Distributed Systems

Naming & Binding

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- My 15" MacBook Pro
- The rightmost computer on my desk
- Paul's aluminum laptop, but not the big or the small one.
- hedwig
- hedwig.pk.org
- 192.168.60.148
- 00:14:51:ec:f2:5b

Naming things

- User names
  - Login, email
- Machine names
  - rlogin, email, web
- Files
- Devices
- Variables in programs
- Network services

Naming Service

Allows you to look up names
- Often returns an *address* as a response

Might be implemented as
- Search through file
- Client-server program
- Database query
- …

What's a name?

Name: identifies what you want

Address: identifies where it is

Route: identifies how to get there

Binding: associates a name with an address

- "choose a lower-level-implementation for a higher-level semantic construct"

RFC 1498: Inter-network Naming, addresses, routing

Names

Need names for:

- **Services**: e.g., time of day
- **Nodes**: computer that can run services
- **Paths**: route
- **Objects within service**: e.g. files on a file server

Naming convention can take any format

- Ideally one that will suit application and user
- E.g., human readable names for humans, binary identifiers for machines

Uniqueness of names

Easy on a small scale

Problematic on a large scale

Hierarchy allows uniqueness to be maintained

compound name: set of atomic names connected with a name separator

Terms: Naming convention

Naming system determines syntax for a name

- Unix file names:
  Parse components from left to right separated by /
  /home/paul/src/gps/gui.c
- Internet domain names:
  Ordered right to left and delimited by .
  www.cs.rutgers.edu
- LDAP names
  Attribute/value pairs ordered right to left, delimited by ,
  cn=Paul Krzyzanowski, o=Rutgers, c=US

Terms: Context

- A particular set of name → object bindings
- Each context has an associated naming convention
- A name is *always* interpreted relative to some context
  - E.g., directory /usr in a UNIX file system

Terms: Naming System

Connected set of contexts of the same type (same naming convention) along with a common set of operations

For example:

- System that implements DNS
- System that implements LDAP

Terms: Name space

Set of names in the naming system

For example,

- Names of all files and directories in a UNIX file system
- All domain names on the Internet

Terms: Resolution

Name lookup

- Return the underlying representation of the name

For example,

- www.rutgers.edu $\rightarrow$ 128.6.4.5

Directory Service

Extension of naming service:

- Associates names with objects
- Allows objects to have attributes
- Can search based on attributes

For example,

- Netscape directory: general-purpose directory service based on LDAP
- Directory can be object store:
  - Look up printer object and send data stream to it

Name resolution

To send data to a service:

1. Find a node on which the service resides (service name resolution)
2. Find an address (or network attachment point) for that node (node name location)
3. Find a path from this location to the service (routing service)

Name resolution

E.g., access "paul's service":

File lookup:
"paul's service"→cs.rutgers.edu:1234

DNS lookup:
cs.rutgers.edu →128.6.4.2

ARP resolution:
128.6.4.2 →08:00:20:90:9c:23

IP routing:
route: remus →lcsr-gw →aramis

Binding

The association of a resolution

Static binding
- Hard-coded

Early binding
- Look up binding before use
- Cache previously used binding

Late binding
- Look up just before use

IP Domain Names

Human readable names
e.g. remus.rutgers.edu

Hierarchical naming scheme
- No relation to IP address or network class

Example: DNS

Internet Domain Name Service
- Maps machine names (www.rutgers.edu) to IP addresses (128.6.4.5)

In the past:
- Search /etc/hosts for machine name
- File periodically downloaded from Network Information Center (NIC) at the Stanford Research Institute (SRI)

Internet Domain Name Space

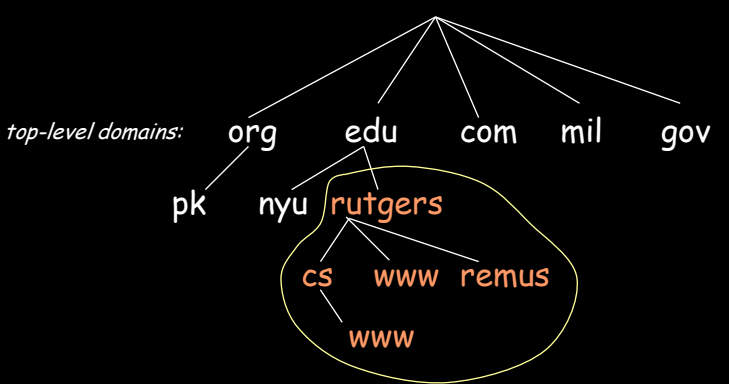
Tree structure

- Each node has resource information associated with it
- **owner**: domain name whose resource record is found
- **type of resource**:
  - Host address (A)
  - Alias name (C)
  - Name server for domain (NS)
  - Mail server (MX)
- **TTL** (time to live) → *for* ***caching***
- **Relevant data** (e.g., address)

Domain Name Server

Essential task

Answer queries about data in its *zone*
(group of machines under a root – e.g. rutgers)



Sample Query

- Rutgers registers rutgers.edu with a domain registry
  - educause.net for .edu domain
  - See internic.net for ICANN-accredited list of registrars for top-level domains
- Top-level domain names and their associated name server info loaded to root name servers
  - 13 computers: replicated information
  - Contain addresses for all registries of top-level domains (.com, .edu, .org, …)

Sample Query

Submit query to a local *DNS resolver:*

1. query(cs.rutgers.edu) → root name server
   root name servers identify authoritative servers for top-level domains
   send query to A.ROOT_SERVERS.NET: 198.41.0.4
2. *referral* to *edu* name server
   returns list of DNS servers for .edu:
   L3.NSTLD.COM: 192.41.162.32
3. query(cs.rutgers.edu) → edu name server
   send query to 192.41.162.32
4. *referral to rutgers.edu* name servers:
   - DNS1.rutgers.edu 165.230.144.131
   - DNS2.rutgers.edu 128.6.21.9
   - DNS3.rutgers.edu 198.151.130.254
5. query(cs.rutgers.edu) → rutgers name server
   send query to 165.230.144.131
6. rutgers name server returns
   A: 128.6.4.2 *address*
   MX: dragon.rutgers.edu *domain name for email*

DNS

BIND

- Implementation of DNS provided by the Internet Software Consortium (www.isc.org)

Programs to perform queries:

- dnsquery, nslookup, dig, host

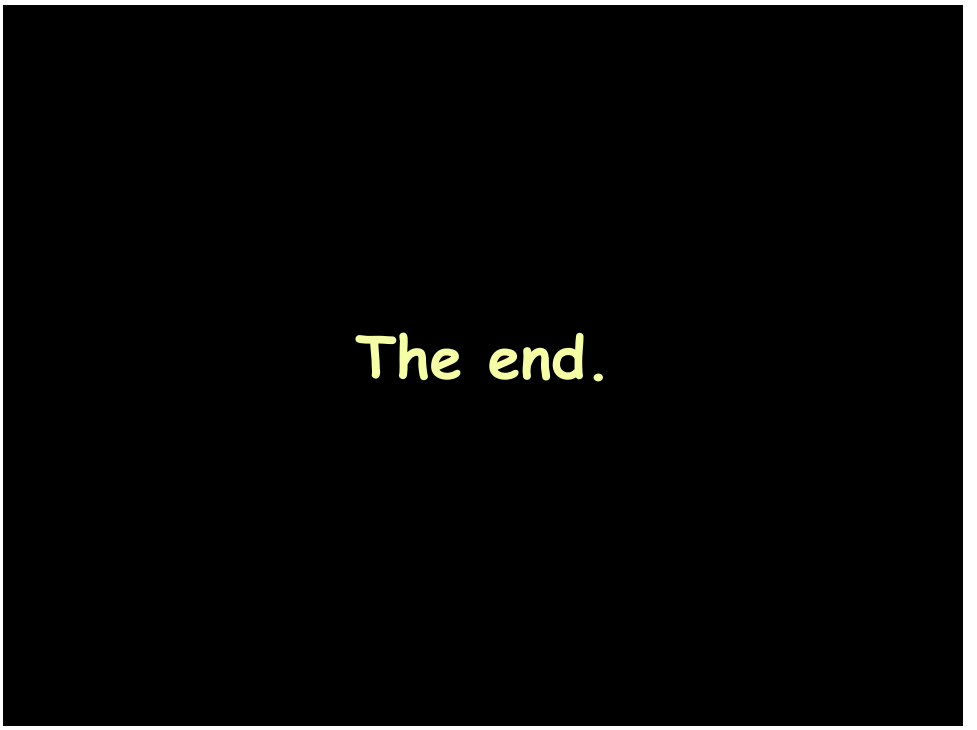
Naming: files

File system maps file pathname

/home/paul/src/map.c

namei in kernel

major=3, minor=6, inode=6160


The end.