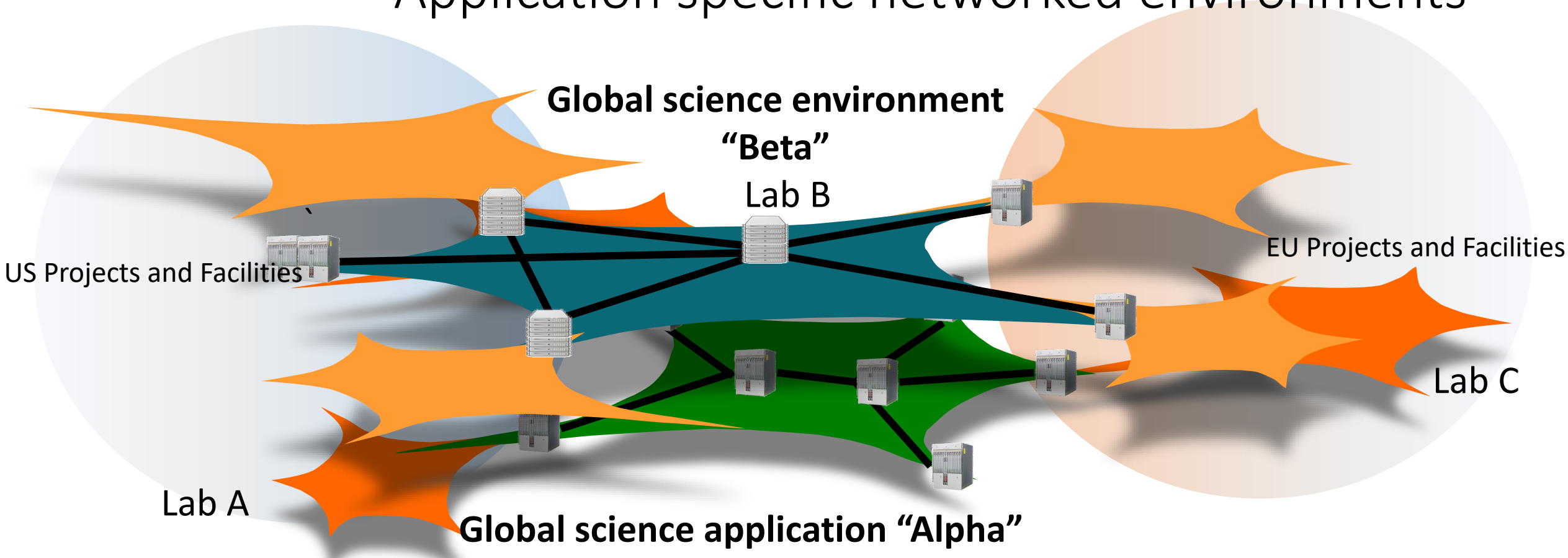
6. Resource ID information is returned to the user and user controls the testbed via the User GUI and other GTS API primitives

US-EU Collaborative Research

- The BRIDGES project is working with over 30 network and CS research projects in the US and EU. These are the initial collaborators and/or beneficiaries of the project
  - FABRIC, COSMOS, Chameleon, CloudLab, Esnet, EdgeNet, StarLight/iCAIR, Internet2, AutoGOLE
  - SLICES, Fed4FIRE, EUWireless, Onelab, 5G EMPOWER, PlanetLab-EU, Grid5000, NetherLight/SURF, SCION, UvA, GEANT, CESnet, DFN, NORDUnet
- BRIDGES PIs work closely with both US and European network research communities and can act as liaison for US projects to reach potential EU collaborators - and vice-versa
- BRIDGES is seeking additional scientific applications that can benefit from highly customizable international cyber-resources
- “Equitable Reciprocity” – The governing BRIDGES access/usage policy that enables open access to projects and infrastructures in US and EU.
  - ER is essential to developing advanced automated policy engines that can be adopted/adapted to the larger R&E global infrastructure domains

BRIDGES Virtual Network Architecture

Application specific networked environments



A customized WAN infrastrcuture consisting of a broad range of dynamically allocated resources that are controlled by the client using SDN principles

Whats Missing?

- Simplification – reduce the operational complexity of deployment, configuration, and management of a virtual CI architecture.
  - This will aid in adoption and common virtualized resource objects
- Federation – this relies upon:
  - Multi-Domain+Transparency – ability to allocate resources from/across many administrative domains transparently into an integrated user environment
  - Scalable Adaptable Policy Engine – to allow domains to better manage their available resources across many global user communities and priorities.
- Advanced mapping algorithms for optimization (placement, migration, and grooming) of virtual resources across physical infrastructure and multiple policy domains. Integration of AI driven mapping and grooming
- Explore sensor virtualization
- Enhanced 5G virtualization

Timeline.

- BRIDGES is a 3 yr Project:
  - Year 1 Oct 2020 – Sep 2021
    - Build out Washington and Paris nodes and Trans-Atlantic wave
    - Deploy GVS software
    - First connectors Q2/Q3 2021
    - Target Initial In-Service date ~Jul 2021
  - Year 2. Oct 2021 – Sep 2022
    - Build out Amsterdam and New York pops and terrestrial optical links in US and EU
    - Target In-Service dates Jan-Mar 2022
    - More connectors, More software features
    - Deploy second 100 Gbps wave. NYC-AMS
  - Year 3 Oct 2022 – Sep 2023
    - NYC-AMS wave In-Service :Jan 2023. Ring closed.
    - Software focus – new features

Looking forward down the road…

- The BRIDGES concept envisions a future integrated global CI environment in which dynamic and deterministic “virtual” cyber-resources become the standard coin of the realm.
  - Instead of physical infrastructure, networks and science applications are constructed from virtual resources (both hardware analogs and software functions) that offer secure, predictable performance; agile dynamic allocation or modification, and ease of use and operation.
- BRIDGES would like to extend the GVM architecture to other national and international deployments, incrementally extending the experimental virtualization canvas to a global reach.

Conclusion: Key BRIDGES Concepts

- Network research and global applications require **experimental facilities** - very flexible, agile, and deterministic cyber-infrastructure environment – with a **global reach** - in order to innovate, evaluate, and evolve
- Cyber-infrastructure is going virtual and software processes are critical to managing these CI resources. But automation and orchestration of CI, and the integration of different CI elements is dependent upon a common model for defining and manipulating these virtual resources – **a Generic Virtualization Model.**
- **BRIDGES provides the experiment cyber-infrastructure and the virtualization layer software to do this.**

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- Web site under construction – tba very soon.