PlanetLab: A Blueprint for Introducing Disruptive Technology into the Internet

Larry Peterson
Princeton University / Intel Research

PlanetLab vs Grid

- The Grid is the next generation supercomputer
- PlanetLab is the next generation Internet

PLANETLAB

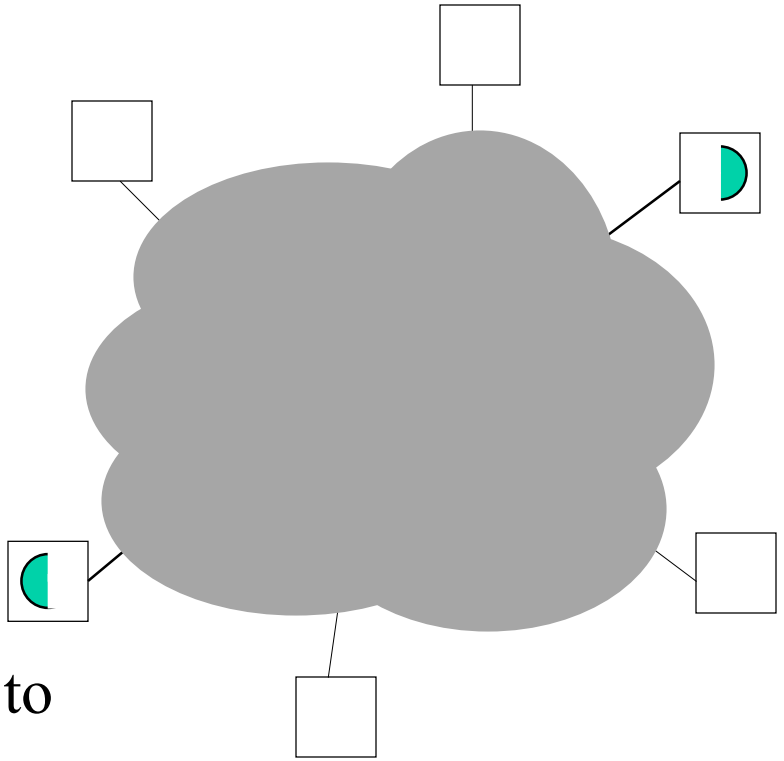
Innovator's Dilemma

- The Internet is an enormous success story
  - commercially
  - impact on our daily lives
  - global reach
- Success has an unexpected cost: *ossification*
  - difficult to deploy disruptive technologies
    - correct vulnerabilities
    - introduce new capabilities

PLANETLAB

Today's Internet

Best-Effort Packet Delivery Service



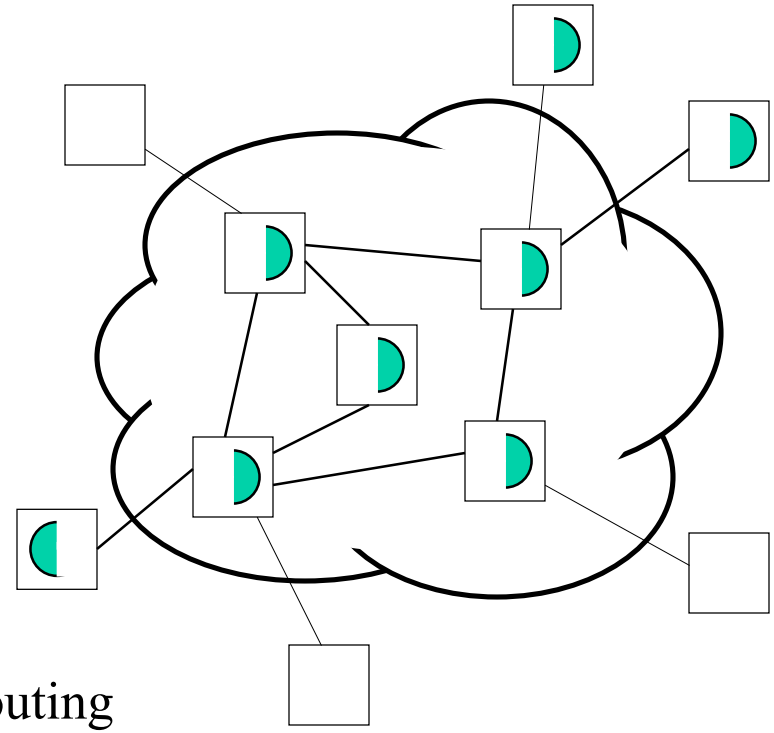
Limitations

- the Internet is "opaque" making it difficult to adapt to current network conditions
- applications cannot be widely distributed (typically split into two pieces: client and server)

PLANETLAB

Tomorrow's Internet

Collection of Planetary-Scale Services



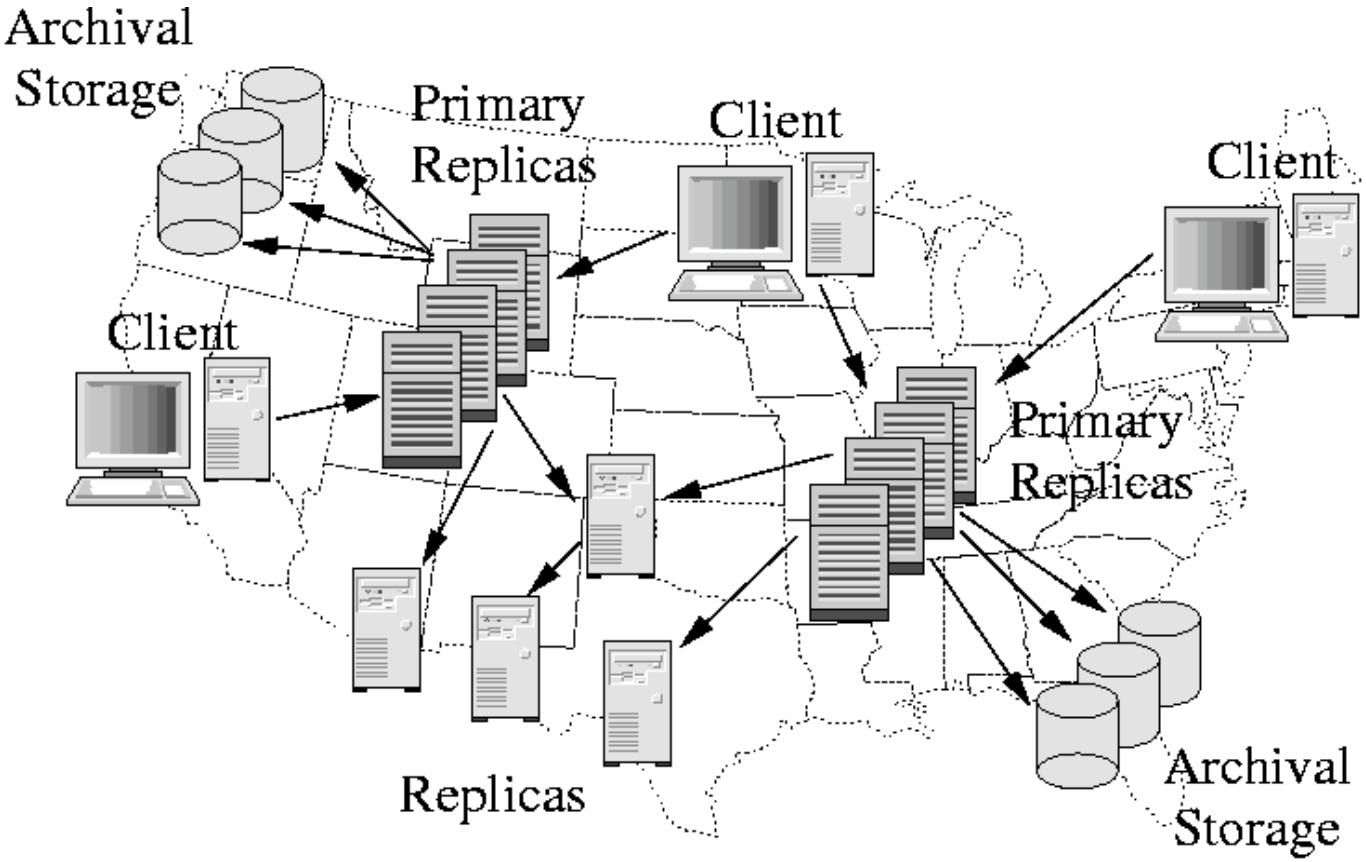
<u>Opportunities</u>

- multiple vantage points
  - anomaly detection, robust routing
- proximity to data sources/sinks
  - content distribution, data fusion
- multiple, independent domains
  - survivable storage

PLANETLAB

Berkeley: OceanStore

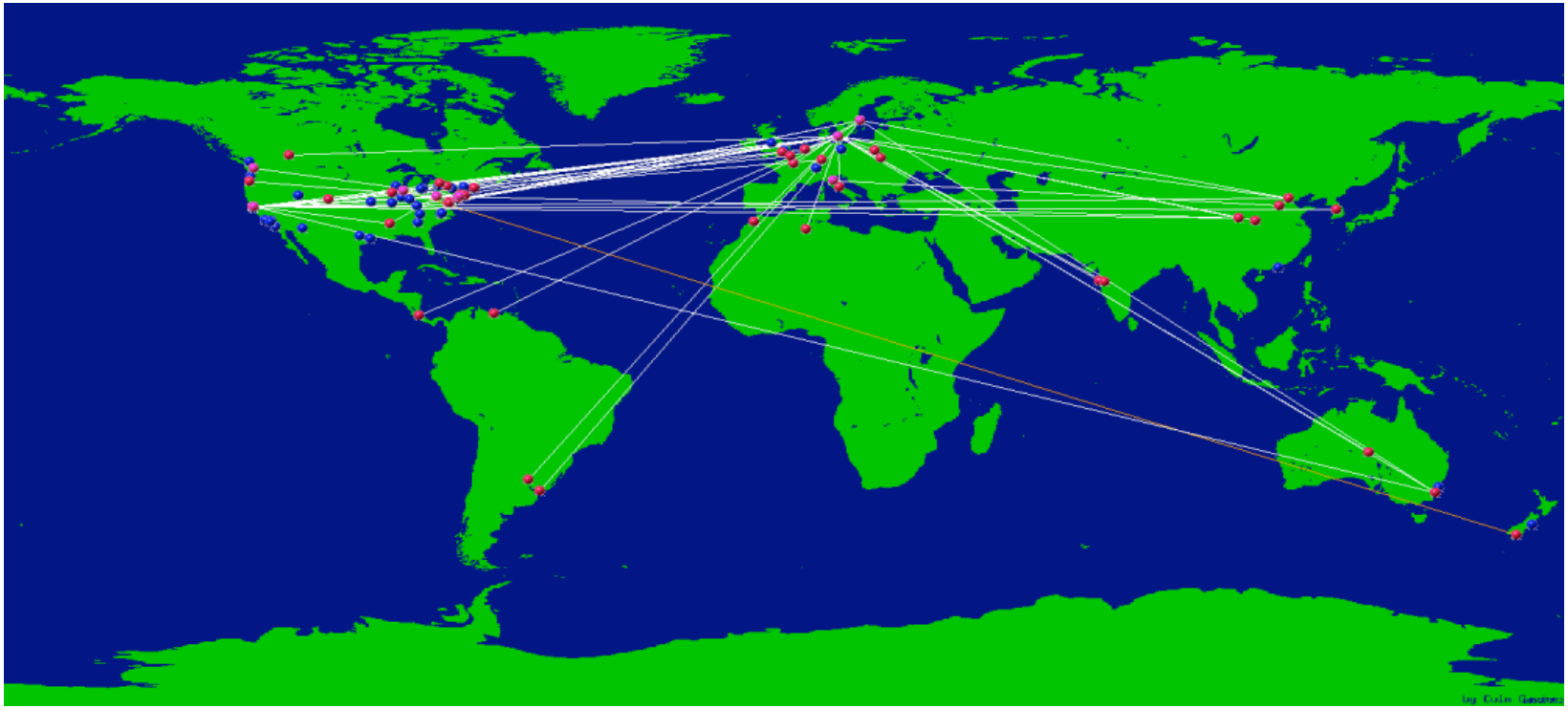
RAID distributed over the whole Internet



PLANETLAB

Intel: Netbait

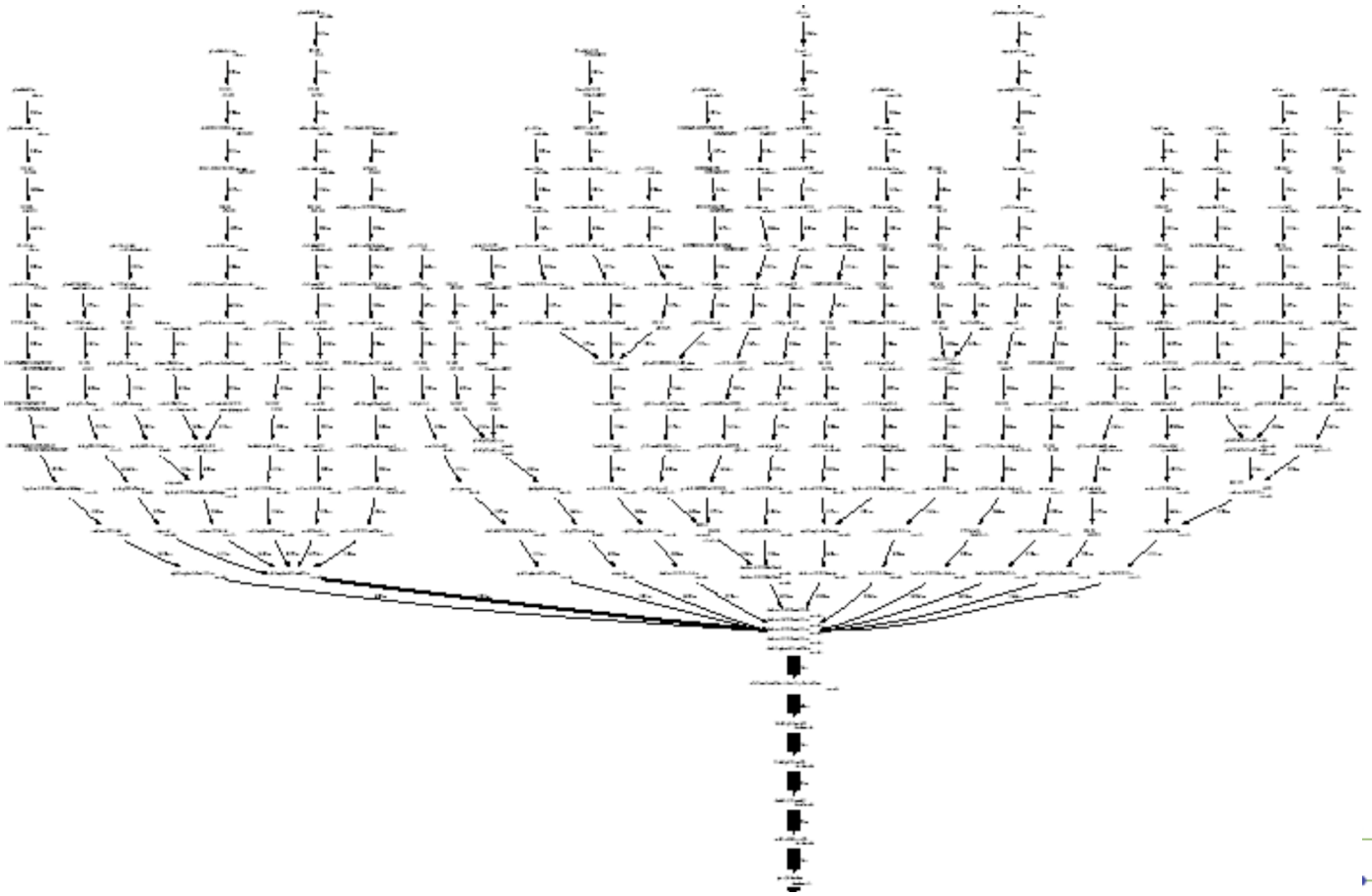
Detect and track Internet worms globally



PLANETLAB

Washington: ScriptRoute

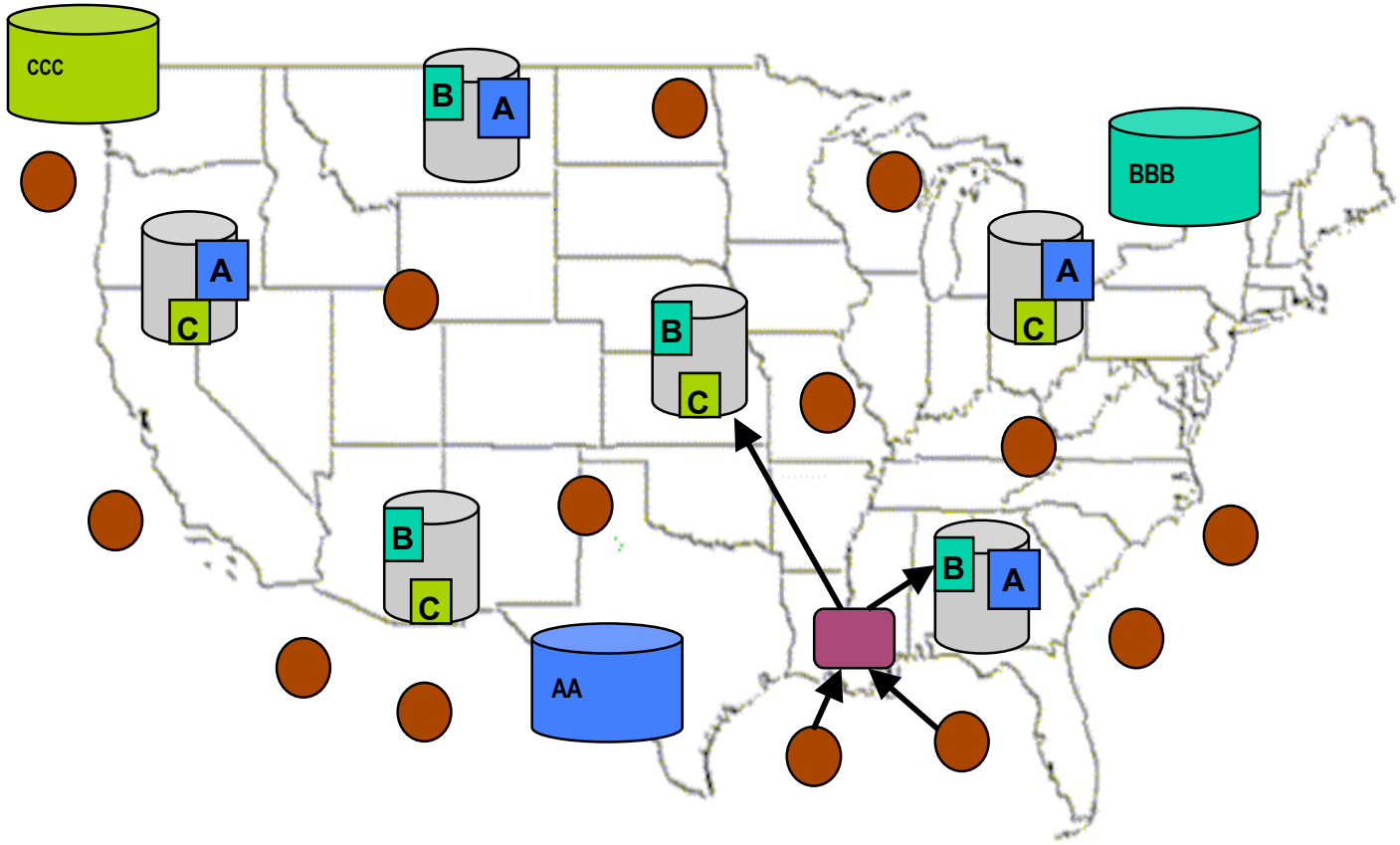
Internet Measurement Tool



PLANETLAB

Princeton: CoDeeN

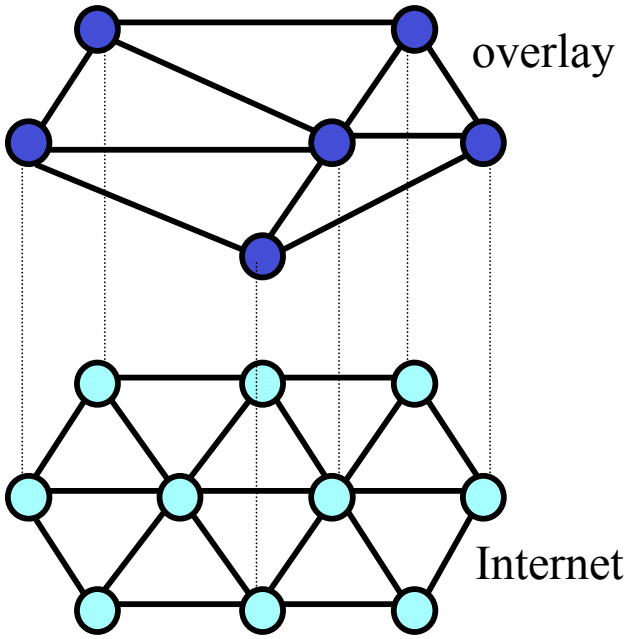
Open Content Distribution Network



PLANETLAB

Evolving the Internet

- Add a new layer to the network architecture
  - overlay networks
    - purpose-built virtual networks that use the existing Internet for transmission
    - the Internet was once deployed as an overlay on top of the telephony network



- Challenge
  - how to innovate & deploy at scale

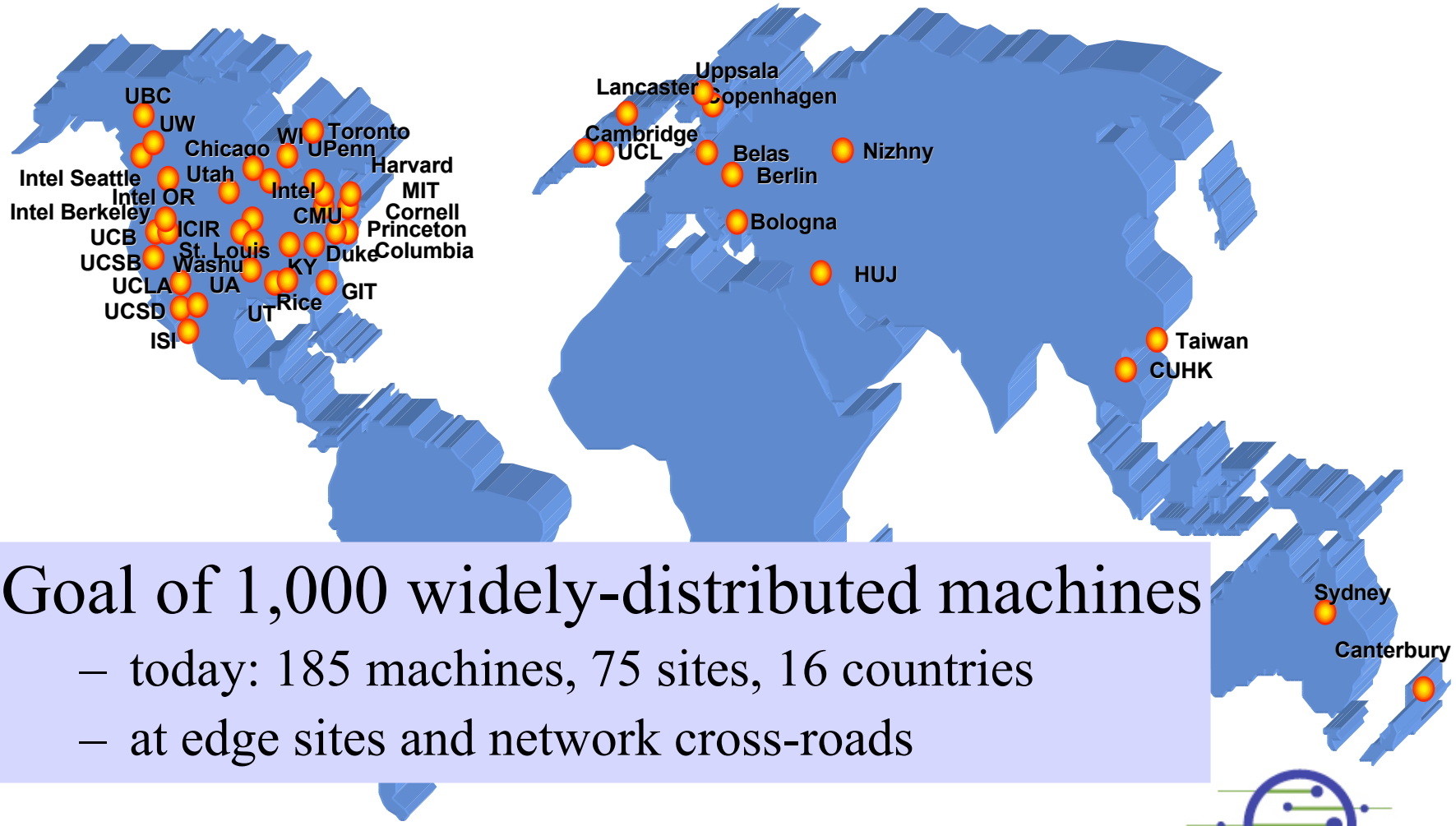
PLANETLAB

The Story so Far

- The Internet is a tremendous success, but…
  - the architecture has fundamental limits
  - its very success makes it hard to change
- The research community is teeming with innovative planetary-scale services
  - exploit multiple points-of-presence throughout the net
- Overlays offer an attractive way to introduce disruptive technology into the Internet, but…
  - there is a high barrier-to-entry

PLANETLAB

PlanetLab is…



Goal of 1,000 widely-distributed machines

- today: 185 machines, 75 sites, 16 countries
- at edge sites and network cross-roads

PLANETLAB

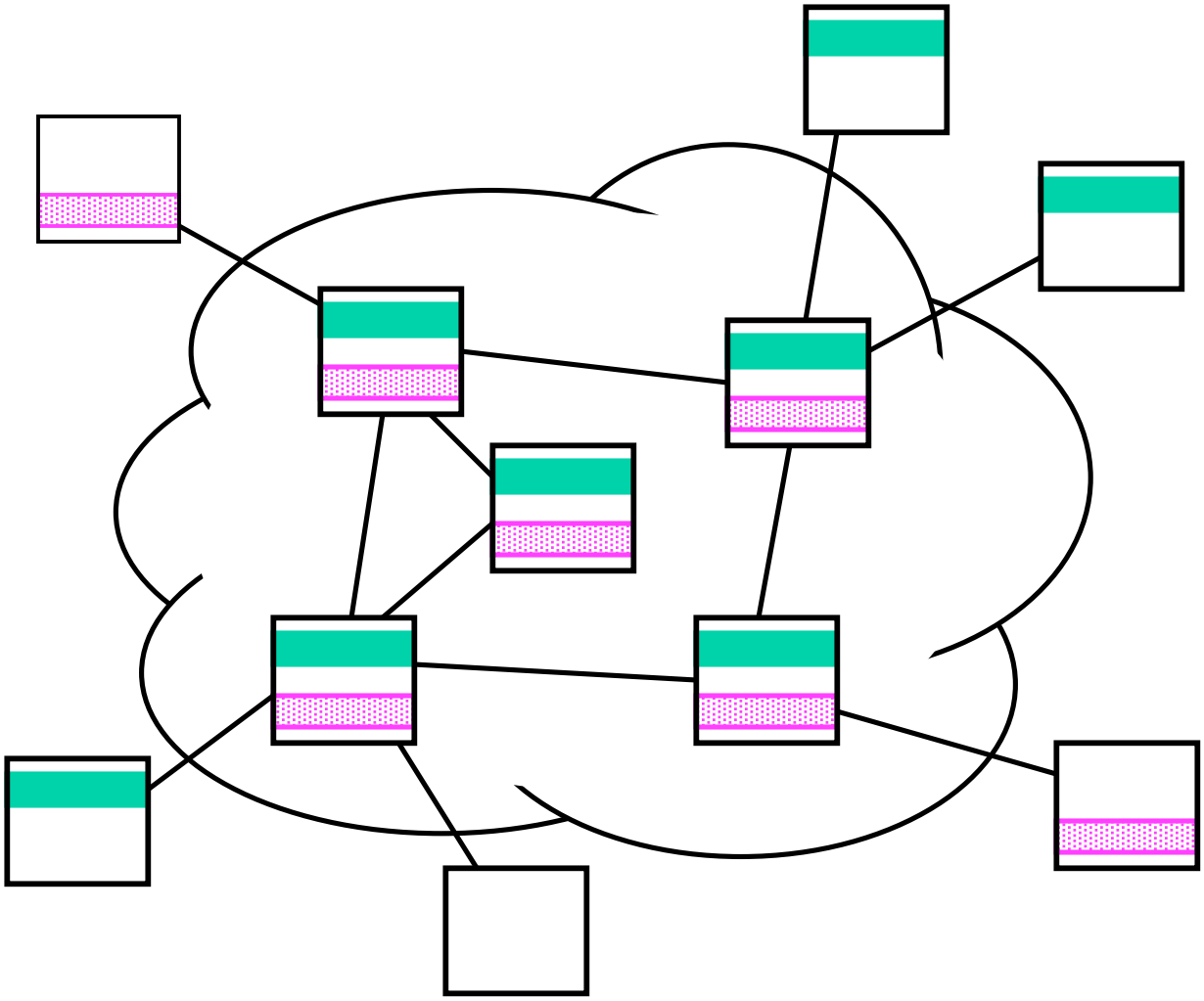
PlanetLab is…

A common software package

- Main components
  - Linux kernel w/ extensions to support isolation
  - bootstrapping and software distribution mechanisms
  - collection of *unbundled management* services
- Collectively support distributed virtualization
  - run many overlay networks simultaneously
  - each service (overlay) runs in a *slice* of PlanetLab's global resources

PLANETLAB

Slices



PLANETLAB

PlanetLab is…

A test-bed for experimenting with network services

- 120+ active research projects
- Advantages
  - experiment at scale
  - experiment under real-world conditions
  - potential for real workloads and users

PLANETLAB

PlanetLab is…

A deployment platform

- Continuously-running services
  - CoDeeN content distribution network (Princeton)
  - Sophia distributed query processing engine (Princeton)
  - PIER distributed query processing engine (Berkeley)
  - ScriptRoute network measurement tool (Washington)
  - NetBait worm detection service (Intel)
  - Chord scalable object location service (MIT, Berkeley)
  - OceanStore storage system (Berkeley)

PLANETLAB

PlanetLab is…

A microcosm of the next Internet

- Fold services back into PlanetLab
  - evolve core technologies to support overlays and slices
- Examples
  - Sophia used to monitor health of PlanetLab nodes
  - Chord provides scalable object location
- Long-term goals
  - develop open protocols and standards
    - allow federation of public & private “PlanetLabs” to co-exist
  - discover common sub-services

PLANETLAB

PlanetLab is…

A research community

- Started as a grass-roots effort
  - 35 researchers gathered in March of 2002
  - Intel provided seed funding
  - self-organized into five working groups
- Next Phase: Academic/Industrial Consortium
  - hosted by Princeton (w/ Berkeley and Washington)
  - build-out and operate the infrastructure
  - lower the barrier to entry for research and teaching

PLANETLAB

Software Architecture

- Support distributed virtualization
  - *slice*: a network of virtual machines
  - multiple services run concurrently (some long-lived)
  - deploy version *i* of PlanetLab on version *i+1*
- Per-Node Components
  - create and isolate virtual machines
- Global Components (Services)
  - create slice across a set of nodes
  - monitor node health
  - routing underlay

PLANETLAB

Per-Node Components

- Node Manager
  - responds to requests to create a virtual machine
  - defines spec for VM
    - resources consumed
    - network name space consumed
  - performs admission control
- Vserver: virtualizes at system call interface
  - each vserver runs in its own security context
    - private UID/GID name space
    - limited superuser capabilities (e.g., no CAP_NET_RAW)
  - uses **`chroot`** for file system isolation
  - scales to hundreds of vservers per node

PLANETLAB

Per-Node (cont)

- plkmod: kernel module that enforces VM isolation
  - processor and link scheduling
  - virtualizes the network
    - safe raw sockets
    - port-space isolation
    - address space sandboxing
- Sensors: uniform interface to node status info
  - HTTP-based
  - core set + user-defined
- Admin Slice: local admin control
  - set bw limits
  - run tcpdump

Creating Slices

- Two-stage process
  - discover available resources
    - use monitoring service
  - create virtual machine on each selected node
    - contact broker for rights to resources (receive *tickets*)
    - contact node manager to redeem tickets
    - node manager implements admission control
- Status
  - prototypes of mechanisms
  - simple policies in the near-term
  - create a market for resources in the long-term

Monitoring Services

- Serve several purposes
  - discover/select resources for a slice
  - monitor node/network health
  - measure/monitor Internet activity
- Exploit sensors
  - local state + local view of the network
- Multiple services being built
  - Sophia: distributed Prolog engine
  - PIER: distributed SQL query processor
  - IrisNet: XML-based queries
  - service-specific mechanisms (e.g., CoDeeN)

Routing Underlay

Overlay Services

Library of Routing Services

- *k*-disjoint paths
- *k*-nearest neighbors

Topology Probing Layer

- peering graph
- path from *x* to *y*
- latency from *x* to *y*

Raw Topology Information

- local BGP feed

PLANETLAB

Current Institutions

Academia Sinica, Taiwan
Boston University
Caltech
Carnegie Mellon University
Chinese Univ of Hong Kong
Columbia University
Cornell University
Datalogisk Institut Copenhagen
Duke University
Georgia Tech
Harvard University
HP Labs
Intel Research
Johns Hopkins
Lancaster University
Lawrence Berkeley Laboratory
MIT
Michigan State University
National Tsing Hua Univ.
New York University
Northwestern University
Princeton University
Purdue University
Rensselaer Polytechnic Inst.
Rice University
Rutgers University
Stanford University
Technische Universitat Berlin
The Hebrew Univ of Jerusalem
University College London
University of Arizona
University of Basel
University of Bologna
University of British Columbia
UC Berkeley
UCLA
UC San Diego
UC Santa Barbara
University of Cambridge
University of Canterbury
University of Chicago
University of Illinois
University of Kansas
University of Kentucky
University of Maryland
University of Massachusetts
University of Michigan
University of North Carolina
University of Pennsylvania
University of Rochester
USC / ISI
University of Technology Sydney
University of Tennessee
University of Texas
University of Toronto
University of Utah
University of Virginia
University of Washington
University of Wisconsin
Uppsala University, Sweden
Washington University in St Louis
Wayne State University

PLANETLAB

More Information

www.planet-lab.org

PLANETLAB