PlanetLab: A Blueprint for Introducing Disruptive Technology into the Internet

Larry Peterson
Princeton University
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
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)
Tomorrow’s Internet

Collection of Planetary-Scale Services

Opportunities

– multiple vantage points
  ▪ anomaly detection, robust routing
– proximity to data sources/sinks
  ▪ content distribution, data fusion
– multiple, independent domains
  ▪ survivable storage
Berkeley: OceanStore

RAID distributed over the whole Internet
Intel: Netbait

Globally detect and track Internet worms
Washington: ScriptRoute

Internet Measurement Tool
Princeton: CoDeeN

Open Content Distribution Network
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 is...

Goal of 1,000 widely-distributed machines
  – today: 350 machines, 140 sites, 20 countries
  – at edge sites and network cross-roads
PlanetLab is...

A common software architecture

- OS running on each node
- Remote installation mechanism
- Remote management capability
- Central account management service
PlanetLab is…

A network testbed
• 450 active research projects
  – experiment at scale
  – experiment under real-world conditions
  – potential for real workloads and users

A deployment platform
• 15 continuously running services

→ design → deploy

measure ↫
PlanetLab is…

A microcosm of the next Internet

- Fold services back into PlanetLab
  - evolve core technologies to support overlays and slices
  - discover common sub-services

- Long-term goals
  - become *the* way users interact with the Internet
  - define standards that support multiple “PlanetLabs”
Software Architecture

• Distributed virtualization
  – \textit{slice} $\rightarrow$ a network of virtual machines
  – isolation
    ▪ isolate services from each other
    ▪ protect the Internet from PlanetLab

• Unbundled Management
  – OS defines only local (per-node) behavior
    ▪ global (network-wide) behavior implemented by services
  – multiple competing services running in parallel
    ▪ shared, unprivileged interfaces
Slices
Per-Node View

Virtual Machine Monitor (VMM)
Virtualization

• Hypervisors (e.g., VMWare)
  – don’t scale well
  – don’t need multi-OS functionality

• Paravirtualization (e.g., Xen, Denali)
  – not yet mature

• Virtualize at system call interface (e.g., Jail, Vservers)
  – reasonable compromise
  – doesn’t provide the isolation that hypervisors do

• Unix processes
  – isolation is problematic

• Java Virtual Machine
  – too high-level
PlanetLab VMM

- Linux: significant mind-share
- Vservers: virtualizes at the 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 1000 vservers per node (29MB each)
- Plkmod: enforces isolation
  - processor and link schedulers, disk quotas
  - network virtualization
    - safe raw sockets (UDP, TCP, ICMP, GRE)
    - rate limits exceptional packets, unique addrs/ports
Infrastructure Services

• Brokerage Services
  – buy, sell, trade, pool resources
  – least mature / greatest potential (market-based)

• Environment Services
  – create / maintain programming environments
  – challenge: space efficiency

• Monitoring Services
  – resource discovery
  – network / service health
  – adaptive applications

• Routing Underlay
  – discover network topology
PLC: Brokerage Service

create_slice(name, credentials)
delete_slice(name, credentials)
assign_owners(name, ssh_keys[], credentials)
set_state(name, boot_script, credentials)
set_resources(name, share, credentials)
instantiate_slice(name, nodes[], credentials)

rcap = acquire(rspec)
bind(name, rcap)
Stork: Environment Service

• Defines a `boot_script` to be run when VM inits
  – invokes Stork

• Maintains a central repository of packages
  – those registered by a client service + dependencies

• Maintains a shared package area on each node
  – retrieves one copy of each required package
  – installation scripts run in context of client VM

• Optionally…
  – manages user accounts for client slices
  – establishes tunnels to neighboring nodes
Sophia: Monitoring Service

Distributed query processor

Information Plane

observe
analyze
react

S S ... S

A A ... A
Pluto: Routing Underlay

Service Overlay Networks

Library of Routing Services

Primitives

Topology Probing Kernel

Raw Topology Information

Expense

Scope
## 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
More Information

www.planet-lab.org