Lecture Notes

CS 417 – DISTRIBUTED SYSTEMS

Week 7: Distributed Lookup

Part 3: Domain Name System (DNS)

Paul Krzyzanowski

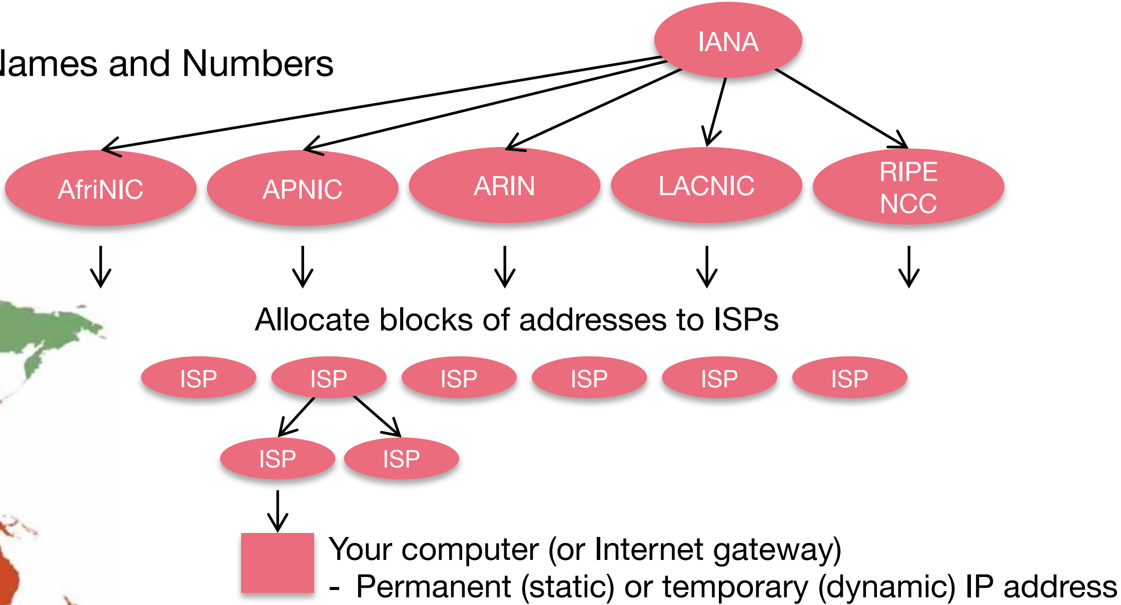
How are IP addresses assigned?

IP addresses are distributed hierarchically

Internet Assigned Numbers Authority (IANA) at the top

- IANA is currently run by ICANN
  - Internet Corporation for Assigned Names and Numbers

Regional Internet Registries (RIR)

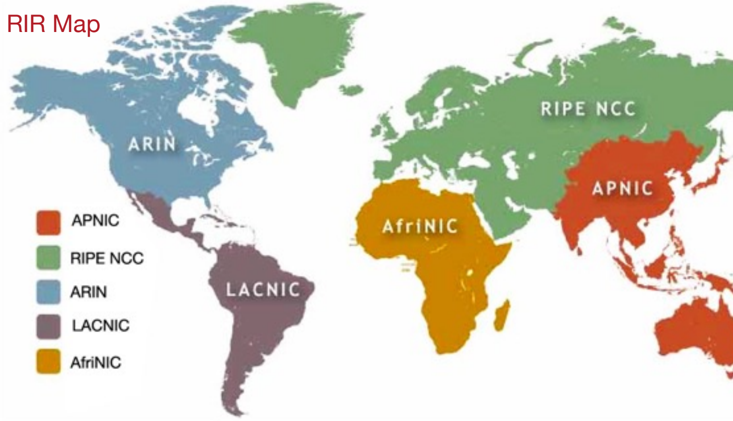


Allocate blocks of addresses to ISPs

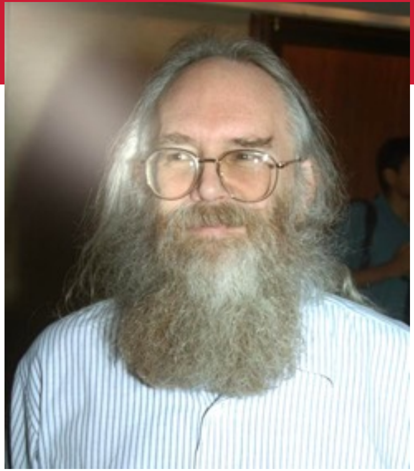
Your computer (or Internet gateway)

- Permanent (static) or temporary (dynamic) IP address

RIR Map



How are machine names assigned?

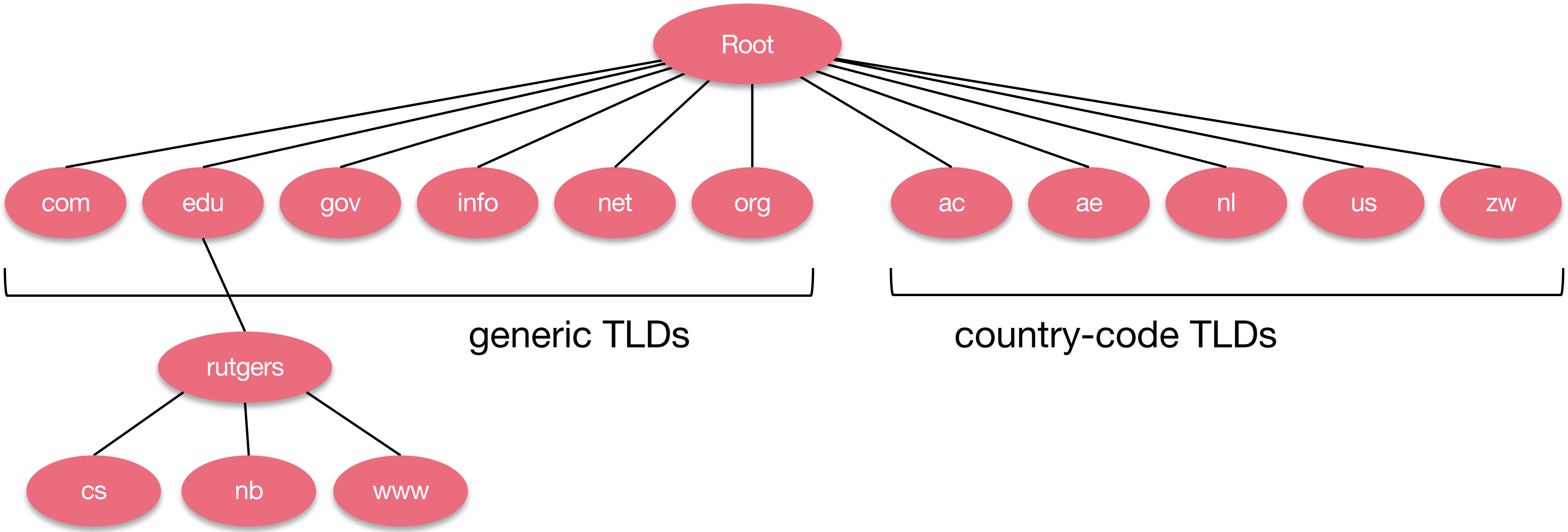


Jon Postel
maintained, approved
and tracked computer
names & addresses
on the Internet

- Early ARPANET
  - Globally unique names per machine (e.g., UCBVAX)
  - Kept track at the Network Information Center (NIC) at the Stanford Research Institute (SRI)
- That doesn't scale!
- A domain hierarchy was created in 1984 (RFC 920)
  - Domains are administrative entities: divide name management
  - Tree-structured global name space
  - Textual representation of domain names

```
www.cs.rutgers.edu
```

Domain Name Hierarchy



Top Level Domains (TLDs)

ccTLD

Country-code domains
ISO 3166 codes
e.g., .us, .de, .ca, .es

IDN ccTLD

Internationalized
country-code domains
e.g., .السعودية, .中國 , .рф

gTLD

Generic top-level domains
e.g., .biz, .com, .edu,
.gov, .info, .net, .org,
.audio, .catering, .网络

There are currently 1,591 top-level domains (as of March 6, 2023)

Each top-level domain has an administrator assigned to it

Assignment is delegated to various organizations by the Internet Assigned Numbers Authority (IANA)

IANA keeps track of the root servers

See http://www.iana.org/domains/root/db for the latest count

Shared registration

- Domain name registry: *this is the database*
  - Keeps track of all domain names registered under a top-level domain

- Domain name registry operator: *this is the company that runs the DB*
  - NIC = Network Information Center – the organization that keeps track of the registration of domain names under a top-level domain
    - Keeps the database of domain names
    - See https://www.icann.org/resources/pages/listing-2012-02-25-en

- Domain name registrar: *this is the company you use to register*
  - Company that lets you register a domain name
  - Registrars update the registry database at the NIC
  - See https://www.iana.org/assignments/registrar-ids/registrar-ids.xhtml

Shared registration

- Multiple domain **registrars** provide domain registration services
  - 2,437 registars as of March 2021, including 1202 unique DropCatch.com registrars
- The registrar you choose becomes the **designated registrar** for your domain
  - Maximum period of registration for a domain name = 10 years
- The **registry operator** keeps the central registry database for the top-level domain

- Only the designated registrar can change information about domain names
  - A domain name owner may invoke a domain transfer process

Example

- *Namecheap* is the designated registrar for `poopybrain.com`
- *VeriSign*, Inc. is the registry operator for the `.com` gTLD

See https://www.icann.org/registrar-reports/accredited-list.html for the latest list of registrars

The problem

Every device connected to the internet has a unique Internet Protocol (IP) address

How do you resolve user-friendly machine names to IP addresses?

`www.cs.rutgers.edu` ⟶ `128.6.4.24`

Original solution

In the early days (up through the 1980s)

- Search `/etc/hosts` file for machine name (see RFC 606)
- File periodically downloaded from Network Information Center (NIC) at the Stanford Research Institute (SRI)
- This was not sustainable with millions of hosts on the Internet
  - A lot of data
  - A lot of churn in the data: new hosts added, deleted, addresses changed
  - Maintenance
  - Traffic volume

Solution doesn't scale!

DNS: Domain Name System

Distributed database: a hierarchy of name servers

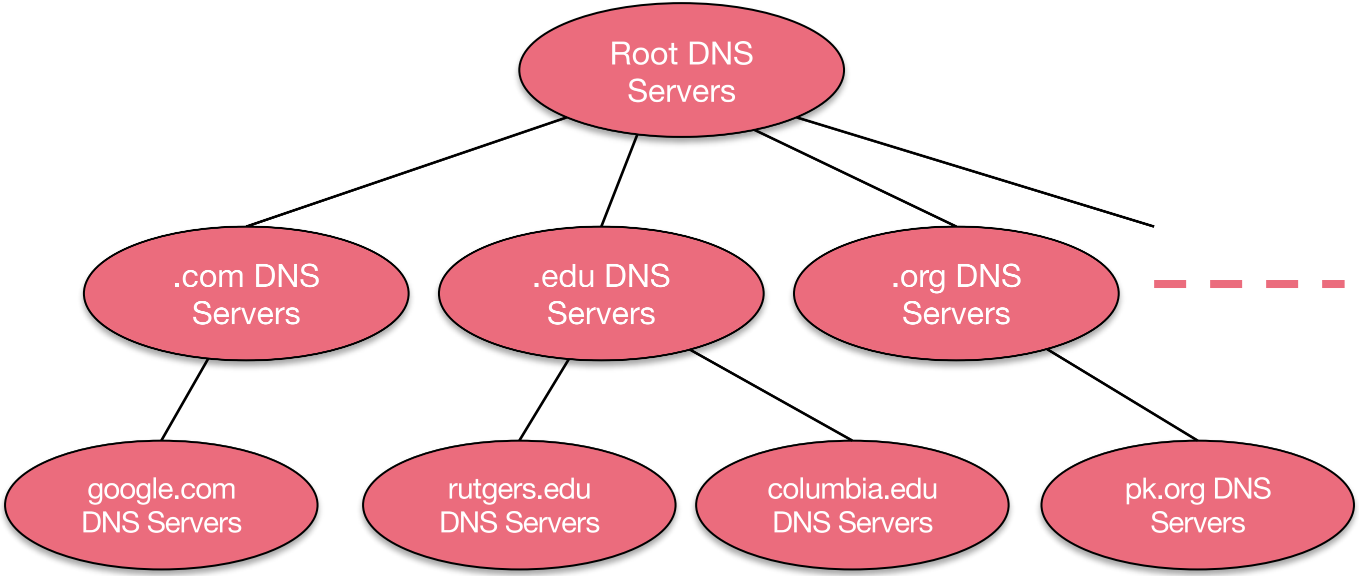
- **DNS** is an application-layer protocol
  - Name-address resolution is handled at the edge
  - The network core is unaware of host names … and does not care
  - There is no special relationship between names and addresses
    - Example: cs.poopybrain.com can resolve to cs.rutgers.edu

```
cs.poopybrain.com → cs.rutgers.edu
```

DNS servers provide…

- Name to IP address translation
- Aliasing of names (called canonical names)
- Identification of name servers
- Names of mail servers
- Load distribution:
  - Multiple name servers may handle a query for a domain
  - Caching – store past look-ups
  - Ability to provide a set of IP addresses for a name

DNS is a distributed, hierarchical database



A collection of DNS servers

Authoritative DNS server

- An authoritative name server is responsible for answering queries about its zone
  - Provides *real* answers vs. *cached* answers
  - Configured by the administrator

- Zone = group of machines under a node in the tree

  E.g., rutgers.edu

A DNS server returns answers to queries

Key data that a DNS server maintains (partial list)

Information	Abbreviation	Description
Host	A	Host address (name to address) Includes name, IP address, time-to-live (TTL)
Canonical name	CNAME	Name for an alias
Mail exchanger	MX	Host that handles email for the domain
Name server	NS	Identifies the name server for the zone: tell other servers that yours is the authority for info within the domain
Start of Zone Authority	SOA	Specifies authoritative server for the zone. Identifies the zone, time-to-live, and primary name server for the zone

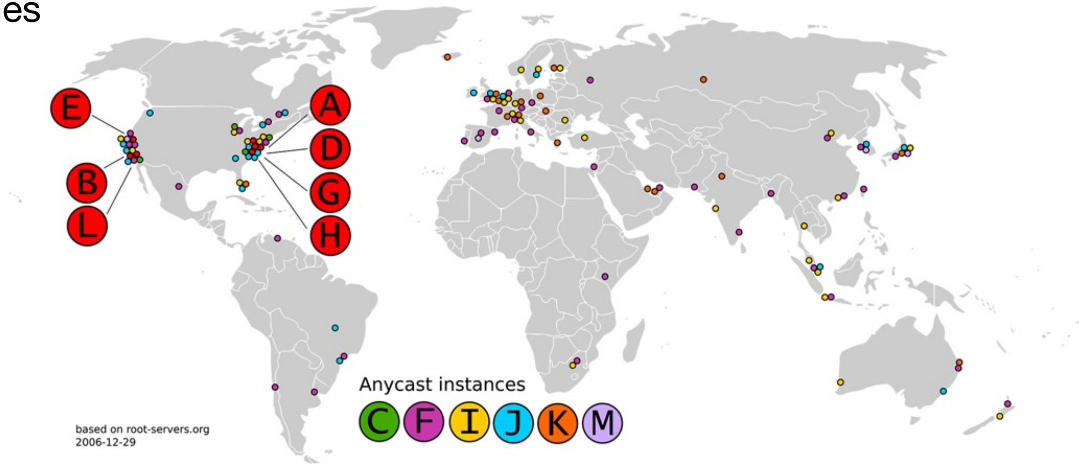
Finding your way

- How do you find the DNS Server for rutgers.edu?
  - That’s what the domain registry keeps track of
  - When you register a domain,
    - You supply the addresses of at least two DNS servers that can answer queries for your zone
    - You give this to the domain registrar, who updates the database at the domain registry

- So how do you find the right DNS server?
  - Start at the root

Root name servers

- The root name server answers can return a list of authoritative name servers for top-level domains
- 13 root name servers
  - `A.ROOT-SERVERS.NET`, `B.ROOT-SERVERS.NET`, …
  - Each has redundancy (via *anycast* routing or load balancing)
    - Each server is really a set of machines



based on root-servers.org
2006-12-29

Download the latest list at http://www.internic.net/domain/named.root

DNS Queries

- Iterative (non-recursive) name resolution
  - DNS server will return a definitive answer or a **referral** to another DNS server
    - *referral* = reference to a DNS server for a lower level of the queried namespace
    - Server returns intermediate results to the client
  1. Send query to a root name server
  2. Send query to an edu name server
  3. Send query to a rutgers name server
  - Advantage: stateless

Most top-level DNS servers only support iterative queries

- Recursive DNS name resolution
  - Name server will take on the responsibility of fully resolving the name
    - May query multiple other DNS servers on your behalf
  - DNS server cannot refer the client to a different server
  - Disadvantage: name server has more work; has to keep track of state
  - Advantages: Caching opportunities, less work for the client!

DNS Resolvers: local name server

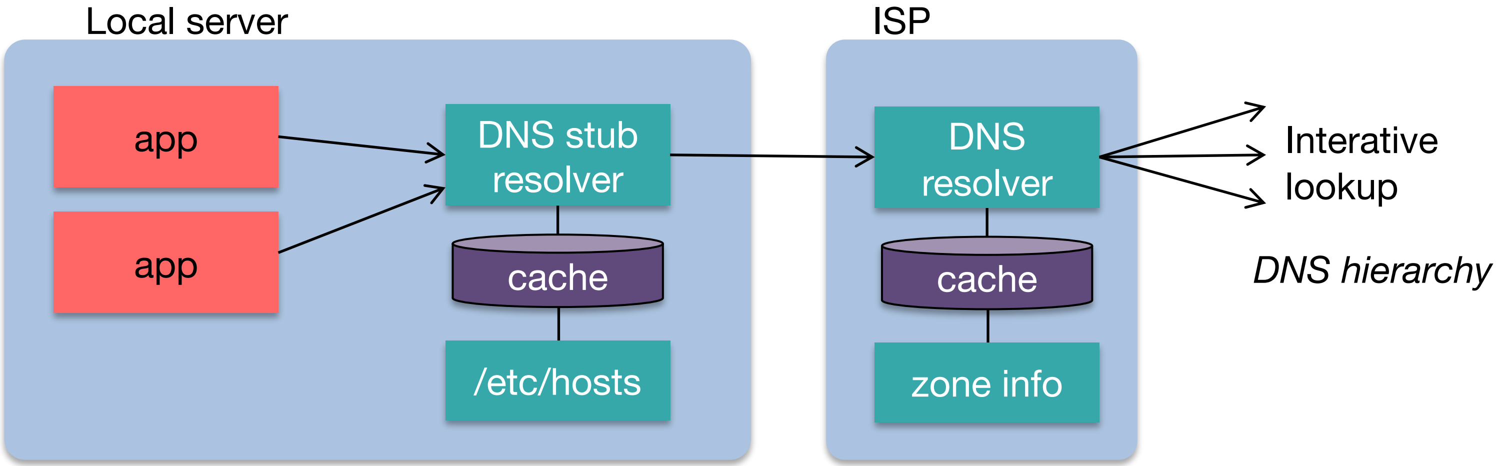
DNS Resolver = client side of DNS

- Not really a part of the DNS hierarchy
- Acts as an intermediary between programs that need to resolve names and the name servers
- A resolver is responsible for performing the full resolution of the query

- Where are the resolvers?
  - Each local system has one: that's what applications contact
    - Local cache; may be a process or a library
    - On Linux & Windows, these are limited DNS servers (called stub resolvers)
      - Usually not capable of handling referrals and expect to talk with a name server that can handle recursion (full resolution)
  - ISPs (and organizations) run them on behalf of their customers
    - Including a bunch of free ones (OpenDNS, Google Public DNS)

- Resolvers cache past lookups – they are not responsible for zones

DNS Resolvers in action



Local stub resolver:
- check local cache
- check local hosts file
- send request to external resolver

E.g., on Linux: resolver is configured via the `/etc/resolv.conf` file

External resolver

- DNS server that accepts recursion
- Running at ISP, Cloudflare, Google Public DNS, OpenDNS, etc.

Sample query

- Rutgers registered rutgers.edu with the .edu domain
  - educause.net is the domain registry for the .edu gTLD
  - Registration includes defining the name servers for .rutgers.edu
    - `ns124.a2.incapsecuredns.net`: 192.230.123.124
    - `ns8.a1.incapsecuredns.net`: 192.230.122.8
    - `ns87.a0.incapsecuredns.net`: 192.230.121.87
- EDUCAUSE registered its name servers with root name servers
    - `ns1.twtelecom.net`
    - `ns1.educause.edu`
    - `ns1.twtelecom.net`

  Name servers for .edu
- We know how to get to root name servers
    - Download http://www.internic.net/domain/named.root

Sample Query

Submit query to a local *DNS resolver:*

1. *query(cs.rutgers.edu)* → any root name server

   send query to f.root-servers.net: 192.5.5.241

2. Receive *referral* to a list of DNS servers for *edu*

   a.edu-servers.net: 192.5.6.30 … d.edu-servers.net: 192.31.80.30 …

3. *query(cs.rutgers.edu)* → edu name server

   send query to d.edu-servers.net: 192.31.80.30

4. *Receive referral to rutgers.edu* name servers:

- dns2.rutgers.edu.	192.230.121.86
- ns1.rutgers.edu.	192.230.122.7
- ru-ufl.rutgers.edu.	192.230.123.123
- ns6.dnsmadeeasy.com.	208.80.124.13

5. query(cs.rutgers.edu) → rutgers name server

   send query to 208.80.124.13

6. The rutgers name server returns

   A 128.6.48.178 *address record*

   MX 10 cs-rutgers-edu.mail.protection.outlook.com. *mx (mail exchange): domain name for email*

Caching

- Starting every query at the root would place a huge load on root name servers

- A name server can **cache** results of previous queries
  - Save query results for a *time-to-live* amount of time
  - The time-to-live value is specified in the domain name record by an authoritative name server

The End