PlanetLab: Evolution vs Intelligent Design in Global Network Infrastructure

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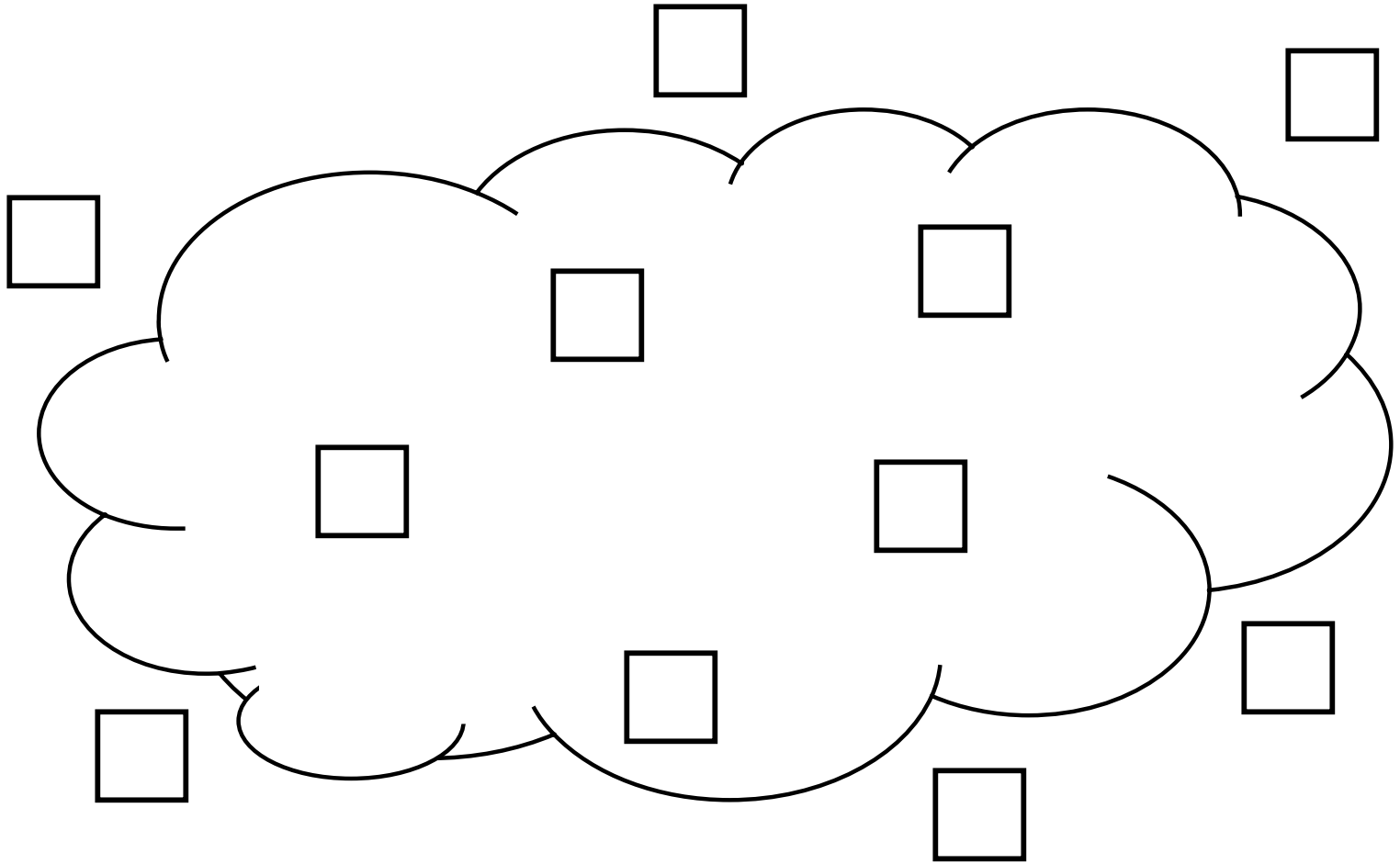
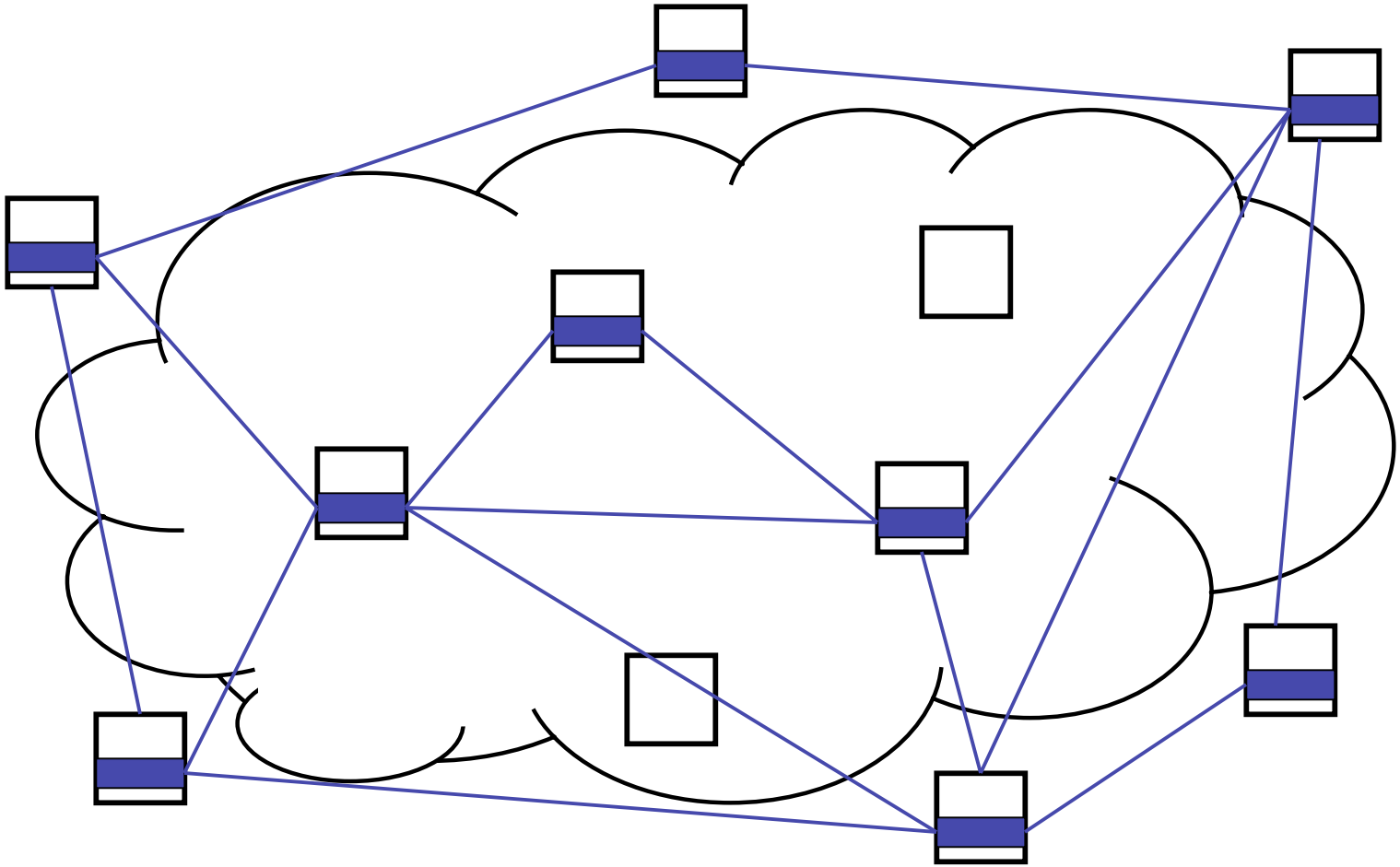
PlanetLab

- 670 machines spanning 325 sites and 35 countries
  - nodes within a LAN-hop of > 3M users
- Supports *distributed virtualization*
  - each of 600+ network services running in their own *slice*

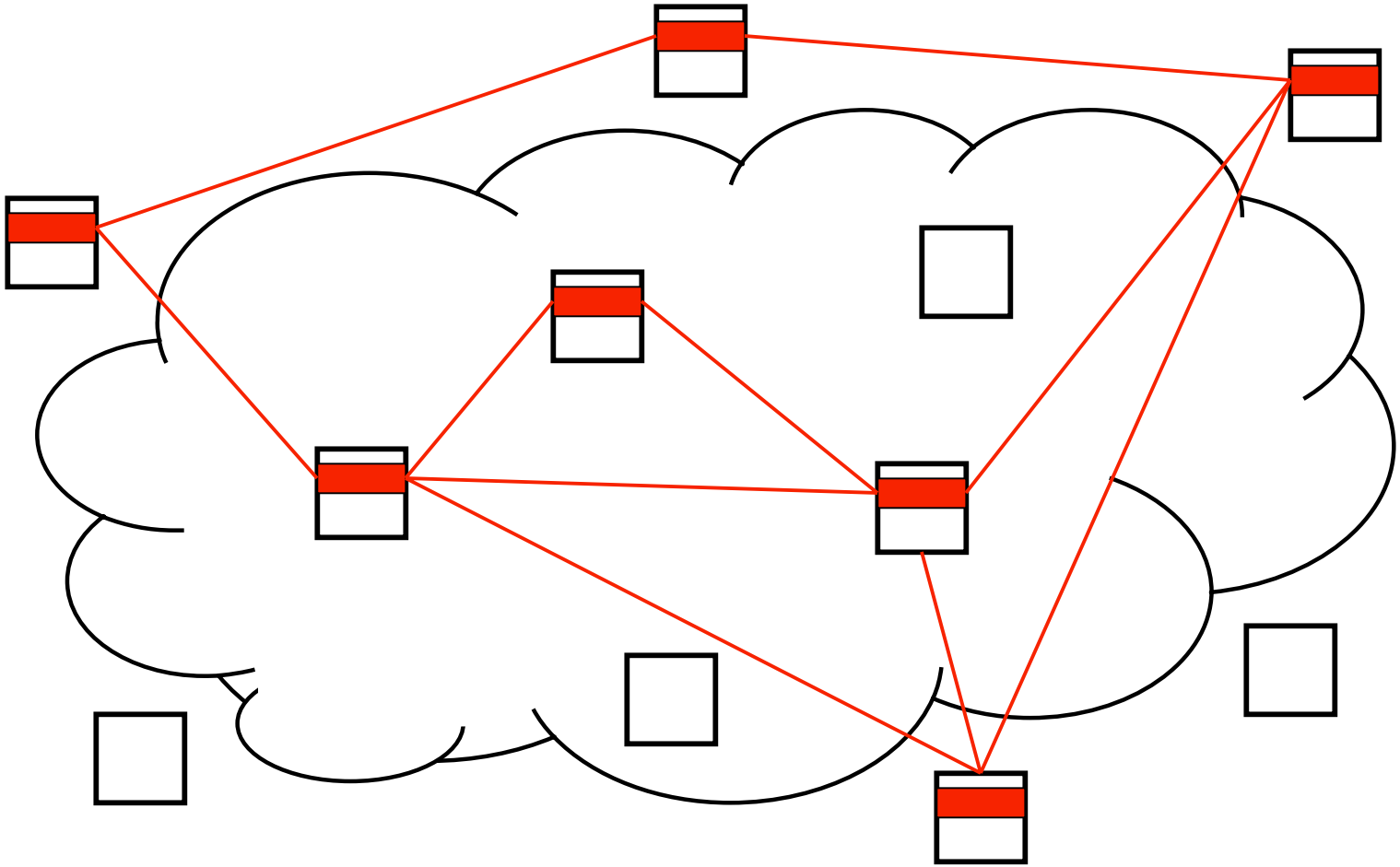
Slices



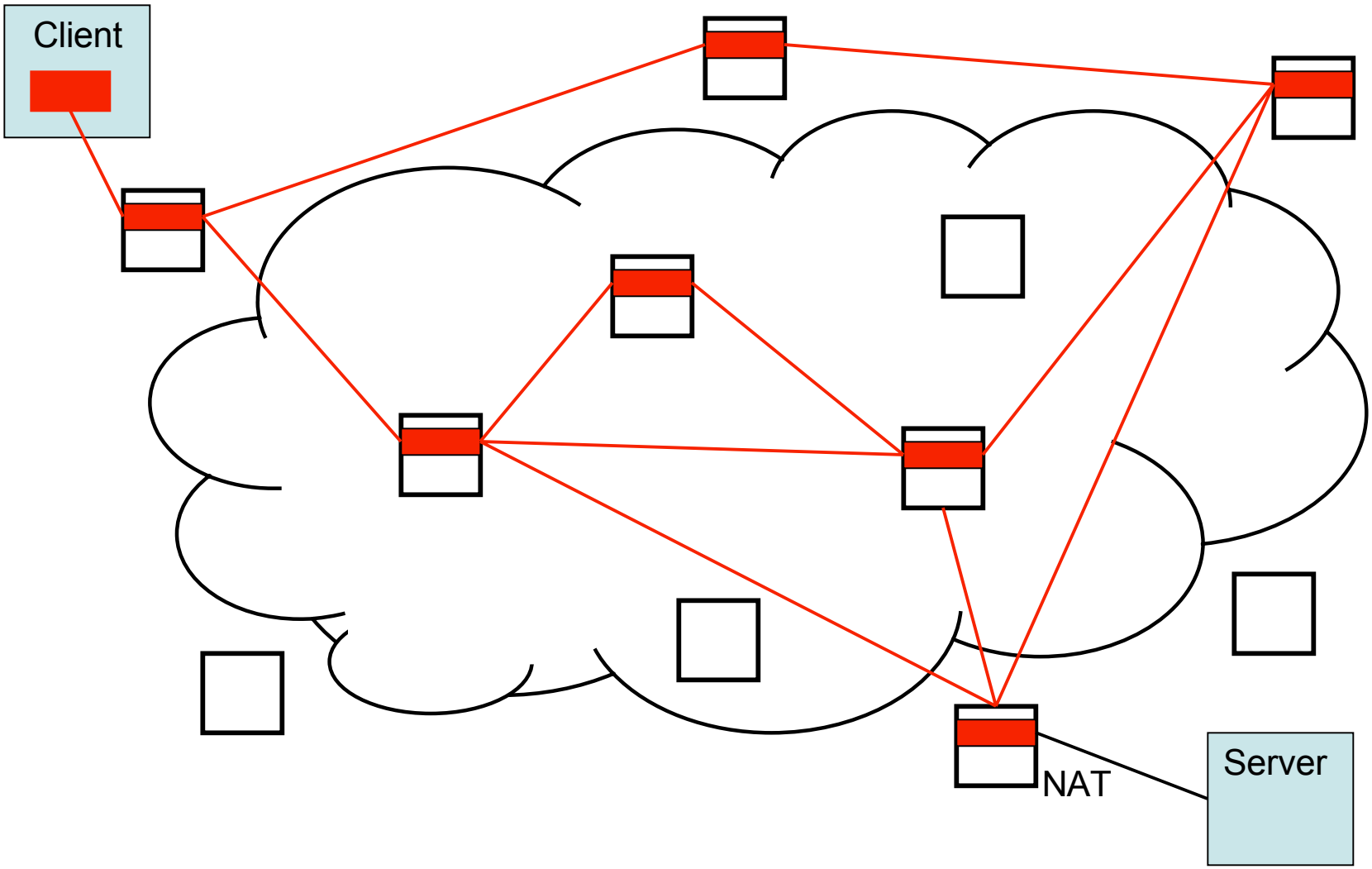
Slices



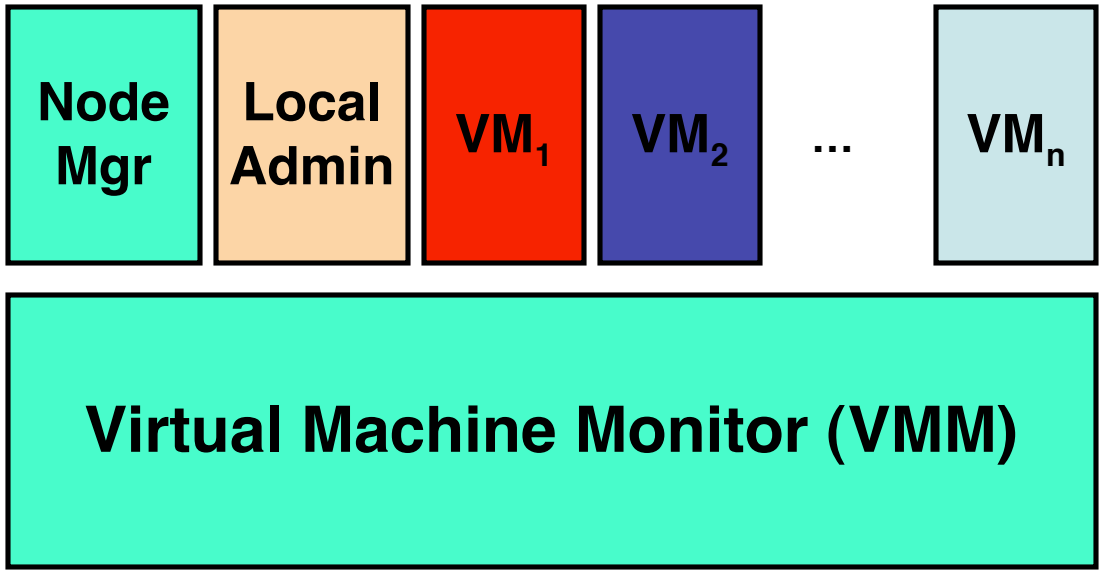
Slices



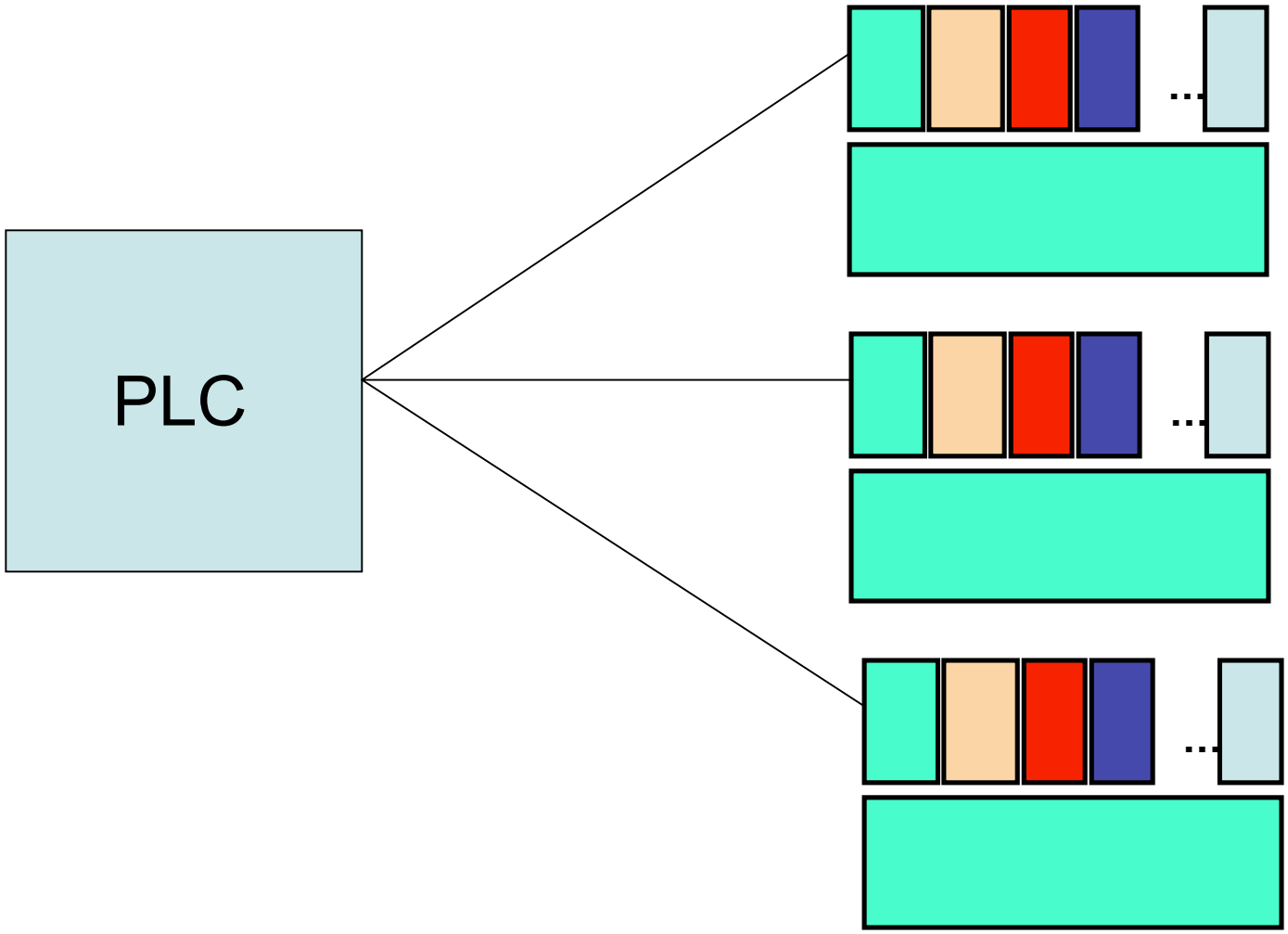
User Opt-in



Per-Node View



Global View



Long-Running Services

- Content Distribution
  - CoDeeN: Princeton
  - Coral: NYU
  - Cobweb: Cornell
- Storage & Large File Transfer
  - LOCI: Tennessee
  - CoBlitz: Princeton
- Anomaly Detection & Fault Diagnosis
  - PIER: Berkeley, Intel
  - PlanetSeer: Princeton
- DHT
  - Bamboo (OpenDHT): Berkeley, Intel
  - Chord (DHash): MIT

Services (cont)

- Routing / Mobile Access
  - i3: Berkeley
  - DHARMA: UIUC
  - VINI: Princeton
- DNS
  - CoDNS: Princeton
  - CoDoNs: Cornell
- Multicast
  - End System Multicast: CMU
  - Tmesh: Michigan
- Anycast / Location Service
  - Meridian: Cornell
  - Oasis: NYU

Services (cont)

- Internet Measurement
  - ScriptRoute: Washington, Maryland
- Pub-Sub
  - Corona: Cornell
- Email
  - ePost: Rice
- Management Services
  - Stork (environment service): Arizona
  - Emulab (provisioning service): Utah
  - Sirius (brokerage service): Georgia
  - CoMon (monitoring service): Princeton
  - PlanetFlow (auditing service): Princeton
  - SWORD (discovery service): Berkeley, UCSD

Usage Stats

- Slices: 600+
- Users: 2500+
- Bytes-per-day: 3 - 4 TB
- IP-flows-per-day: 190M
- Unique IP-addrs-per-day: 1M

Two Views of PlanetLab

- Useful research instrument
- Prototype of a new network architecture

- What's interesting about this architecture?
  - more an issue of synthesis than a single clever technique
  - technical decisions that address non-technical requirements

Requirements

1) It must provide a global platform that supports both short-term experiments and long-running services.
   - services must be isolated from each other
   - multiple services must run concurrently
   - must support real client workloads

Requirements

2) It must be available now, even though no one knows for sure what “it” is.
   - deploy what we have today, and evolve over time
   - make the system as familiar as possible (e.g., Linux)
   - accommodate third-party management services

Requirements

3) We must convince sites to host nodes running code written by unknown researchers from other organizations.
   - protect the Internet from PlanetLab traffic
   - must get the trust relationships right

Requirements

4) Sustaining growth depends on support for site autonomy and decentralized control.
   - sites have final say over the nodes they host
   - must minimize (eliminate) centralized control

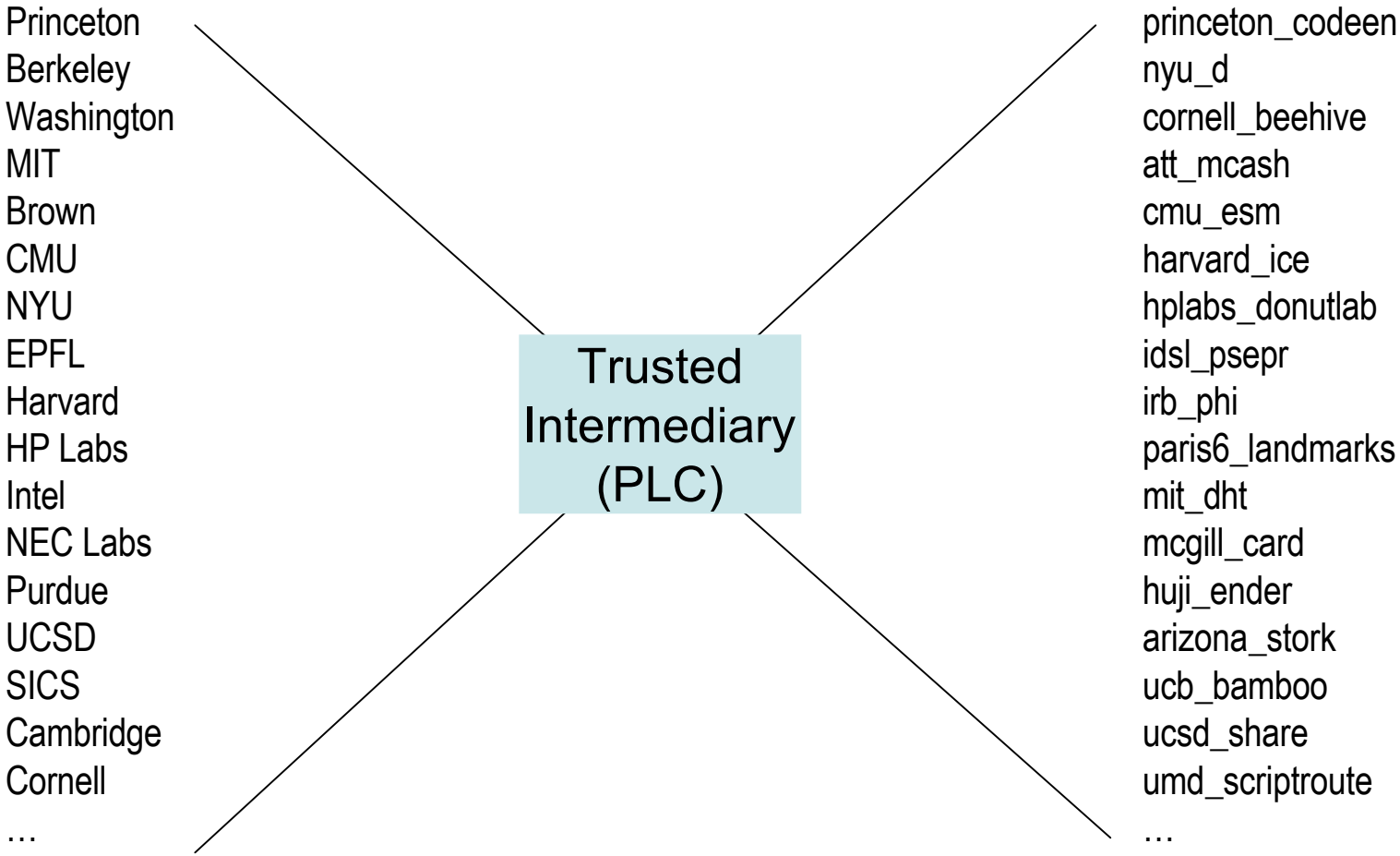
Requirements

5) It must scale to support many users with minimal resources available.
   - expect under-provisioned state to be the norm
   - shortage of logical resources too (e.g., IP addresses)

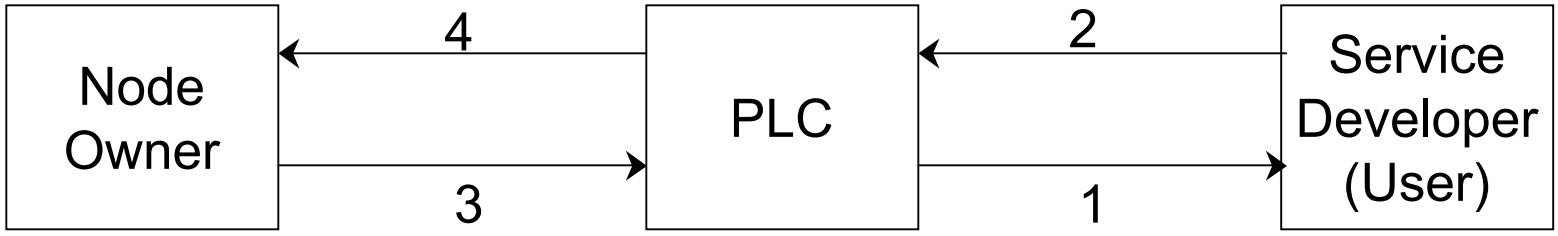
Design Challenges

- Develop a management (control) plane that accommodates these often conflicting requirements.
- Balance the need for isolation with the reality of scarce resources.
- Maintain a stable and usable system while continuously evolving it.

Trust Relationships



Trust Relationships (cont)



1) PLC expresses trust in a user by issuing it credentials to access a slice

2) Users trust PLC to create slices on their behalf and inspect credentials

3) Owner trusts PLC to vet users and map network activity to right user

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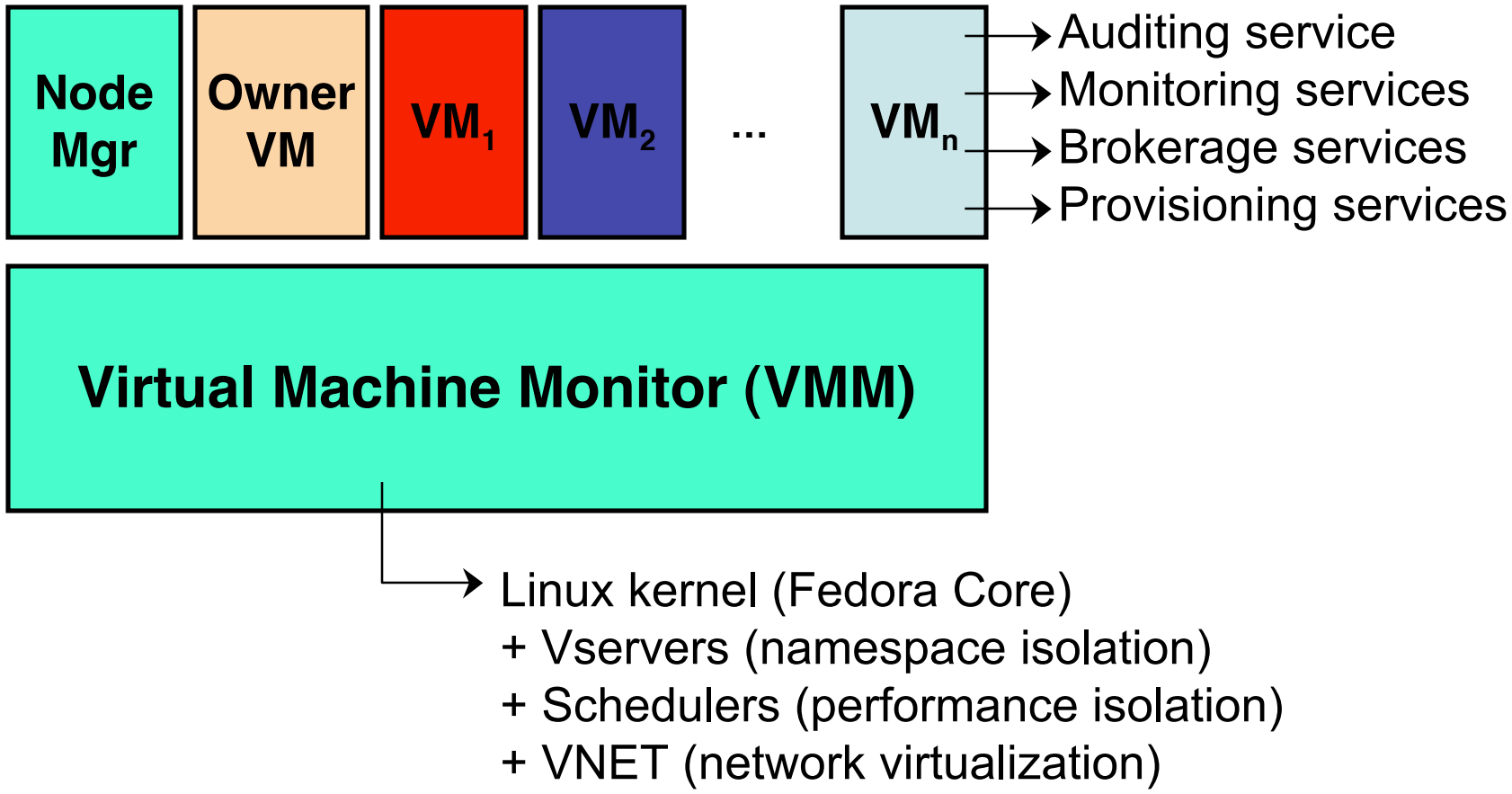
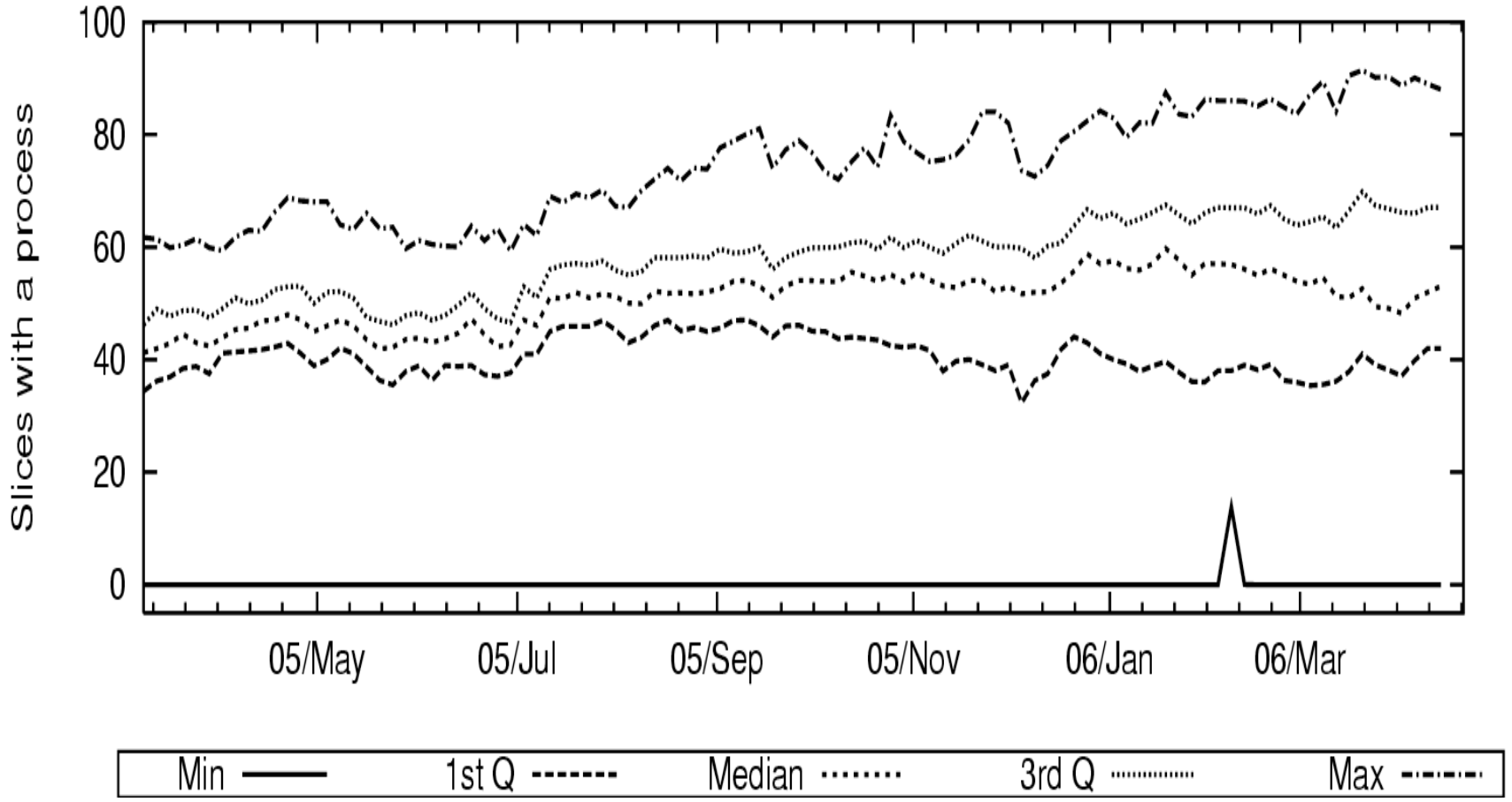
Decentralized Control

- Owner autonomy
  - owners allocate resources to favored slices
  - owners selectively disallow unfavored slices
- Delegation
  - PLC grants tickets that are redeemed at nodes
  - enables third-party management services
- Federation
  - create “private” PlanetLabs using MyPLC
  - establish peering agreements

Virtualization



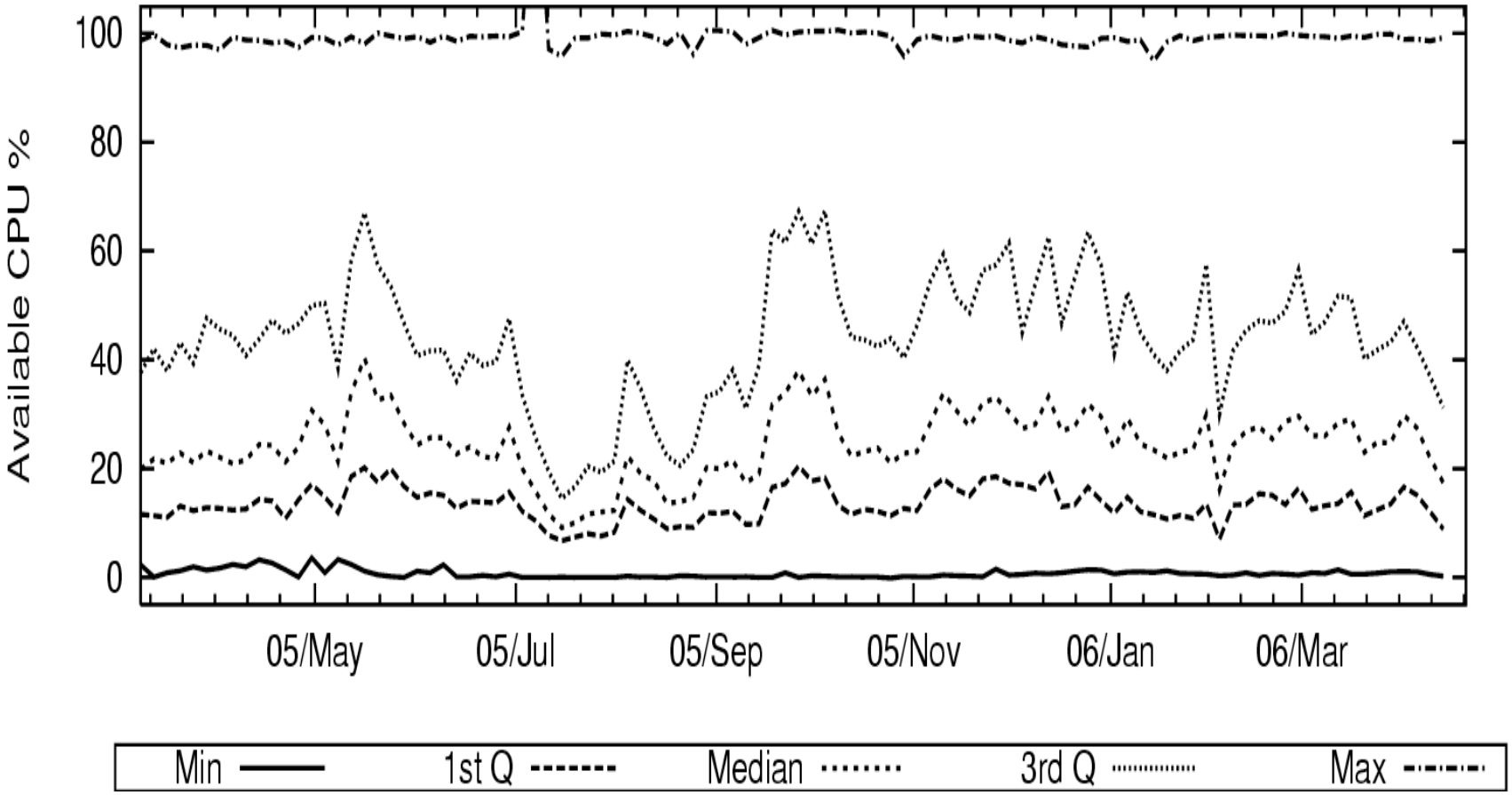
Active Slices



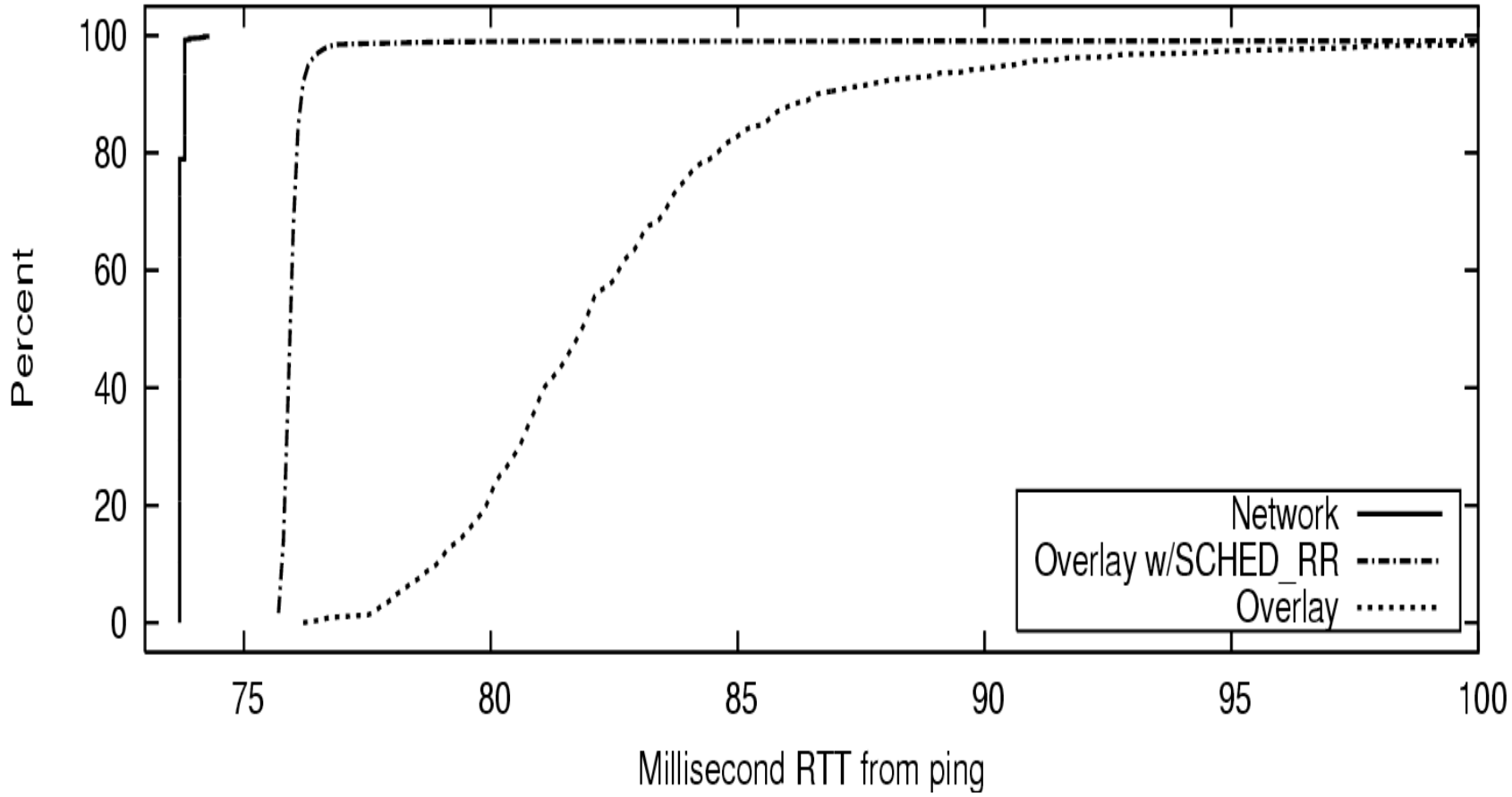
Resource Allocation

- Decouple slice creation and resource allocation
  - given a "fair share" by default when created
  - acquire additional resources, including guarantees
- Fair share with protection against thrashing
  - 1/N*th* of CPU
  - 1/N*th* of link bandwidth
    - owner limits peak rate
    - upper bound on average rate (protect campus bandwidth)
  - disk quota
  - memory limits not practical
    - kill largest user of physical memory when swap at 90%
    - reset node when swap at 95%

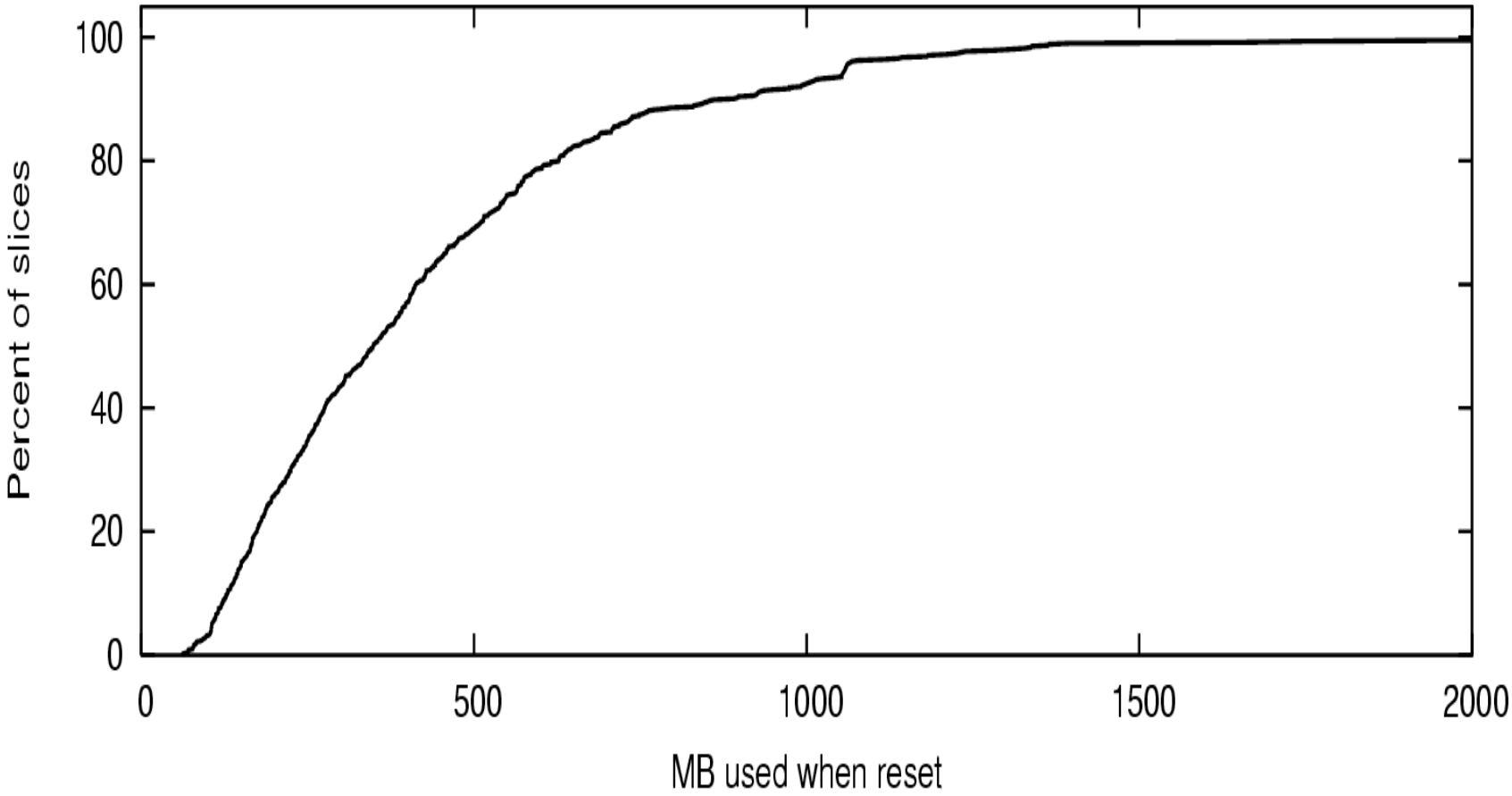
CPU Availability



Scheduling Jitter



Memory Availability



Evolution vs Intelligent Design

- Favor evolution over clean slate
- Favor design principles over a fixed architecture
- Specifically…
  - leverage existing software and interfaces
  - keep VMM and control plane orthogonal
  - exploit virtualization
    - vertical: management services run in slices
    - horizontal: stacks of VMs
  - give no one root (least privilege + level playing field)
  - support federation (divergent code paths going forward)

Other Lessons

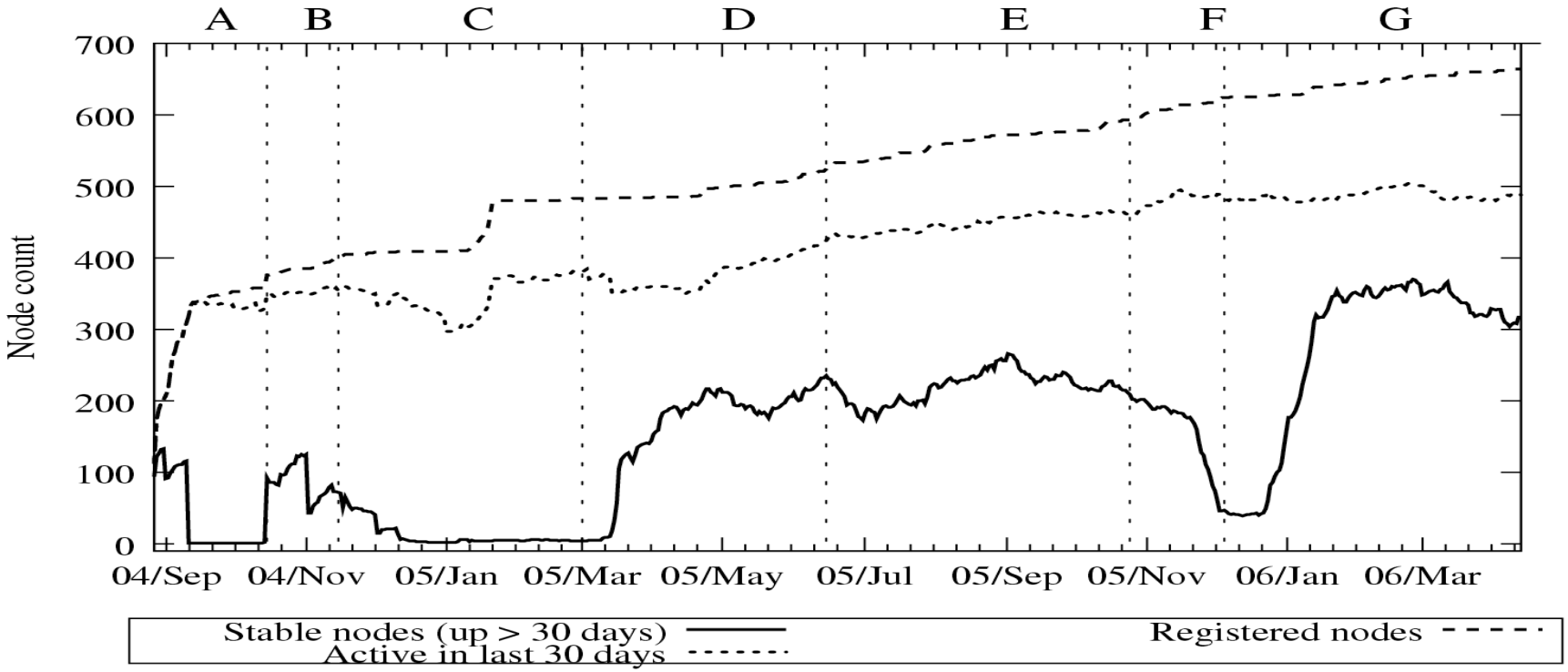
- Inferior tracks lead to superior locomotives
- Empower the user: **`yum`**
- Build it and they (research papers) will come
- Overlays are not networks
- Networks are just overlays
- PlanetLab: We debug your network
- From universal connectivity to gated communities
- If you don't talk to your university's general counsel, you aren't doing network research
- Work fast, before anyone cares

Collaborators

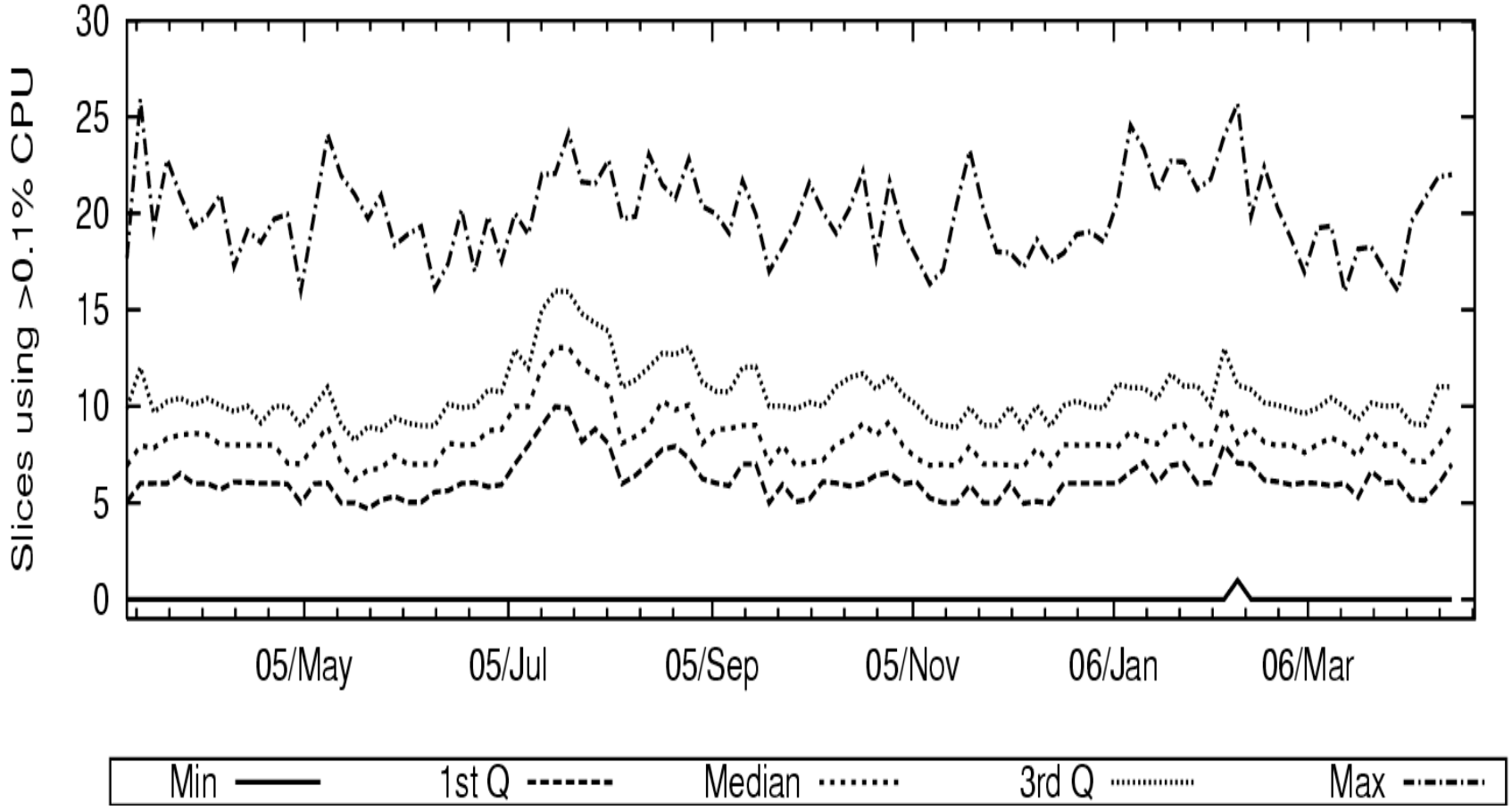
- Andy Bavier
- Marc Fiuczynski
- Mark Huang
- Scott Karlin
- Aaron Klingaman
- Martin Makowiecki
- Reid Moran
- Steve Muir
- Stephen Soltesz
- Mike Wawrzoniak
- David Culler, Berkeley
- Tom Anderson, UW
- Timothy Roscoe, Intel
- Mic Bowman, Intel
- John Hartman, Arizona
- David Lowenthal, UGA
- Vivek Pai, Princeton
- David Parkes, Harvard
- Amin Vahdat, UCSD
- Rick McGeer, HP Labs

Node Availability

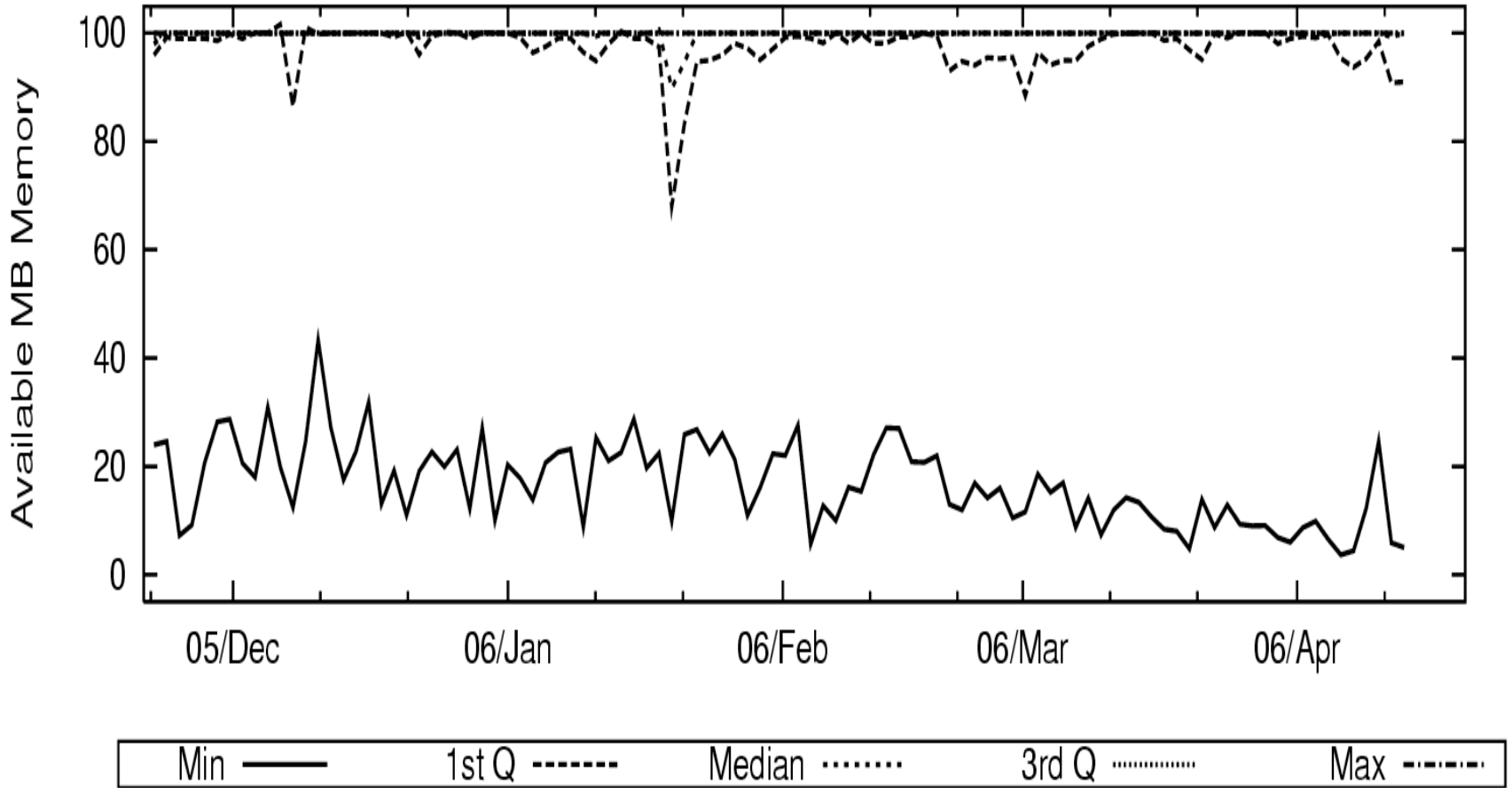
A: Runup to NSDI '05 deadline
B: After NSDI '05 deadline
C: 3.0 rollout begins
D: 3.0 stable release
E: 3.1 stable release
F: 3.2 rollout begins
G: 3.2 stable release



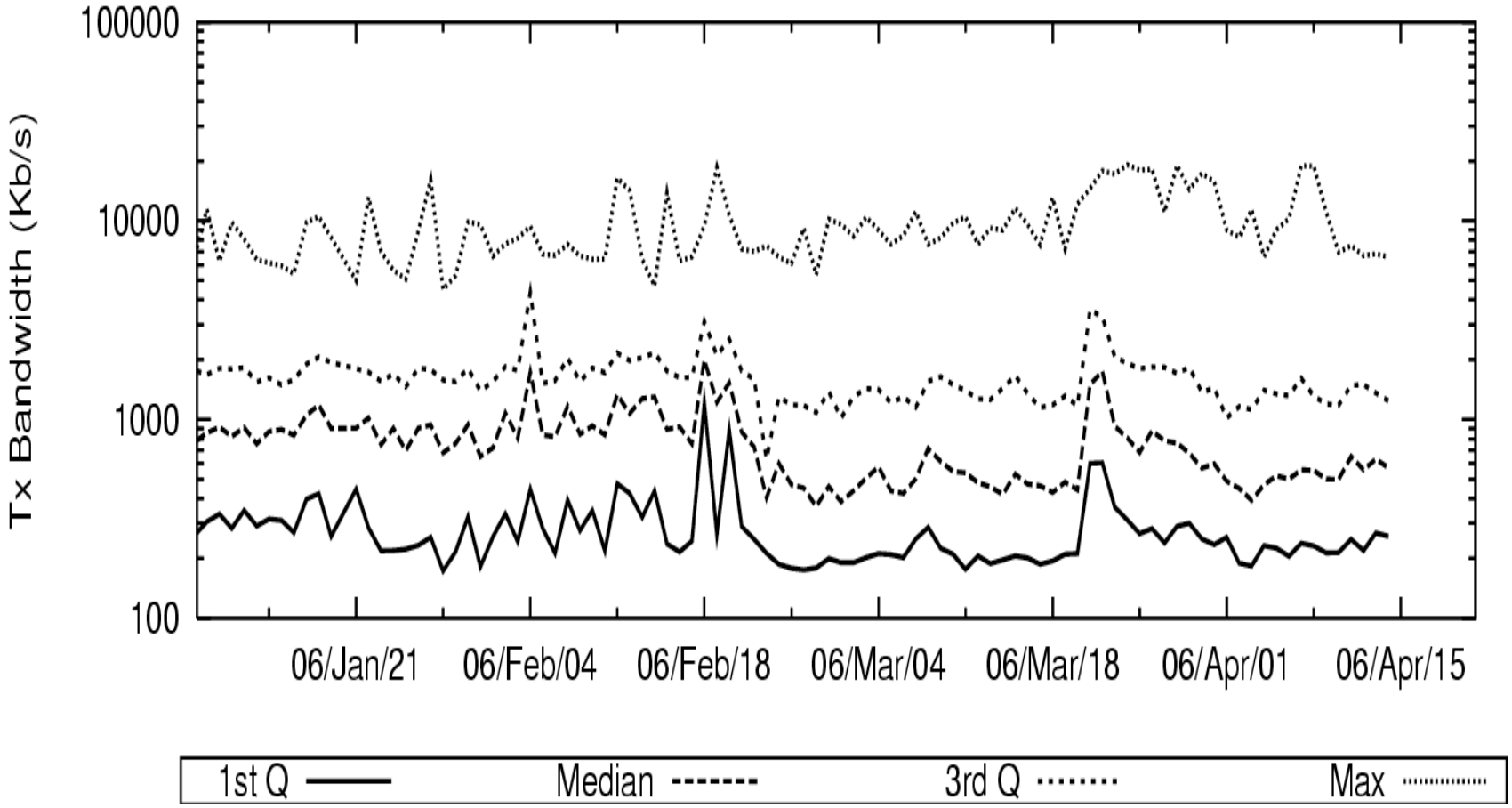
Live Slices


Slices using >0.1% CPU
30
25
20
15
10
5
0
05/May
05/Jul
05/Sep
05/Nov
06/Jan
06/Mar
Min
1st Q
Median
3rd Q
Max

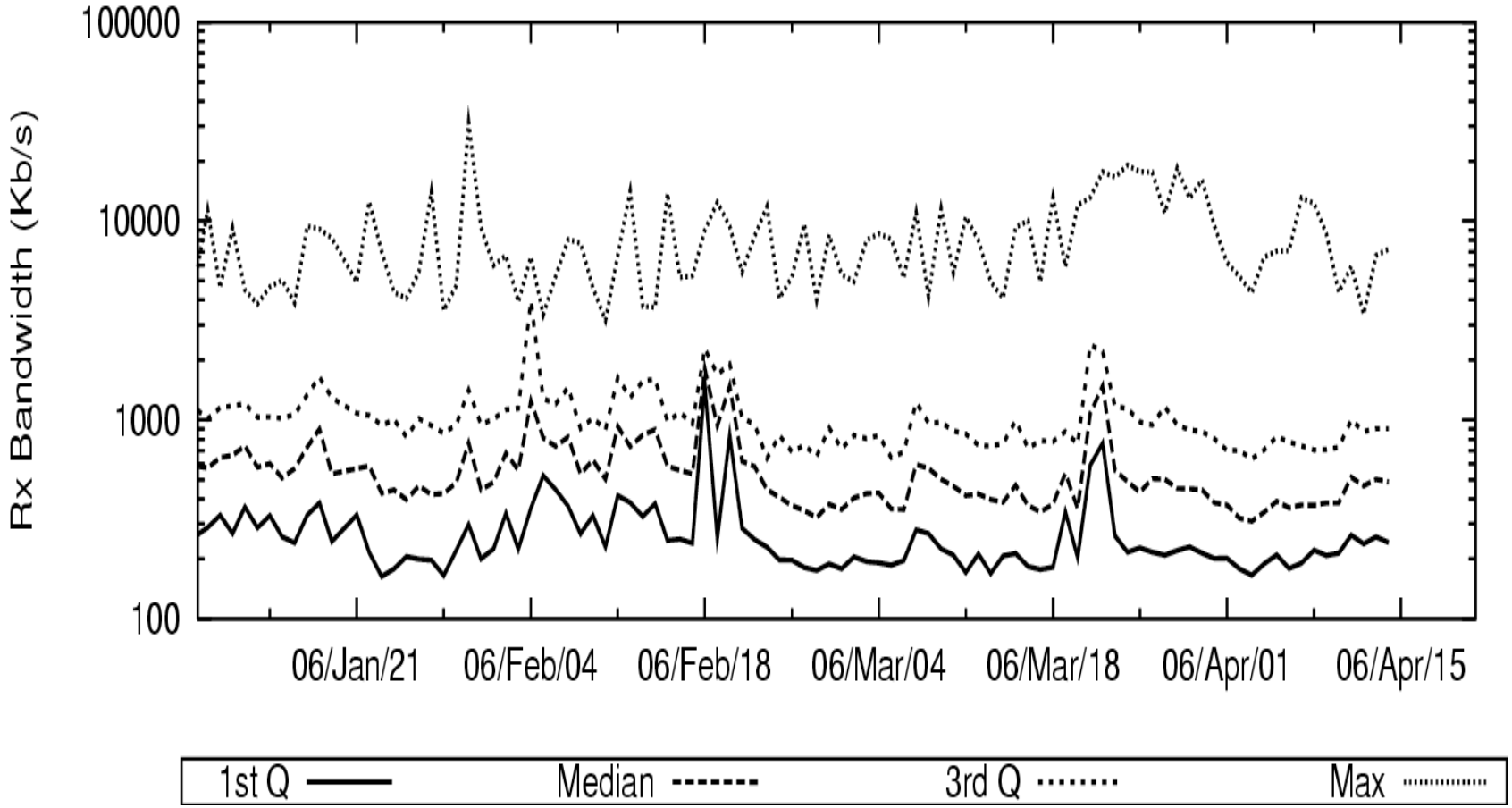
Memory Availability



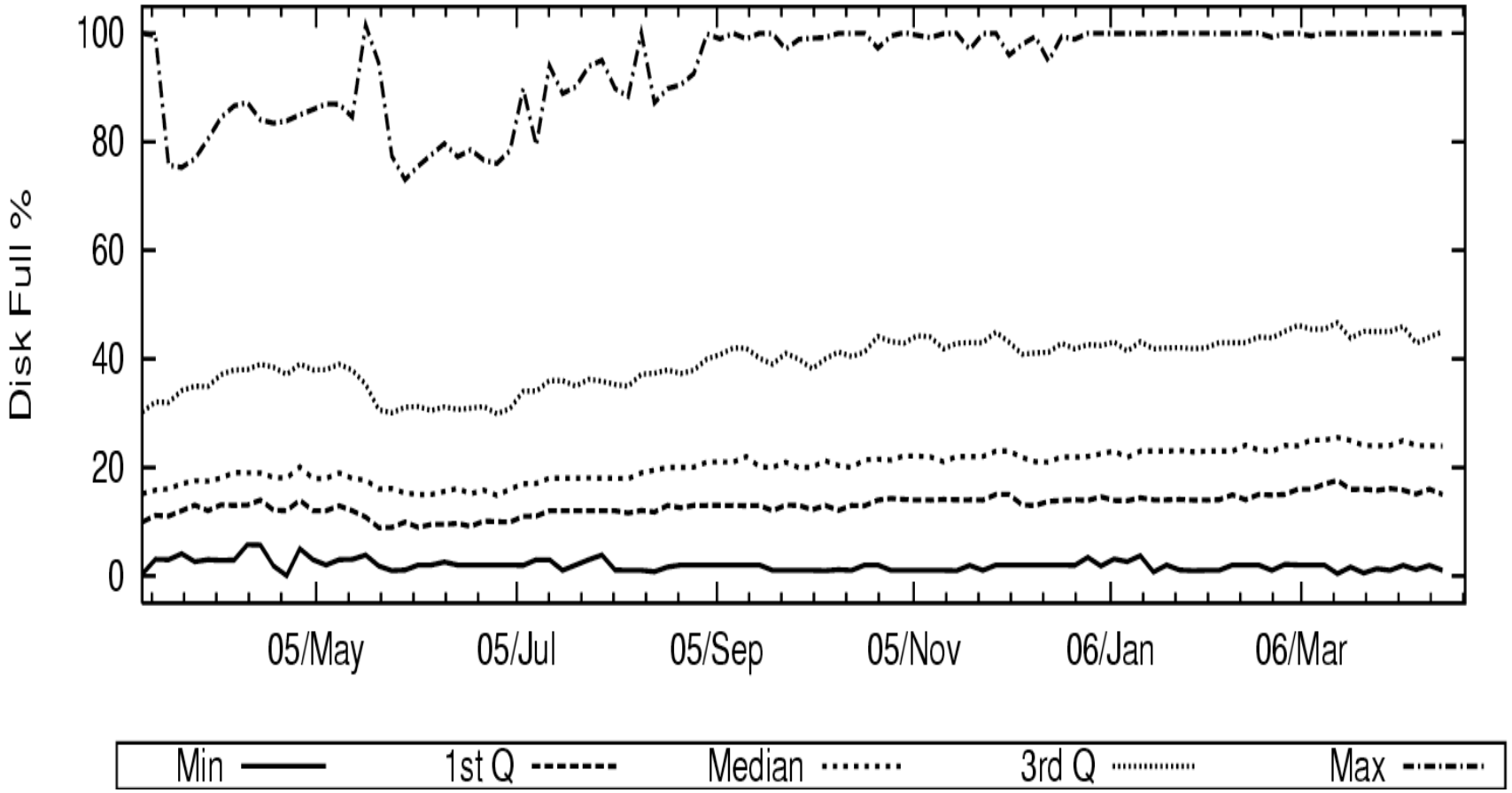
Bandwidth Out



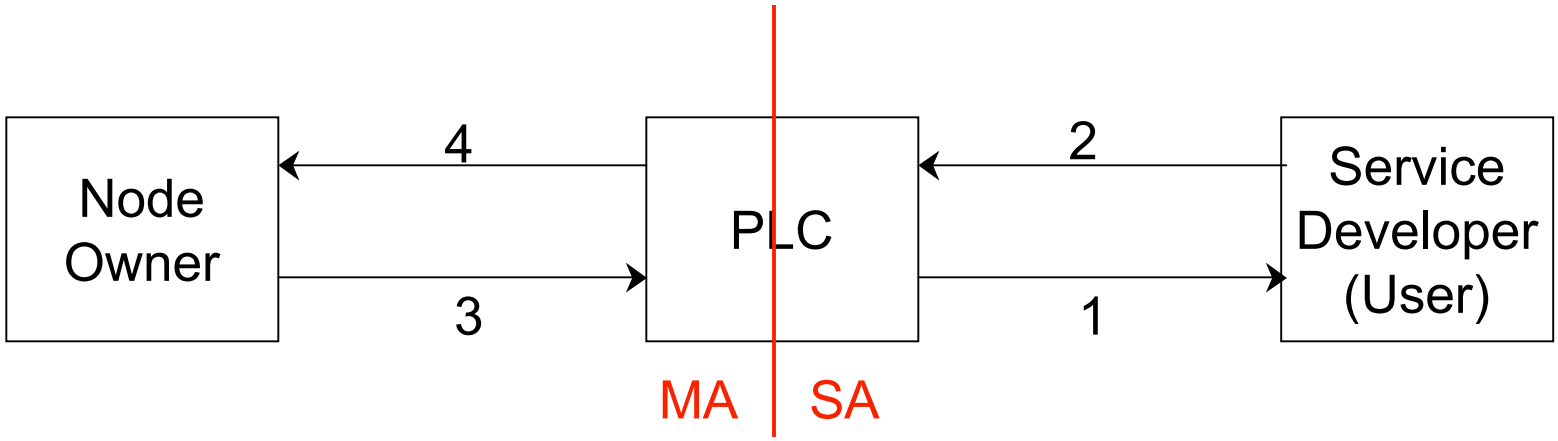
Bandwidth In



Disk Usage


Disk Full %
100
80
60
40
20
0
05/May
05/Jul
05/Sep
05/Nov
06/Jan
06/Mar
Min
1st Q
Median
3rd Q
Max

Trust Relationships (cont)



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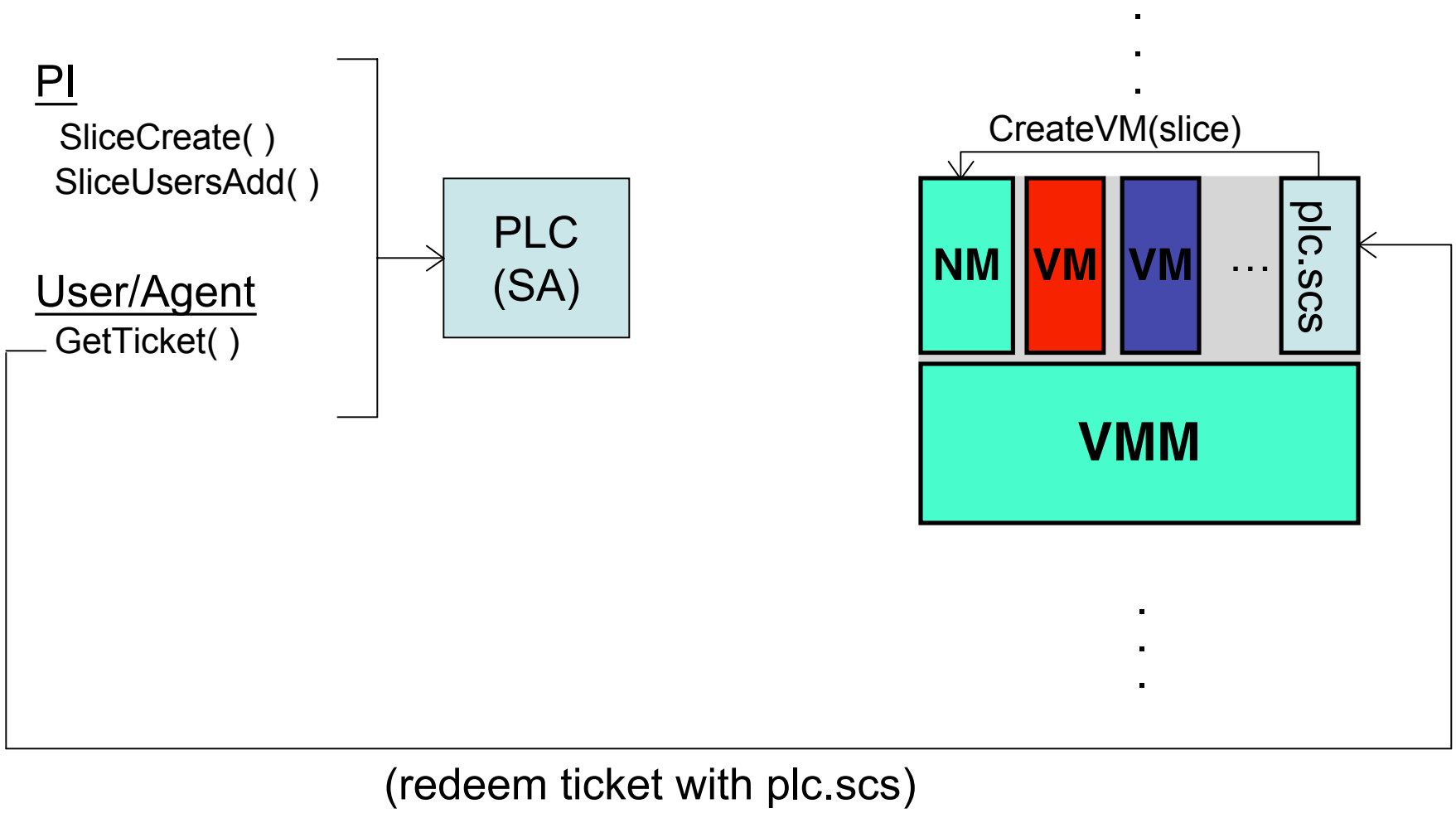
MA = Management Authority | SA = Slice Authority

Slice Creation



Brokerage Service