GENI Backbone Working Group
NSF and GPO (June 26, 2007)

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Agenda

- Introduction
  - High-level backbone architecture
  - Related GENI Design Documents
- Packet processing system
  - Reference design and low-level software
  - Prototype MetaRouter system
- Management software
  - Component manager, gateways, libraries
  - Prototypes of VINI and Meta Management
- Open issues and discussion

Some Comments on the Presentations

- Some topics are spread throughout the talks
  - Example experiments
  - Budget estimates from the WBS
  - Circuit processing system (for future meeting)
  - Relationships to the GENI Design Documents
- Topics are presented in a bottom-up style
  - Emphasis on prototype systems
  - And their connection with the architecture
  - To make the discussion more concrete
- Quite a bit of time allocated for discussion
  - To make sure we address your questions

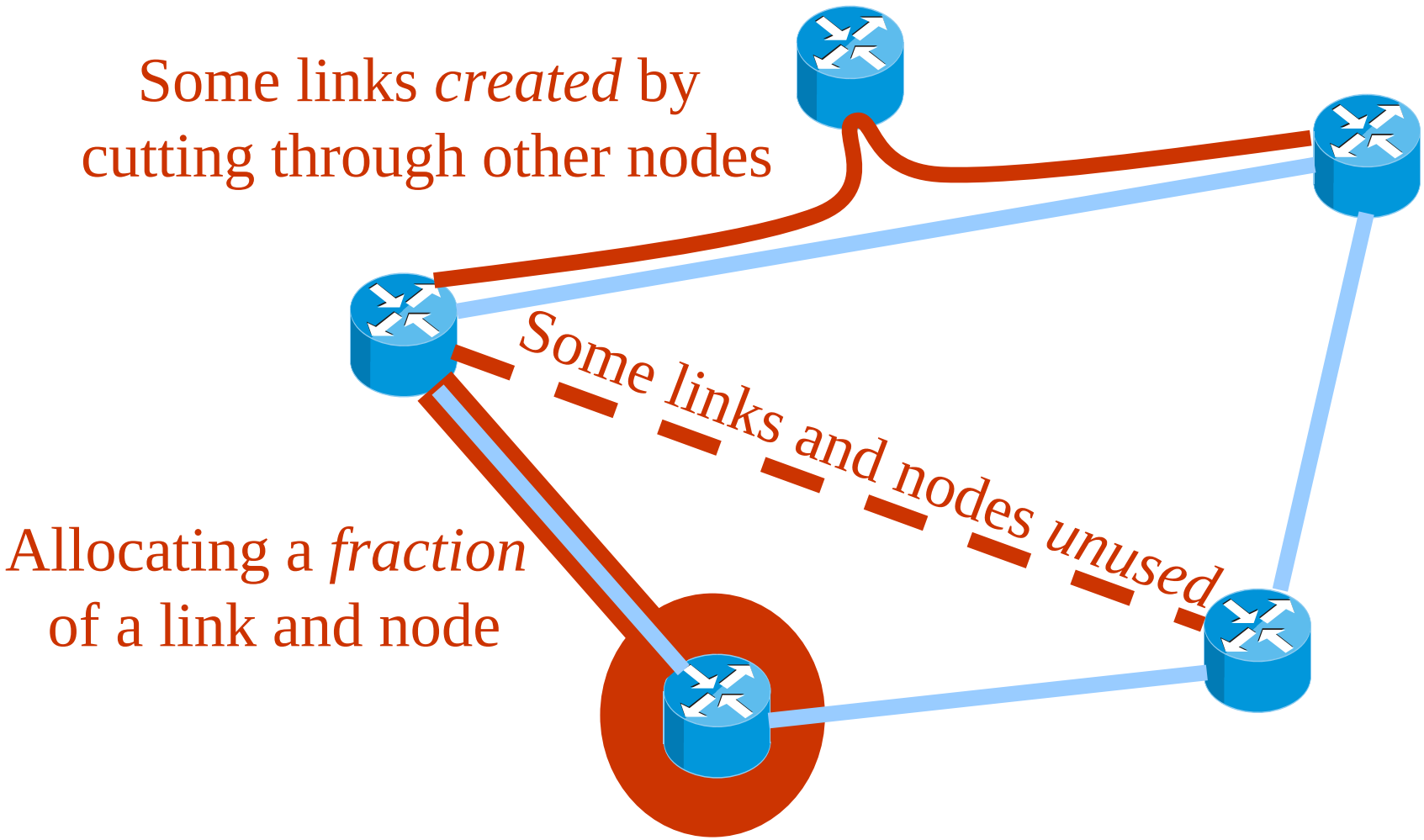
GENI Backbone Requirements

- Programmability
  - Flexible routing, forwarding, addressing, circuit set-up, ...
- Isolation
  - Dedicated bandwidth, circuits, CPU, memory, disk
- Realism
  - User traffic, upstream connections, propagation delays, equipment failure modes
- Control
  - Inject failures, create circuits, exchange routing messages
- Performance
  - High-speed packet forwarding and low delays
- Security
  - Preventing attacks on the Internet, and on GENI itself

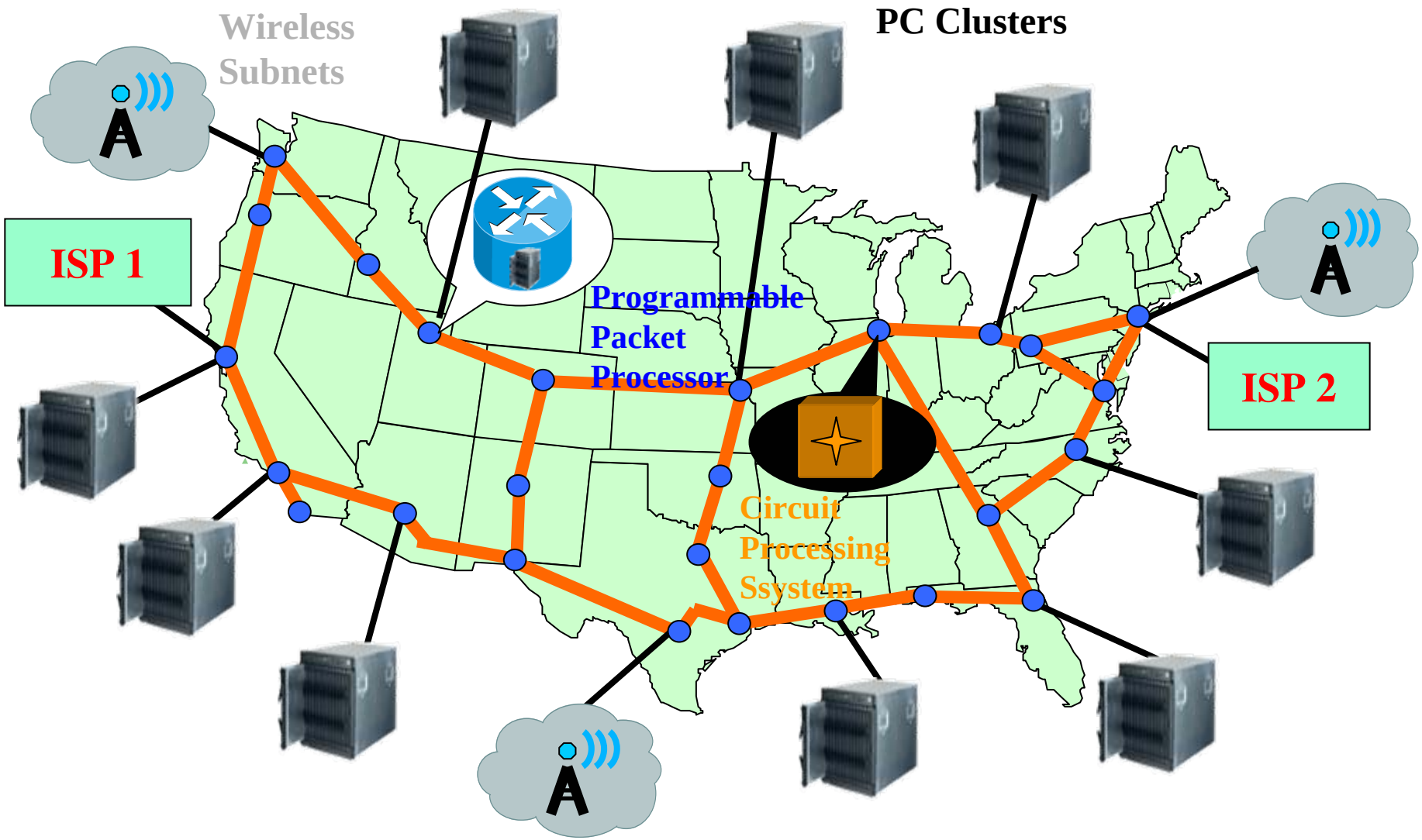
A Researcher's View of GENI Backbone

- Virtual network topology
  - Nodes and links in a particular topology
  - Resources and capabilities per node/link
  - Embedded in the GENI backbone
- Virtual packet processor and virtual circuits
  - To evaluate new architectures (routing, switching, forwarding, addressing, framing, grooming, ...)
- GENI backbone capabilities evolve over time
  - To realize abstraction at finer detail
  - To scale to large number of experiments

Creating a Virtual Topology



GENI Backbone



GENI Backbone Phases

- Phase 0: general purpose processors
  - General purpose processors connected to switch
  - Virtualization platform for multiple virtual routers
- Phase 1: high-end programmable packet processor
  - General-purpose processors, NPs, FPGAs, and line cards
  - Faster packet processing and line-card cut through
- Phase 2: reconfigurable optics
  - Cross-connect and off-the-shelf framer/groomer
  - True circuits and bypass of packet processor
- Phase 3: programmable optics
  - Dynamic optical switch with programmable framer
  - Experimental flexibility for framing, grooming, set-up, ...

Feasibility of the Design

- Industrial trends and standards
  - Advanced Telecom Computing Architecture (ATCA)
  - Network processors and FPGAs
  - SONET cross connects and ROADMs
- Open-source networking software
  - Routing protocols, packet forwarding, network address translation, diverting traffic to an overlay
- Existing infrastructure
  - Experiences from PlanetLab, Orbit, Emulab, ...
  - National Lambda Rail and Internet2 backbones
  - Ongoing work on the MetaRouter and VINI

Budget Estimates from the WBS

- Packet processing hardware (1.2.2.1.1.1)
  - $14M, mostly equipment costs
- Packet processing software (1.2.2.1.1.2)
  - $9M, mostly software development and testing
- Backbone management aggregate (1.2.2.4)
  - $8M, mostly software development and testing
- Internet exchange point deployment (1.2.3)
  - $20M, mostly fees for the bandwidth

Existing GENI Design Documents

- General GENI facility
  - GDD-06-27: "GENI Topology Design"
    - *Why ~25 nodes, why ~200 edge sites*
  - GDD-06-47: “Life of a Packet within a GENI Experiment”
    - *Connecting sites, multiplexing headers, cut-throughs*
- Backbone node architecture
  - GDD-06-09:“A Proposed Architecture for the GENI Backbone Platform”
    - *Packet processing system*
  - GDD-06-26: “GENI Backbone Network Node Architecture: Requirements and Architecture”
    - *Circuit processing system*

Existing GENI Design Documents (Cont.)

- Backbone management software
  - GDD-06-25: “Backbone Software Architecture”
    - *Initial outline of the backbone software (obsoleted)*
  - GDD-06-31: "In VINI Veritas: Realistic and Controlled Network Experimentation”
    - *Design, implementation, & evaluation of VINI prototype*
  - GDD-06-36: “GENI Backbone Run-Time Software for Experimenters”
    - *Experiment libraries, gateways, Internet connections*
  - GDD-06-37: “Meta-Management System for GENI”
    - *Boot-strapping of communication for management*

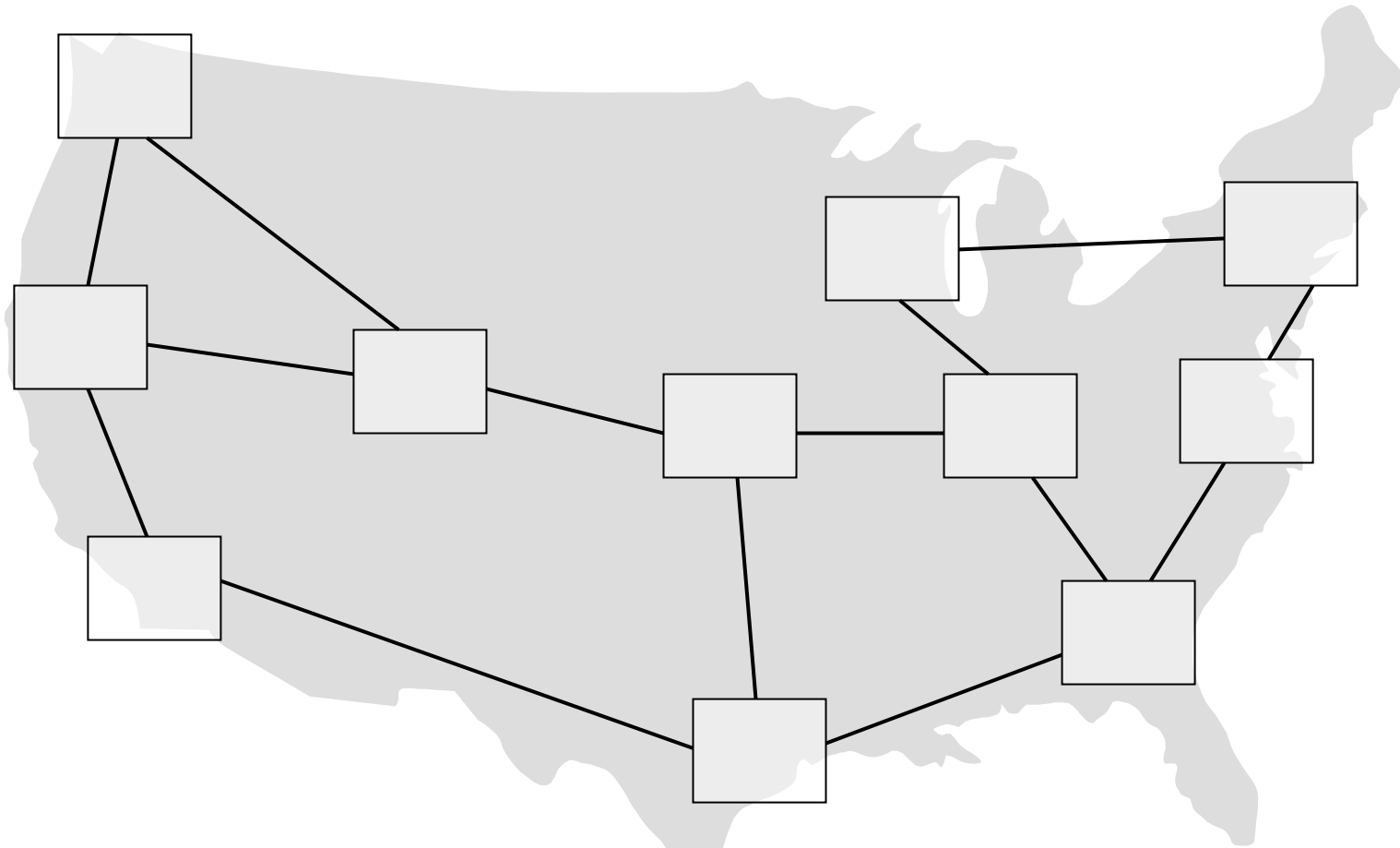
GENI Backbone Software

Goals of This Presentation

- Architectural components
  - Component manager
  - Management aggregate
- Experiment support
  - Installing forwarding-table entries in data plane
  - Sending data packets to/from the Internet
  - Sharing BGP sessions with neighboring ISPs
- Prototype systems
  - VINI overview and status
  - Meta-management system
- Example experiments

VINI Physical Deployment

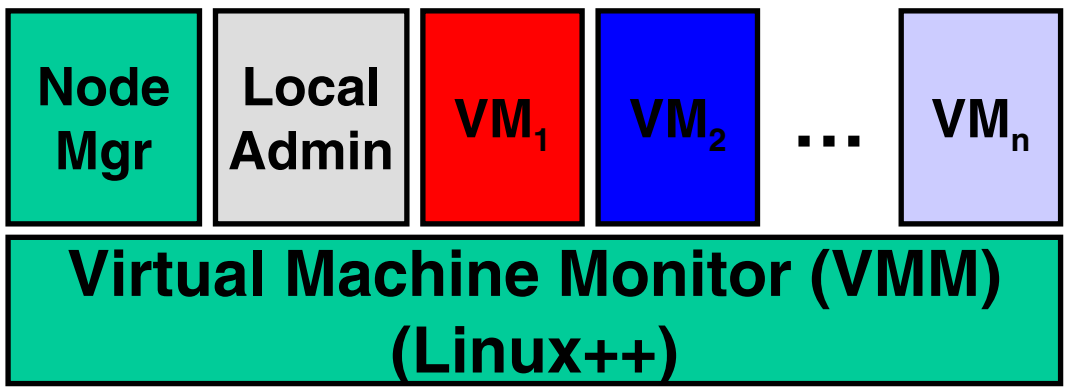
http://www.vini-veritas.net



Deployed high-end servers in National Lambda Rail and Abilene, and PoPs in Seattle and Virginia

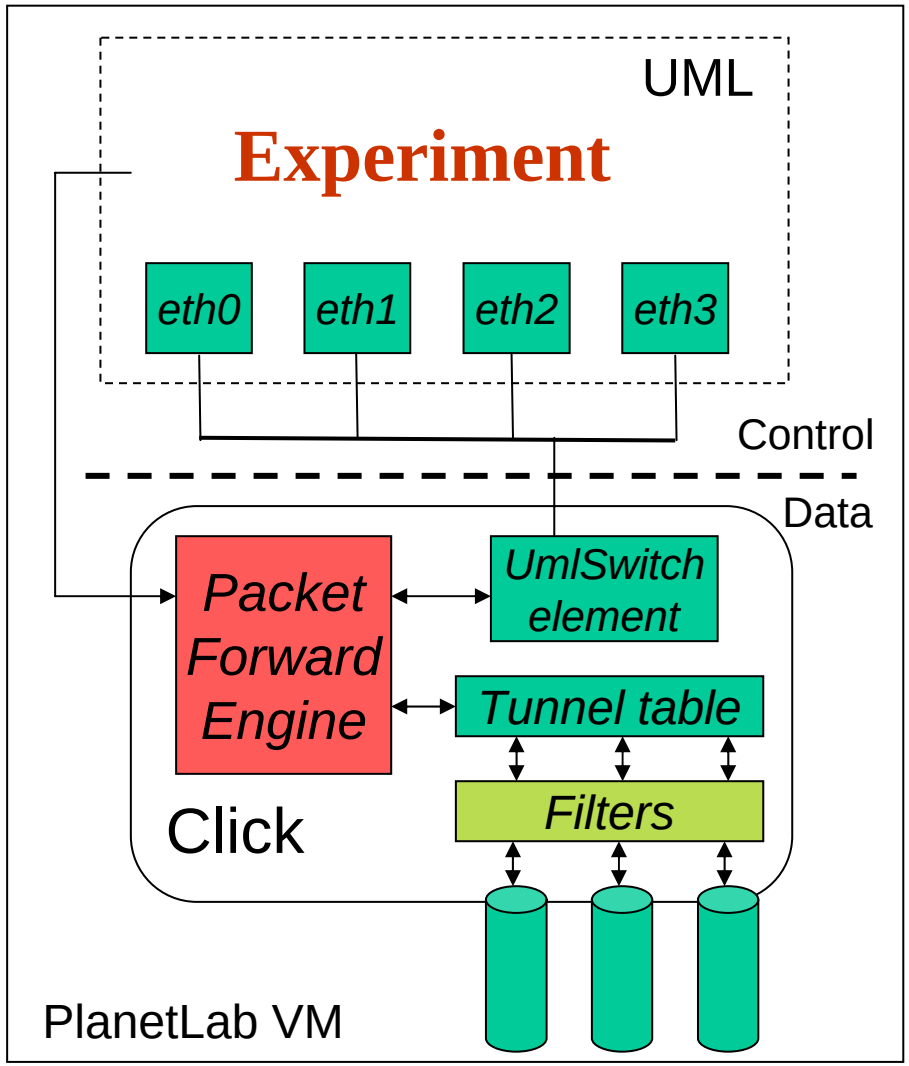
VINI Node Software: Underlying Substrate

- Started with the PlanetLab software
  - Virtual machines with name-space isolation
  - Each has “root” in its own VM, and can customize
  - Reserve CPU and bandwidth per experiment



VINI Node Software: Deployed Base

- Added net virtualization
  - Virtual interfaces
  - Bound to tunnels
- Initially using User-Mode Linux (UML)
  - Click packet forwarding
  - In user space (200 Mbps)
- Installing the FIB
  - Click Forwarding Element Abstraction (FEA)
  - Linux iptables
- In deployment and use



VINI Node Software: Faster Forwarding

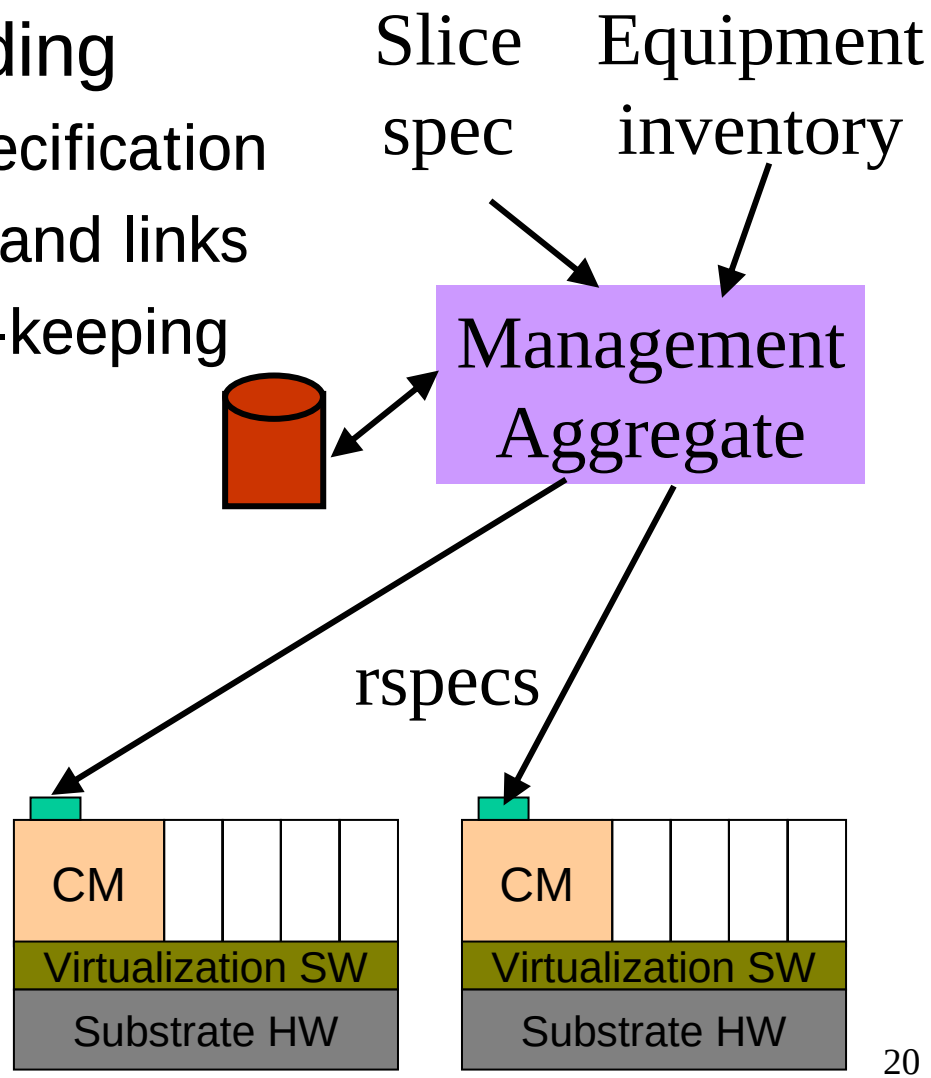
- Virtualized network stack in Linux
  - Network views that are bound to processes
  - Separate kernel forwarding tables per view
  - Supports virtualization *within* an experiment
- Status of enhancements to Linux
  - Current doing testing and performance studies
  - Scheduled for deployment at summer's end
  - Working to incorporate changes in mainline Linux
- Hardware support through FPGAs and NPs
  - Nick McKeown's NetFPGA project
  - Jon Turner's MetaRouter project

GENI Node Software: Experiment Libraries

- Wide range of researchers
  - Using the backbone just for the connectivity
    - No backbone processing of the data packets
  - Experimenting only in the control plane
    - Running conventional IPv4/IPv6/Ethernet data plane
  - Building their own data plane
    - In Click, in C, in Verilog/VHDL
- Multiple ways to install forwarding tables
  - Raw access to the network processor
  - Shadowing the Linux iptables
  - Click Forwarding Element Abstraction (FEA)
  - IETF ForCES standard

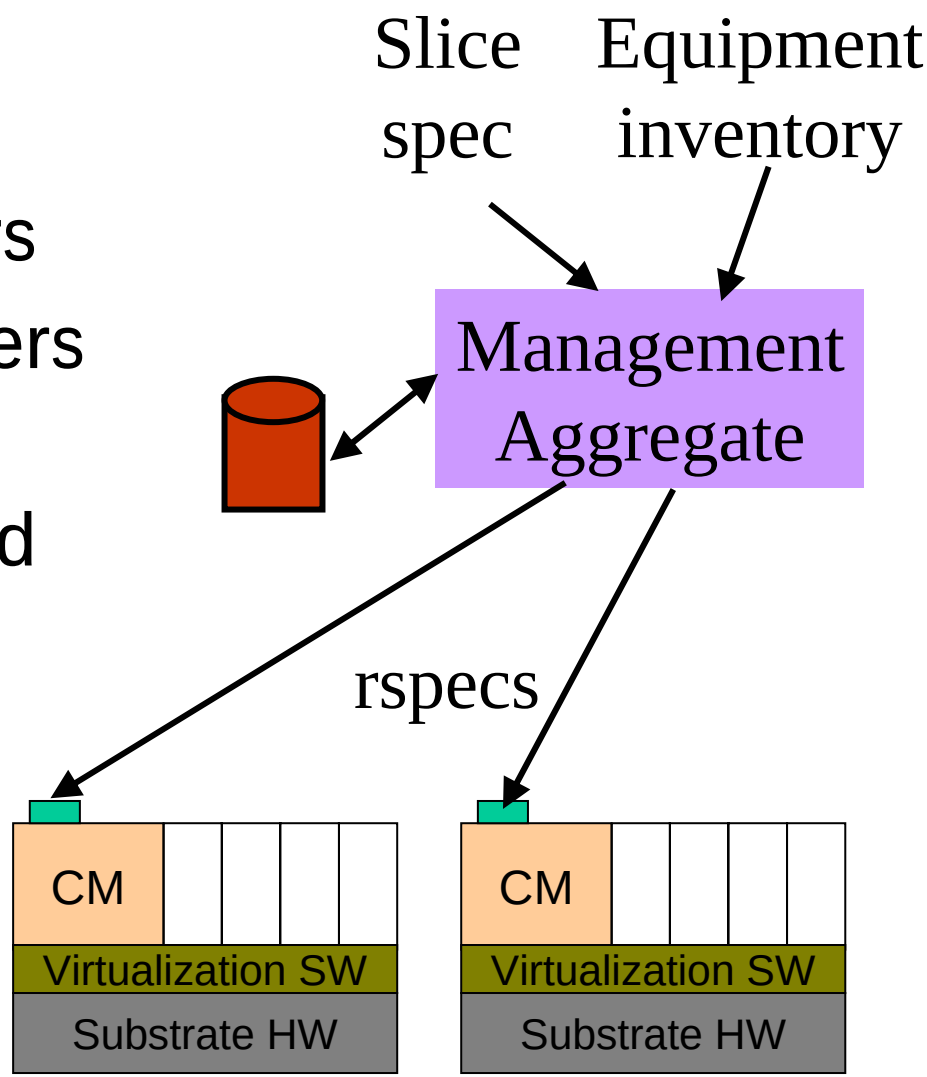
VINI Management Software

- Management aggregate
  - Virtual network embedding
    - Given slice backbone specification
    - Selects substrate nodes and links
    - Admission control, book-keeping
  - Slice creation
    - Generates and “rspec” for each component
    - Sends to component
- Current status
  - Simple Ruby scripts
  - Working on DB



VINI Management Software

- Component manager
  - Creates the virtual machine and containers
  - Associates the containers with tunnels
  - Configures the CPU and bandwidth schedulers
- Current status
  - Simple scripts



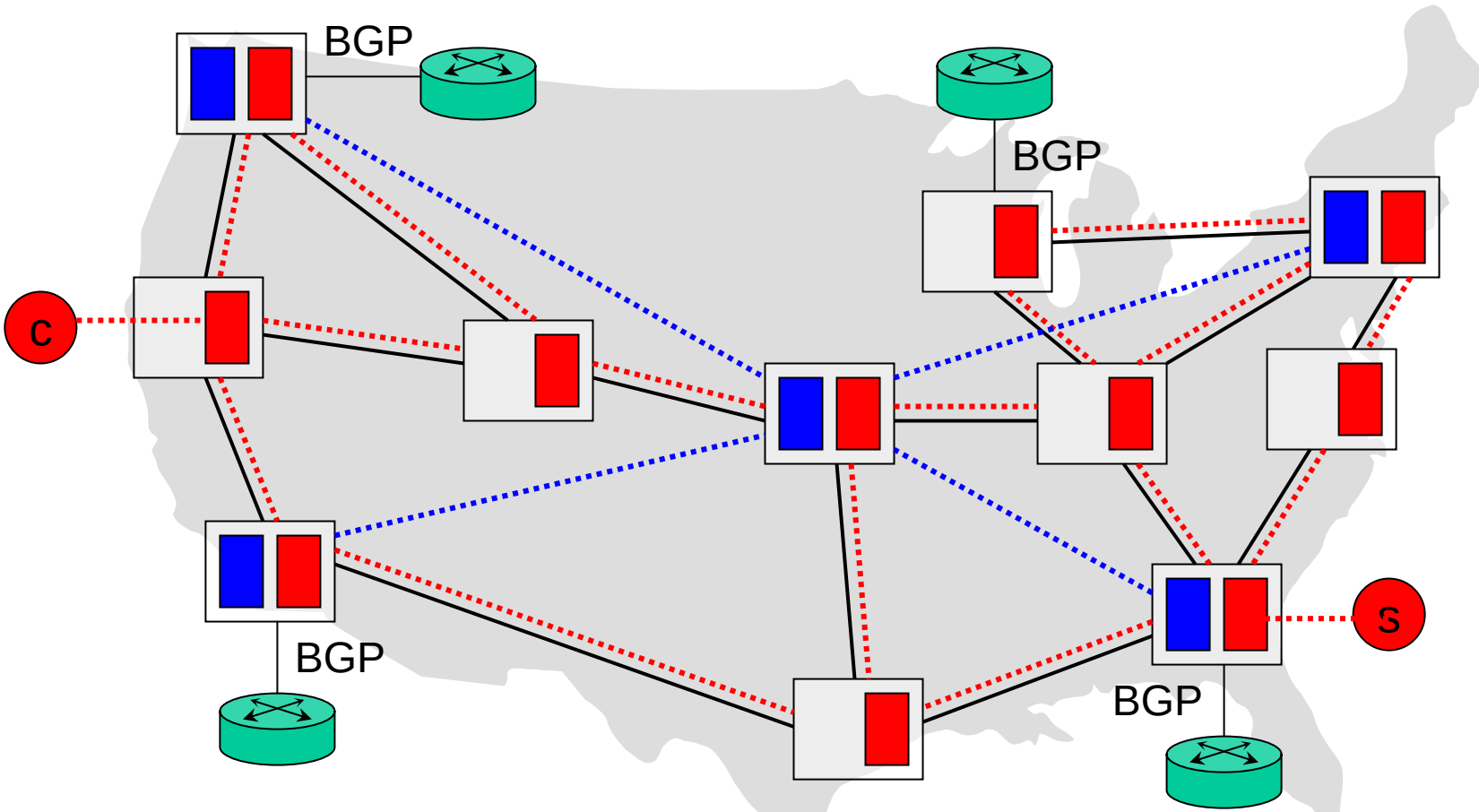
Toward the GENI Management Software

- VINI has a simple initial rspec design
  - Node has CPU resources, link has bandwidth
  - Best-effort or guaranteed fixed resources
  - No QoS support from intermediate switches
- Packet processor has more sophisticated rpsec
  - Multiple types of cards in the MetaRouter
  - Shared vs. dedicated network processors
  - Additional resources like SRAM and TCAM space, inter-chassis bandwidth, switch-fabric resources
- Component manager monitoring
  - Reporting on node and sliver status

Connecting to the Legacy Internet

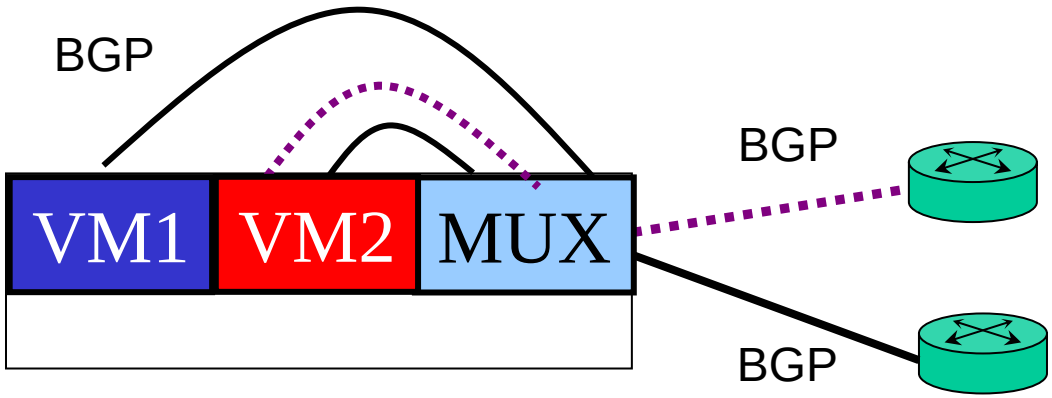
- Experiments need to connect to the Internet
  - Allow users from non-GENI sites to “opt in”
  - Access content and applications on the Internet
- VINI connecting to end users
  - OpenVPN server running in an experiment
  - Application-level proxy running in an experiment
- VINI connecting to the rest of the Internet
  - Network address translation at boundary point
  - To share a limited public address space (/20)
  - And to ensure return traffic reaches experiment

External Routing Adjacencies



Experiments can participate in Internet routing (to control outbound traffic, or announce prefixes)

BGP Mux: Sharing a BGP Session



- Provides illusion of dedicated BGP sessions
  - While maintaining a single session per neighbor
- Filters route updates to protect Internet
  - Only address blocks the experiment “owns”
  - Within some limits on update frequency
- Initial prototype as an extension to Quagga

A General Need for Gateways

- Some resources are easy to share
  - CPU: time sharing
  - Bandwidth: time sharing, frequency sharing
- But logical resources are harder to share
  - BGP session to a neighboring ISP
  - Command-line access to optical equipment
- Gateways to arbitrate access
  - Provide the illusion of dedicated access
  - While providing resource isolation
  - And protecting against misbehavior, crashes, ...

Getting VINI Closer to the Optics

- VINI today is essentially an overlay
  - VINI nodes are connected by IP
  - Typically over a single IP-layer hop
  - Though the substrate reroutes us around failures
- Going forward: ongoing plans with Abilene
  - Connect VINI nodes directly to Ciena CoreDirector
  - Establish dedicated circuits between VINI nodes
- Planning to follow a phased approach
  - Initially, a fixed substrate topology
  - Later, allow per-experiment topologies
  - And perhaps later to span ESnet and GEANT

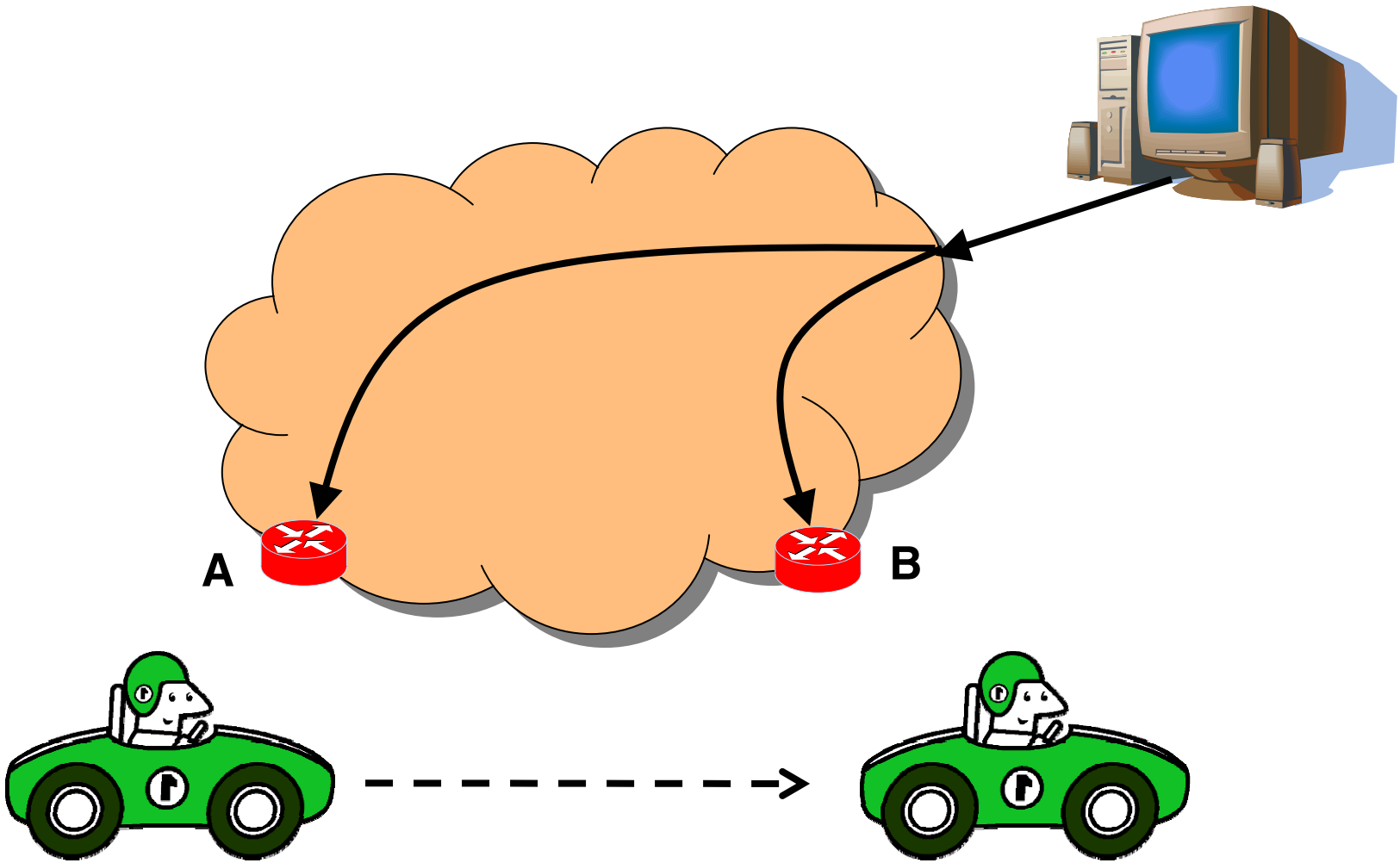
Experiments Run on VINI:
Example of Joint ORBIT/VINI Experiment

Example VINI Experiments

- Evaluating routing-protocol convergence
  - Web download during link failure in XORP, Quagga
- Network-layer support for overlay services
  - Overlay forwarding and notification in data plane
- Piggybacking diagnostic data on packets
  - Data plane support for network troubleshooting
- Scaling Ethernet to a large enterprise
  - Flat addressing and hash-based location resolution
- **Backbone support for mobile hosts**
  - **Injecting end-host addresses in to OSPF**

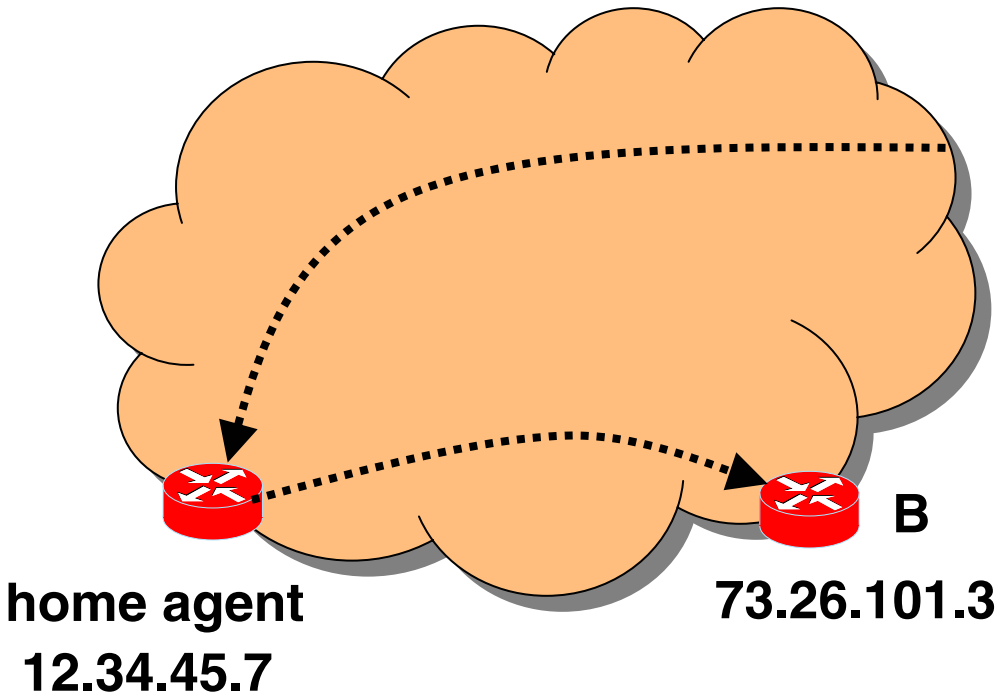
Mobility Challenges

- Seamless transmission to a mobile host



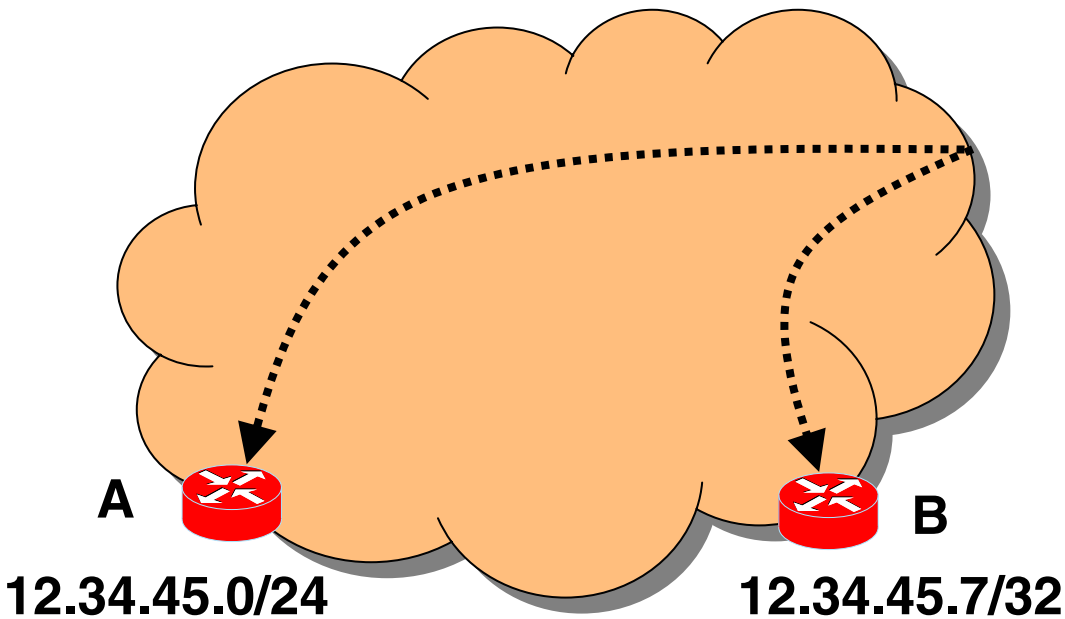
No Backbone Changes: Mobile IP

- Mobile node has two addresses
  - Home address: fixed
  - Care-of address: changes as the host moves
- Packets relayed through the home agent



No Changes to Hosts: Route Injection

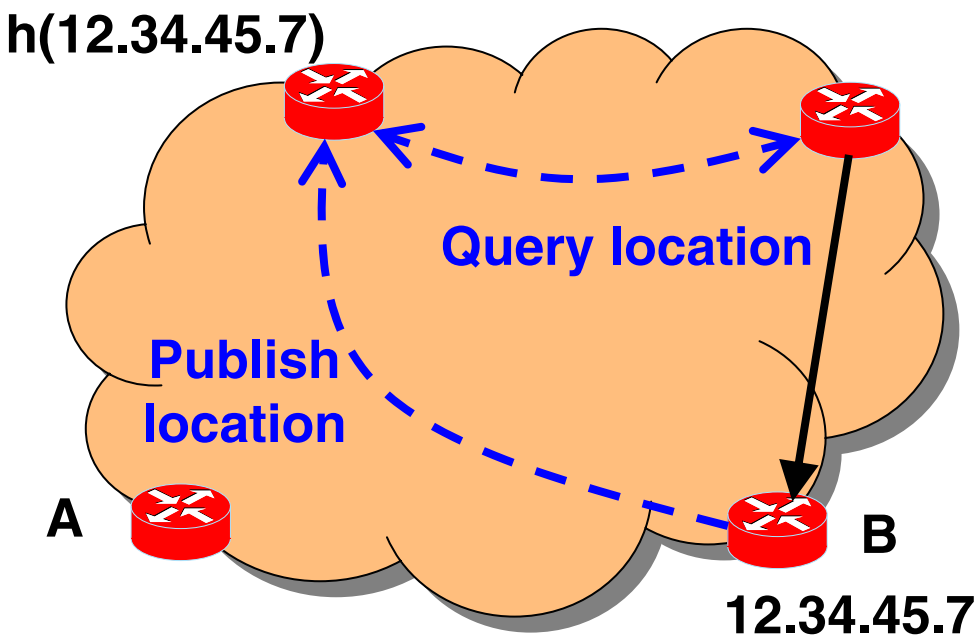
- Mobile node has a single, persistent address
- Address injected into routing protocol (e.g., OSPF)
- But, flat addressing causes scalability challenges



Similar to approach used in the Boeing Connexion service…

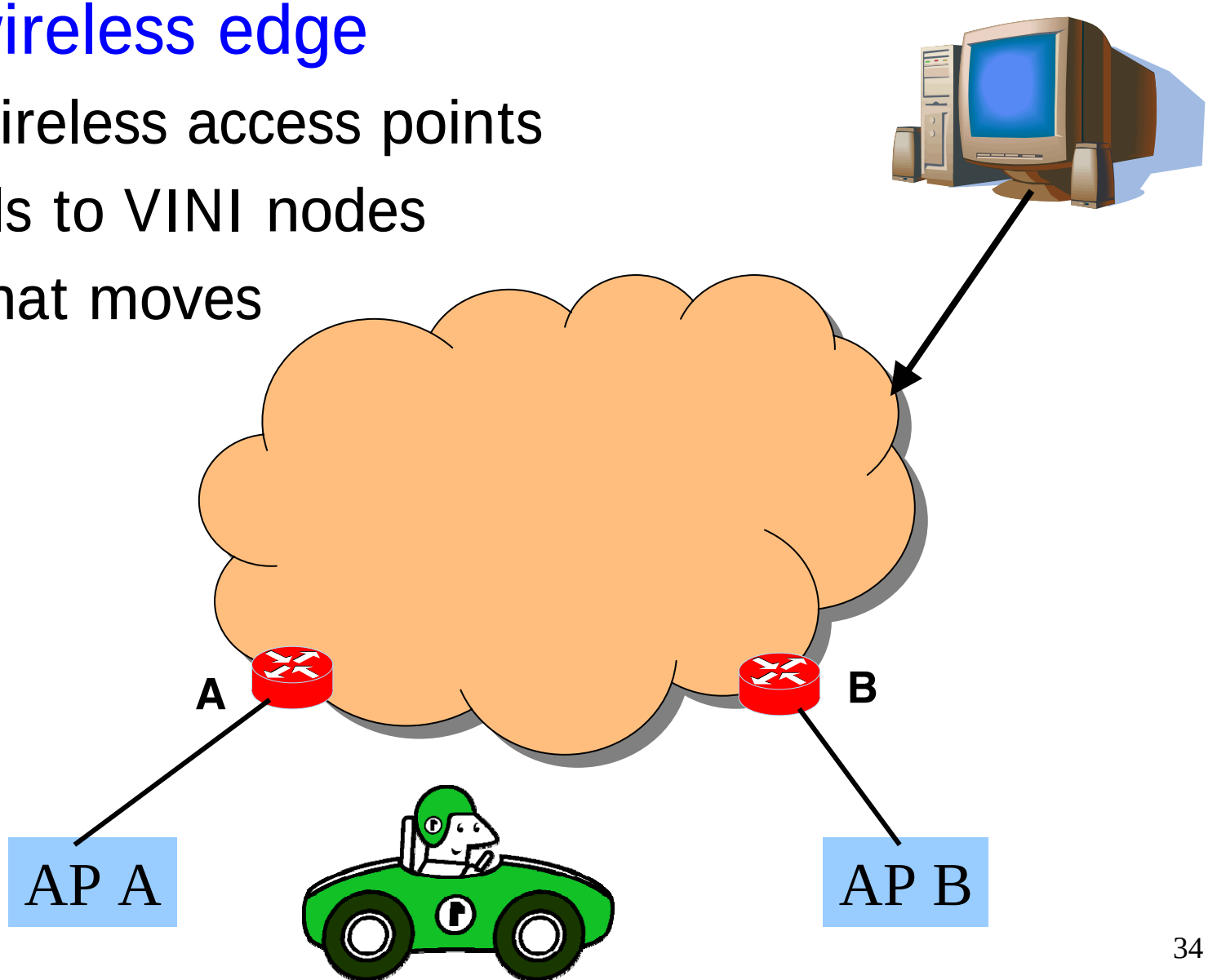
Scalable Support for Flat Addressing

- Store location info at a small set of nodes
  - Fetch based on hash of address
- Cache location info at ingress node
  - Cut-through to send traffic directly to mobile node



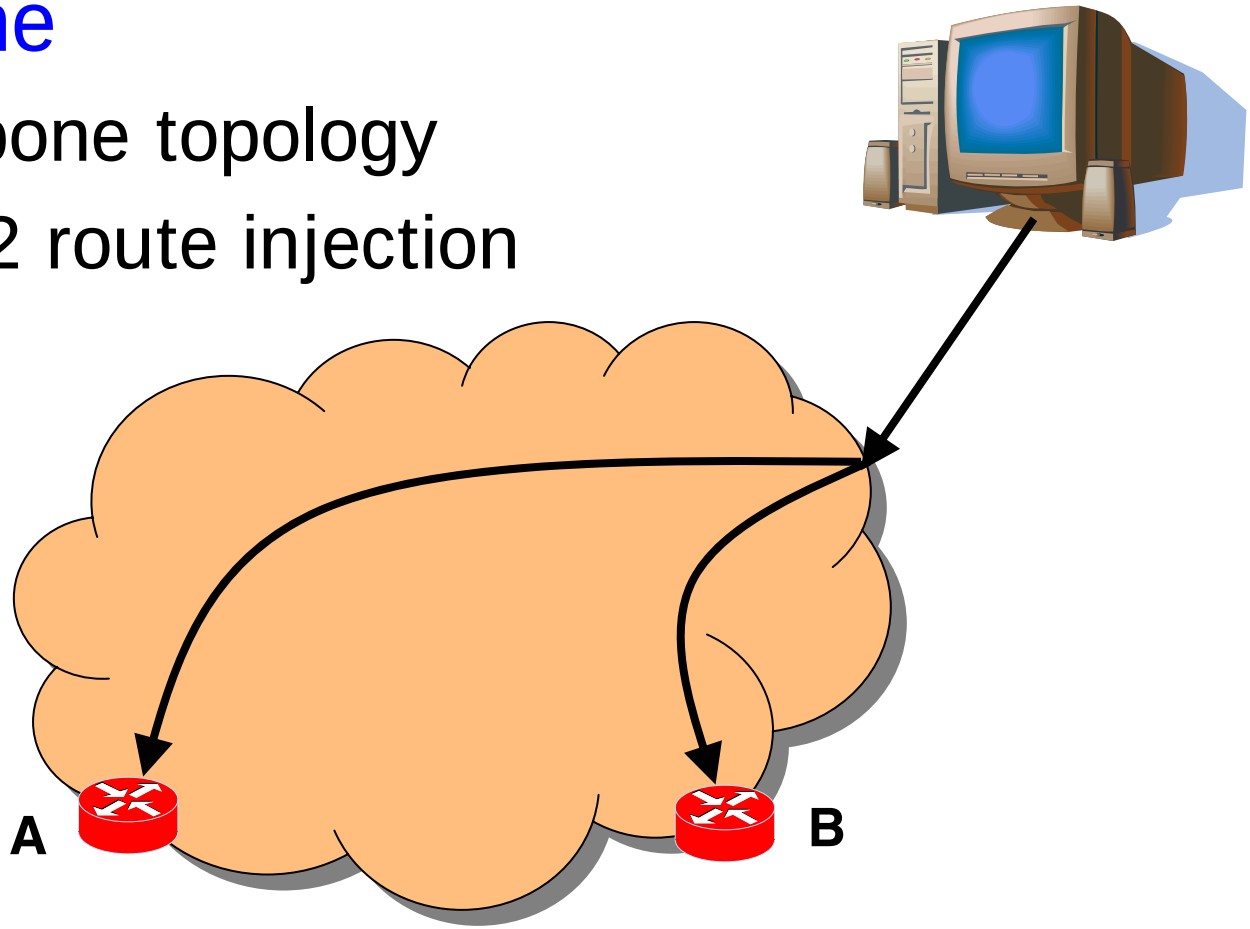
Joint Orbit and VINI Experiment

- Orbit: wireless edge
  - Two wireless access points
  - Tunnels to VINI nodes
  - Host that moves



Joint Orbit and VINI Experiment

- VINI: backbone
  - Abilene backbone topology
  - OSPF with /32 route injection



Joint ORBIT and VINI Experiment

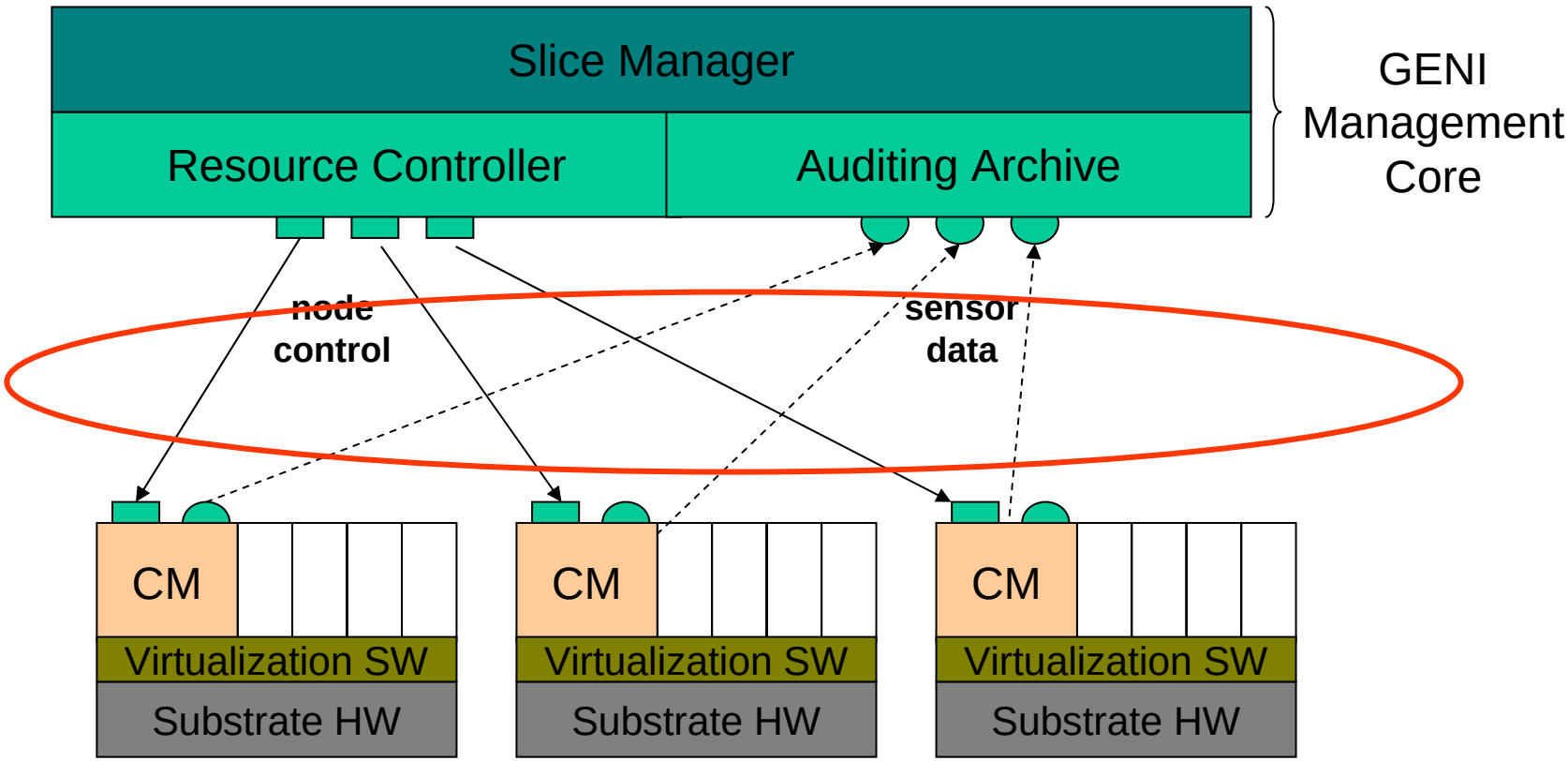
- Experiment/demo
  - Download a video stream from a server
  - While the wireless node is moving
  - Observe the quality of the video stream
- Current status
  - Joint experiment with route injection
  - Separate testing of hash-based scheme
  - Plan to experiment with the hash-based scheme
- Lessons learned
  - Support for non-IP protocols
  - Connecting to nodes behind firewall/NAT

Meta Management System

Zheng Cai, Hemant Gogineni,
David A. Maltz, T. S. Eugene Ng,
Hong Yan, and Hui Zhang

How Does GMC Communicate with CMs?

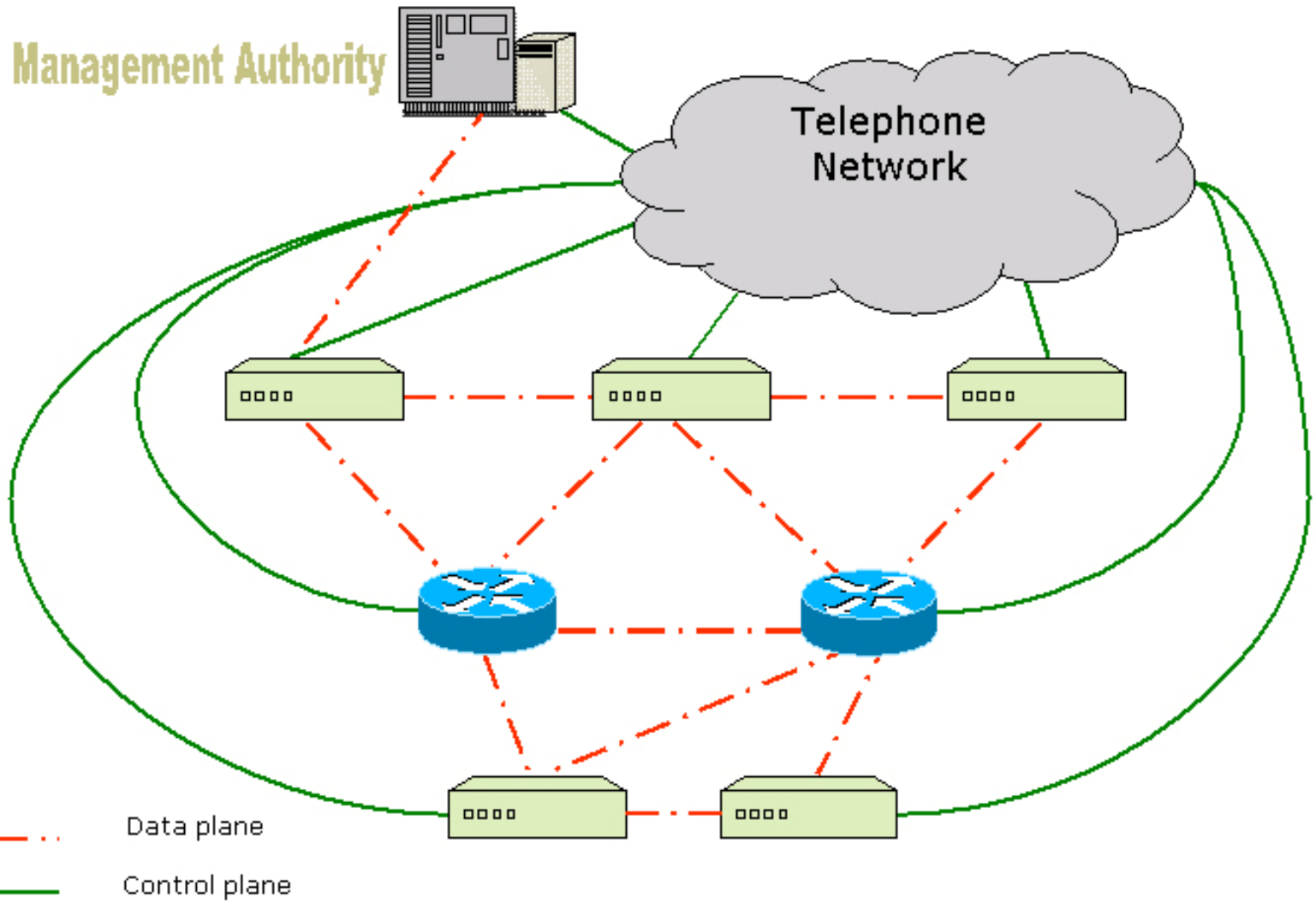
- Fundamental architectural issue that affects overall network manageability and security



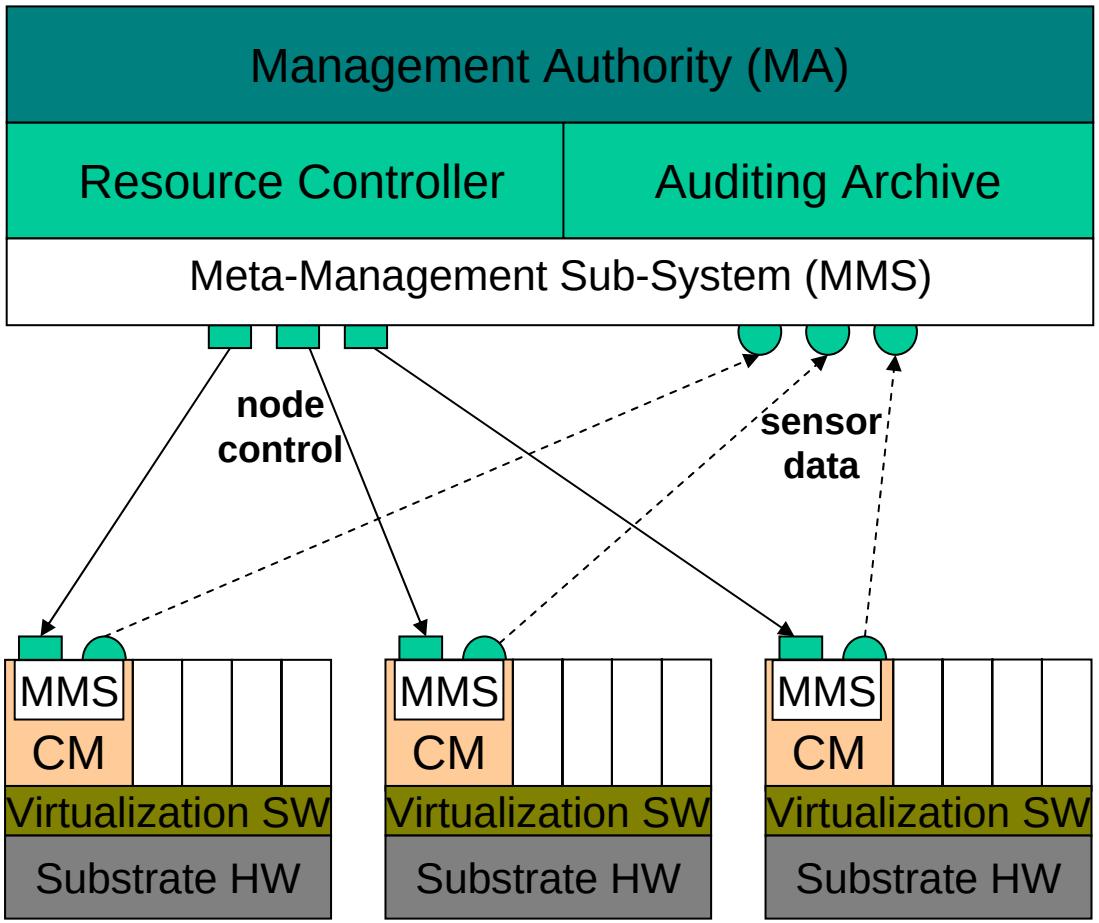
Example GMC Management Scenarios

- Remote router failure diagnosis and reboot
  - Remote diagnosis of a packet processor
  - If necessary, GMC may reboot the node
- Network wide failure diagnosis and reboot
  - Troubleshooting during service disruption
  - Rebooting the entire network, if necessary
- Network maintenance
  - Temporarily remove a node for maintenance
- Network service migration
  - Migrate native in-band service from one (e.g. IPv4) to another (e.g. IPv6)

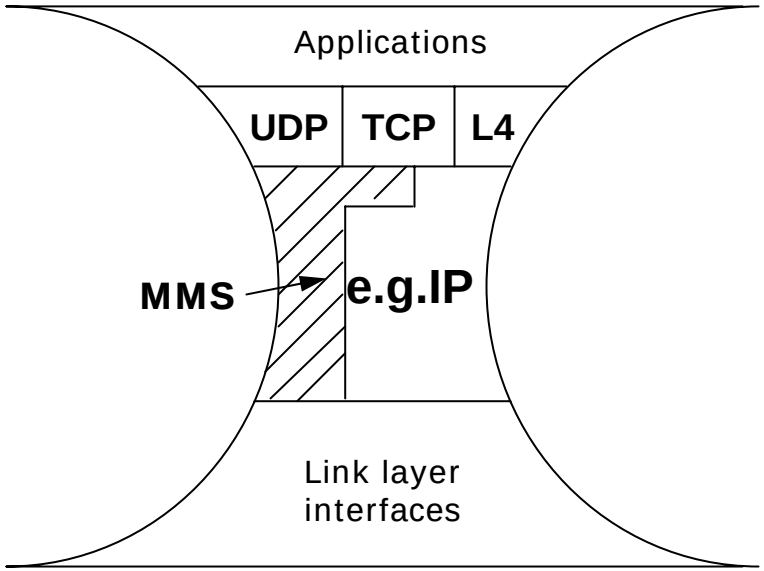
Today: Out-of-Band Management



GENI Meta-Management Sub-System



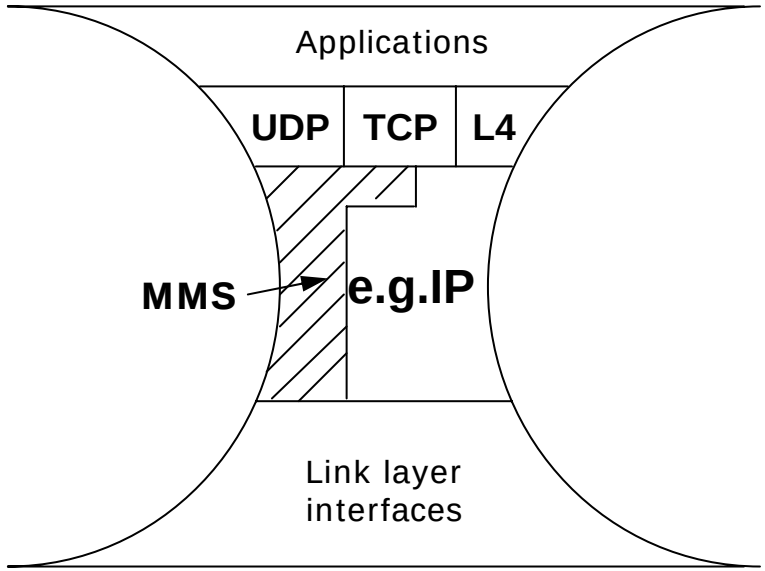
A Meta-Management System (MMS)



- Secure and robust management channel
  - As long as there is physical network connectivity
  - Does not need a separate network

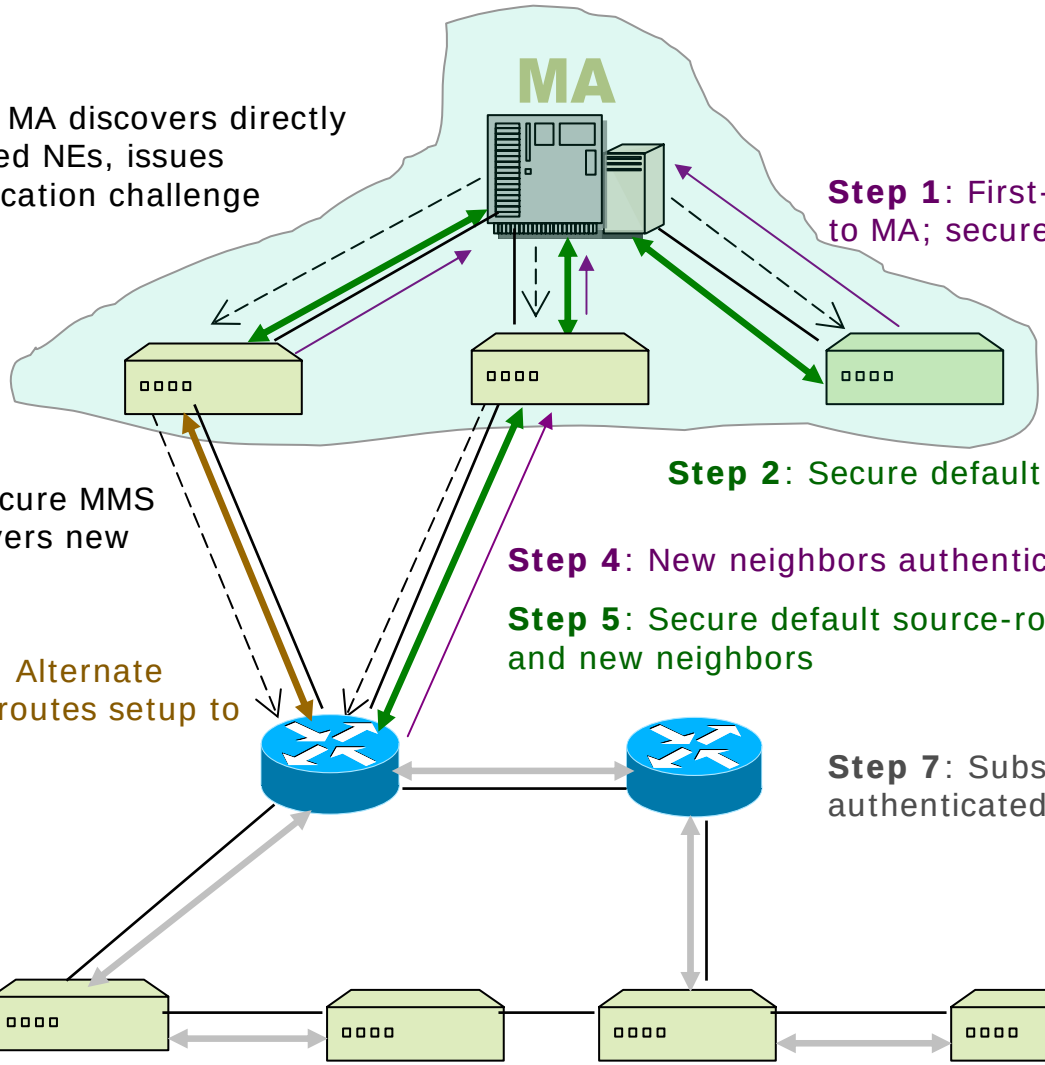
A Meta-Management System (MMS)

- Service on power-up
  - No complex configuration
- Self-contained software
  - Minimizes dependency
- "BIOS" for the network



- Same familiar socket programming interface
  - IP-based management applications still work
- Independent of data-plane services
  - Regular traffic can continue using IP, or not

MMS Authentication & Secure Source Routing



Step 0: MA discovers directly connected NEs, issues authentication challenge

Step 1: First-hop nodes authenticate to MA; secure MMS zone established

Step 2: Secure default source routes are setup to MA

Step 3: Secure MMS zone discovers new neighbors

Step 4: New neighbors authenticate to MA via secure zone

Step 5: Secure default source-routes setup between MA and new neighbors

Step 6: Alternate source-routes setup to MA

Step 7: Subsequent NEs discovered and authenticated recursively

MMS Status

- Prototype system in Linux
  - Linux loadable kernel module
  - Provides a virtual interface (mm0)
  - Detects physical interfaces & discovers neighbors
  - Encryption and authentication of messages
- Attractive alternative to having communication between GMC and CMs via the Internet...

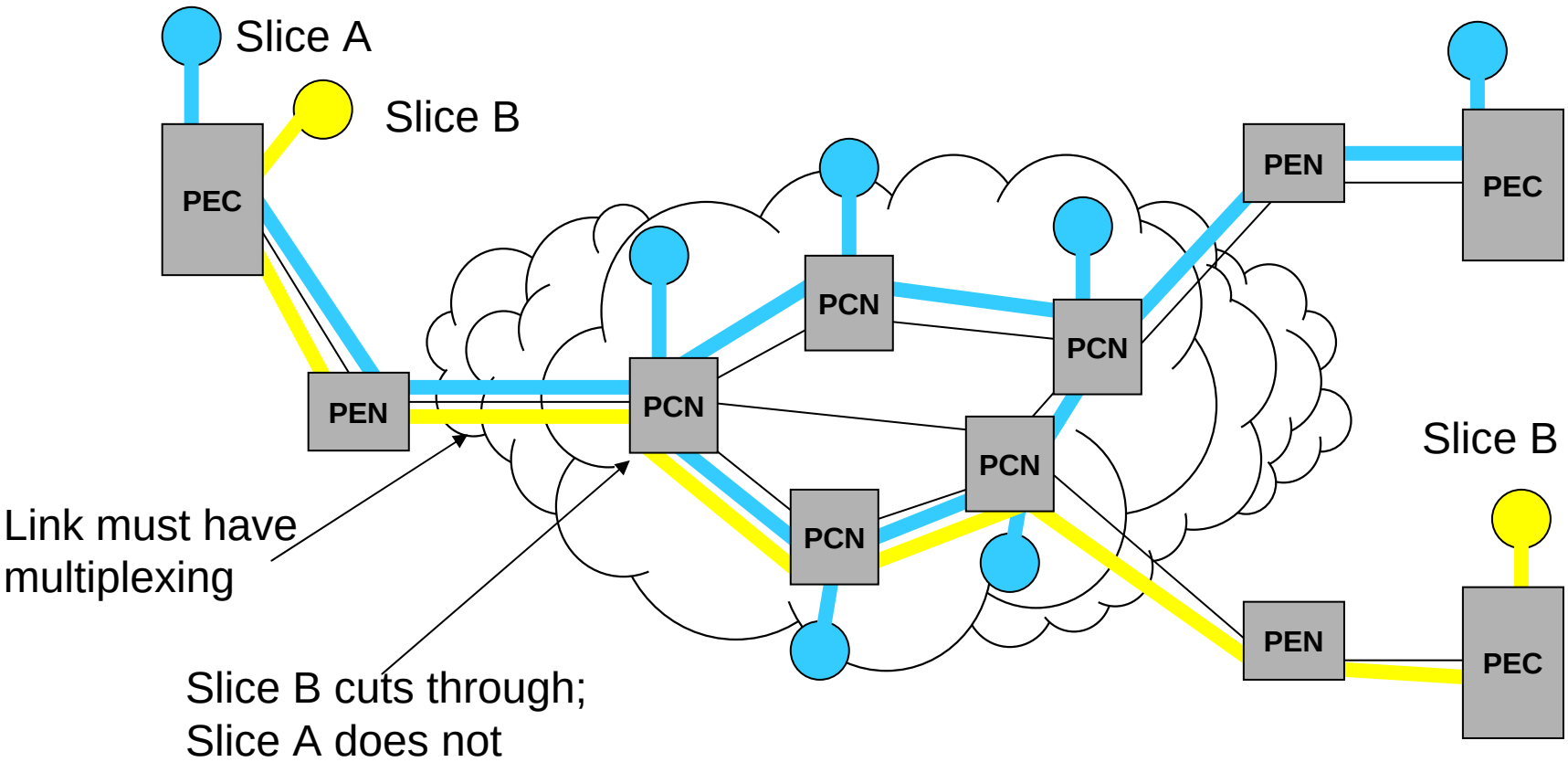
Open Issues

Backbone Issues

- Hardware platform
  - Role of multi-core vs. network processors
  - Right mix of cards in packet processing system
  - Programmability vs. share-ability of processors
  - Monitoring capabilities on high-speed links
- Management software
  - Top-down configuration vs. end-to-end signaling
  - Gateway for interaction with the optical node
  - Division between management aggregate and CM
- Exposing layer 2 and layer 1 failures
  - Explicit notification vs. probing by the substrate

General Issues: Life of a Packet

- Component multiplexes slivers through its VM
- Component must (de)multiplex link traffic
- “Cut through”: no local process in component



General Questions: Packet Headers

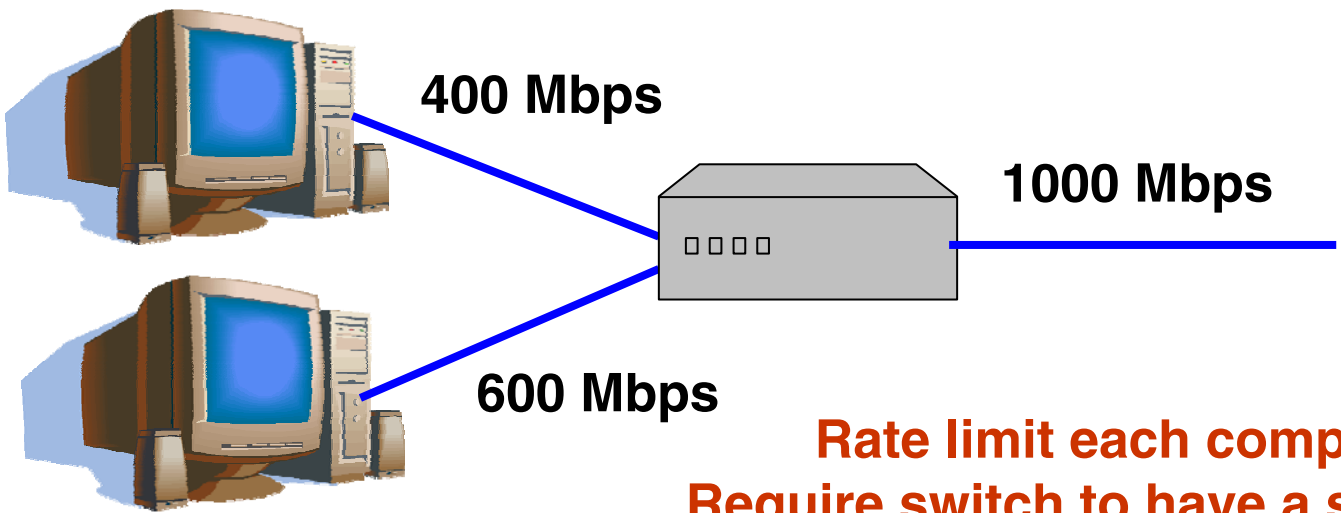
- Common format across all components?
  - Or, allow each link in GENI to use its own?
- Common id for a slice across all hops?
  - Globally unique id vs. link-local ids?
- Existing header format vs. define new one
  - E.g., MPLS tag, IP/port, VLAN tag, ...
- GENI-wide MTU vs. fragmentation in substrate
  - If an MTU, what size?
- One answer: global format, link local, IP address/port, 1500B with no fragmentation

General Issues: Quality-of-Service

- Agree on a set of service models?
  - Best-effort with fair sharing of excess
  - Min bandwidth or max delay guarantee
  - Non-work-conserving for repeatability
- Mechanisms for enforcement
  - Shaping vs. scheduling?
  - At every sliver (VM) or also at cut-through hops?
  - Handling non-QoS capable intermediate devices?
- How much agreement is needed GENI-wide?
  - Vs. how much can we keep under-specified?

General Issues: Non-QoS Capable Devices

- Intermediate devices that don't do QoS
  - Several computers connected to a single link
  - Some best-effort slices, and some guaranteed
- Simple case: rate limit each computer
  - Slivers only capitalize on excess b/w on same CPU
  - No overbooking, so no overload of the link



Rate limit each computer?
Require switch to have a scheduler?