GENI: Global Environment for Network Innovations

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March 10, 2006

GENI Initiative

- Research Program
  - e.g., FIND program in NeTS solicitation
- Experimental Facility
  - proposal to MREFC program
    - jointly from CISE and the research community
  - funds (cutting-edge) facility construction, not research
  - we currently have a “Conceptual Design” document
  - will eventually require Congressional approval

Planning Group

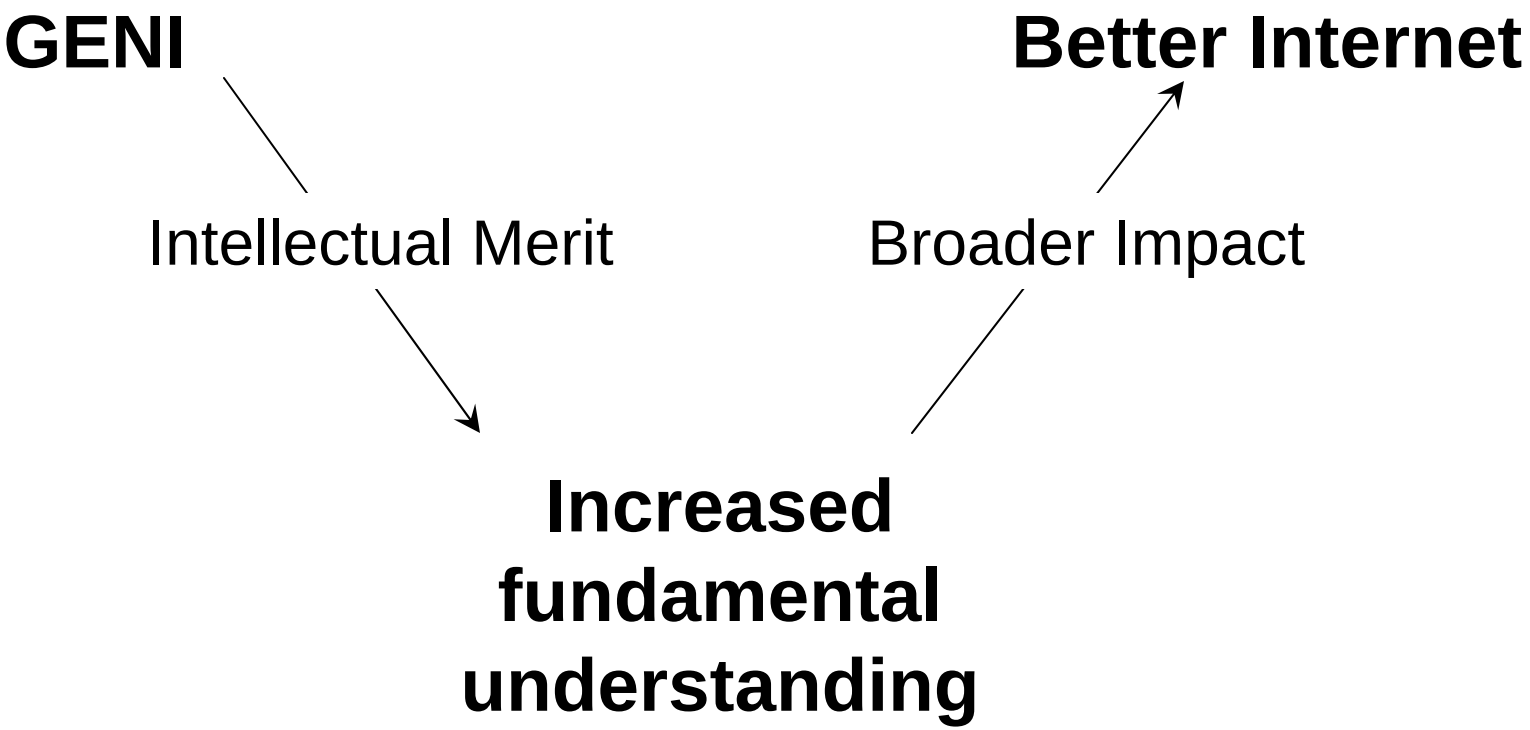
- Tom Anderson, *Washington*
- Dan Blumenthal, *UCSB*
- Dean Casey, *Ngenet Research*
- David Clark, *MIT*
- Deborah Estrin, *UCLA*
- Larry Peterson, *Princeton* (Chair)
- Dipankar Raychaudhuri, *Rutgers*
- Mike Reiter, *CMU*
- Jennifer Rexford, *Princeton*
- Scott Shenker, *Berkeley*
- John Wroclawski, *USC/ISI*

Project Summary

- 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 move from a fully empirical to a more rigorously understood design process.

Change the Process



Broader Impact

- Lead to artifacts that provide value to society
  - An Internet for tomorrow
    - more secure, available, manageable, usable
    - suited for computing in the next decade
  - Catalyze the distributed digitized world
    - personal control of your personal life
    - real time sensing of the planet
- Lead to artifacts that provide value to science
  - Enhanced services that improve the scientific process

Intellectual Merit

- GENI will allow us to experimentally answer questions about complex systems, giving us an increased understanding about their dynamics, stability, evolvability, emergent behaviors, and so on. **[Science]**
- GENI will allow us to evaluate alternative architectural structures, and reconcile the contradictory goals a network architecture must meet. **[Architecture]**
- GENI will help us evaluate engineering tradeoffs, and test theories about how different architectual elements might be designed. **[Engineering]**

Outline

- Project Rationale
  - scientific case
  - need for a new facility
- Facility Design
  - physical substrate
  - software management framework
- Construction Plan
  - management organization
  - development teams

Research Scope

- Security and robustness
- New network technologies
  - wireless
  - optical transport
- New computing technologies
  - sensors, embedded systems, consumer electronics
- New distributed applications and services
- Service in times of crisis
- Network management
- Economic incentives

Research Scope (cont)

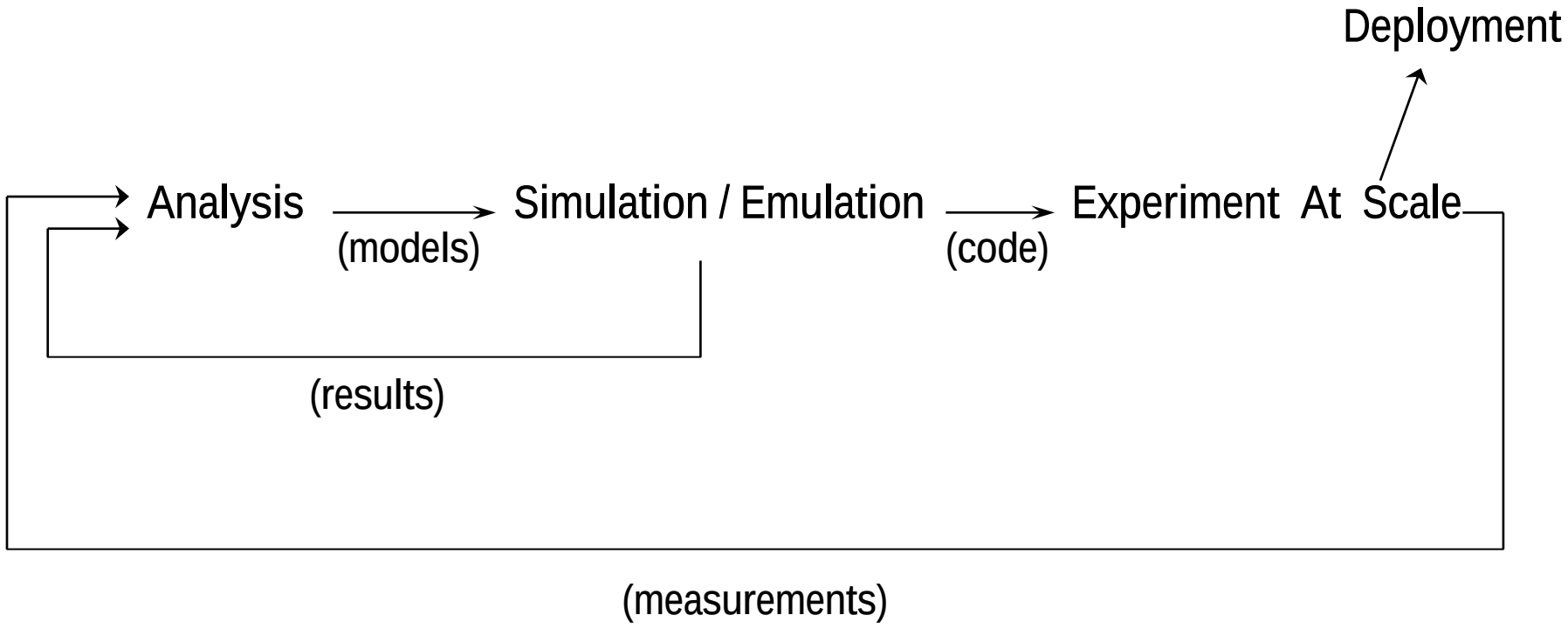
- Theoretical underpinnings
  - science of design
- Architectural limits
  - overlays versus new core
- Analysis and modeling
  - instrumentation built-in from the start
- Cross-boundary opportunities
  - network, distributed systems, wireless, optical
- Interdisciplinary opportunities
  - privacy, legal, societal, economic issues

Research Landscape

- Industry alone will not solve the problem
  - no incentive for architectural work
- Academic “research as usual” is not enough
  - not being “Internet compatible” is viewed as risky
- Architectural research starting to be done
  - vision papers, preliminary designs, feasibility studies
- Strategic choices
  - clean slate is a process, not an end goal
  - leverage different aspects of today’s architecture
  - work across traditional layers (not just “new IP”)
  - multiple “tech transfer” paths

Need for Infrastructure

Goal: Seamless conception-to-deployment process



Existing Tools

- Simulators
  - ns
- Emulators
  - Emulab
  - WAIL
- Wireless Testbeds
  - ORBIT
  - Emulab
- Wide-Area Testbeds
  - PlanetLab
  - RON
  - X-bone
  - DETER

Today's Tools Have Limitations

- Simulation based on simple models
  - topologies, admin policies, workloads, failures…
- Emulation (and "in lab" tests) are similarly limited
  - only as good as the models
- Traditional testbeds are targeted
  - often of limited reach
  - often with limited programmability
- Testbed dilemma
  - production: real users but incremental change
  - research: radical change but no real users

PlanetLab

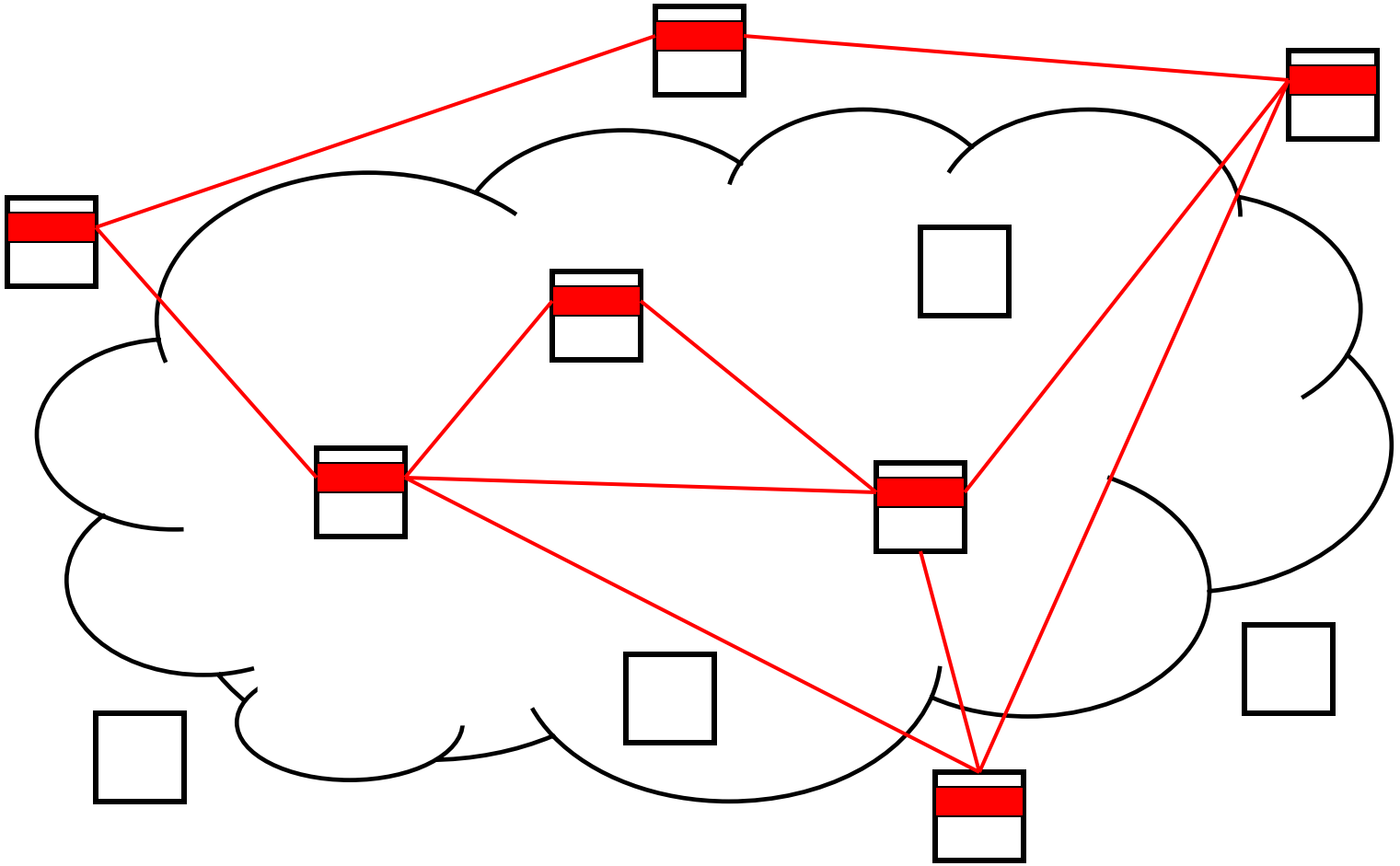
- New paradigm for network research infrastructure
  - Support experimental validation of new services
    - simultaneously support real users and clean slate designs
    - allow a thousand flowers to bloom
  - Provide plausible deployment path
- Key ideas
  - Virtualization
    - multiple architectures on a shared infrastructure
  - Programmable
    - virtually no limit on new designs
  - Opt-in on a per-user / per-application basis
    - attract real users
    - demand drives deployment / adoption

PlanetLab (cont)

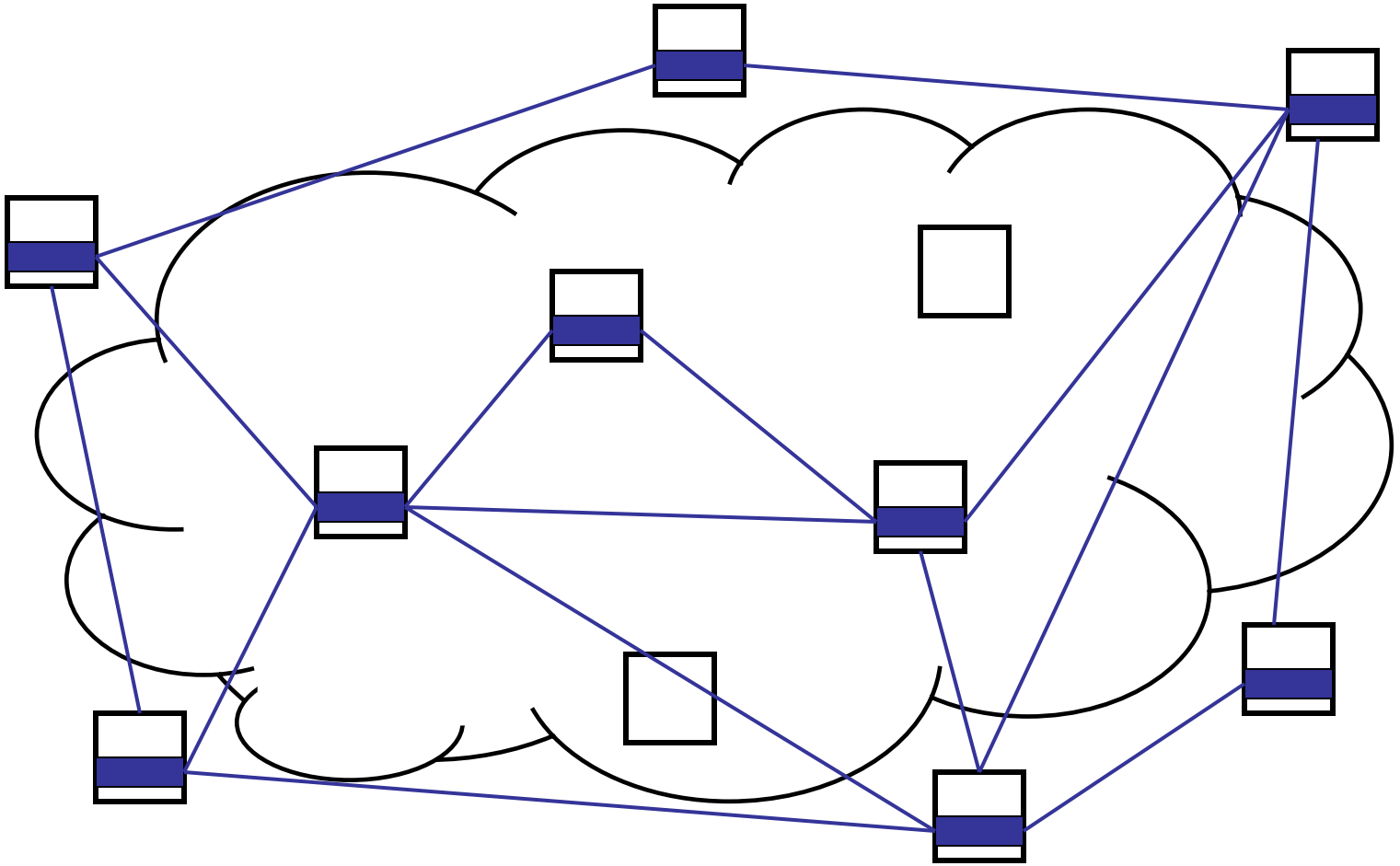
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- 645 machines spanning 310 sites and 35 countries
  - nodes within a LAN-hop of > 3M users
- Supports *distributed virtualization*
  - each of 375 network services running in their own *slice*
- Carries real user traffic
  - 3-4 TB per day / connects to over 1M unique IP address each day

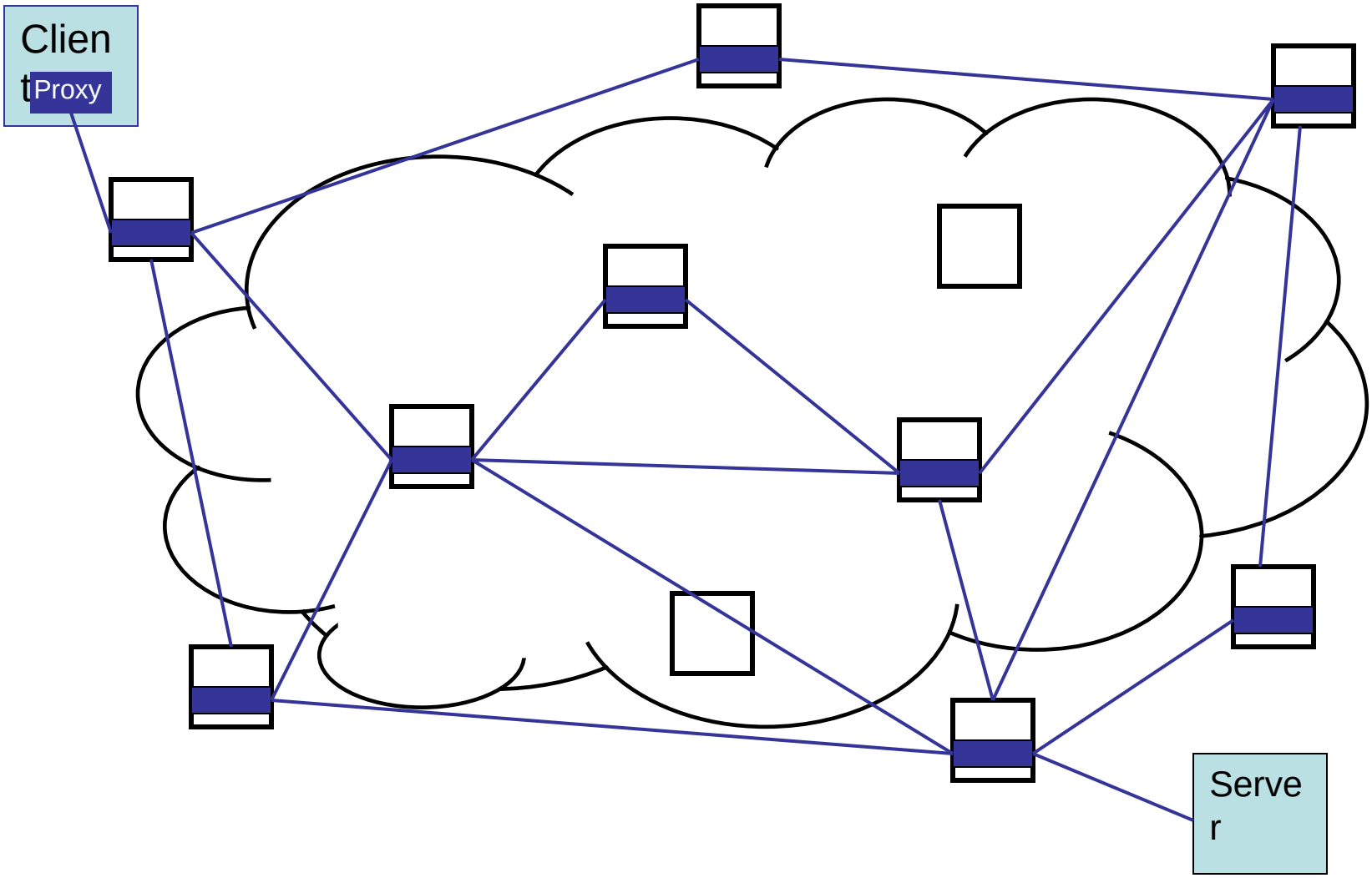
Slices



Slices



User Opt-in



Assessment

- Borrow ideas from PlanetLab
  - virtualization (slice abstraction)
  - support for user opt-in
- Improve upon this start
  - better provisioned
  - gentler learning curve for users
- Incorporate advantages of other testbeds
  - containment
  - reproducibility
  - heterogeneity (more diverse set of components)
- Extend in completely new ways
  - can be extended to incorporate new technologies
  - support for federation

Summary of Requirements

- Architecture/Service Neutrality
  - substrate is programmable
- Shared across multiple experiments
  - substrate is virtualizable (sliceable)
- Attracts real users
  - low barrier-to-entry for user opt-in
  - global reach
  - connected to legacy Internet
- Sustainable / Unbounded Potential
  - federation across multiple countries and communities
- Diverse and Extensible
  - defines interfaces that permit new technologies

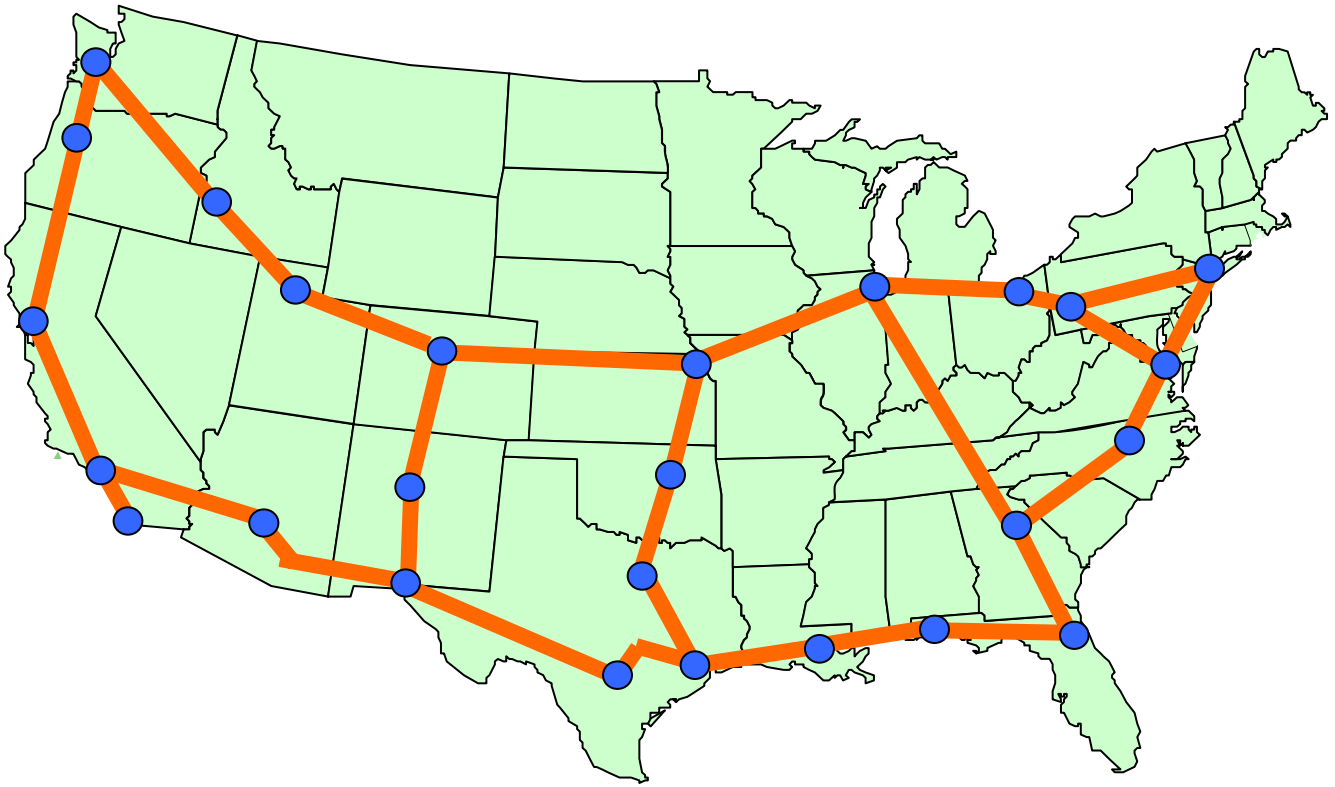
Success Scenarios

- Caveat: unexpected consequences (uses)
- Change the research process
- Possible outcomes (broad impact)
  - create new network services
  - converge on a single new architecture and deploy it
  - virtualization wins: plurality of architectures
  - architectural clarity for current incremental path
- Deployment scenarios
  - transformational pressure
  - alternative “ISPs” emerge

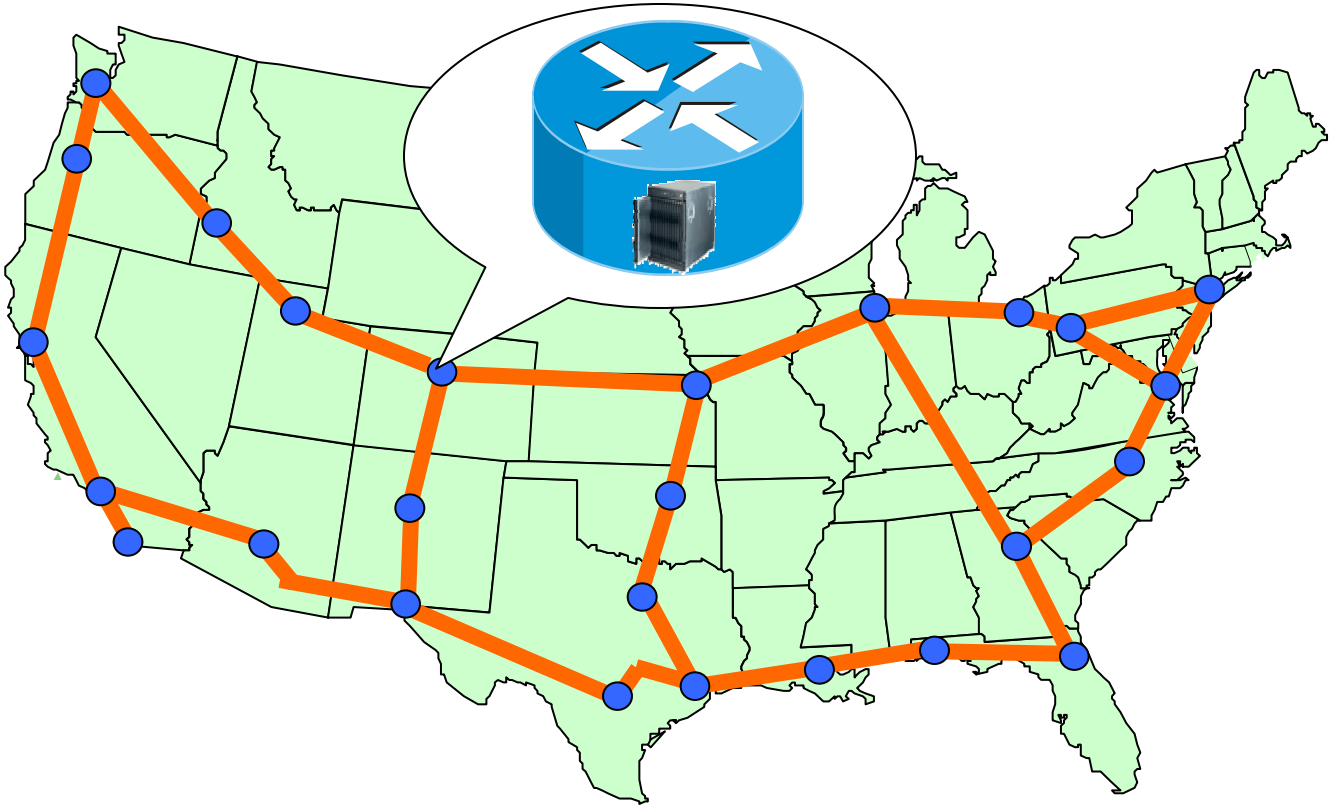
GENI Design

- Key Idea
  - *Slices* embedded in a *substrate* of networking resources
- Two central pieces
  - Physical network substrate
    - expandable collection of building block components
    - nodes / links / subnets
  - Software management framework
    - knits building blocks together into a coherent facility
    - embeds slices in the physical substrate

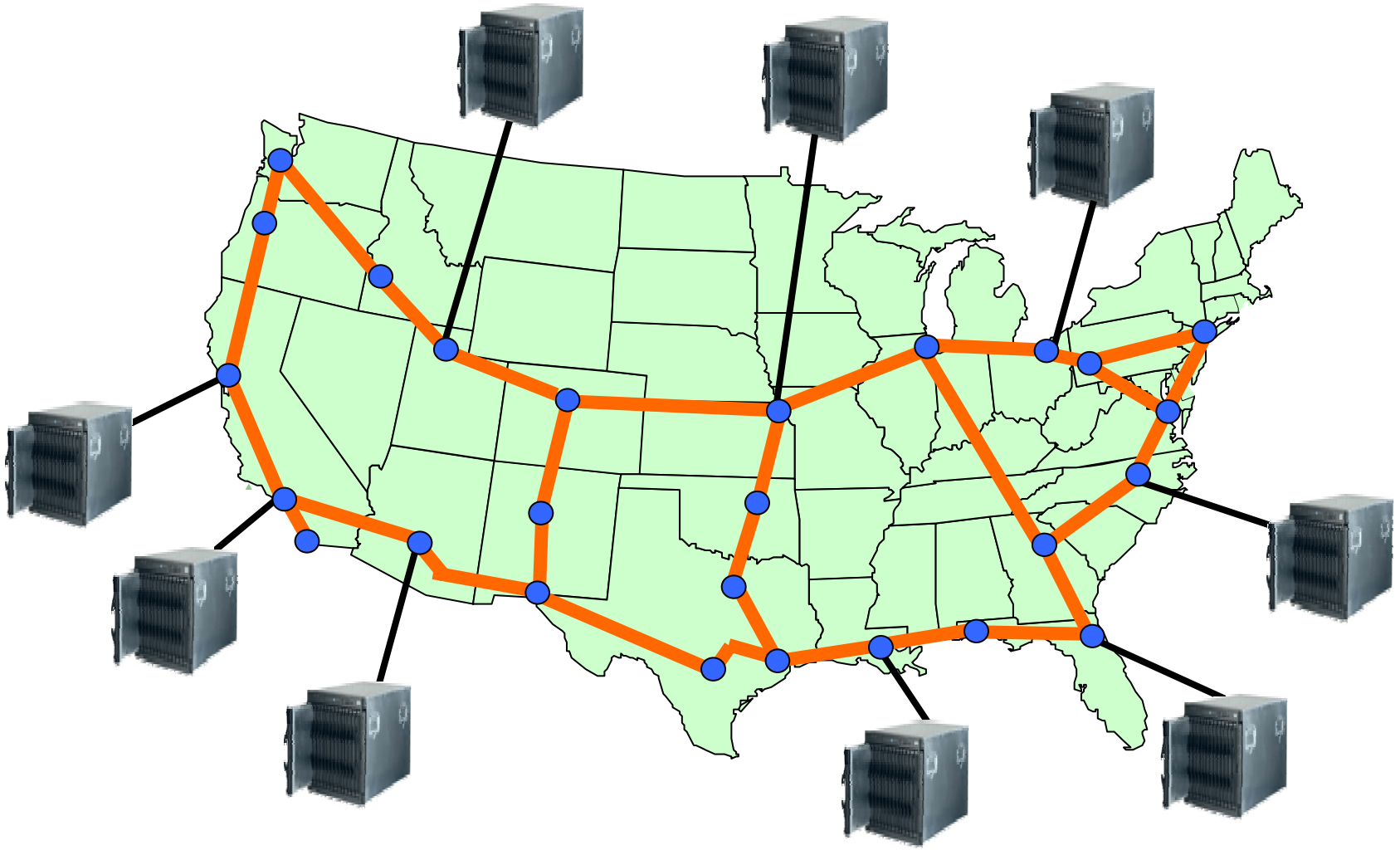
National Fiber Facility



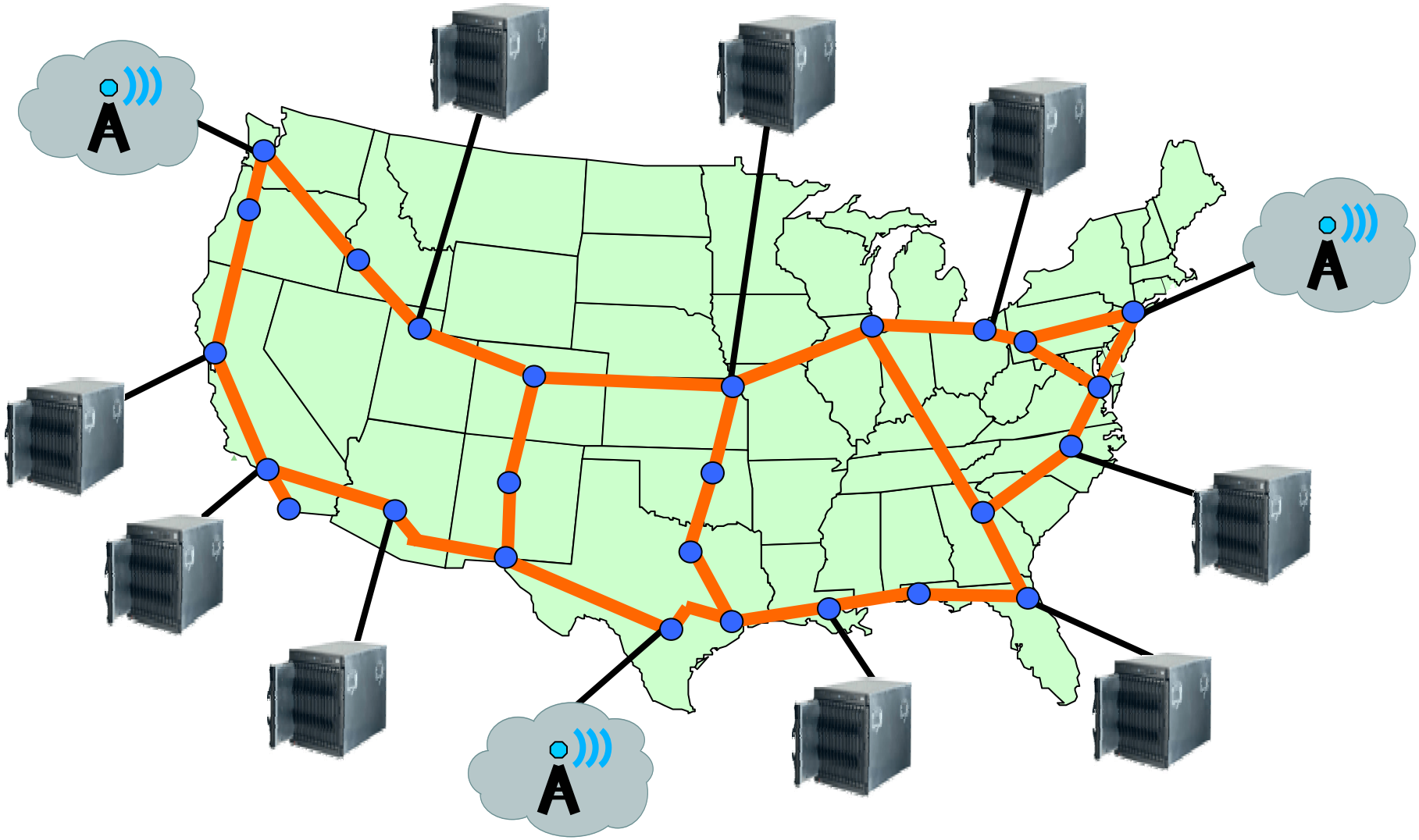
+ Programmable Routers



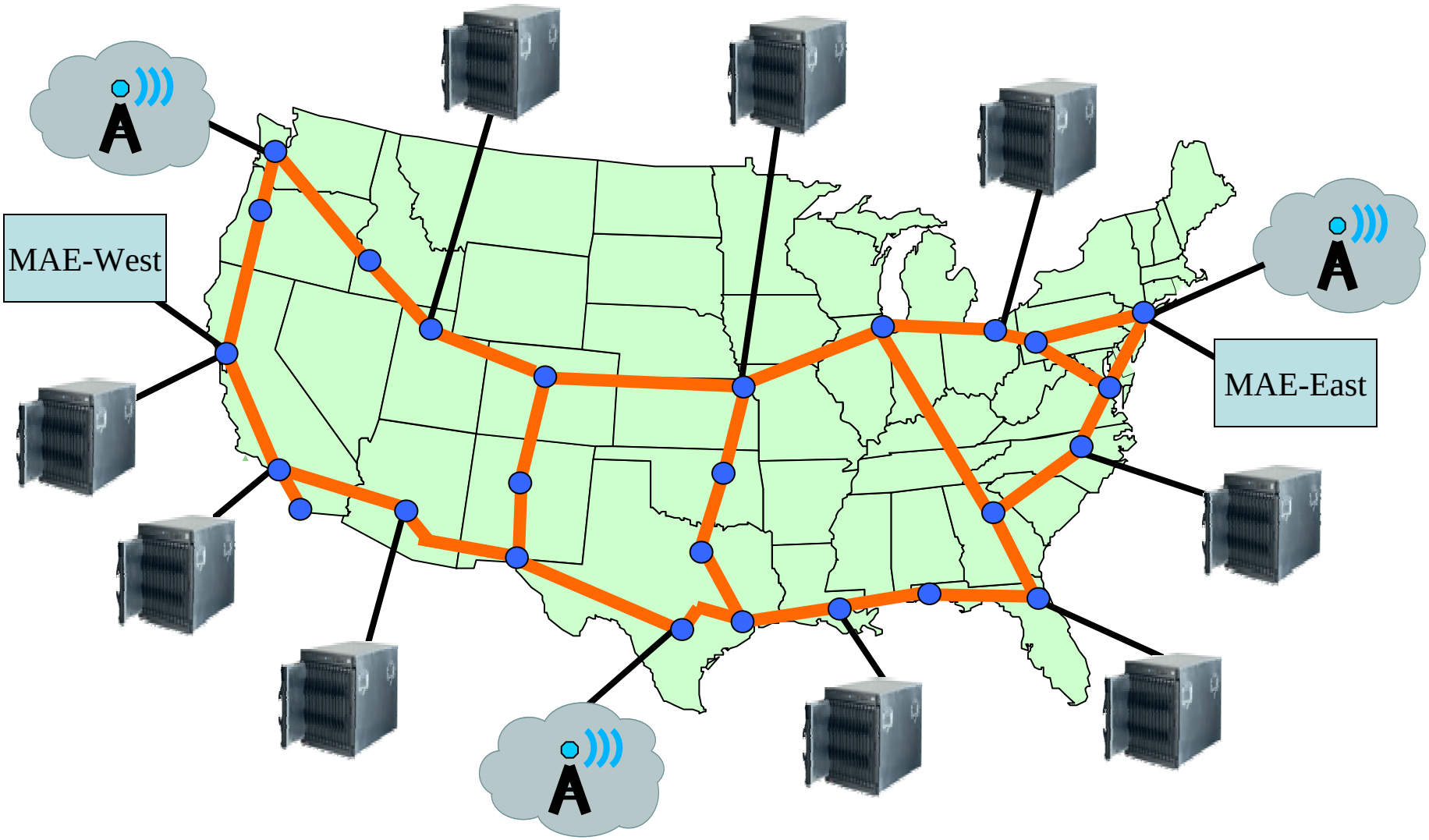
+ Clusters at Edge Sites



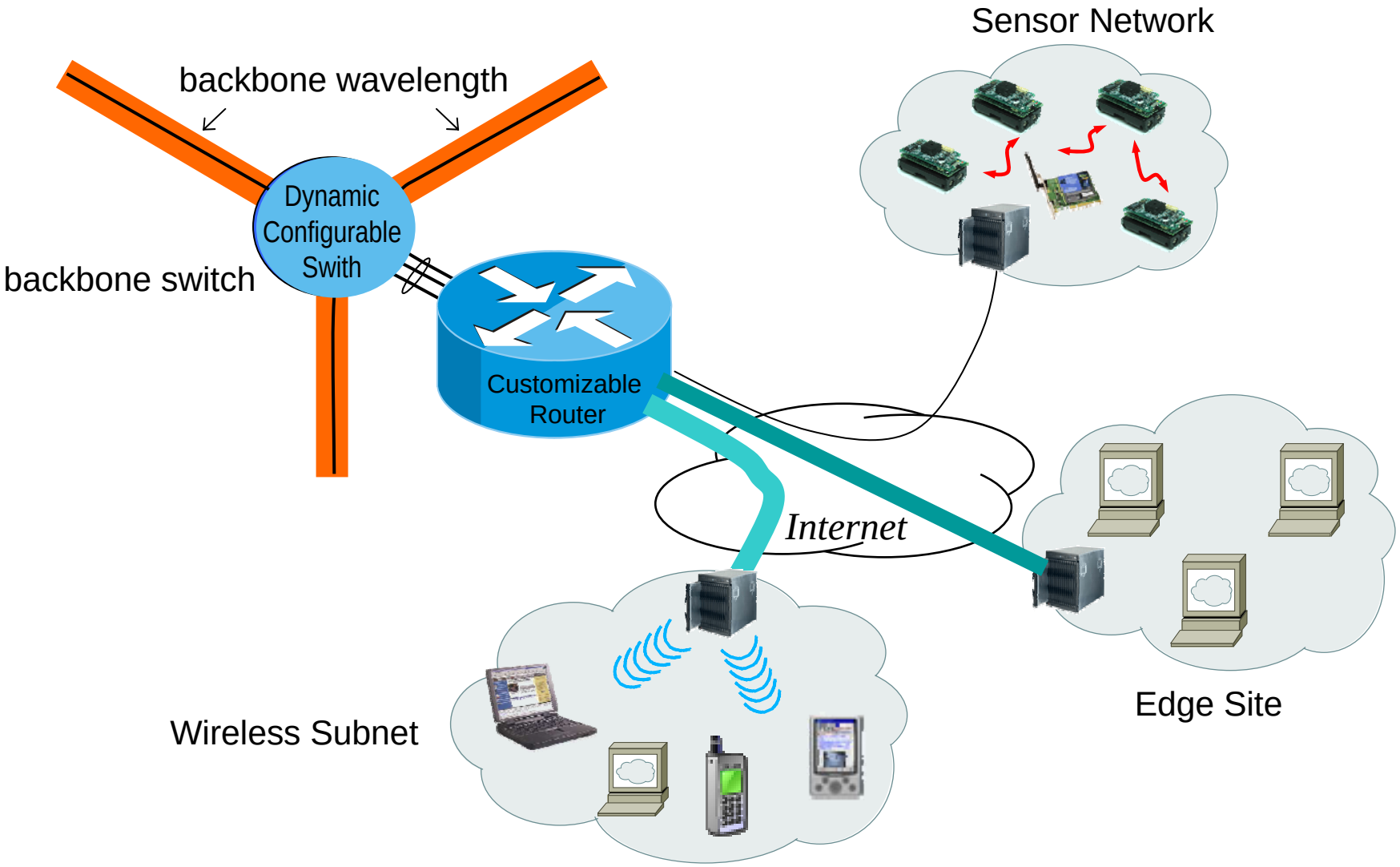
+ Wireless Subnets



+ ISP Peers



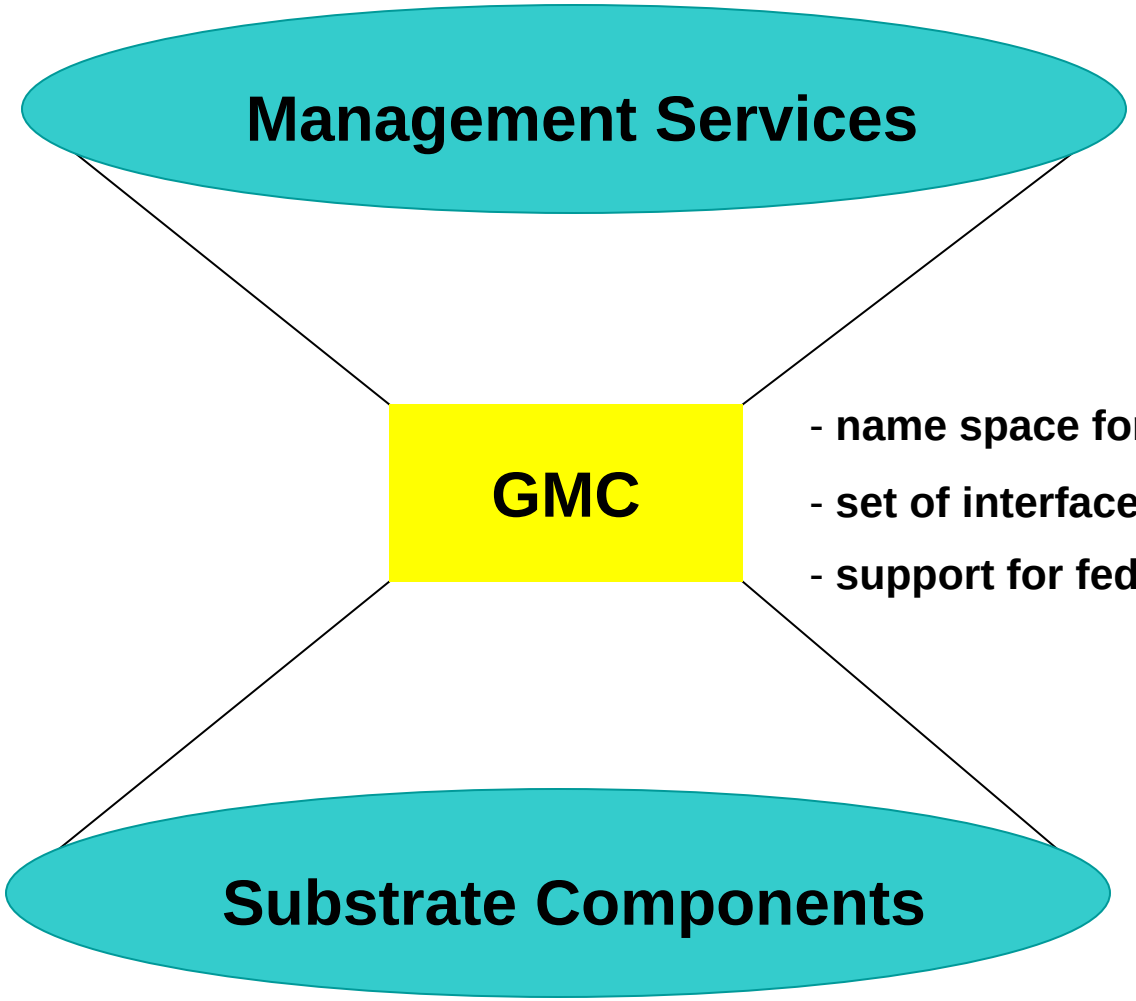
Closer Look


Sensor Network
backbone wavelength
Dynamic Configurable Swith
backbone switch
Customizable Router
Internet
Edge Site
Wireless Subnet

Summary of Substrate

- Node Components
  - edge devices
  - customizable routers
  - optical switches
- Bandwidth
  - national fiber facility
  - tail circuits (including tunnels)
- Wireless Subnets
  - urban 802.11
  - wide-area 3G/WiMax
  - cognitive radio
  - sensor net
  - emulation

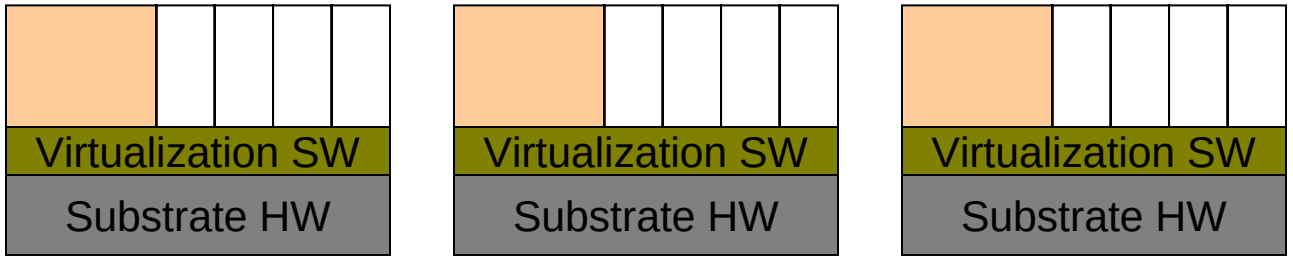
Management Framework



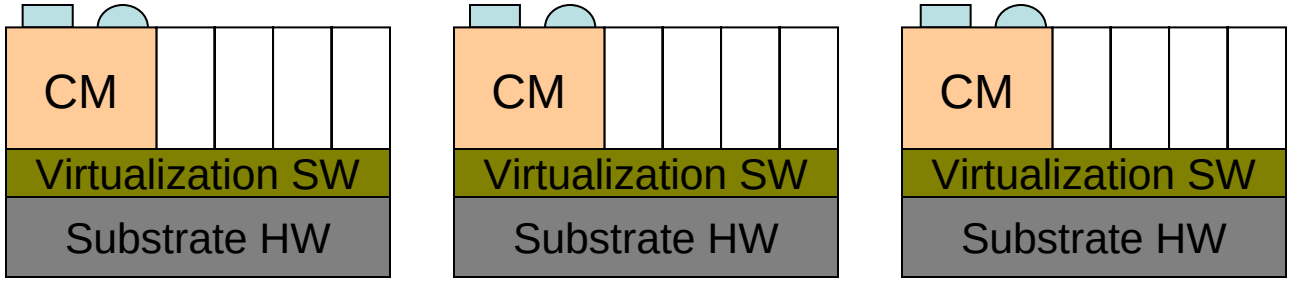
- name space for users, slices, & components
- set of interfaces (“plug in” new components)
- support for federation (“plug in” new partners)

Hardware Components

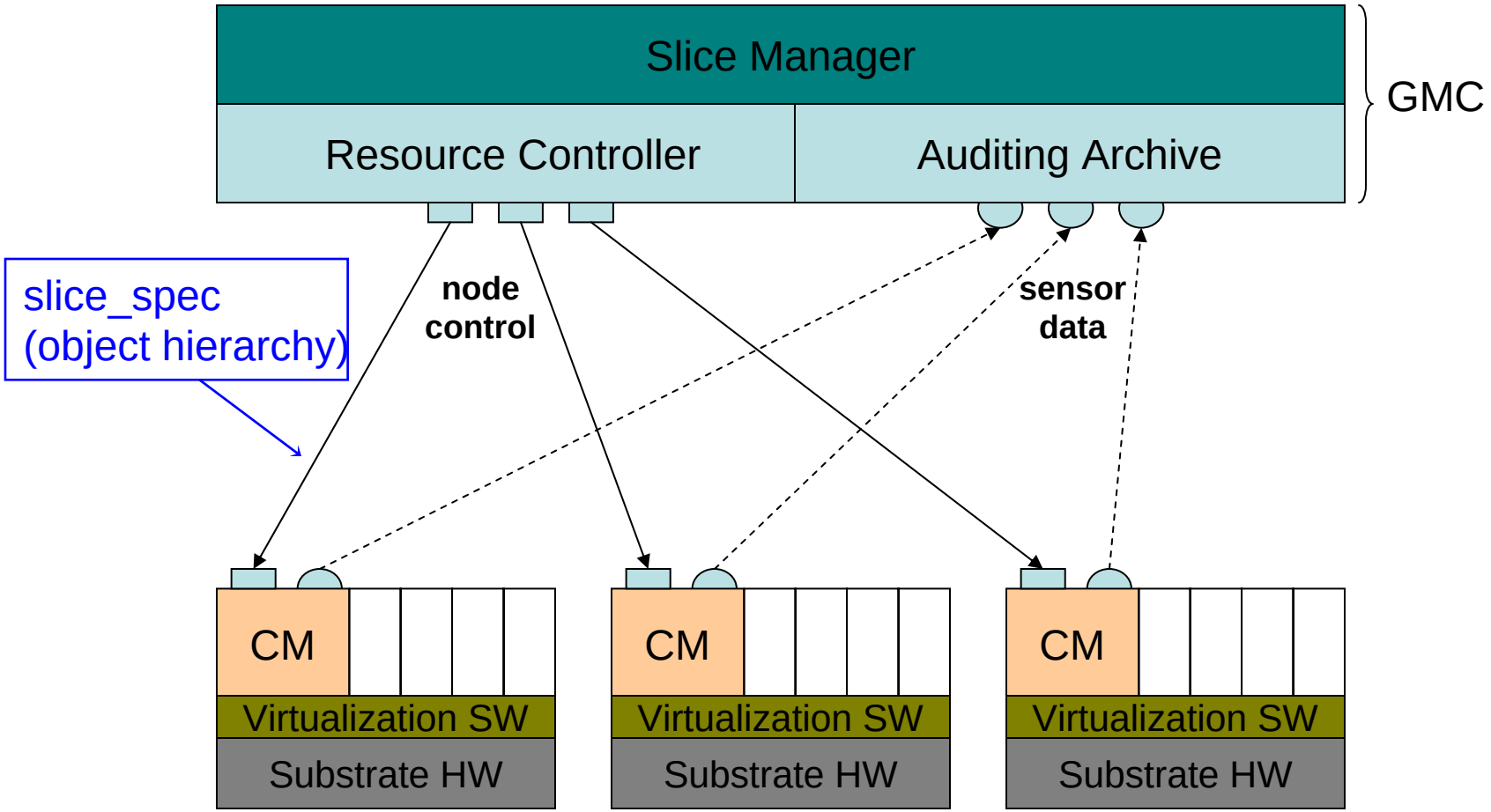
Virtualization Software



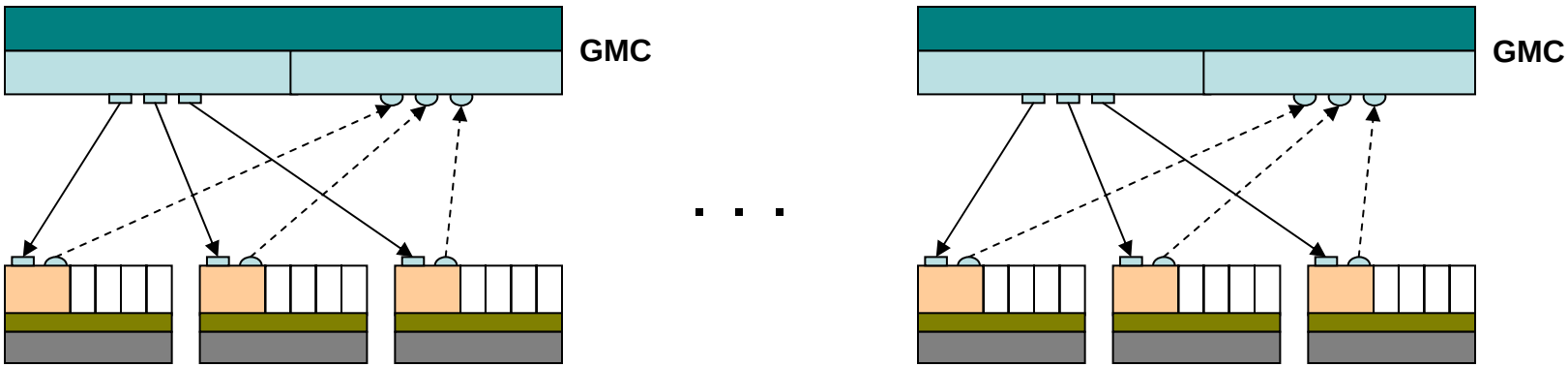
Component Manager



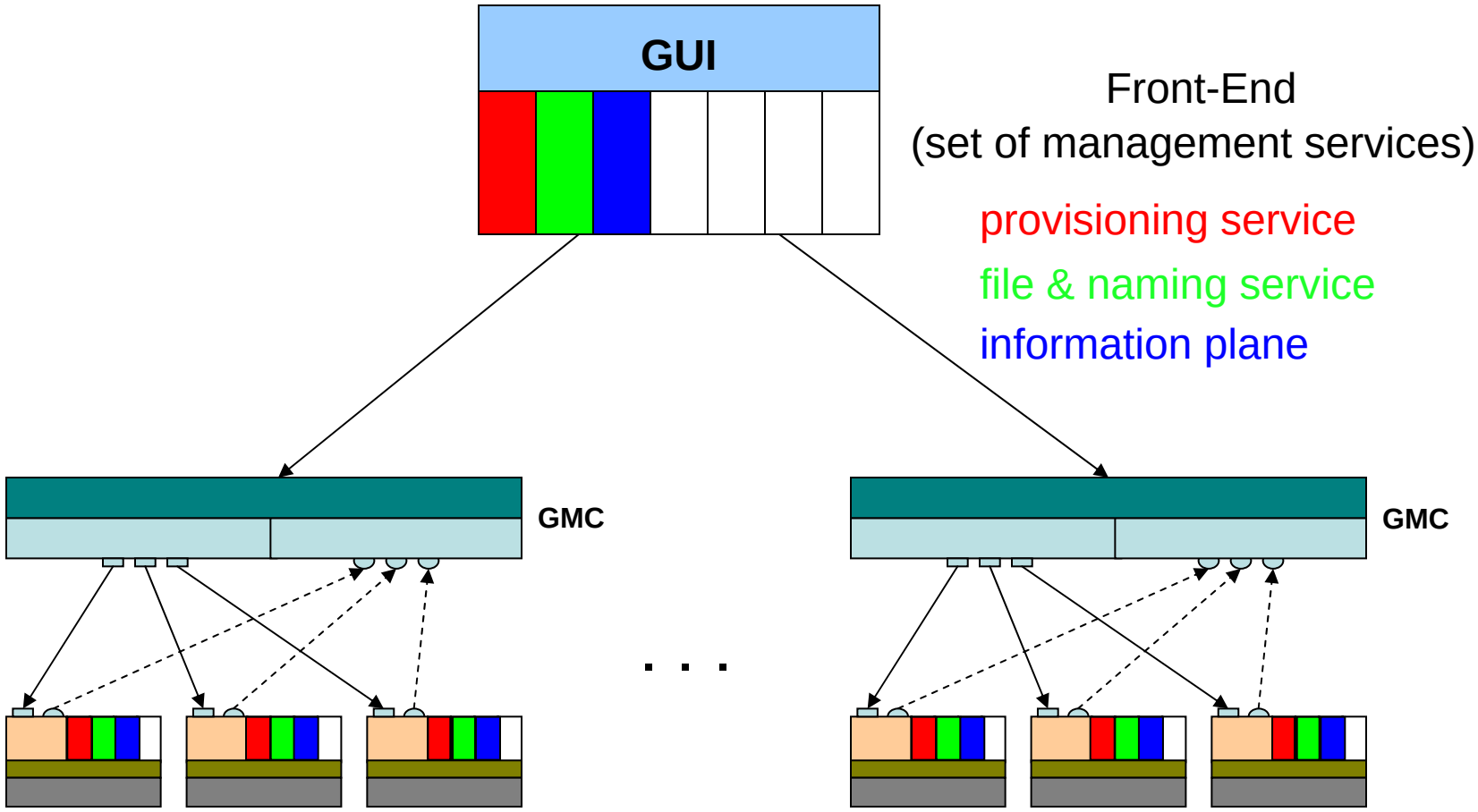
GENI Management Core (GMC)



Federation



User Front-End(s)



Virtualization

- Multiple levels possible
  - different level required by different experiments
  - different level depending on the technology
    - in the limit, we may need to slice “physical component array”
- Example “base cases”
  - virtual server (socket interface / overlay tunnels)
  - virtual router (virtual line card / static circuits)
  - virtual switch (virtual control interface / dynamic circuits)
  - virtual AP (virtual MAC / fixed spectrum allocation)
- Specialization
  - the ability to install software in your own virtual-*

Distributed Services

- Goals
  - Complete the GENI management story
  - Lower the barrier-to-entry for researchers (students)
- Example focus areas
  - Provisioning (Slice Embedder)
  - Security
  - Information Plane
  - Resource Allocation
  - File & Naming
  - Topology Discovery
  - Development Tools
  - Utility Networking (Internet in a Slice)

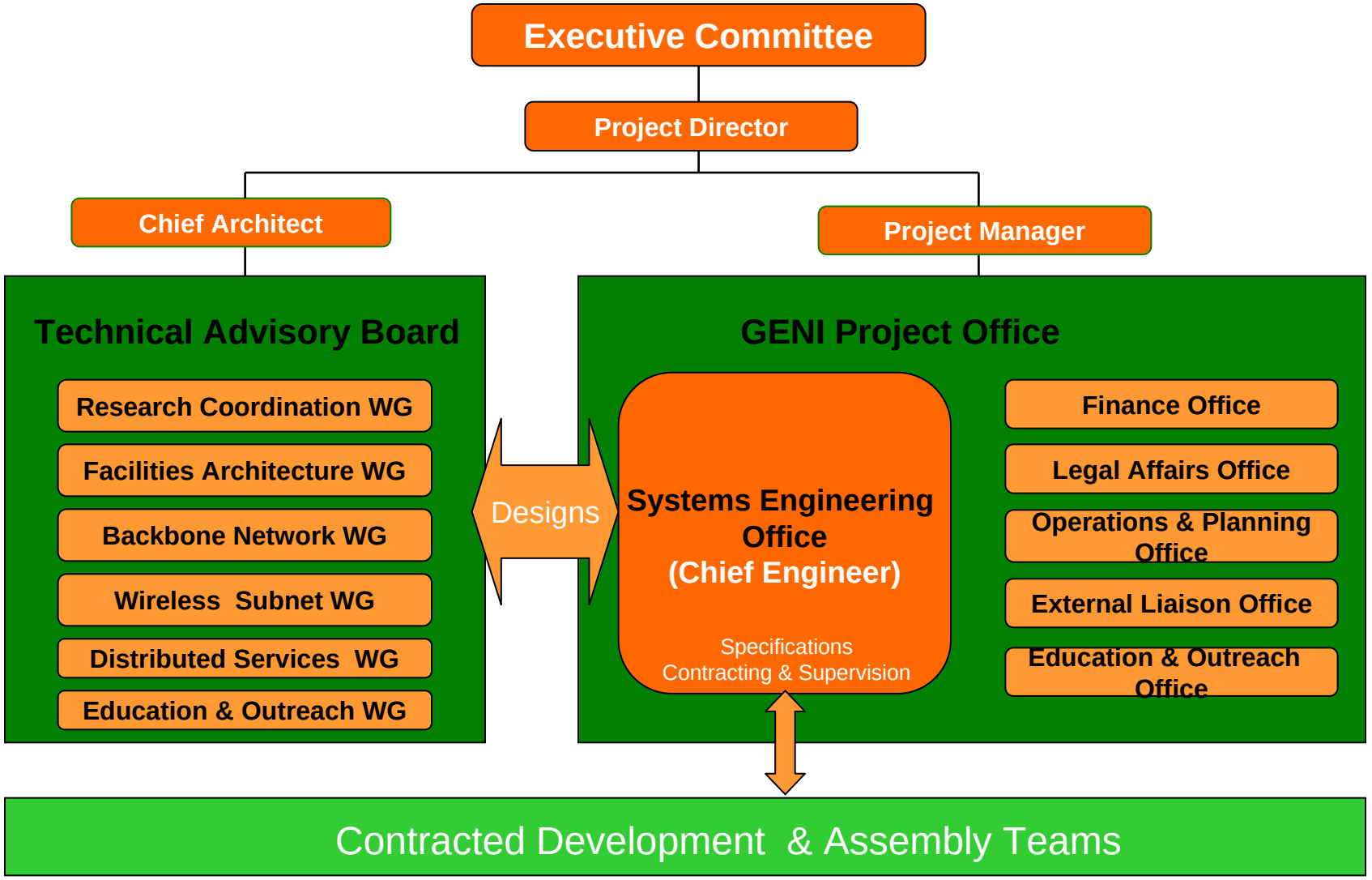
Containment & Auditing

- Limits placed on slice “reach”
  - restricted to slice and GENI components
  - restricted to GENI sites
  - allowed to compose with other slices
  - allowed to interoperate with legacy Internet
- Limits on resources consumed by slices
  - cycles, bandwidth, disk, memory
  - rate of particular packet types, unique addrs per second
- Mistakes (and abuse) will still happen
  - auditing will be essential
  - network activity ⟶ slice ⟶ responsible user(s)

Project Management

- GENI Community Consortium (GCC)
  - Executive Committee (EC)
    - provides project oversight
    - appoints Project Director and Project Manager
    - directs sub-contract selection process
  - Technical Advisory Board (TAB)
    - provides technical leadership for the project
    - establishes a set of working groups
  - GENI Project Office (GPO)
    - serves as the “operational arm” of the effort
    - on the hook to deliver the facility

Management (cont)



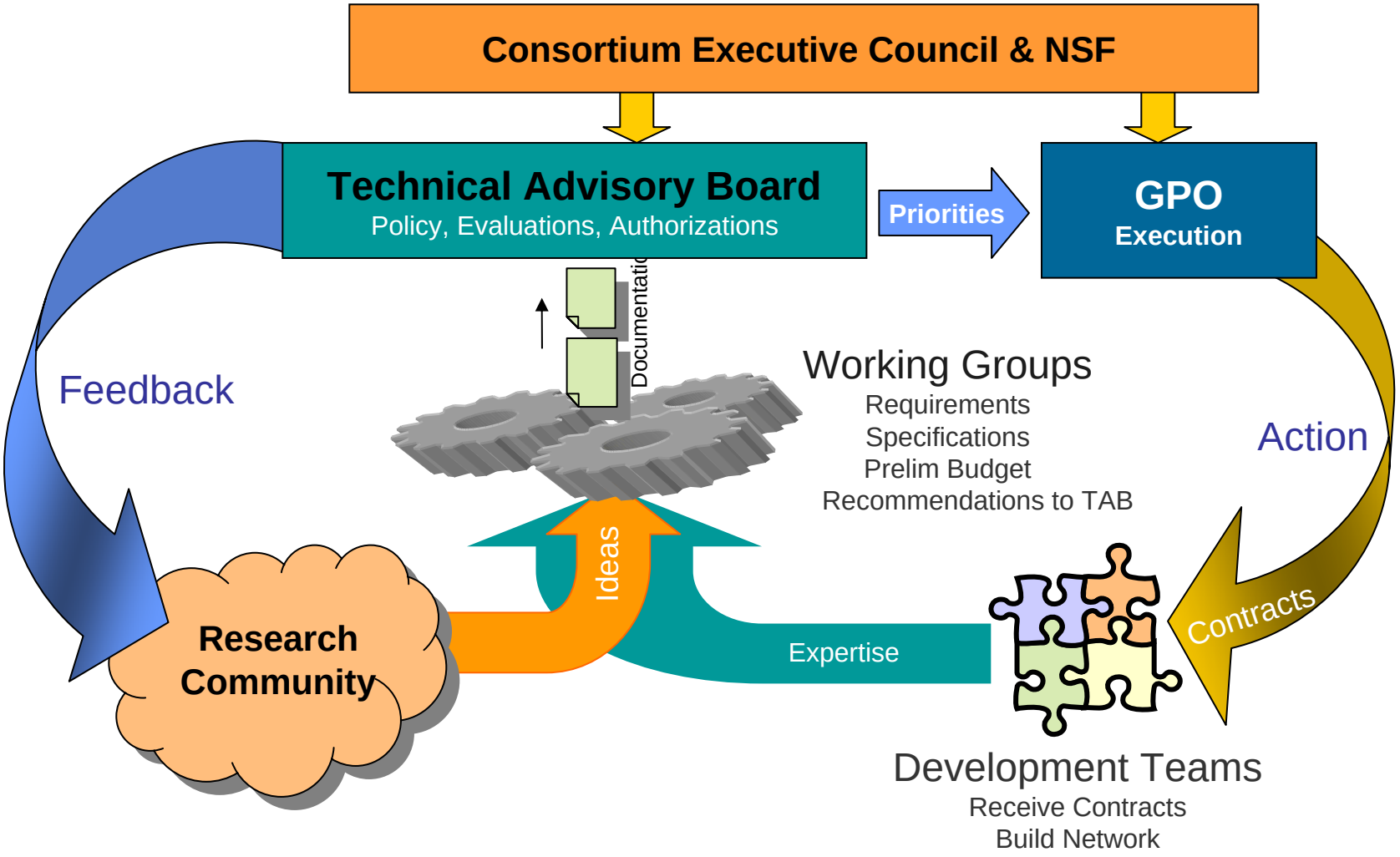
Working Groups

- Research
  - usage policy / requirements / instrumentation
  - Clark (co-chair), Shenker (co-chair)
- Architecture
  - define core modules & interfaces
  - Peterson (co-chair), Wroclawski (co-chair), Barford, Brassil, Schwab
- Backbone
  - fiber facility / routers & switches / tail circuits / peering
  - Rexford (chair), Blumenthal, Casey, Lakshman, McKeown, Turner, Zhang

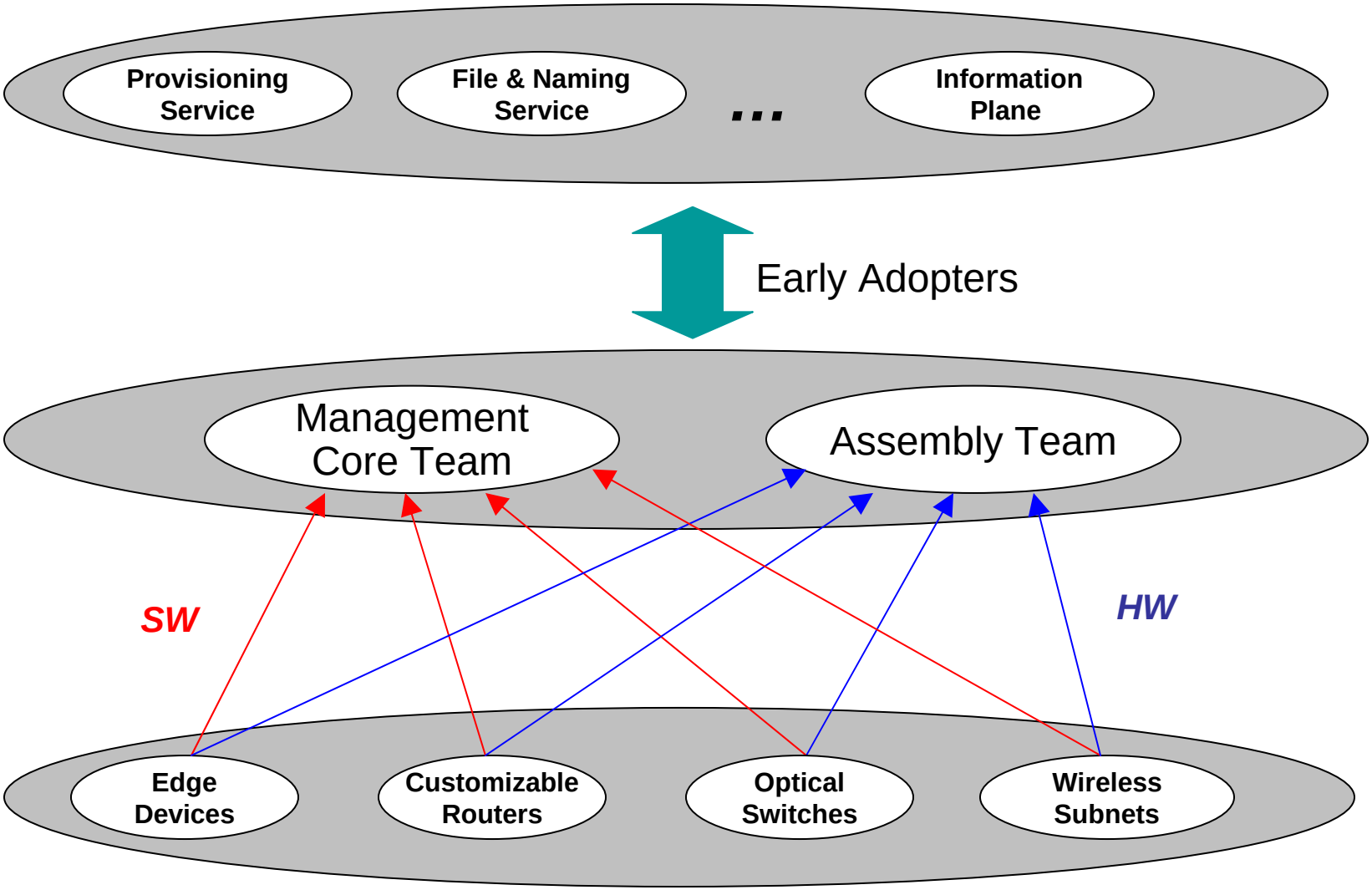
Working Groups (cont)

- Wireless
  - RF technologies / deployment
  - Raychaudhuri (chair), Bahl, Estrin, Evans, Gerla, Heidemann, Minden, Seshan
- Services
  - edge sites / infrastructure & underlay services
  - Anderson (chair), Andersen, Kaashoek, Pai, Reiter, Roscoe, Stoica, Vahdat
- Education
  - training / outreach / course development
  - TBD

Workflow


Consortium Executive Council & NSF
Technical Advisory Board
Policy, Evaluations, Authorizations
Priorities
GPO
Execution
Documentation
Working Groups
Requirements
Specifications
Prelim Budget
Recommendations to TAB
Feedback
Action
Ideas
Expertise
Contracts
Research Community
Development Teams
Receive Contracts
Build Network

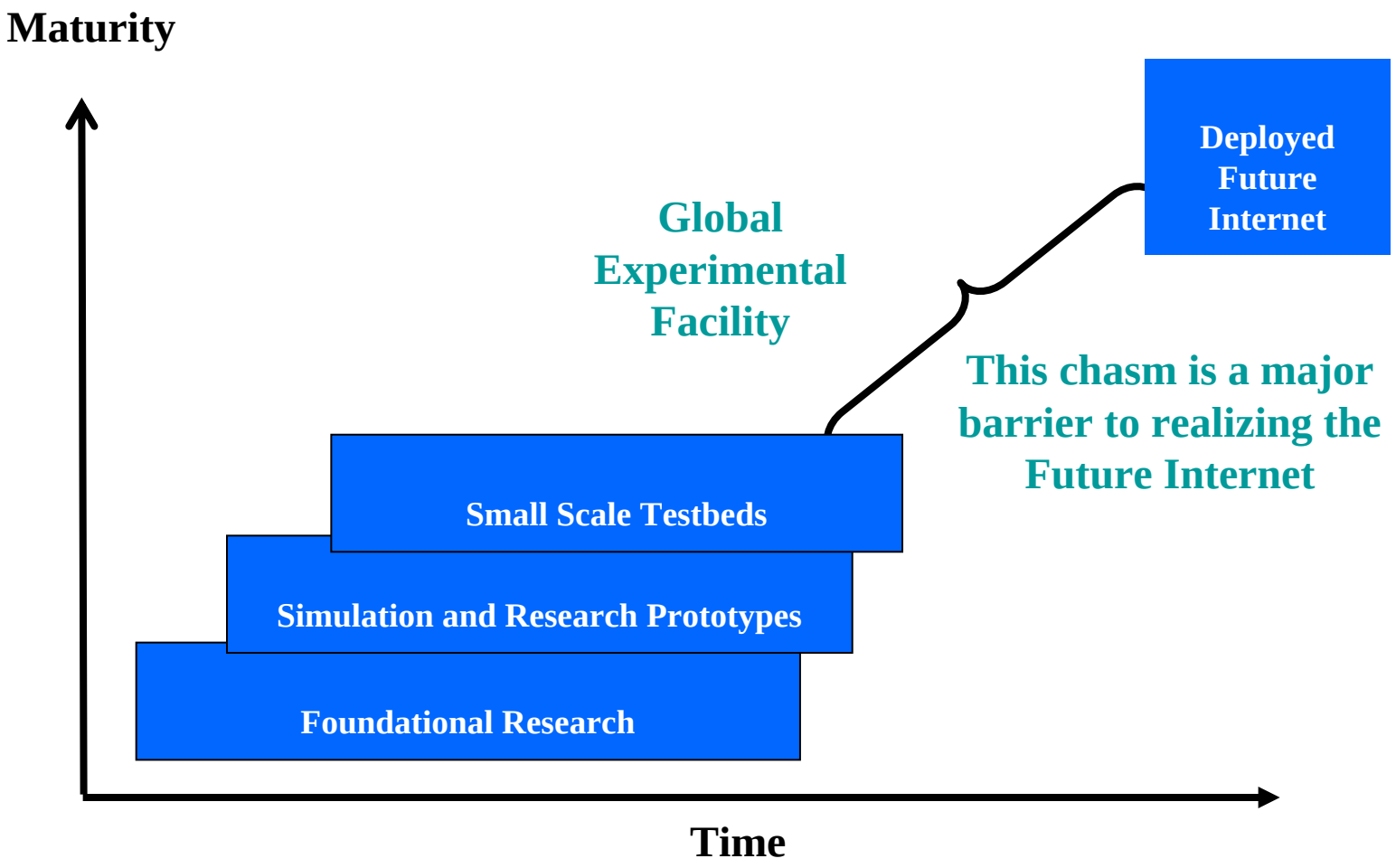
Development Teams



More Information

www.geni.net

Chasm


Maturity
Deployed Future Internet
Global Experimental Facility
This chasm is a major barrier to realizing the Future Internet
Small Scale Testbeds
Simulation and Research Prototypes
Foundational Research
Time