# DNS

*CS640, 2015-04-07*

**Naming Hosts**

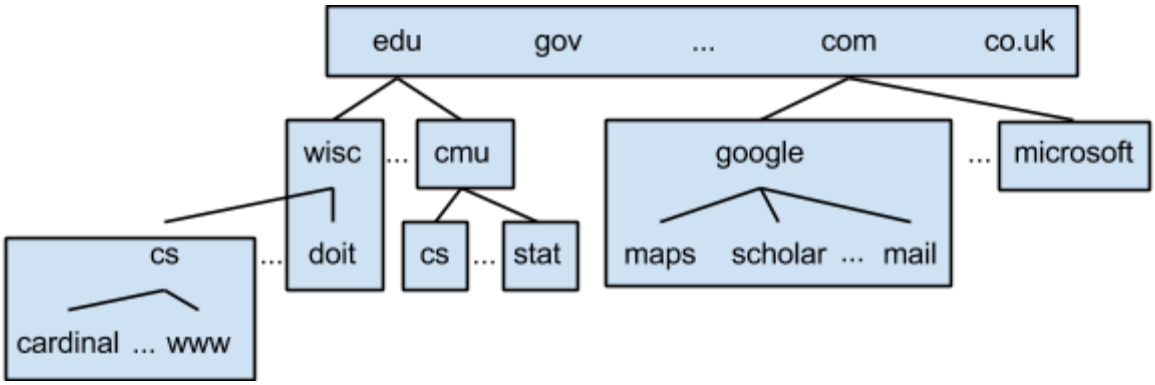
- Thus far we have identified hosts using IP addresses and MAC address
    - Hard for humans to remember these identifiers
- Want to assign human readable names to hosts
    - Routing still needs IP addresses
    - Need a way to define and lookup the mapping between a hostname and an IP address
- Early Internet: a file mapping IP addresses to hostnames was manually updated and manually copied to all hosts in the Internet
    - Problem: does not scale
        - Still useful for small local networks -- look at the /etc/hosts file on a CS dept machine
- Domain name system (DNS)
    - Distributed name resolution system
        - Many name servers (NSs) distributed throughout the Internet -- in IPSs, in campus/enterprise networks, in department networks, etc.
    - Domain names (DNs) are hierarchical
        - A single NS doesn't need to store the name for every host in the Internet
    - DNs can be mapped to IPv4 addresses, IPv6 addresses, and other DNs
        - Mapping can be changed over time, or based on other factors (e.g., geo location)
    - Queries are issued to a sequence of NSs
        - Each knows about a different part of the DN hierarchy
        - Answers can be cached to avoid the overhead of frequent lookups

**Domain Name Hierarchy**

- DNs are processed right to left, with periods as the separator
    - Rightmost name is at the top of the hierarchy, and leftmost is at the bottom

- Rightmost name is referred to as the top-level domain (TLD)
    - Since DNS was invented in the US, originally TLDs were designed for the US -- edu, com, gov, mil, org, net
    - Expanded to include TLDs for countries -- uk, cn, etc.
        - Sometimes TLDs from other countries are used such that the full DN is a specific word or phrase -- e.g., bit.ly uses the ly TLD for the country Libya,
    - Expanded to address high demand for .com -- .biz, .info, .tv, etc.
    - Recently expanded to include arbitrary TLDs
        - Lots of contention over who should have the rights to a specific TLD
- Second from right is the second-level domain (SLD)
- DN consisting of 3+ names is often referred to as a *subdomain*
    - E.g., *cs.wisc.edu* is a subdomain of *wisc.edu*

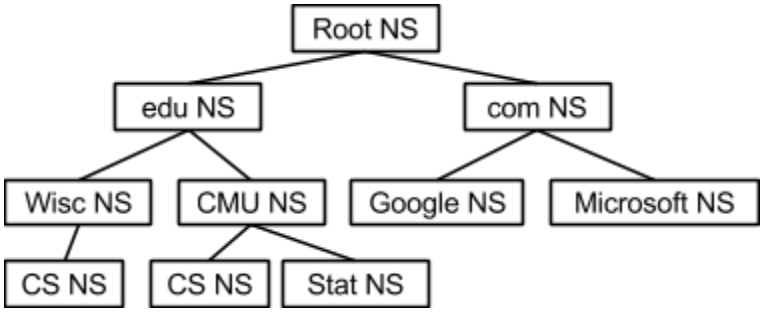
- Example




- Complete hierarchy only exists conceptually -- no single DNS server stores the entire hierarchy
- How do we divide responsibility for different parts of the hierarchy to different DNS servers?

**Zones**

- Zone: a portion of the hierarchy that is managed by administrative entity
  - Internet Corporation for Assigned Names and Numbers (ICANN) is responsible for zone containing all TLDs
  - UW (DoIT) is responsible for zone containing *wisc.edu* and some subdomains (e.g., *doit.wisc.edu*)
  - CS department is responsible for zone containing *cs.wisc.edu* and all subdomains (e.g., *cardinal.cs.wisc.edu*, *www.cs.wisc.edu*, etc.)
  - Google is responsible for zone containing *google.com* and all subdomains (e.g., *maps.google.com*, *scholar.google.com*, *mail.google.com*, etc.)
- Two or more name servers (NSs) are responsible for each zone
  - Multiple NSs per zone to ensure availability in case of a failure
  - Each stores information for all domain names in the zone
  - Example




**DNS Records**

- Record has: name, type, value, and TTL
- Name = DN
- Types
  - A -- value is an IPv4 address
  - AAAA -- value is an IPv6 address
  - NS -- value is domain name for a DNS server that is responsible for the zone containing the DN
  - CNAME -- value is another domain name for a particular host
  - MX -- value is the domain name for a mail server that accepts messages for the DN
- TTL specifies how long another DNS server can cache the record

- Example
  - Root NS
    - edu, NS, a.edu-servers.net
    - edu, NS, c.edu-servers.net
    - ...
    - a.edu-servers.net, A, 192.5.6.30
    - c.edu-servers.net, A, 192.26.92.30
    - ...
  - edu NS
    - wisc.edu, NS, adns1.doit.wisc.edu
    - wisc.edu, NS, adns3.doit.wisc.edu
    - wisc.edu, NS, dns2.itd.umich.edu
    - ...
    - adns1.doit.wisc.edu, A, 144.92.9.21
    - adns3.doit.wisc.edu, A, 144.92.104.21
    - adns3.doit.wisc.edu, AAAA, 2607:f388::a53:3
    - dns2.itd.umich.edu, A, 192.12.80.222
    - ...
    - cmu.edu, NS, NSAUTH1.net.cmu.edu
    - …
    - NSAUTH1.net.cmu.edu, A, 128.2.1.8
    - NSAUTH1.net.cmu.edu, AAAA, 2607:fb28::4
    - …
  - wisc NS
    - cs.wisc.edu, NS, dns.cs.wisc.edu.
    - cs.wisc.edu, NS, dns2.cs.wisc.edu
    - …
    - dns.cs.wisc.edu, A, 128.105.2.10
    - dns2.cs.wisc.edu, A, 128.105.6.12
    - …
  - cs NS
    - cardinal.cs.wisc.edu, A, 128.105.14.122
    - www.cs.wisc.edu, A, 128.105.7.31
    - cs.wisc.edu, MX, granite.cs.wisc.edu
    - cs.wisc.edu, MX, obsidian.cs.wisc.edu
    - …
    - granite.cs.wisc.edu, A, 128.105.6.24
    - obsidian.cs.wisc.edu, A, 128.105.6.13
    - ...

**Name resolution**

- Algorithm
  - Client contacts local NS
    - Local NSis provided to client by DHCP or set in client configuration
  - Local NS contacts root name server
  - Root NS provides NS & A records for NS  that can resolve TLD
  - Local NS contacts NS for TLD
  - NS for TLD provides NS & A record for NS that can resolve SLD
  - Local NS contacts NS for SLD
  - NS for SLD for provides A record for domain, or NS & A for NS that can resolve domain
  - …
- Local DNS server will cache any records it receives
- Example:
  - Resolve cardinal.cs.wisc.edu
  - Resolve stat.cmu.edu
  - Resolve mail.google.com
    - Google NS
      - mail.google.com, CNAME, googlemail.l.google.com
      - googlemail.l.google.com, A, 74.125.225.53
      - googlemail.l.google.com, A, 74.125.225.54
      - ...
      - maps.google.com, A, 64.15.120.20
      - maps.google.com, A, 64.15.120.21
      - …
  - Resolve email server for cs.wisc.edu
    - Assume query for *cardinal.cs.wisc.edu* has already happened and local NS has cached some records
- May be fewer/more interactions with NSs depending on
  - How many parts there are to the DN (e.g., *wisc.edu* vs. *cardinal.cs.wisc.edu*)
  - How many levels in the name hierarchy are in the same zone (e.g., *wisc.edu* and *doit.wisc.edu* are in the same zone, while *wisc.edu* and *cs.wisc.edu* are in different zones)
  - Whether there are CNAMEs that require contacting a different NS
  - What records the local NS has already cached

**Advanced Name Resolution**

- NS can return different sets of records for different queries
  - Use for load balancing or geo-based server selection
- Load balancing
  - Assign short TTL to records
  - Return different A records for each query for a DN -- cycle through A records in weighted round-robin order; weight is based on server load
- Geo-based server selection
  - Used by content distribution networks (CDNs)
  - CDN's NS is configured with approximate geo-location of certain IP blocks
  - Address of NS that issued query is compared against IP blocks to determine rough location of client that issued query
  - Based on location, CDN's NS returns CNAME record whose value is DN for nearby server

- Example: *google.com*
  - Local NS contacts root NS
  - Root NS provides NS & A records for com NS
  - Local NS contacts com NS
  - com NS provides NS & A record for Google NS -- e.g., *ns1.google.com*, *216.239.32.10*
  - Local NS contacts Google NS
  - Google NS looks at source IP for query and provides different address based on estimated location of source IP
    - from home (Charter): 64.15.120.52
    - from Milwaukee (AT&T DSL): 74.125.225.32
    - from Los Angeles: 74.125.239.161

**Content Centric Networking**

- Emerging research focuses on naming content rather than naming hosts
- Same content (e.g. a specific research paper) could reside in multiple different locations (e.g., on a conference website, on the author's website, and on a digital library website)
- Any host with the content can provide it to the user
- Challenges
  - How do we address the content?
  - How do we determine where the content is located?
  - How do we determine if two pieces of data have the same content? -- e.g., is a video on YouTube and a video on Vimeo the same, but just encoded differently?
  - Can we performing routing based on content identifiers instead of based on IP addresses?