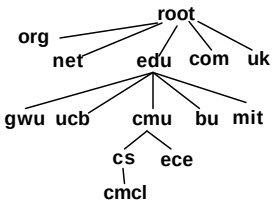
15-441 Computer Networking

Lecture 5 – Applications
DNS, Web

Outline

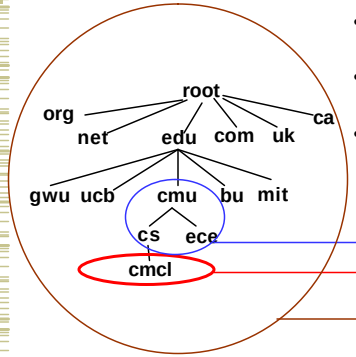
- How DNS resolves names
- How well does DNS work today
- HTTP intro and details

DNS Design: Hierarchy Definitions



- Each node in hierarchy stores a list of names that end with same suffix
  - Suffix = path up tree
- E.g., given this tree, where would following be stored:
  - Fred.com
  - Fred.edu
  - Fred.cmu.edu
  - Fred.cmcl.cs.cmu.edu
  - Fred.cs.mit.edu

DNS Design: Zone Definitions



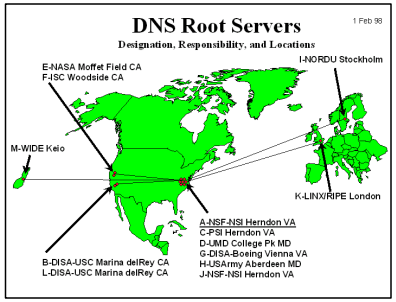
- Zone = contiguous section of name space
- E.g., Complete tree, single node or subtree
- A zone has an associated set of name servers
  - Must store list of names and tree links

DNS Design: Cont.

- Zones are created by convincing owner node to create/delegate a subzone
  - Records within zone stored multiple redundant name servers
  - Primary/master name server updated manually
  - Secondary/redundant servers updated by zone transfer of name space
    - Zone transfer is a bulk transfer of the "configuration" of a DNS server – uses TCP to ensure reliability
- Example:
  - CS.CMU.EDU created by CMU.EDU administrators
  - Who creates CMU.EDU?

DNS: Root Name Servers

- Responsible for "root" zone
- Approx. dozen root name servers worldwide
  - Currently {a-m}.root-servers.net
- Local name servers contact root servers when they cannot resolve a name
  - Configured with well-known root servers



Servers/Resolvers

- Each host has a resolver
  - Typically a library that applications can link to
  - Local name servers hand-configured (e.g. /etc/resolv.conf)
- Name servers
  - Either responsible for some zone or…
  - Local servers
    - Do lookup of distant host names for local hosts
    - Typically answer queries about local zone

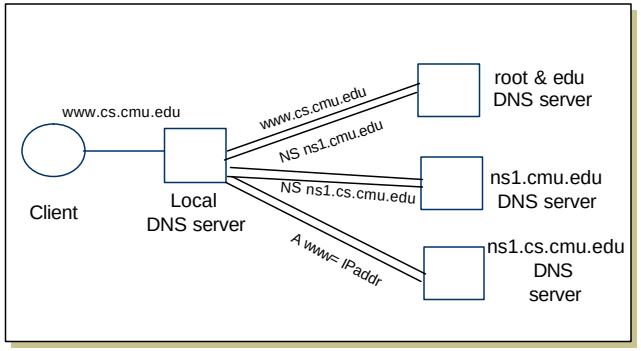
DNS Message Format

12 bytes	Identification	Flags
	No. of Questions	No. of Answer RRs
	No. of Authority RRs	No. of Additional RRs
Name, type fields for a query	Questions (variable number of answers)	
RRs in response to query	Answers (variable number of resource records)	
Records for authoritative servers	Authority (variable number of resource records)	
Additional "helpful info that may be used	Additional Info (variable number of resource records)	

DNS Header Fields

- Identification
  - Used to match up request/response
- Flags
  - 1-bit to mark query or response
  - 1-bit to mark authoritative or not
  - 1-bit to request recursive resolution
  - 1-bit to indicate support for recursive resolution

Typical Resolution



Typical Resolution

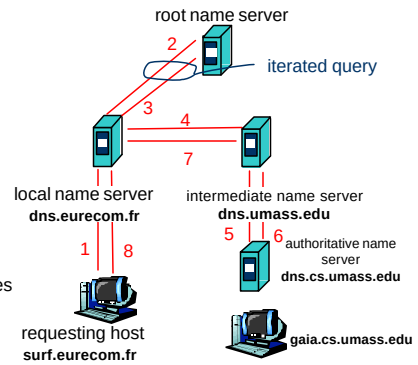
- Steps for resolving www.cmu.edu
  - Application calls gethostbyname() (RESOLVER)
  - Resolver contacts local name server (S_1)
  - S_1 queries root server (S_2) for (www.cmu.edu)
  - S_2 returns NS record for cmu.edu (S_3)
  - What about A record for S_3?
    - This is what the additional information section is for (PREFETCHING)
  - S_1 queries S_3 for www.cmu.edu
  - S_3 returns A record for www.cmu.edu
- Can return multiple A records → what does this mean?

Lookup Methods

Recursive query:
- Server goes out and searches for more info (recursive)
- Only returns final answer or "not found"

Iterative query:
- Server responds with as much as it knows (iterative)
- "I don't know this name, but ask this server"

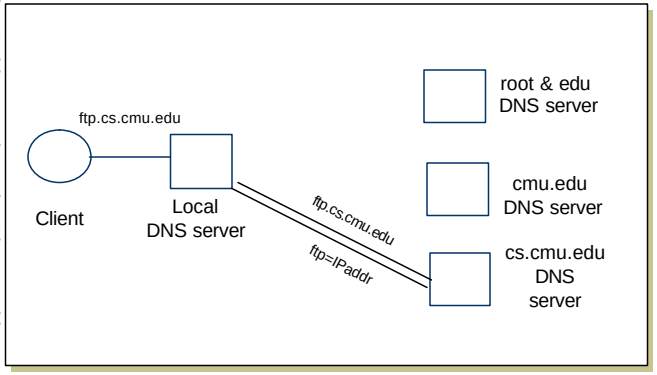
Workload impact on choice?
- Local server typically does recursive
- Root/distant server does iterative



Workload and Caching

- What workload do you expect for different servers?
  - Why might this be a problem? How can we solve this problem?
- DNS responses are cached
  - Quick response for repeated translations
  - Other queries may reuse some parts of lookup
    - NS records for domains
- DNS negative queries are cached
  - Don't have to repeat past mistakes
  - E.g. misspellings, search strings in resolv.conf
- Cached data periodically times out

Subsequent Lookup Example



Reliability

- DNS servers are replicated
  - Name service available if = one replica is up
  - Queries can be load balanced between replicas
- UDP used for queries
  - Need reliability → must implement this on top of UDP!
  - Why not just use TCP?

Reliability

- Try alternate servers on timeout → what's a timeout?
- What's a good value for a timeout?
  - Hard to tell → what are the tradeoffs?
  - Better be conservative!
- Exponential backoff when retrying same server
  - Why do we need this?
- Same identifier for all queries
  - Don't care which server responds

Reverse Name Lookup

- 128.2.206.138?
  - Lookup 138.206.2.128.in-addr.arpa
  - Why is the address reversed?
  - Happens to be www.intel-iris.net and mammoth.cmcl.cs.cmu.edu → what will reverse lookup return? Both?
    - Should only return name that reflects address allocation mechanism

Prefetching

- Name servers can add additional data to any response
- Typically used for prefetching
  - CNAME/MX/NS typically point to another host name
  - Responses include address of host referred to in "additional section"

Mail Addresses

- MX records point to mail exchanger for a name
  - E.g. mail.acm.org is MX for acm.org
- Addition of MX record type proved to be a challenge
  - How to get mail programs to lookup MX record for mail delivery?
  - Needed critical mass of such mailers

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DNS Experience

- One of the greatest challenges seemed to be getting good name server implementations
  - Developers were typically happy with “good enough” implementation
  - Challenging, large scale, wide area distributed system
    - Like routing, but easier to have broken implementations that work

DNS Experience

- Common bugs
  - Looped NS/CNAME record handling
  - Poor static configuration (root server list)
  - Lack of exponential backoff
  - No centralized caching per site
    - Each machine runs own caching local server
    - Why is this a problem?
    - How many hosts do we need to share cache? → recent studies suggest 10-20 hosts

Recent Measurements

- Hit rate for DNS = 80%
  - Is this good or bad?
- Most Internet traffic is Web
  - What does a typical page look like? → average of 4-5 imbedded objects → needs 4-5 transfers
  - This alone accounts for 80% hit rate!
- Lower TTLs for A records does not affect performance
- DNS performance really relies more on NS-record caching

Root Zone

- Generic Top Level Domains (gTLD) = .com, .net, .org, etc…
- Country Code Top Level Domain (ccTLD) = .us, .ca, .fi, .uk, etc…
- Root server ({a-m}.root-servers.net) also used to cover gTLD domains
  - Load on root servers was growing quickly!
  - Moving .com, .net, .org off root servers was clearly necessary to reduce load → done Aug 2000

New gTLDs

- .info → general info
- .biz → businesses
- .aero → air-transport industry
- .coop → business cooperatives
- .name → individuals
- .pro → accountants, lawyers, and physicians
- .museum → museums
- Only new one actives so far = .info, .biz, .name

New Registrars

- Network Solutions (NSI) used to handle all registrations, root servers, etc…
  - Clearly not the democratic (Internet) way
  - Large number of registrars that can create new domains → However NSI still handle root servers

DNS (Summary)

- Motivations → large distributed database
  - Scalability
  - Independent update
  - Robustness
- Hierarchical database structure
  - Zones
  - How is a lookup done
- Caching/prefetching and TTLs
- Reverse name lookup
- What are the steps to creating your own domain?

BREAK!!!

- Come see Mor & I get killed at Halo
  - Sunday 7pm, 7500 WeH

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HTTP Basics

- HTTP layered over bidirectional byte stream
  - Almost always TCP
- Interaction
  - Client sends request to server, followed by response from server to client
  - Requests/responses are encoded in text
- Stateless
  - Server maintains no information about past client requests

How to Mark End of Message?

- Size of message → Content-Length
  - Must know size of transfer in advance
- Delimiter → MIME style Content-Type
  - Server must “escape” delimiter in content
- Close connection
  - Only server can do this

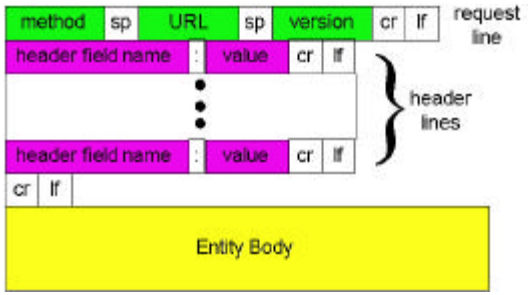
HTTP Request

- Request line
  - Method
    - GET – return URI
    - HEAD – return headers only of GET response
    - POST – send data to the server (forms, etc.)
  - URI
    - E.g. http://www.intel-iris.net/index.html with a proxy
    - E.g. /index.html if no proxy
  - HTTP version

HTTP Request

- Request headers
  - Authorization – authentication info
  - Acceptable document types/encodings
  - From – user email
  - If-Modified-Since
  - Referrer – what caused this page to be requested
  - User-Agent – client software
- Blank-line
- Body

HTTP Request



HTTP Request Example

GET / HTTP/1.1
Accept: */*
Accept-Language: en-us
Accept-Encoding: gzip, deflate
User-Agent: Mozilla/4.0 (compatible; MSIE 5.5; Windows NT 5.0)
Host: www.intel-iris.net
Connection: Keep-Alive

HTTP Response

- Status-line
  - HTTP version
  - 3 digit response code
    - 1XX – informational
    - 2XX – success
      - 200 OK
    - 3XX – redirection
      - 301 Moved Permanently
      - 303 Moved Temporarily
      - 304 Not Modified
    - 4XX – client error
      - 404 Not Found
    - 5XX – server error
      - 505 HTTP Version Not Supported
  - Reason phrase

HTTP Response

- Headers
  - Location – for redirection
  - Server – server software
  - WWW-Authenticate – request for authentication
  - Allow – list of methods supported (get, head, etc)
  - Content-Encoding – E.g x-gzip
  - Content-Length
  - Content-Type
  - Expires
  - Last-Modified
- Blank-line
- Body

HTTP Response Example

HTTP/1.1 200 OK
Date: Tue, 27 Mar 2001 03:49:38 GMT
Server: Apache/1.3.14 (Unix) (Red-Hat/Linux) mod_ssl/2.7.1
OpenSSL/0.9.5a DAV/1.0.2 PHP/4.0.1pl2 mod_perl/1.24
Last-Modified: Mon, 29 Jan 2001 17:54:18 GMT
ETag: "7a11f-10ed-3a75ae4a"
Accept-Ranges: bytes
Content-Length: 4333
Keep-Alive: timeout=15, max=100
Connection: Keep-Alive
Content-Type: text/html
…..

Cookies: Keeping "state"

Many major Web sites use cookies

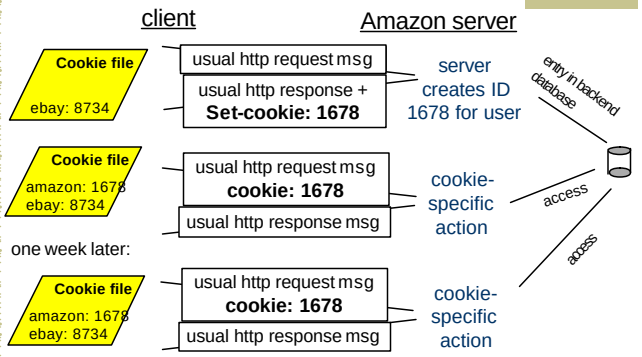
Four components:

1) Cookie header line in the HTTP response message
2) Cookie header line in HTTP request message
3) Cookie file kept on user's host and managed by user's browser
4) Back-end database at Web site

Example:

- Susan access Internet always from same PC
- She visits a specific e-commerce site for first time
- When initial HTTP requests arrives at site, site creates a unique ID and creates an entry in backend database for ID

Cookies: Keeping "State" (Cont.)



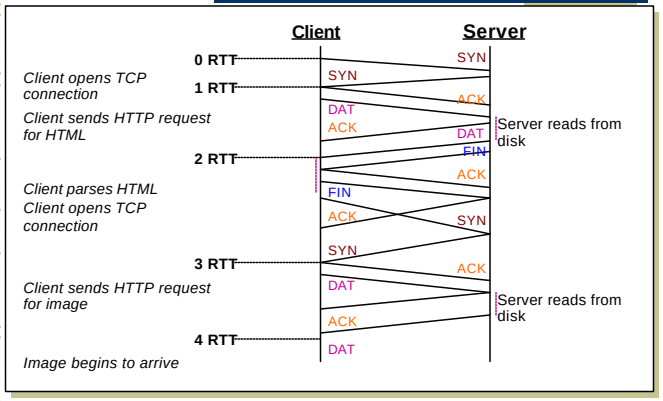
Typical Workload (Web Pages)

- Multiple (typically small) objects per page
- File sizes
  - Why different than request sizes?
  - Also heavy-tailed
    - Pareto distribution for tail
    - Lognormal for body of distribution
- Embedded references
  - Number of embedded objects = pareto – $p(x) = ak^a x^{-(a+1)}$

HTTP 0.9/1.0

- One request/response per TCP connection
  - Simple to implement
- Disadvantages
  - Multiple connection setups → three-way handshake each time
    - Several extra round trips added to transfer
  - Multiple slow starts

Single Transfer Example



More Problems

- Short transfers are hard on TCP
  - Stuck in slow start
  - Loss recovery is poor when windows are small
- Lots of extra connections
  - Increases server state/processing
- Server also forced to keep TIME_WAIT connection state
  - Why must server keep these?
  - Tends to be an order of magnitude greater than # of active connections, why?

Next Lecture

- HTTP Improvements
- Server Selection
- Content Distribution Networks