416 Distributed Systems

Feb 24, 2016 – DNS and CDNs

Outline

- DNS Design
- Content Distribution Networks

Naming

- How do we efficiently locate resources?
  - DNS: name → IP address
- Challenge
  - How do we scale this to the wide area?

Obvious Solutions (1)

Why not use /etc/hosts?

- Original Name to Address Mapping
  - Flat namespace
  - /etc/hosts
  - SRI kept main copy
  - Downloaded regularly
- Count of hosts was increasing: machine per domain → machine per user
  - Many more downloads
  - Many more updates

Obvious Solutions (2)

Why not centralize DNS?

- Single point of failure
- Traffic volume
- Distant centralized database
- Single point of update

- Doesn't *scale!*

Domain Name System Goals

- Basically a wide-area distributed database
- Scalability
- Decentralized maintenance
- Robustness
- Global scope
  - Names mean the same thing everywhere
- Don’t need
  - Atomicity
  - Strong consistency

Programmer's View of DNS

- Conceptually, programmers can view the DNS database as a collection of millions of *host entry structures*:

```
/* DNS host entry structure */
struct addrinfo {
    int     ai_family;              /* host address type (AF_INET) */
    size_t  ai_addrlen;             /* length of an address, in bytes */
    struct sockaddr *ai_addr;       /* address! */
    char    *ai_canonname;          /* official domain name of host */
    struct addrinfo *ai_next;       /* other entries for host */
};
```

- Functions for retrieving host entries from DNS:
  - `getaddrinfo`: query key is a DNS host name.
  - `getnameinfo`: query key is an IP address.

DNS Records

RR format: **(class, name, value, type, ttl)**

- DB contains tuples called resource records (RRs)
  - Classes = Internet (IN), Chaosnet (CH), etc.
  - Each class defines value associated with type

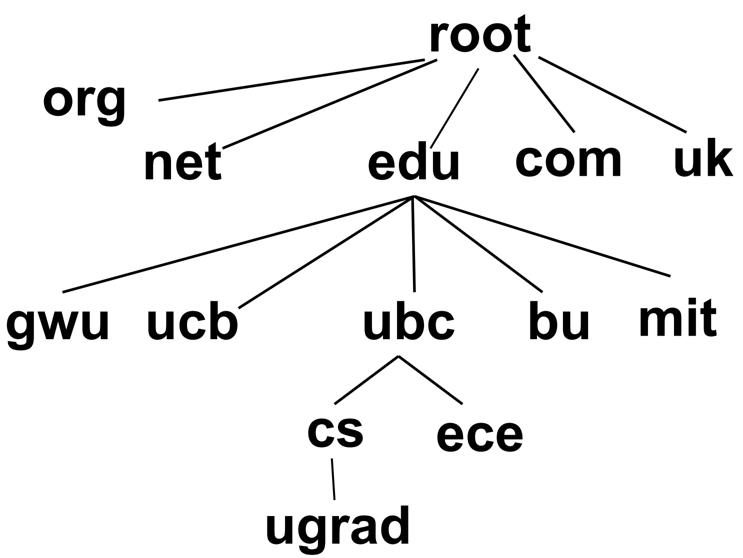
FOR IN class:

- Type=A
  - **name** is hostname
  - **value** is IP address
- Type=NS
  - **name** is domain (e.g. foo.com)
  - **value** is name of authoritative name server for this domain
- Type=CNAME
  - **name** is an alias name for some “canonical” (the real) name
  - **value** is canonical name
- Type=MX
  - **value** is hostname of mailserver associated with **name**

Properties of DNS Host Entries

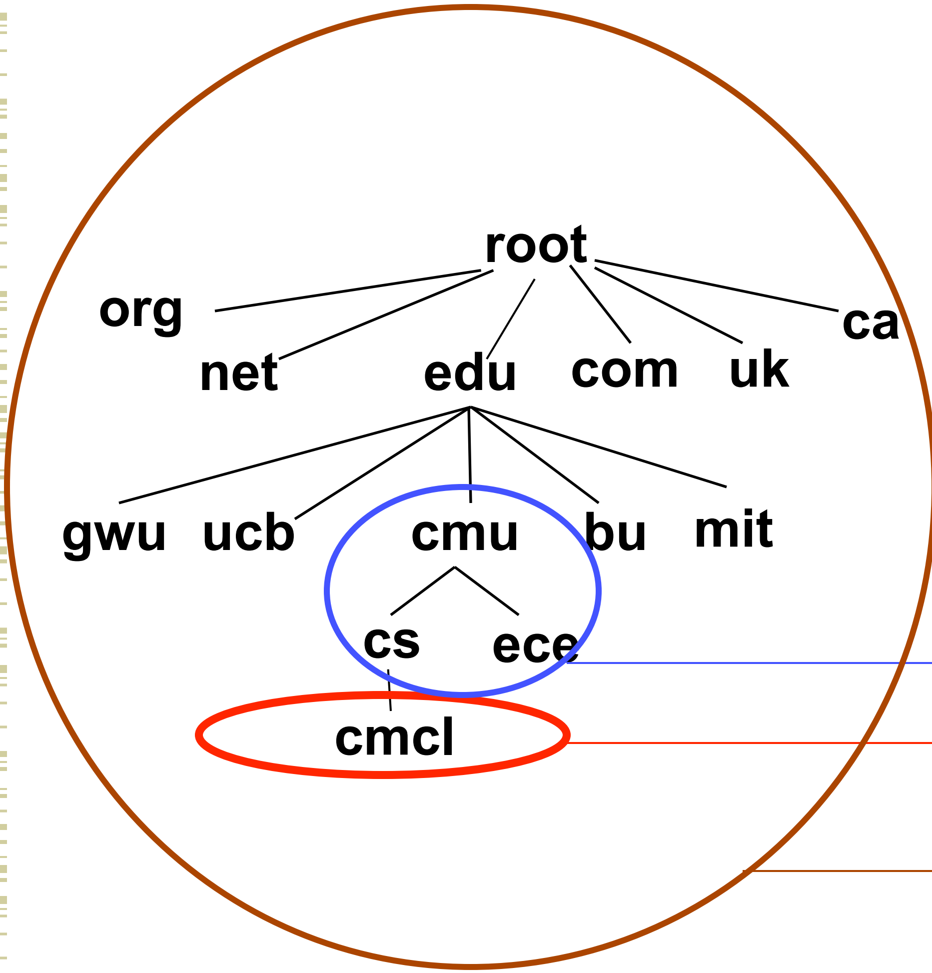
- Different kinds of mappings are possible:
  - Simple case: 1-1 mapping between domain name and IP addr:
    - `kittyhawk.cmcl.cs.cmu.edu` maps to `128.2.194.242`
  - Multiple domain names maps to the same IP address:
    - `eecs.mit.edu` and `cs.mit.edu` both map to `18.62.1.6`
  - Single domain name maps to multiple IP addresses:
    - `aol.com` and `www.aol.com` map to multiple IP addrs.
  - Some valid domain names don't map to any IP address:

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.cs.ubc.edu
  - Fred.ugrad.cs.ubc.edu
  - Fred.cs.mit.edu

DNS Design: Zone Definitions



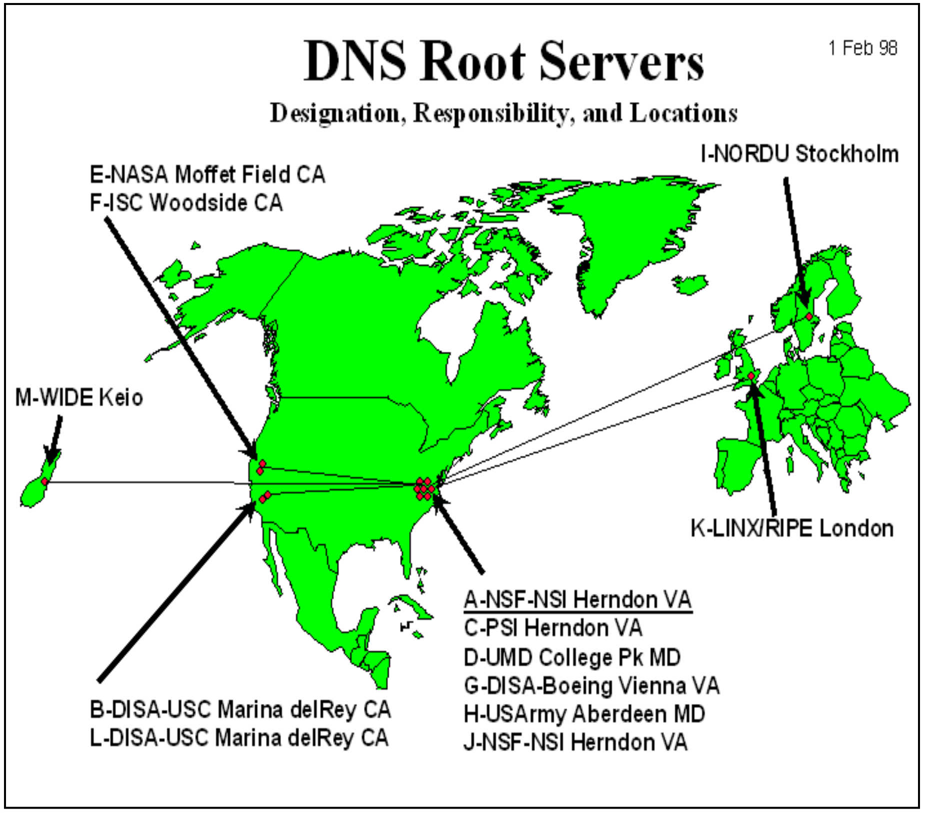
- Zone = contiguous section of name space
  - E.g., Complete tree, single node or subtree
- A zone has an associated set of name servers
  - Must store list of names and tree links

DNS Design: Cont.

- Zones are created by convincing owner node to create/delegate a subzone
  - Records within zone stored at 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.UBC.EDU created by UBC.EDU administrators
  - Who creates UBC.EDU or .EDU?

DNS: Root Name Servers

- Responsible for "root" zone
- Approx. 13 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
  - Newer picture → www.root-servers.org



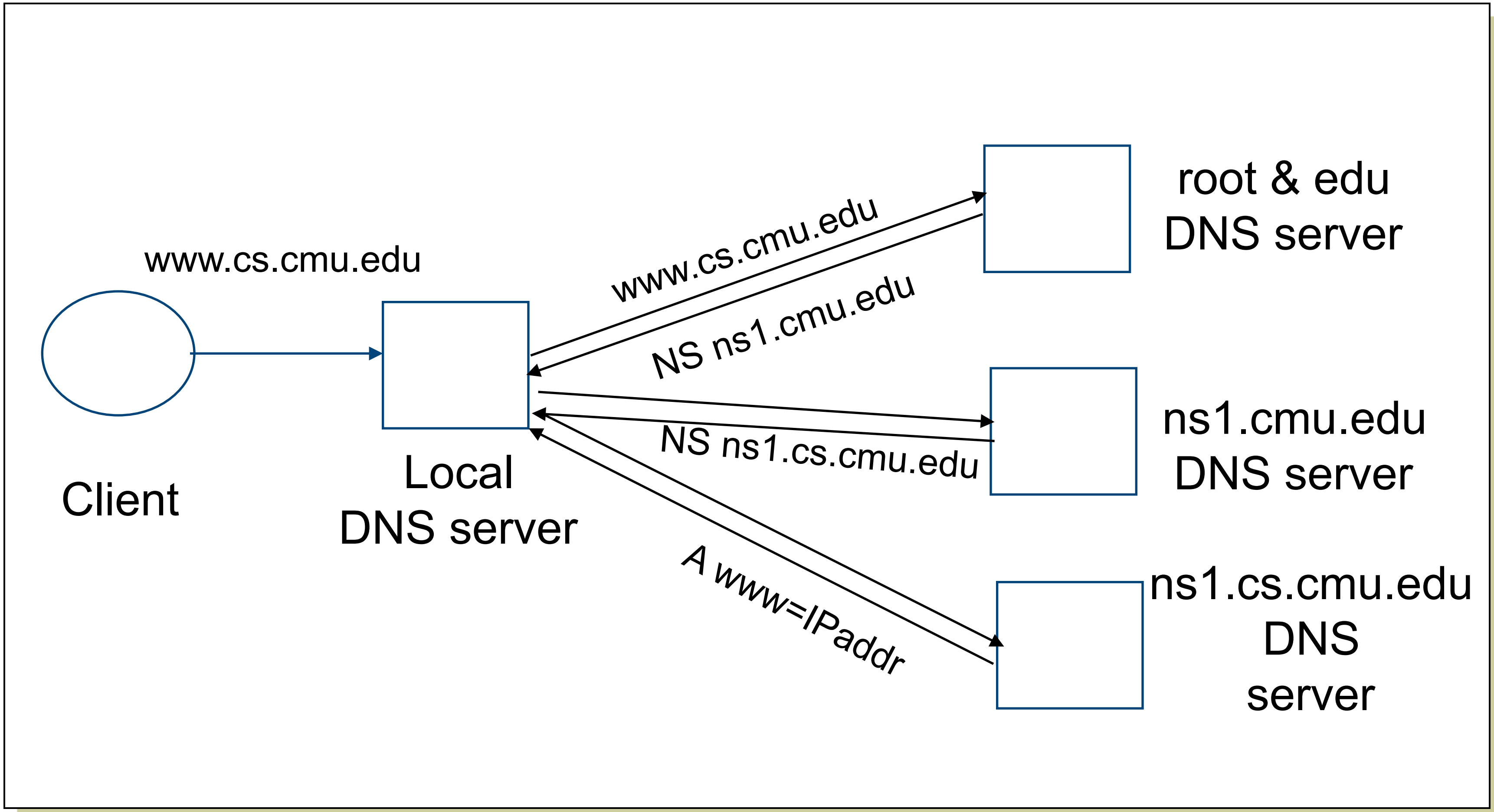
Physical Root Name Servers

- Several root servers have multiple physical servers
- Packets routed to “nearest” server by “Anycast” protocol
- 346 servers total

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

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)
  - S_1 queries S_3 for www.cmu.edu
  - S_3 returns A record for www.cmu.edu

Lookup Methods

<u>Recursive query:</u>

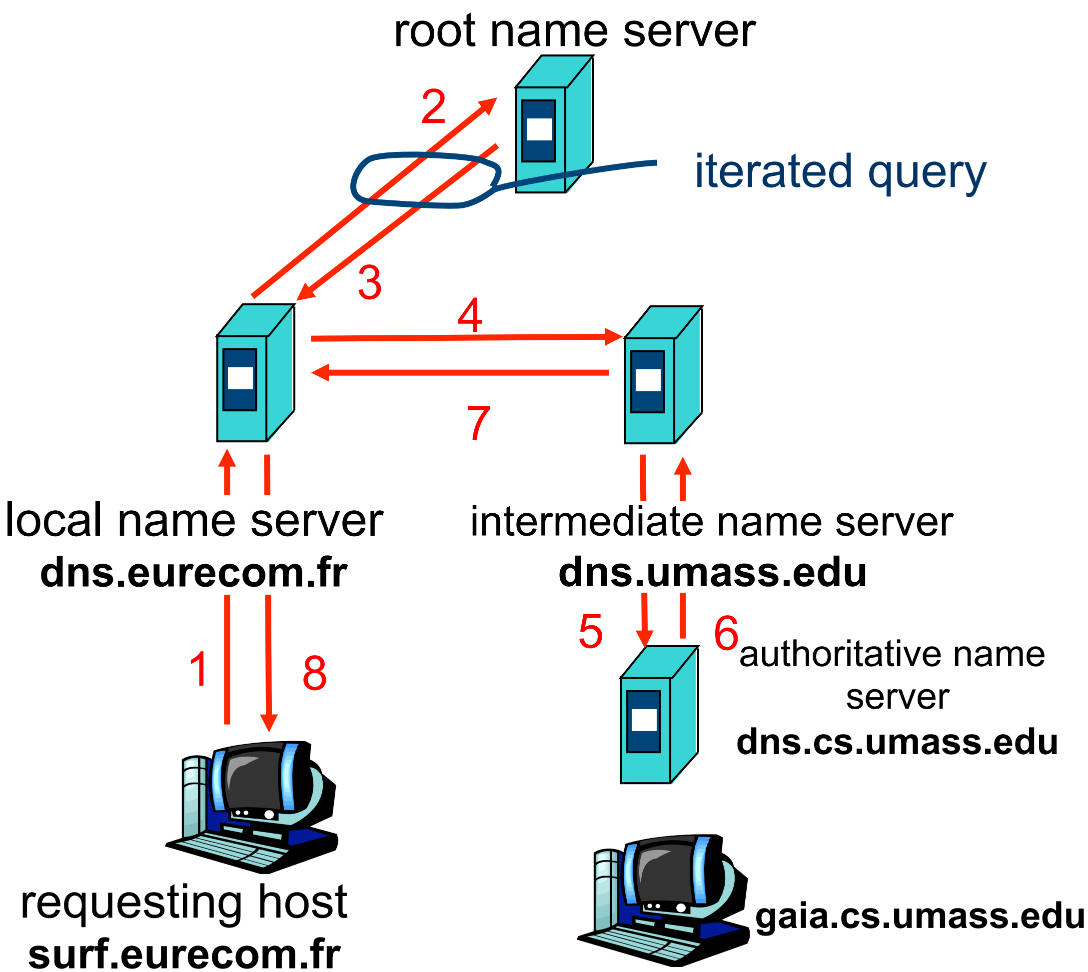
- Server goes out and searches for more info (recursive)
- Only returns final answer or “not found”

<u>Iterative query:</u>

- Server responds with as much as it knows (iterative)
- “I don’t know this name, but ask this server”

Workload impact on choice?

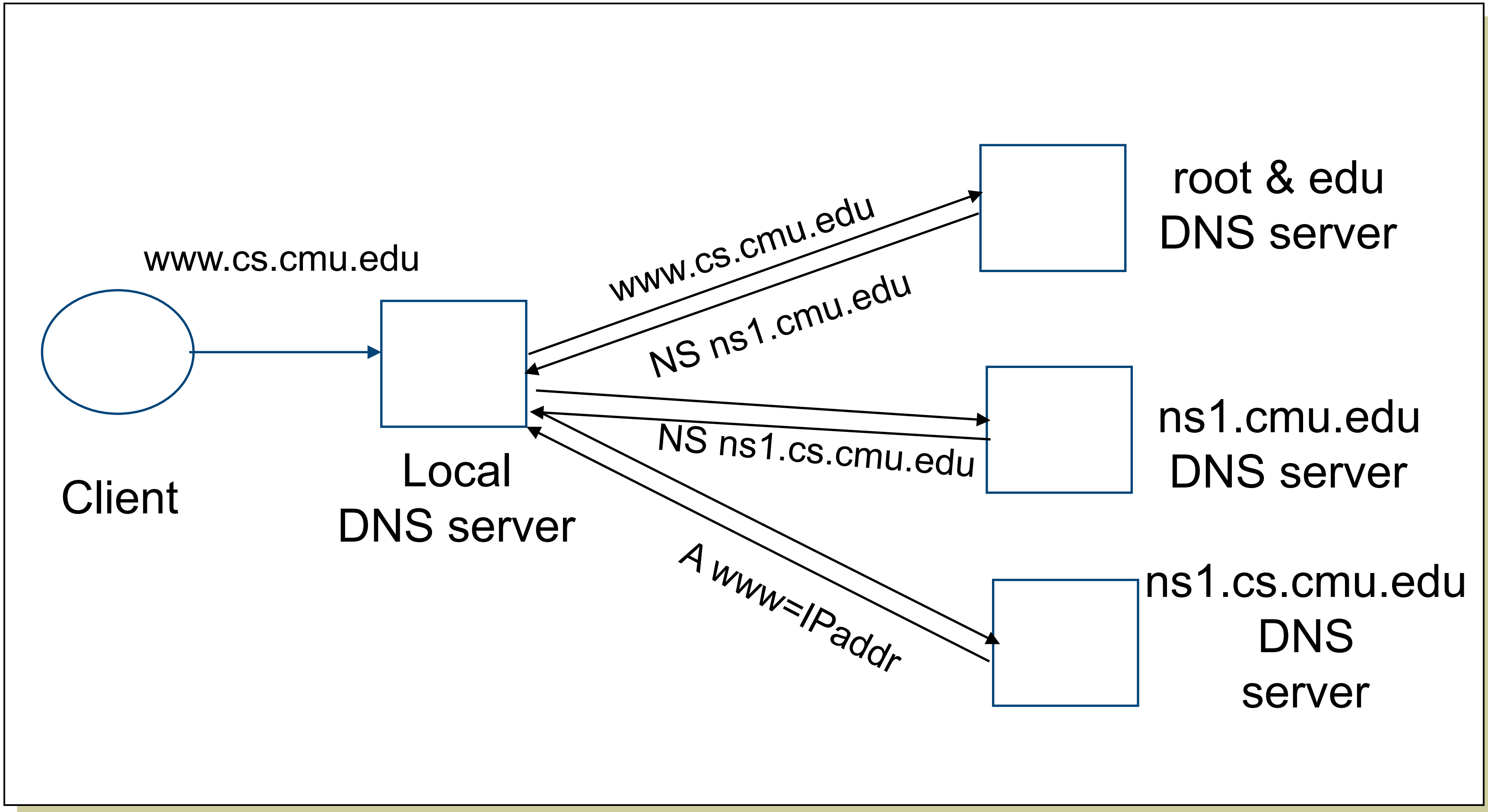
- Local server typically does recursive
- Root/distant server does iterative



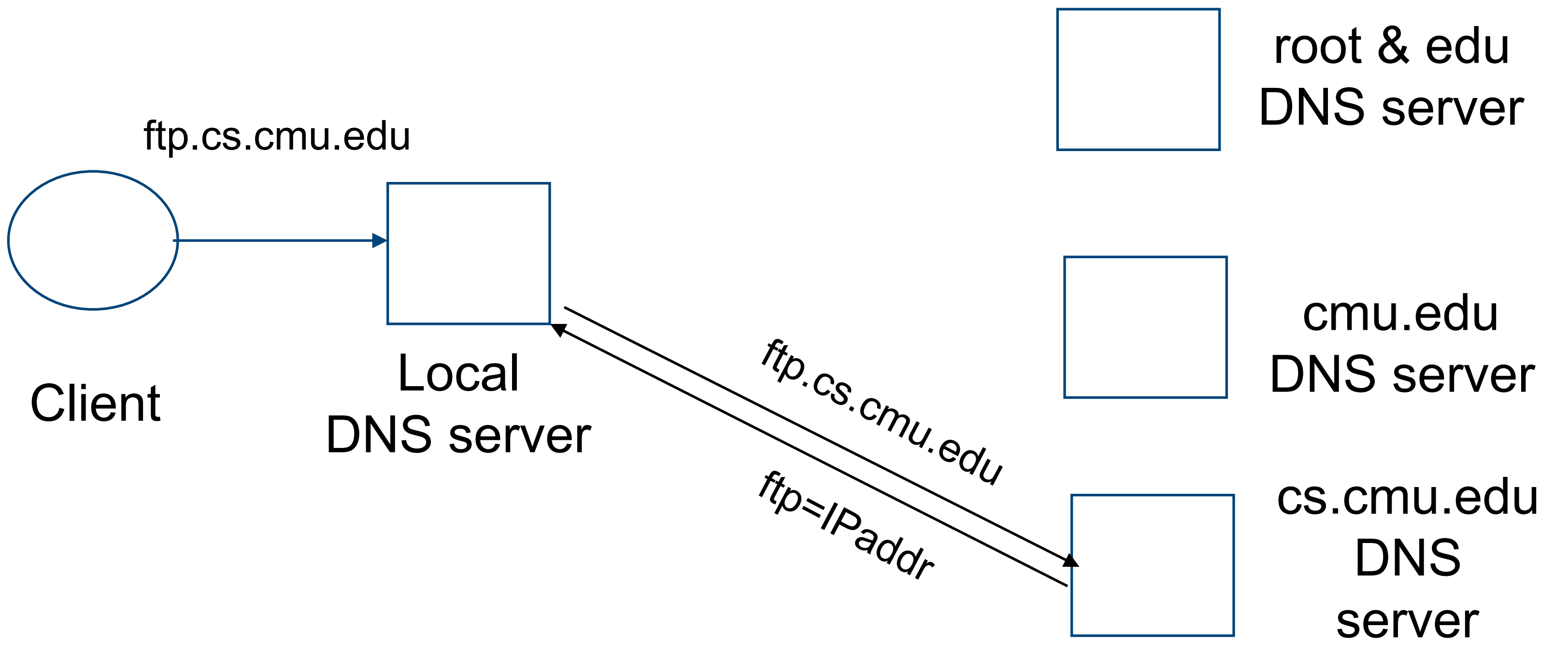
Workload and Caching

- Are all servers/names likely to be equally popular?
  - 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
  - Lifetime (TTL) of data controlled by owner of data
  - TTL passed with every record

Typical Resolution



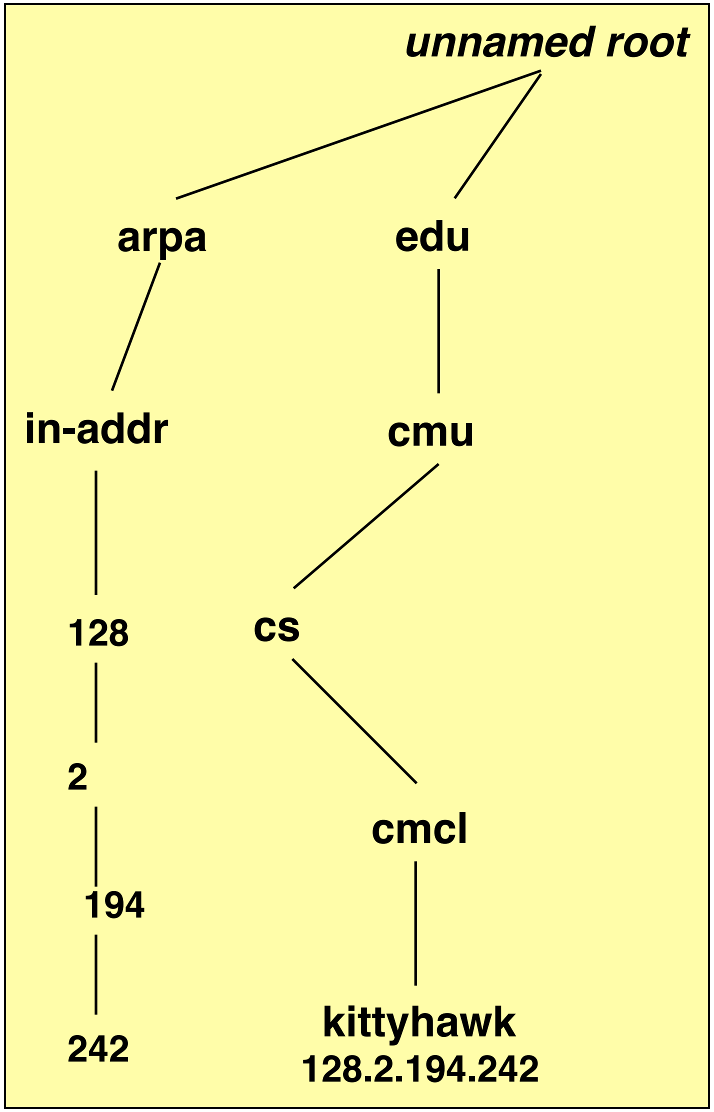
Subsequent Lookup Example



Reliability

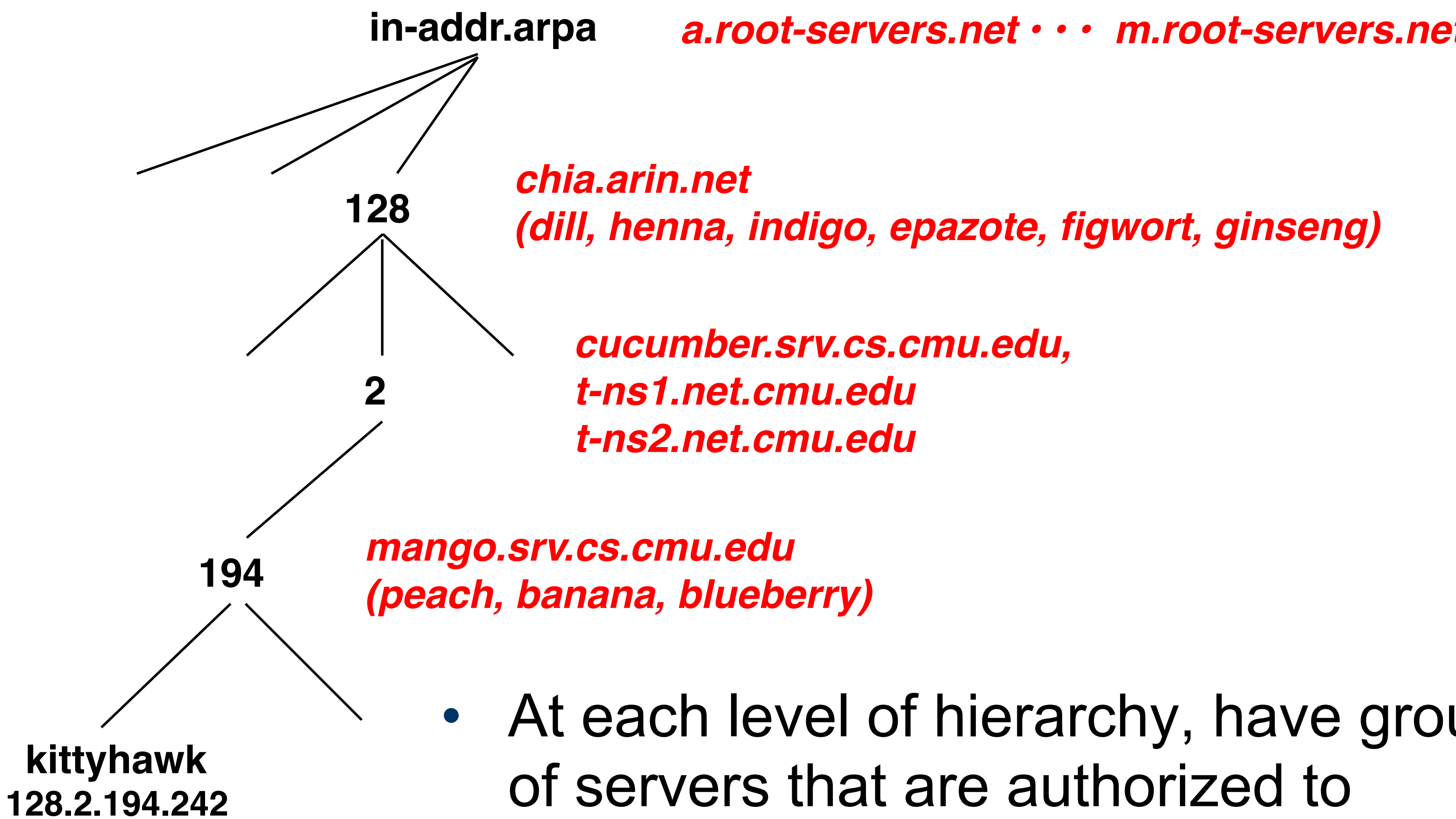
- DNS servers are replicated
  - Name service available if ≥ one replica is up
  - Queries can be load balanced between replicas
- UDP used for queries
  - Need reliability → must implement this on top of UDP!
  - Why not just use TCP?
- Try alternate servers on timeout
  - Exponential backoff when retrying same server
- Same identifier for all queries
  - Don't care which server responds

Reverse DNS



- Task
  - Given IP address, find its name
- Method
  - Maintain separate hierarchy based on IP names
  - Write 128.2.194.242 as 242.194.2.128.in-addr.arpa
    - Why is the address reversed?
- Managing
  - Authority manages IP addresses assigned to it
  - E.g., CMU manages name space 128.2.in-addr.arpa

.arpa Name Server hierarchy/replication



- At each level of hierarchy, have group of servers that are authorized to handle that region of hierarchy

Prefetching

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

Tracing Hierarchy (1)

- Dig Program
  - Use flags to find name server (NS)
  - Disable recursion so that operates one step at a time

```
unix> dig +norecurse @a.root-servers.net NS
greatwhite.ics.cs.cmu.edu

;; ADDITIONAL SECTION:
a.edu-servers.net     172800   IN     A        192.5.6.30
c.edu-servers.net.    172800   IN     A        192.26.92.30
d.edu-servers.net.    172800   IN     A        192.31.80.30
f.edu-servers.net.    172800   IN     A        192.35.51.30
g.edu-servers.net.    172800   IN     A        192.42.93.30
g.edu-servers.net.    172800   IN     AAAA     2001:503:cc2c::2:36
l.edu-servers.net.    172800   IN     A        192.41.162.30
```

IP v6 address

- All .edu names handled by set of servers