CS 43: Computer Networks
Naming and DNS

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Agenda

• Identifiers and addressing

• Domain Name System
  – History
  – Query sequences
  – Record types
  – Load balancing
Recall: TCP/IP Protocol Stack

- **Application Layer**: HTTP → TCP → IP
- **Transport Layer**: TCP → IP
- **Network Layer**: IP
- **Link Layer**: Ethernet interface → SONET interface → Ethernet interface
Recall: TCP/IP Protocol Stack

Human-readable strings: www.example.com

(Not much addressing here, ports to ID socket)

IP addresses (32-bit IPv4, 128-bit IPv6)

(Network dependent) Ethernet: 48-bit MAC address
Identifiers

• **Host name** (e.g., www.swarthmore.edu)
  – Used by *humans* to specify host of interest
  – Unique, selected by host administrator
  – Hierarchical, variable-length string of alphanumeric characters

• **IP address** (e.g., 130.58.68.164)
  – Used by *routers* to forward packets
  – Unique, topologically meaningful locator
  – Hierarchical namespace of 32 bits

• **MAC address** (e.g., D8:D3:85:94:5F:1E)
  – Used by *network adaptors* to identify interesting frames
  – Unique, hard-coded identifier burned into network adaptor
  – Flat name space (of 48 bits in Ethernet)
What’s in a name?

- **Host name**: `web.cs.swarthmore.edu`
  - **Domain**: registrar for each top-level domain (e.g., `.edu`)
  - **Host name**: local administrator assigns to each host

- **IP addresses**: `130.58.68.164`
  - **Prefixes**: ICANN, regional Internet registries, and ISPs
  - **Hosts**: static configuration, or dynamic using DHCP

- **MAC addresses**: `D8:D3:85:94:5F:1E`
  - **OIDs**: assigned to vendors by the IEEE
  - **Adapters**: assigned by the vendor from its block
What’s in a name?

• Host name: web.cs.swarthmore.edu (today)
  – Domain: registrar for each top-level domain (e.g., .edu)
  – Host name: local administrator assigns to each host

• IP addresses: 130.58.68.164 (a few weeks)
  – Prefixes: ICANN, regional Internet registries, and ISPs
  – Hosts: static configuration, or dynamic using DHCP

• MAC addresses: D8:D3:85:94:5F:1E
  – OIDs: assigned to vendors by the IEEE
  – Adapters: assigned by the vendor from its block
Mapping Between Identifiers

• Domain Name System (DNS)
  – Given a host name, provide the IP address
  – Given an IP address, provide the host name

• Address Resolution Protocol (ARP)
  – Given an IP address, provide the MAC address
  – To enable communication within the Local Area Network

• Dynamic Host Configuration Protocol (DHCP)
  – Automates host boot-up process
  – Given a MAC address, assign a unique IP address
  – ... and tell host other stuff about the Local Area Network
What’s the biggest challenge for DNS?
What’s the biggest challenge for DNS?

A. It’s old.

B. The fact that the Internet is global.

C. The fact that DNS is now critical infrastructure.

D. The sheer number of name lookups happening at any given time.

E. How and when the name -> IP address mapping should change.
In the old days...

- Pre-1982, everyone downloads a “hosts.txt” file from SRI
- Pre-1998, Jon Postel, researcher at USC, runs the Internet Assigned Numbers Authority (IANA)
  - RFCs 882 & 883 in 1983
  - RFCs 1034 & 1035 in 1987
- Emailed 8/12 root DNS servers, asked change to his authority. They did.
- [http://www.wired.com/wiredenterprise/2012/10/joe-postel/](http://www.wired.com/wiredenterprise/2012/10/joe-postel/)
Since 1998...

• Control of Internet Assigned Numbers Authority (IANA) transferred to Internet Corporation for Assigned Names and Numbers (ICANN)
  – ICANN is a private non-profit blessed by US DOC
  – Global advisory committee for dealing with international issues
  – 2011: ICANN no longer partnered with DOC
  – United Nations ITU (International Telecommunications Union) repeatedly argues it should be in charge of DNS. US says... no.

• Lots of geopolitics here...
Should the US/ICANN retain control of DNS or let the UN take care of it?

A. US/ICANN

B. UN

C. Someone else
Recent Controversy

• Is ICANN working in the world’s best interest?

• New “top level domains” added, for auction

• Example the “.sucks” TLD (+ many others)
Reality

• As computer scientists, it’s probably not up to us to decide. 😞

• Let’s focus on the technical aspects of DNS. 😊
DNS Services

• DNS is an application-layer protocol. (E2E design!)

• It provides:
  – Hostname to IP address translation
  – Host aliasing (canonical and alias names)
  – Mail server aliasing
  – Load distribution (one name may resolve to multiple IP addresses)
  – Lots of other stuff that you might use a directory service to find. (Wikipedia: List of DNS record types)
**DNS Records**

**DNS:** distributed db storing resource records (RR)

RR format: \((\text{name}, \text{value}, \text{type}, \text{ttl})\)

**type=A**
- **name** is hostname
- **value** is IP address

**type=NS**
- **name** is domain (e.g., foo.com)
- **value** is hostname of authoritative name server for this domain

**type=CNAME**
- **name** is alias name for some “canonical” (the real) name
  - **www.ibm.com** is really servereast.backup2.ibm.com
- **value** is canonical name

**type=MX**
- **value** is name of mailserver associated with **name**
DNS protocol, messages

- *query* and *reply* messages, both with same *message format*

**Message header**
- **identification**: 16 bit # for query, reply to query uses same #
- **flags**:  
  - query or reply  
  - recursion desired  
  - recursion available  
  - reply is authoritative

**Sent via UDP**
- No connection established  
- Not reliable

<table>
<thead>
<tr>
<th>identification</th>
<th>flags</th>
</tr>
</thead>
<tbody>
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<td># questions</td>
<td># answer RRs</td>
</tr>
<tr>
<td># authority RRs</td>
<td># additional RRs</td>
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<tr>
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<tr>
<td></td>
<td>authority</td>
</tr>
<tr>
<td></td>
<td>additional info</td>
</tr>
</tbody>
</table>
Domain Name System (DNS)

• Distributed administrative control
  – Hierarchical name space divided into zones
  – Distributed over a collection of DNS servers

• Hierarchy of DNS servers
  – Root servers
  – Top-level domain (TLD) servers
  – Authoritative DNS servers

• Performing the translations
  – Local DNS servers
  – Resolver software
DNS: a distributed, hierarchical database

Root DNS Servers

- com DNS servers
  - yahoo.com DNS servers
  - amazon.com DNS servers
- org DNS servers
  - pbs.org DNS servers
- edu DNS servers
  - swarthmore.edu DNS servers
  - umass.edu DNS servers
DNS: a distributed, hierarchical database

Root DNS Servers

... ... ...

com DNS servers

... org DNS servers ... edu DNS servers

... ... ...

amazon.com DNS servers

cs.swarthmore.edu DNS servers

swarthmore.edu DNS servers

pbs.org DNS servers

umass.edu DNS servers

yahoo.com DNS servers

amazon.com DNS servers

swarthmore.edu DNS servers
DNS: a distributed, hierarchical database

- **allspice.cs.swarthmore.edu.**

Nameless root, Usually implied.
Why do we structure DNS like this? Which of these helps the most?

A. It divides up responsibility among parties.

B. It improves performance of the system.

C. It reduces the size of the state that a server needs to store.

D. Some other reason.
DNS: a distributed, hierarchical database

- Root DNS Servers
  - ... (omitted)
  - com DNS servers
    - yahoo.com DNS servers
  - org DNS servers
    - amazon.com DNS servers
  - edu DNS servers
    - swarthmore.edu DNS servers
      - cs.swarthmore.edu DNS servers
        - allspice.cs.swarthmore.edu Host
    - umass.edu DNS servers

DNS: a distributed, hierarchical database
DNS: Root Name Servers

• Root name server:
  – Knows how to find top-level domains (.com, .edu, .gov, etc.)
  – How often does the location of a TLD change?
DNS: Root Name Servers

- **Root name server:**
  - Knows how to find top-level domains (.com, .edu, .gov, etc.)
  - How often does the location of a TLD change?
  - ~300 total root servers
  - Significant amount of traffic is not legitimate
DNS: a distributed, hierarchical database

- Root DNS Servers
- ... ...
- com DNS servers
  - yahoo.com DNS servers
  - amazon.com DNS servers
- org DNS servers
  - pbs.org DNS servers
- edu DNS servers
  - swarthmore.edu DNS servers
  - umass.edu DNS servers
    - cs.swarthmore.edu DNS servers
      - allspice.cs.swarthmore.edu Host
      - (other cs hosts)
Top Level Domains

Top-level domain (TLD) servers:

– Responsible for com, org, net, edu, gov, aero, jobs, museums, and all top-level country domains, e.g.: uk, fr, de, ca, jp, etc.

– Verisign maintains servers for .com and .net TLD

– Educause for .edu TLD (Verisign actually runs backend)

– Others managed by corresponding entity (e.g., local governments or companies)
DNS: a distributed, hierarchical database

Root DNS Servers

... ... ...

com DNS servers
org DNS servers
edu DNS servers

yahoo.com DNS servers
amazon.com DNS servers
pbs.org DNS servers
swarthmore.edu DNS servers
umass.edu DNS servers

cs.swarthmore.edu DNS servers

allspice.cs.swarthmore.edu (other cs hosts)
Host
Authoritative Servers

**Authoritative DNS servers:**

- Organization’s own DNS server(s), providing authoritative hostname to IP mappings for organization’s named hosts
- Can be maintained by organization or service provider, easily changing entries
- Often, but not always, acts as organization’s local name server (for responding to look-ups)
Resolution Process

• End host wants to look up a name, who should it contact?
  – It could traverse the hierarchy, starting at a root
  – More efficient for ISP to provide a local server

• ISP’s local server for handling queries not necessarily a part of the pictured hierarchy
Local DNS Name Server

• Each ISP (residential ISP, company, university) has (at least) one
  – also called “default name server”

• When host makes DNS query, query is sent to its local DNS server
  – has local cache of recent name-to-address translation pairs (but may be out of date!)
  – acts as proxy, forwards query into hierarchy
DNS name resolution example #1

- allspice wants IP address for gaia.cs.umass.edu

**iterative query:**
- contacted server replies with name of server to contact
- “I don’t know this name, but ask this server”
Recursive query:

- Puts burden of name resolution on each name server

Diagram:

1. Requesting host: allspice.cs.swarthmore.edu
2. Local DNS server: dns.cs.swarthmore.edu
3. Root DNS server
4. TLD DNS server: dns.cs.umass.edu
5. Authoritative DNS server: gaia.cs.umass.edu
Which would you use? Why?

A. Iterative

root DNS server

TLD DNS server

local DNS server

dns.cs.swarthmore.edu

authoritative DNS server

dns.cs.umass.edu

requesting host

allspice.cs.swarthmore.edu

B. Recursive

root DNS server

TLD DNS server

local DNS server

dns.cs.swarthmore.edu

authoritative DNS server

dns.cs.umass.edu

requesting host

allspice.cs.swarthmore.edu

gai.cs.umass.edu
Caching

• Once (any) name server learns a mapping, it *caches* mapping
  – cache entries timeout (disappear) after some time (TTL: time to live)
  – TLD servers typically cached in local name servers
    • Thus root name servers not often (legitimately) visited
Caching

- Once (any) name server learns a mapping, it *caches* mapping
  - cache entries timeout (disappear) after some time (TTL: time to live)
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    - Thus root name servers not often (legitimately) visited

- (⊕) Subsequent requests need not burden DNS

- (⊖) Cached entries may be *out-of-date* (best effort!)
  - If host’s name or IP address changes, it may not be known Internet-wide until all TTLs expire
The TTL value should be

A. Short, to make sure that changes are accurately reflected

B. Long, to avoid re-queries of higher-level DNS servers

C. Something else
Inserting (or changing) records

• Example: new startup “Network Utopia”
• Register networkuptopia.com at DNS registrar
  – provide names, IP addresses of authoritative name server (primary and secondary)
  – registrar inserts two RRs into .com TLD server:
    (networkutopia.com, dns1.networkutopia.com, NS)
    (dns1.networkutopia.com, 212.212.212.1, A)
• Set up authoritative server at that name/address
  – Create records for the services:
    • type A record for www.networkuptopia.com
    • type MX record for @networkuptopia.com email
DNS Load Balancing

• One load balancing option (others use routing)

• When the authoritative name server responds
  – Round robin between servers
  – Take server load into account?
  – Take location into account (content distribution)
Reading

• Next topic: Email
  – Section 2.4

• Lab 2: Web server
  – Due Thursday, September 24