DNS Security

Ch 2: DNS Overview: Protocol, Architecture, and Applications

Updated 8-30-17

History

- On ARPANet, host names were mapped to IP addresses in a **hosts.txt** file stored on a single master server

- Other machines downloaded copies of **hosts.txt** periodically

- Unix stored this information in **/etc/hosts**

- This technique didn't scale well. DNS started in 1983.

Design Principles

- Distributed storage
  - DNS data split across many servers
  - Smaller storage requirements for each server
  - Faster transfer of information
  - No single point of failure
- Hierarchical organization of data
  - Allows local control of names and avoids name conflicts

DNS Name Structure

- Up to four **labels** separated by dots form a **Fully Qualified Domain Name (FQDN)**

Host
name

Top Level
Domain
(TLD)

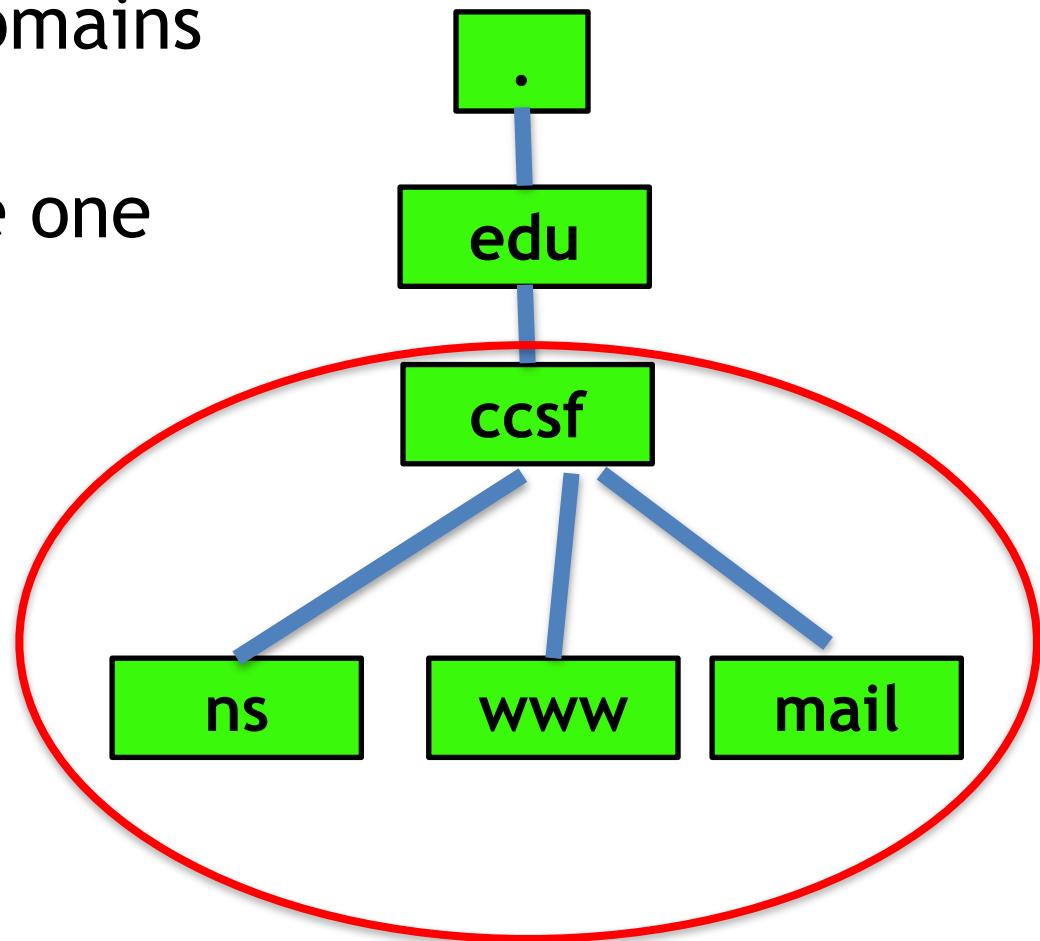# hills.ccsf.edu

Second Level
Domain (SLD)
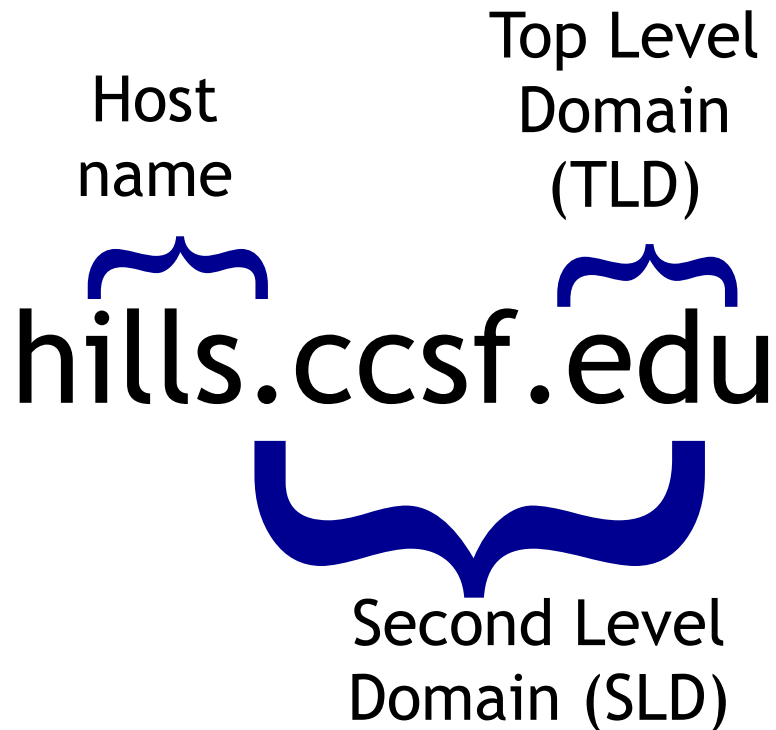
Hierarchical DNS Namespace
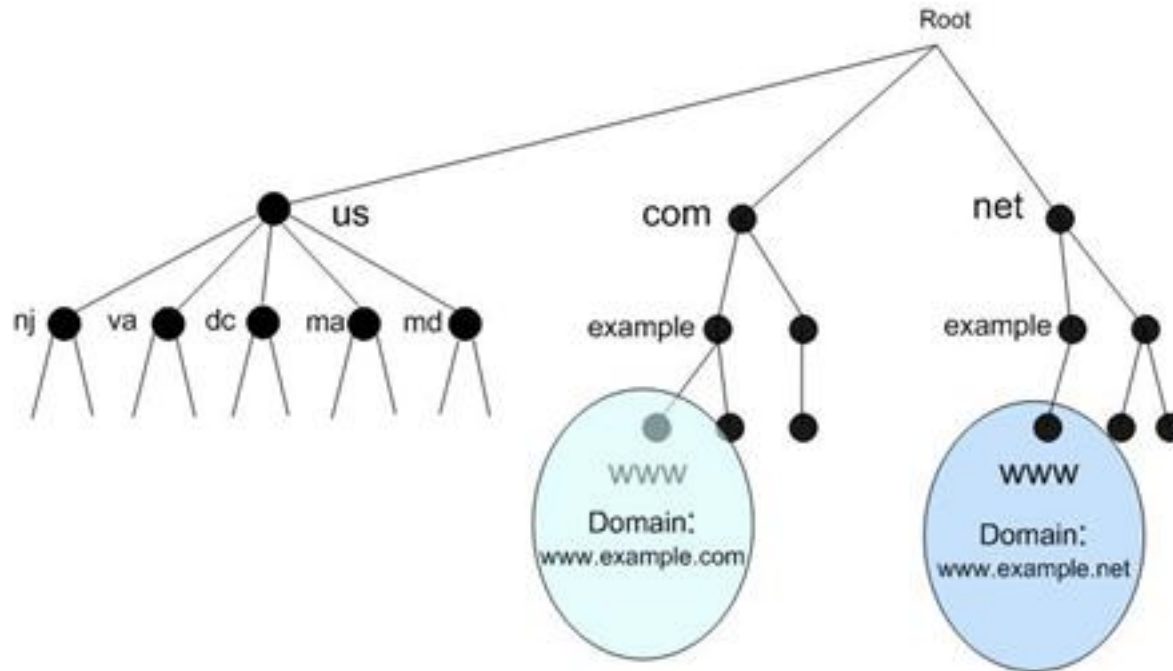
DNS Zones

- Data for a domain and all or some of its subdomains is called a **zone**

- All of CCSF could be one zone, containing
  - ns.ccsf.edu
  - www.ccsf.edu
  - mail.ccsf.edu

Domain Delegation

- CCSF could have separate nameservers on each campus, each responsible for their own subdomain
- The ccsf.edu parent domain would **delegate** responsibility for a subdomain to each campus, making many **zones**
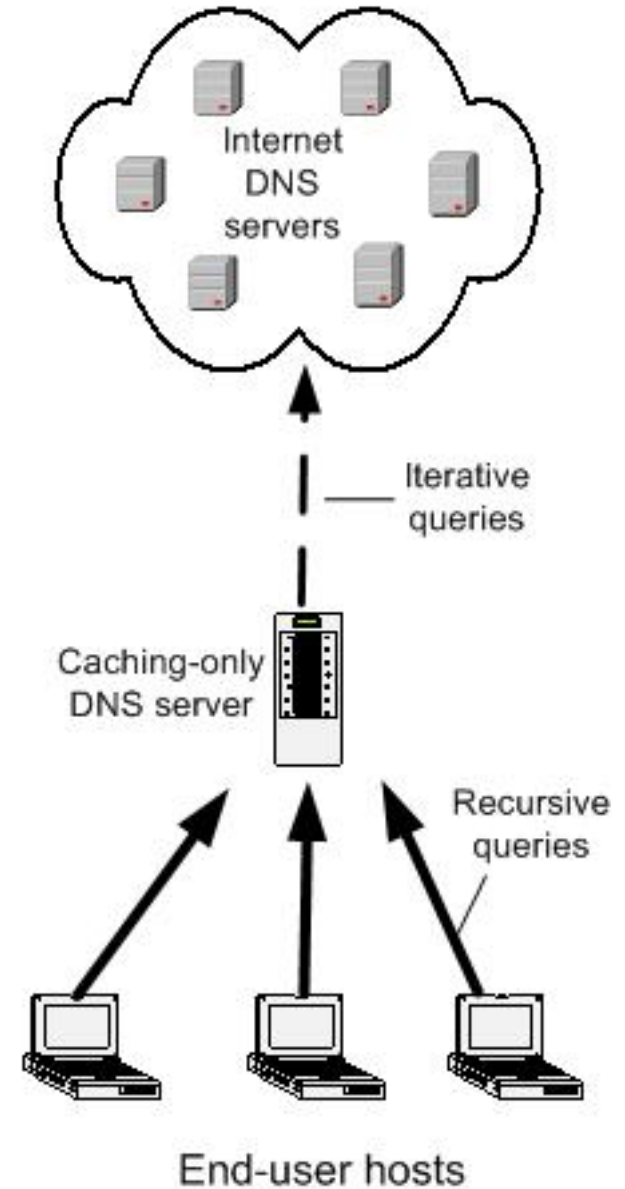- URLs would be longer
  - www.ocean.ccsf.edu
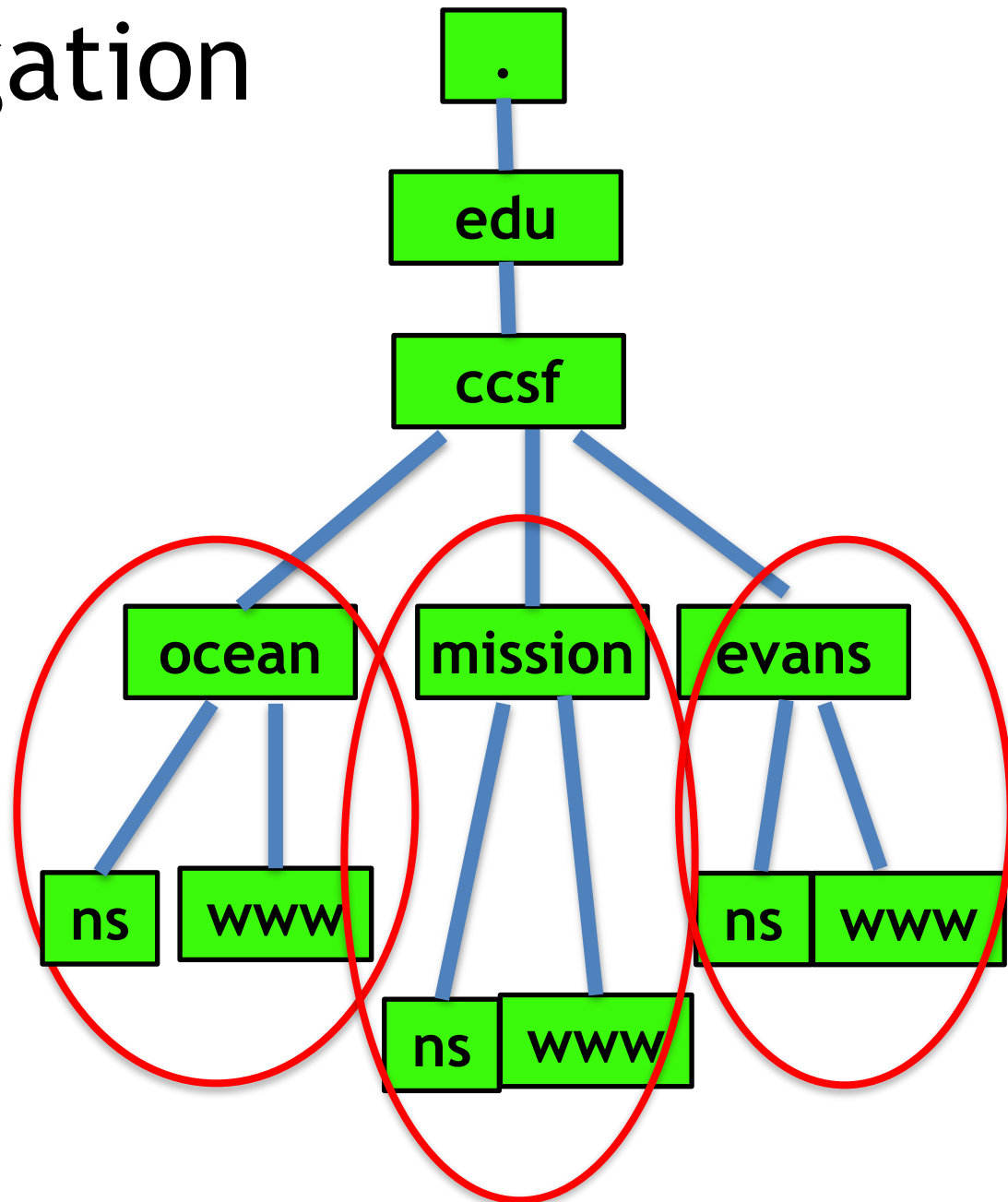
DNS Clients, Servers, and Resolvers

- DNS Client
  - A program like a Web browser using a domain name like **www.ccsf.edu**
- DNS Server
  - Stores and serves DNS data
- DNS Resolver
  - Software that accepts a query from a client, queries one or more DNS servers, and replies to the client

DNS Servers

- **Authoritative** servers manage information about a domain
  - **SOA (Start Of Authority)**
- **Caching** servers store data they copied from other servers
  - Not authoritative for any domain
  - Cache records have a **Time To Live (TTL)**
  - Specified by SOA for each record

Internet DNS servers

Iterative queries

Caching-only DNS server
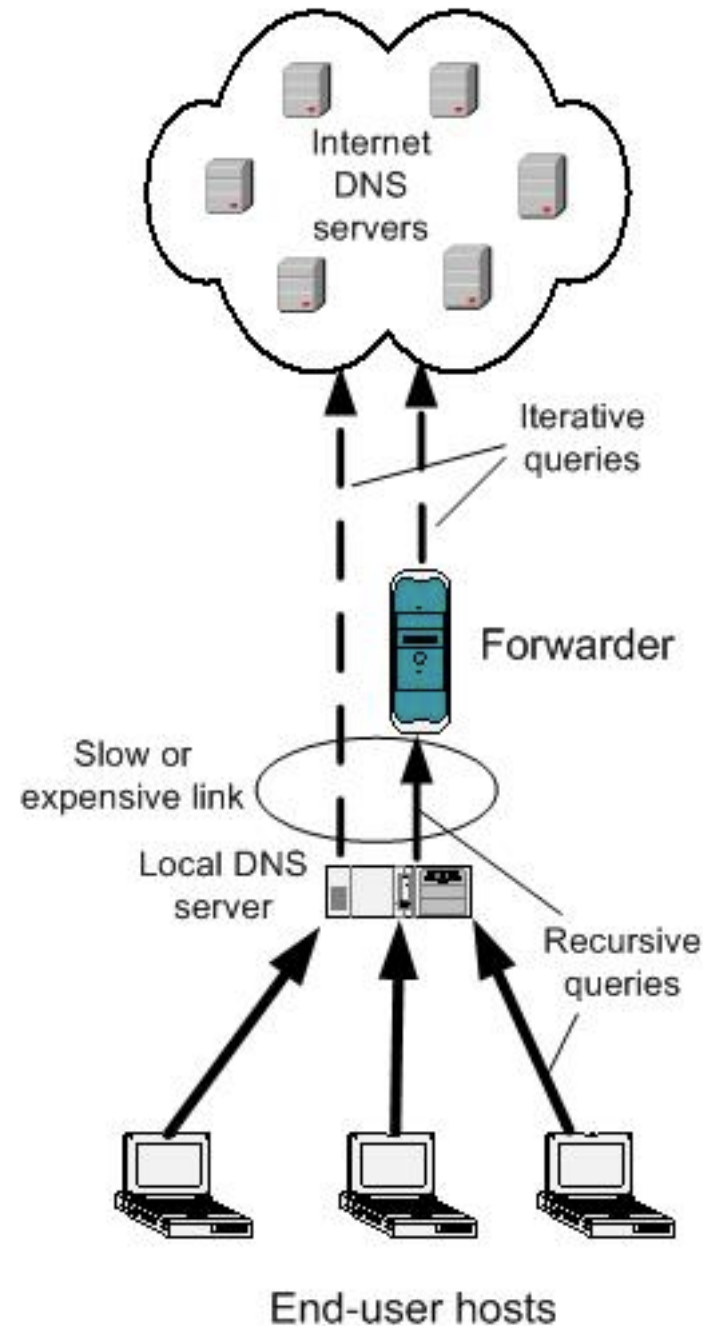
Recursive queries

End-user hosts

DNS Queries

- **Recursive query**
  - Server will find the answer, even if it has to query other servers to get it
  - Server will not respond with a referral to another server
- **Iterative query**
  - If server does not have the answer, it will send a referral to another DNS server
  - Requester has to send another query to hunt for the answer

DNS Forwarder

- Only external queries are sent to the forwarder in this example

- Can reduce traffic through slow or expensive links

- Because it can cache more records

DNS Resolvers

- Receive requests from client applications
- Query DNS servers
- Can cache data
- **Stub resolver**
  - Resolver connected to only one recursive server
  - Cannot follow referrals
  - Part of the operating system on the end device
  - Windows stub resolver caches
  - Linux stub resolver does not cache

Local DNS Server

- Provided by Internet Service Provider (ISP)
- Configured at the client manually or by DHCP

```
C:\Windows\System32>ipconfig /all

Windows IP Configuration

    Host Name . . . . . . . . . . . . : W7
    Primary Dns Suffix  . . . . . . . :
    Node Type . . . . . . . . . . . . : Hybrid
    IP Routing Enabled. . . . . . . . : No
    WINS Proxy Enabled. . . . . . . . : No
    DNS Suffix Search List. . . . . . : localdomain

Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix  . : localdomain
    Description . . . . . . . . . . . : Intel(R) PRO/1000 MT Network Connection
    Physical Address. . . . . . . . . : 00-0C-29-52-34-92
    DHCP Enabled. . . . . . . . . . . : Yes
    Autoconfiguration Enabled . . . . : Yes
    IPv6 Address. . . . . . . . . . . : 2::4(Preferred)
    Link-local IPv6 Address . . . . . : fe80::5a7:33af:ed86:b39f%11(Preferred)
    IPv4 Address. . . . . . . . . . . : 192.168.119.219(Preferred)
    Subnet Mask . . . . . . . . . . . : 255.255.255.0
    Lease Obtained. . . . . . . . . . : Sunday, September 08, 2013 12:06:16 PM
    Lease Expires . . . . . . . . . . : Sunday, September 08, 2013 12:36:16 PM
    Default Gateway . . . . . . . . . : 192.168.119.2
    DHCP Server . . . . . . . . . . . : 192.168.119.254
    DNS Servers . . . . . . . . . . . : 192.168.119.2
    Primary WINS Server . . . . . . . : 192.168.119.2
    NetBIOS over Tcpip. . . . . . . . : Enabled
```

Typical Name Resolution Scenario
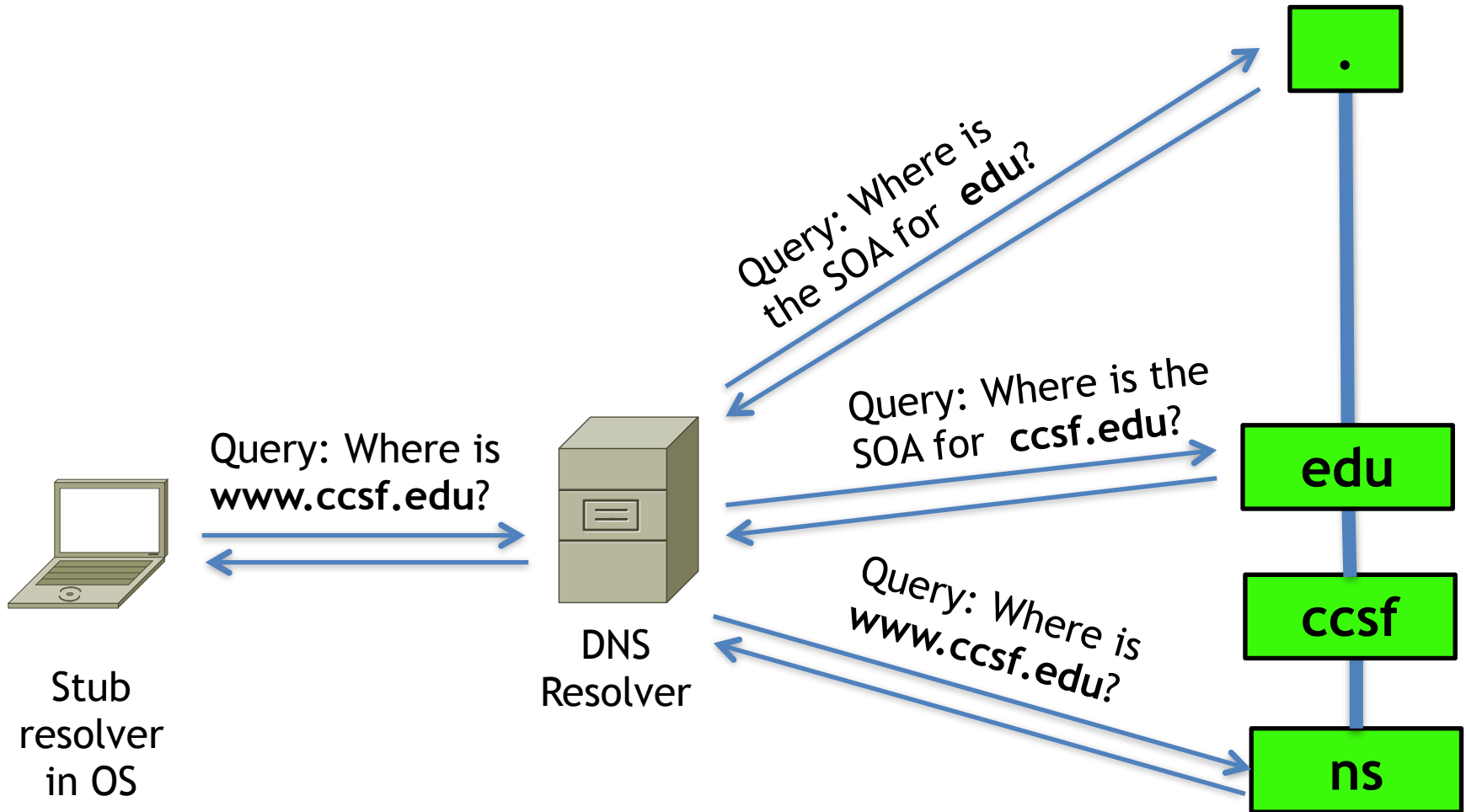
DNS Replication

- **Master server** contains primary zone files
- **Slave servers** have copies of the zone files
- **Zone transfer**
  - The process of copying the files

Root Servers

- Named **.**
  - "dot"
- Has pointers to the top-level domains
  - **com**, **biz**, **mil**, **net**, and so on
- If a DNS server has no data in the cache, e. g. after a reboot
  - Receives a recursive query
  - Is not the SOA for that domain
  - Must query root to find the TLD servers

Root Servers

- Hundreds of servers
- Dispersed around the world
- 13 domain names
  - a.root-servers.net
  - b.root-servers.net
  - …
  - m.root-servers.net

Kahoot!

DNS Resource Record Types and Classes

Each data element in DNS is called a **Resource Record (RR)**

Common RR Types

A   IPv4 address of host
AAAA   IPv6 address of host
MX   Mail exchange
PTR   Host name corresponding to IP address
NS   Host name of SOA name server
CNAME   Canonical Name: alias
SOA   Attributes of zone
TXT   General information

Common RR Types

NAPTR Naming Authority Pointer

SRV   Service (for specific applications)

SPF   Sender Policy Framework
          (used to control spam)
          Also included in TXT records as a
          transitional mechanism

DNSKEY, DS, RRSIG, NSEC   for DNSSEC

dig any ccsf.edu

```
Sams-MacBook-Pro-3:~ sambowne$ dig any ccsf.edu

; <<>> DiG 9.8.3-P1 <<>> any ccsf.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 8747
;; flags: qr rd ra; QUERY: 1, ANSWER: 8, AUTHORITY: 0, ADDITIONAL: 4

;; QUESTION SECTION:
;ccsf.edu.                      IN      ANY

;; ANSWER SECTION:
ccsf.edu.               3600    IN      TXT     "v=spf1 include:spf.protection.outlook.com include:mentormail.cccapply.org -all"
ccsf.edu.               604800  IN      NS      ns6.cenic.org.
ccsf.edu.               604800  IN      NS      ns3.ccsf.edu.
ccsf.edu.               604800  IN      NS      ns4.cenic.org.
ccsf.edu.               604800  IN      NS      ns5.cenic.org.
ccsf.edu.               604800  IN      SOA     ns3.ccsf.edu. root.ccsf.edu. 2016091200 43200 3600 1209600 10800
ccsf.edu.               604800  IN      A       147.144.1.212
ccsf.edu.               3600    IN      MX      0 ccsf-edu.mail.eo.outlook.com.

;; ADDITIONAL SECTION:
ns6.cenic.org.          3306    IN      A       198.188.255.193
ns3.ccsf.edu.           604672  IN      A       147.144.1.247
ns4.cenic.org.          10347   IN      A       137.164.29.67
ns5.cenic.org.          8924    IN      A       137.164.29.69

;; Query time: 19 msec
;; SERVER: 192.168.1.1#53(192.168.1.1)
;; WHEN: Tue Sep 13 09:00:08 2016
;; MSG SIZE  rcvd: 363
```

dig any ietf.org

```
Sams-MacBook-Pro-3:~ sambowne$ dig any ietf.org
;; Truncated, retrying in TCP mode.

; <<>> DiG 9.8.3-P1 <<>> any ietf.org
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 61776
;; flags: qr rd ra; QUERY: 1, ANSWER: 25, AUTHORITY: 0, ADDITIONAL: 5

;; QUESTION SECTION:
;ietf.org.                      IN      ANY

;; ANSWER SECTION:
ietf.org.               1800    IN      TXT     "v=spf1 ip4:12.22.58.0/24 ip4:64.170.98.0/24 ip4:4.31.198.32/27 ip4:209.208.19.192/27 i
p4:72.167.123.204 ip6:2001:1890:123a::/56 ip6:2001:1890:126c::/56 ip6:2001:1900:3001:0011::0/64 ip6:2607:f170:8000:1500::0/64 -all"
ietf.org.               1800    IN      RRSIG   TXT 5 2 1800 20170829151036 20160829141137 40452 ietf.org. zljOeHXZRTNDs7n+MvHXq6h5DZ0O
NG65470Xdx3/OexpJFLhLwvP5Jp0 SahNDOVZwk76m+bLxgmmfbQ5Oq01oZAbqT7VmlygR3uFtfXp+LHxfYje Rzt3mCQSnBz7jps4F66z92OOqH6KYU0T/So6pxvw2wbvj3zS9
y1pw459 jmxqlnUSnfeNAfOGxNsnnXAfEP/jaF6EOct7SvBQQT1fxWLRsdRBNHfu l4VAzpw01RdXuHmit8G2fnBkF6mY3Pq2Z4GCP+NVIC45nZ9yH2UCeAon bI512DPko6Y5e
rsWC7/+X3QeQNQMlbLvIx0/9mgIgodErdMeIFcya1uF HFeCxw==
ietf.org.               1800    IN      DNSKEY  257 3 5 AwEAAavjQ1H6pE8FV8LGP0wQBFVL0EM9BRfqxz9p/sZ+8AByqyFHLdZc HoOGF7CgB5OKYMvGOgysuY
QloPlwbq7Ws5WywbutbXyG24lMWy4jijlJ UsaFrS5EvUu4ydmuRc/TGnEXnN1XQkO+waIT4cLtrmcWjoY8Oqud6lDa Jdj1cKr2nX1NrmMRowIu3DIVtGbQJmzpukpDVZaYMMA
m8M5vz4U2vRCV ETLgDoQ7rhsiD127J8gVExjO8B0113jCajbFRcMtUtFTjH4z7jXP2ZzD cXsgpe4LYFuenFQAcRBRlE6oaykHR7rlPqqmw58nIELJUFoMcb/BdRLg byTeurF
lnxs=
ietf.org.               1800    IN      DNSKEY  256 3 5 AwEAAdDECajHaTjfSoNTY58WcBah1BxPKVIHBz4IfLjfqMvium4lgKtK ZLe97DgJ5/NQrNEGGQmr6f
KvUj67cfrZUojZ2cGRizVhgkOqZ9scaTVX NuXLM5Tw7VWOVIceeXAuuH2mPIiEV6MhJYUsW6dvmNsJ4XwCgNgroAmX hoMEiWEjBB+wjYZQ5GtZHBFKVXACSWTiCtddHcueOeS
VPi5WH94Vlubh HfiytNPZLrObhUCHT6k0tNE6phLoHnXWU+6vpsYpz6GhMw/R9BFxW5Pd PFIWBgoWk2/XFVRSKG9Lr61b2z1R126xeUwvw46RVy3hanV3vNO7LM5H niqaYcl
Bbhk=
```

dig soa ccsf.edu

```
Sams-MacBook-Pro-3:Desktop sambowne$ dig SOA ccsf.edu

; <<>> DiG 9.8.3-P1 <<>> SOA ccsf.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 16598
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;ccsf.edu.                      IN      SOA

;; ANSWER SECTION:
ccsf.edu.               86399   IN      SOA     ns3.ccsf.edu. root.ccsf.edu. 2017082902 43200 3600 1209600 10800

;; Query time: 60 msec
;; SERVER: 8.8.8.8#53(8.8.8.8)
;; WHEN: Wed Aug 30 11:52:06 2017
;; MSG SIZE  rcvd: 71
```

dig soa ccsf.edu +multiline

```
Sams-MacBook-Pro-3:Desktop sambowne$ dig SOA ccsf.edu +multiline

; <<>> DiG 9.8.3-P1 <<>> SOA ccsf.edu +multiline
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 27005
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;ccsf.edu.                     IN SOA

;; ANSWER SECTION:
ccsf.edu.                     86399 IN SOA ns3.ccsf.edu. root.ccsf.edu. (
                                      2017082902 ; serial
                                      43200      ; refresh (12 hours)
                                      3600       ; retry (1 hour)
                                      1209600    ; expire (2 weeks)
                                      10800      ; minimum (3 hours)
                                      )

;; Query time: 86 msec
;; SERVER: 8.8.8.8#53(8.8.8.8)
;; WHEN: Wed Aug 30 11:54:20 2017
;; MSG SIZE  rcvd: 71
```

DNS Looking Glass

Reverse DNS Resolutions

- Start with IP address and query to find the domain name

- Used to block spam email
  - If IP address of server doesn't have a valid domain name, or the domain name is blacklisted, the email is rejected

PTR Records for RDNS

- Reverse the order of the IP address
- Add "in-addr.arpa"
- For example, 147.144.1.212 becomes
- 212.1.144.147.in-addr.arpa.

Reverse DNS Lookup

```
.   .   .   .   .   .   .   .      sambowne Tue Feb 10 16:50:54
~ $dig -x 199.232.41.10

; <<>> DiG 9.8.3-P1 <<>> -x 199.232.41.10
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NXDOMAIN, id: 4088
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 1, ADDITIONAL: 0

;; QUESTION SECTION:
;10.41.232.199.in-addr.arpa.      IN       PTR

;; ANSWER SECTION:
10.41.232.199.in-addr.arpa. 36000 IN     CNAME    rev-c41-10.gnu.org.

;; AUTHORITY SECTION:
gnu.org.                  300      IN      SOA      ns1.gnu.org. hostmaster.gnu.org. 2014031110 3600 120 1209600 3600

;; Query time: 157 msec
;; SERVER: 208.67.222.222#53(208.67.222.222)
;; WHEN: Tue Feb 10 16:52:25 2015
;; MSG SIZE  rcvd: 141
```

Forward Lookup for Google

```
[Sams-MacBook-Pro-3:~ sambowne$ dig aaaa google.com

; <<>> DiG 9.8.3-P1 <<>> aaaa google.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 44671
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;google.com.                        IN      AAAA

;; ANSWER SECTION:
google.com.             114        IN      AAAA     2607:f8b0:4005:806::200e

;; Query time: 797 msec
;; SERVER: 192.168.1.1#53(192.168.1.1)
;; WHEN: Tue Sep 13 09:09:14 2016
;; MSG SIZE  rcvd: 56
```

Reverse Lookup for Google

```
[Sams-MacBook-Pro-3:~ sambowne$ dig -x 2607:f8b0:4005:806::200e

; <<>> DiG 9.8.3-P1 <<>> -x 2607:f8b0:4005:806::200e
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 38139
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;e.0.0.2.0.0.0.0.0.0.0.0.0.0.0.0.6.0.8.0.5.0.0.4.0.b.8.f.7.0.6.2.ip6.arpa. IN PTR

;; ANSWER SECTION:
e.0.0.2.0.0.0.0.0.0.0.0.0.0.0.0.6.0.8.0.5.0.0.4.0.b.8.f.7.0.6.2.ip6.arpa. 41360 IN PTR sfo03s06-in-x0e.1e100.net.

;; Query time: 649 msec
;; SERVER: 192.168.1.1#53(192.168.1.1)
;; WHEN: Tue Sep 13 09:09:43 2016
;; MSG SIZE  rcvd: 129
```
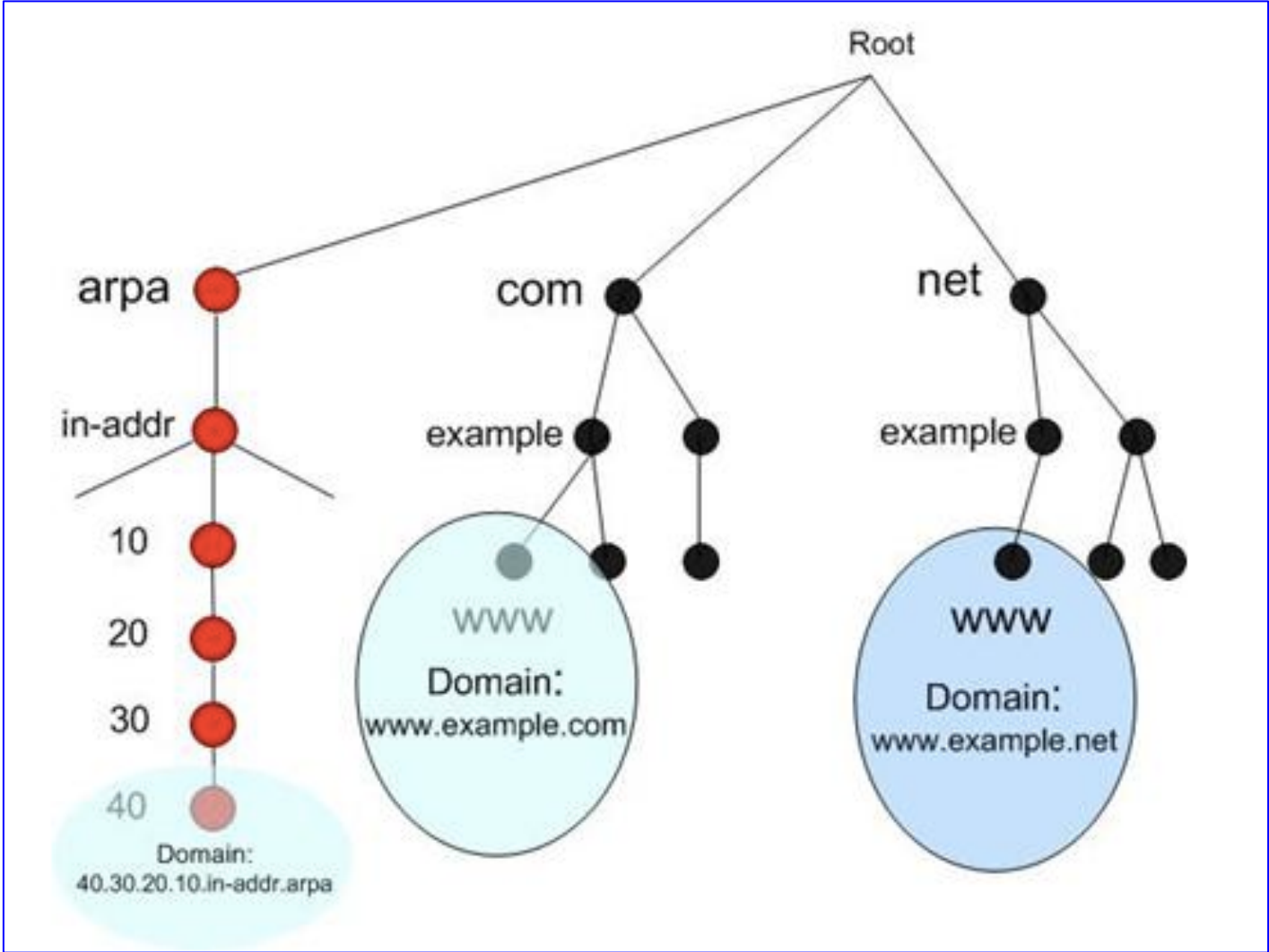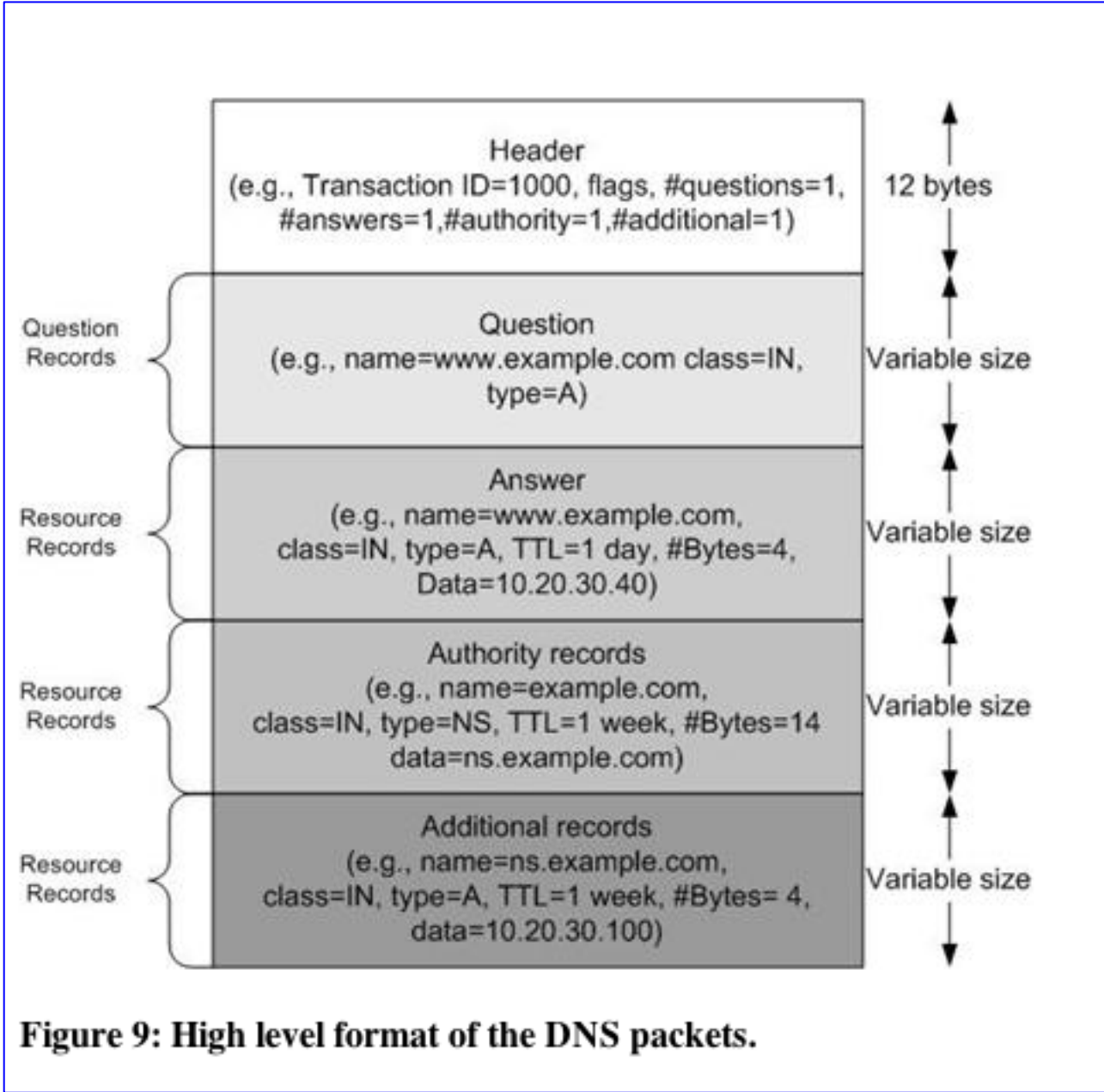
Figure 9: High level format of the DNS packets.

DNS Packet Header Format

← —————————————— 2 bytes —————————————— →

Transaction ID (e.g., "60345")
Flags (e.g., QR=0, Opcode=0, AA=0,TC=0,RD=0,RA=0,RCODE=0)
Number of Questions (e.g., "1")
Number of Answers (e.g., "1")
Number of Authority Records (e.g., "2")
Number of Additional Records (e.g., "2")

DNS Packet Header Flags Format

Bit # 1	2 3 4 5	6	7	8	9	10	11	12	13 14 15 16
QR	Opcode	AA	TC	RD	RA	Z	AD	CD	RCODE

- Flags specify:
  - Query or Response
  - Forward or Reverse
  - Recursive or Iterative

Glue Records

- If the SOA for **ccsf.edu** is **ns3.ccsf.edu** the system fails
  - Q: Where is **www.ccsf.edu**?
  - A: Ask **ns3.ccsf.edu**
  - Q: Where is **ns3.ccsf.edu**?
  - A: Ask **ns3.ccsf.edu**
- To prevent this, each domain has a **glue record** in their top-level domain zone specifying the IP address of the SOA

Viewing Glue Records with dig

1. Find a .edu root NS server

```
.  .   .   .   .   .   .   .     sambowne Tue Feb 10 16:57:51
~ $dig ns edu

; <<>> DiG 9.8.3-P1 <<>> ns edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 23660
;; flags: qr rd ra; QUERY: 1, ANSWER: 6, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;edu.                            IN      NS

;; ANSWER SECTION:
edu.                    170280  IN      NS      g.edu-servers.net.
edu.                    170280  IN      NS      c.edu-servers.net.
edu.                    170280  IN      NS      f.edu-servers.net.
edu.                    170280  IN      NS      d.edu-servers.net.
edu.                    170280  IN      NS      a.edu-servers.net.
edu.                    170280  IN      NS      l.edu-servers.net.
```

2. dig NS domain @root

```
. . . . . . . .    sambowne Tue Feb 10 16:58:01
~ $dig NS ccsf.edu @g.edu-servers.net

; <<>> DiG 9.8.3-P1 <<>> NS ccsf.edu @g.edu-servers.net
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 23224
;; flags: qr rd; QUERY: 1, ANSWER: 0, AUTHORITY: 4, ADDITIONAL: 1
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;ccsf.edu.                      IN      NS

;; AUTHORITY SECTION:
ccsf.edu.              172800   IN      NS      ns4.cenic.org.
ccsf.edu.              172800   IN      NS      ns5.cenic.org.
ccsf.edu.              172800   IN      NS      ns6.cenic.org.
ccsf.edu.              172800   IN      NS      ns3.ccsf.edu.

;; ADDITIONAL SECTION:
ns3.ccsf.edu.          172800   IN      A       147.144.1.247
```

IPv4 Glue for Google

- 1. NS servers for .com

```
.  .  .  .  .  .  .  .     sambowne Tue Feb 10 16:58:37
~ $dig ns com

; <<>> DiG 9.8.3-P1 <<>> ns com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 29
;; flags: qr rd ra; QUERY: 1, ANSWER: 13, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;com.                            IN      NS

;; ANSWER SECTION:
com.                    21893   IN      NS      m.gtld-servers.net.
com.                    21893   IN      NS      c.gtld-servers.net.
```

IPv4 Glue Records for Google

```
  .   .   .   .   .   .   .   .   .   sambowne Tue Feb 10 17:01:30
~ $dig NS google.com @m.gtld-servers.net

; <<>> DiG 9.8.3-P1 <<>> NS google.com @m.gtld-servers.net
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 40276
;; flags: qr rd; QUERY: 1, ANSWER: 0, AUTHORITY: 4, ADDITIONAL: 4
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;google.com.                         IN      NS

;; AUTHORITY SECTION:
google.com.              172800  IN      NS      ns2.google.com.
google.com.              172800  IN      NS      ns1.google.com.
google.com.              172800  IN      NS      ns3.google.com.
google.com.              172800  IN      NS      ns4.google.com.

;; ADDITIONAL SECTION:
ns2.google.com.          172800  IN      A       216.239.34.10
ns1.google.com.          172800  IN      A       216.239.32.10
ns3.google.com.          172800  IN      A       216.239.36.10
ns4.google.com.          172800  IN      A       216.239.38.10
```

Bind Version Query

- From c. 2015

```
Sams-MacBook-Air-2:~ sambowne$ dig @rudra.ccsf.cc.ca.us version.bind. txt chaos

; <<>> DiG 9.8.3-P1 <<>> @rudra.ccsf.cc.ca.us version.bind. txt chaos
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 63154
;; flags: qr aa rd; QUERY: 1, ANSWER: 1, AUTHORITY: 1, ADDITIONAL: 0
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;version.bind.                  CH      TXT

;; ANSWER SECTION:
version.bind.           0       CH      TXT     "9.3.5-P1"

;; AUTHORITY SECTION:
version.bind.           0       CH      NS      version.bind.

;; Query time: 222 msec
;; SERVER: 147.144.3.238#53(147.144.3.238)
;; WHEN: Mon Sep  9 11:48:52 2013
;; MSG SIZE  rcvd: 65
```

Bind Version Query 9-13-16

```
[Sams-MacBook-Pro-3:~ sambowne$ dig @ns3.ccsf.edu version.bind txt chaos

; <<>> DiG 9.8.3-P1 <<>> @ns3.ccsf.edu version.bind txt chaos
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 5704
;; flags: qr aa rd; QUERY: 1, ANSWER: 1, AUTHORITY: 1, ADDITIONAL: 0
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;version.bind.                   CH      TXT

;; ANSWER SECTION:
version.bind.           0       CH      TXT     "[secured]"

;; AUTHORITY SECTION:
version.bind.           0       CH      NS      version.bind.

;; Query time: 347 msec
;; SERVER: 147.144.1.247#53(147.144.1.247)
;; WHEN: Tue Sep 13 09:14:25 2016
;; MSG SIZE  rcvd: 66
```

ISC.ORG (Authors of Bind)

```
[Sams-MacBook-Pro-3:~ sambowne$ dig @ord.sns-pb.isc.org version.bind txt chaos

; <<>> DiG 9.8.3-P1 <<>> @ord.sns-pb.isc.org version.bind txt chaos
; (2 servers found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 7861
;; flags: qr aa rd; QUERY: 1, ANSWER: 1, AUTHORITY: 1, ADDITIONAL: 0
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;version.bind.                    CH      TXT

;; ANSWER SECTION:
version.bind.           0        CH      TXT     "9.10.3-P3"

;; AUTHORITY SECTION:
version.bind.           0        CH      NS      version.bind.

;; Query time: 62 msec
;; SERVER: 2001:500:71::30#53(2001:500:71::30)
;; WHEN: Tue Sep 13 09:19:52 2016
;; MSG SIZE  rcvd: 66
```
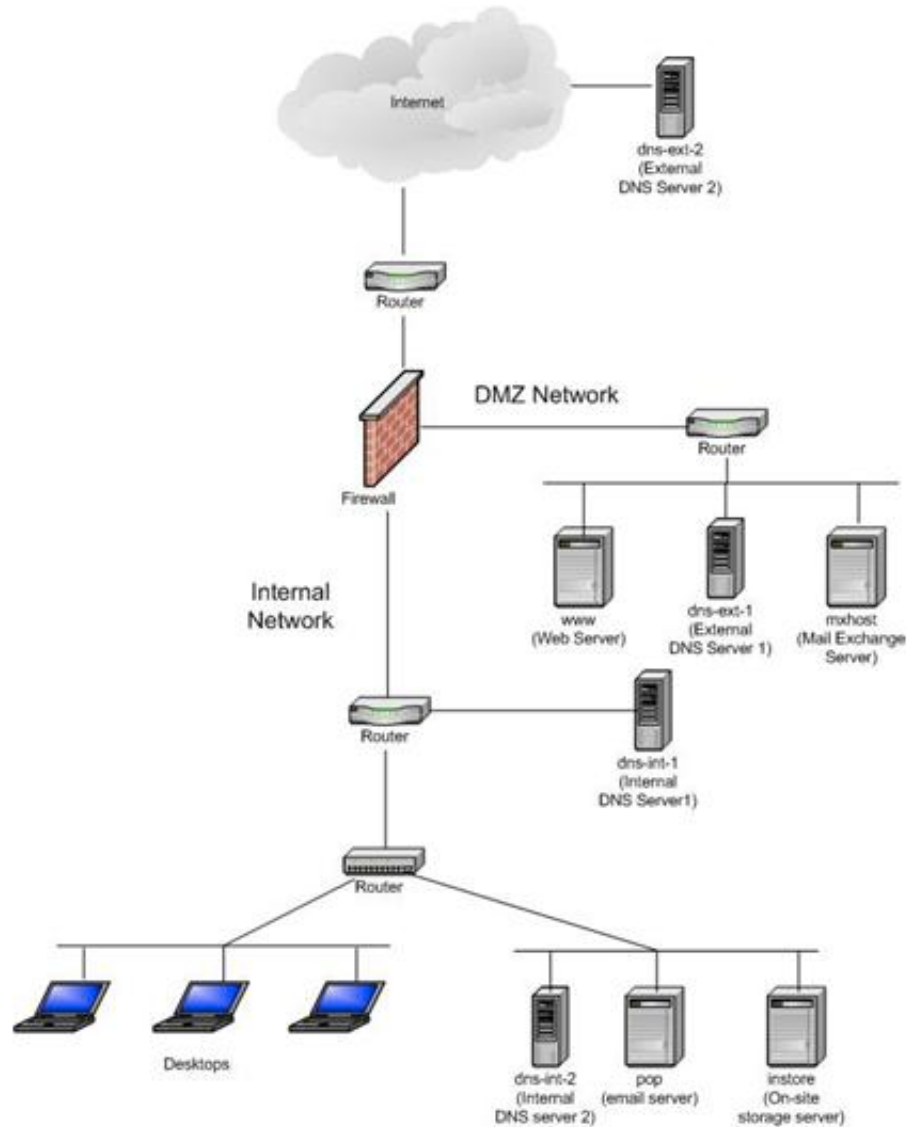
Common Server Architectures
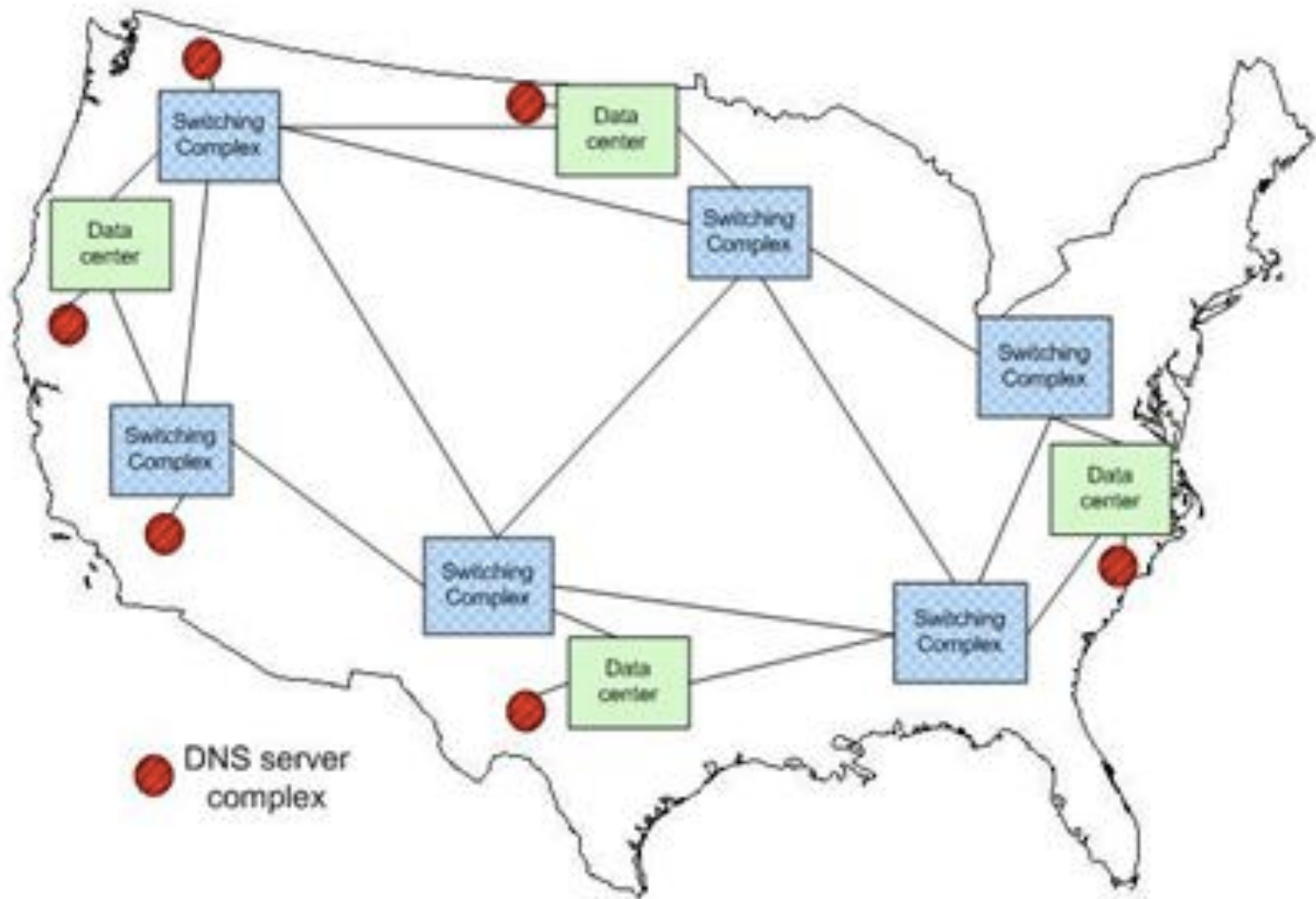
Small Company: Outsource DNS
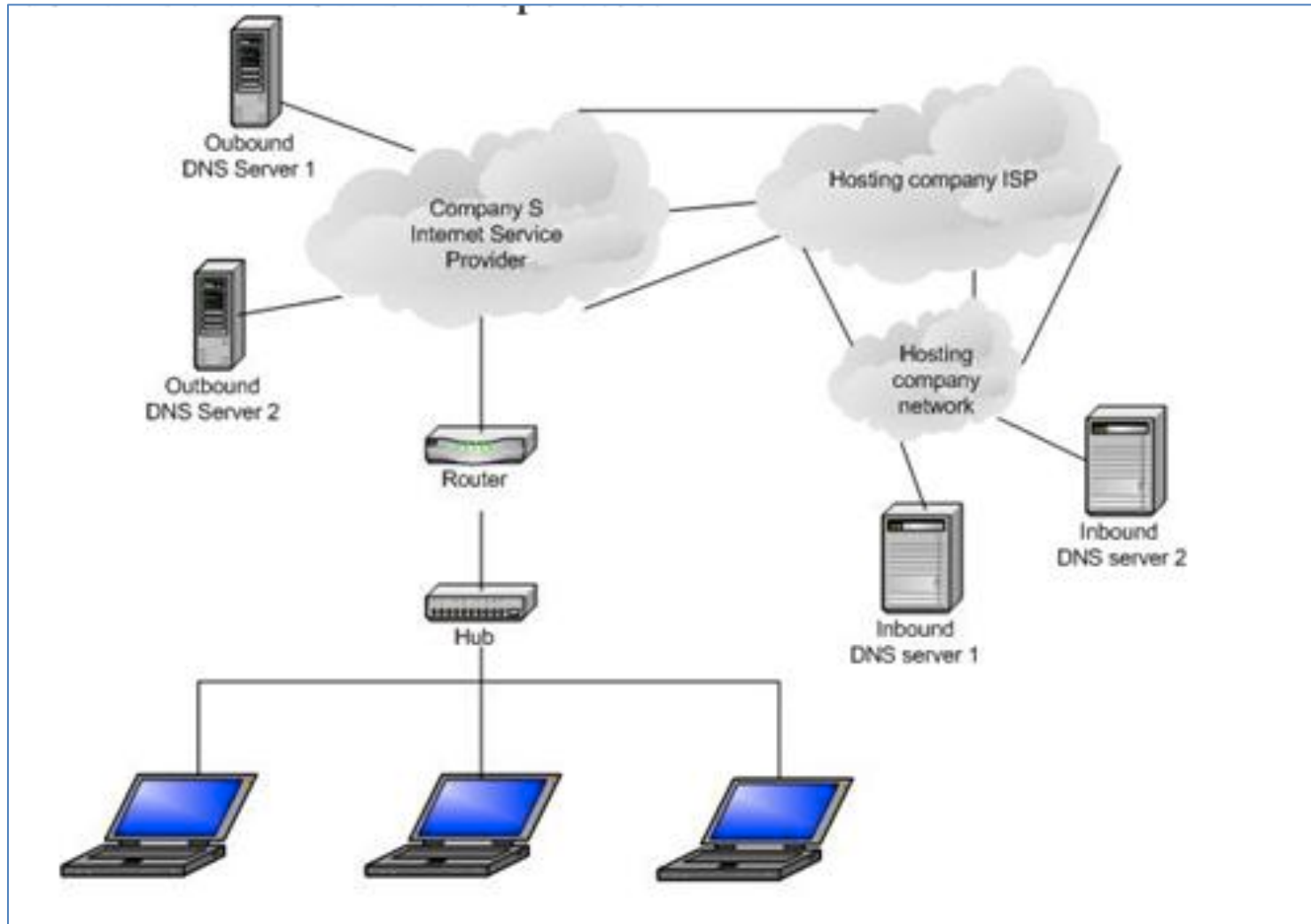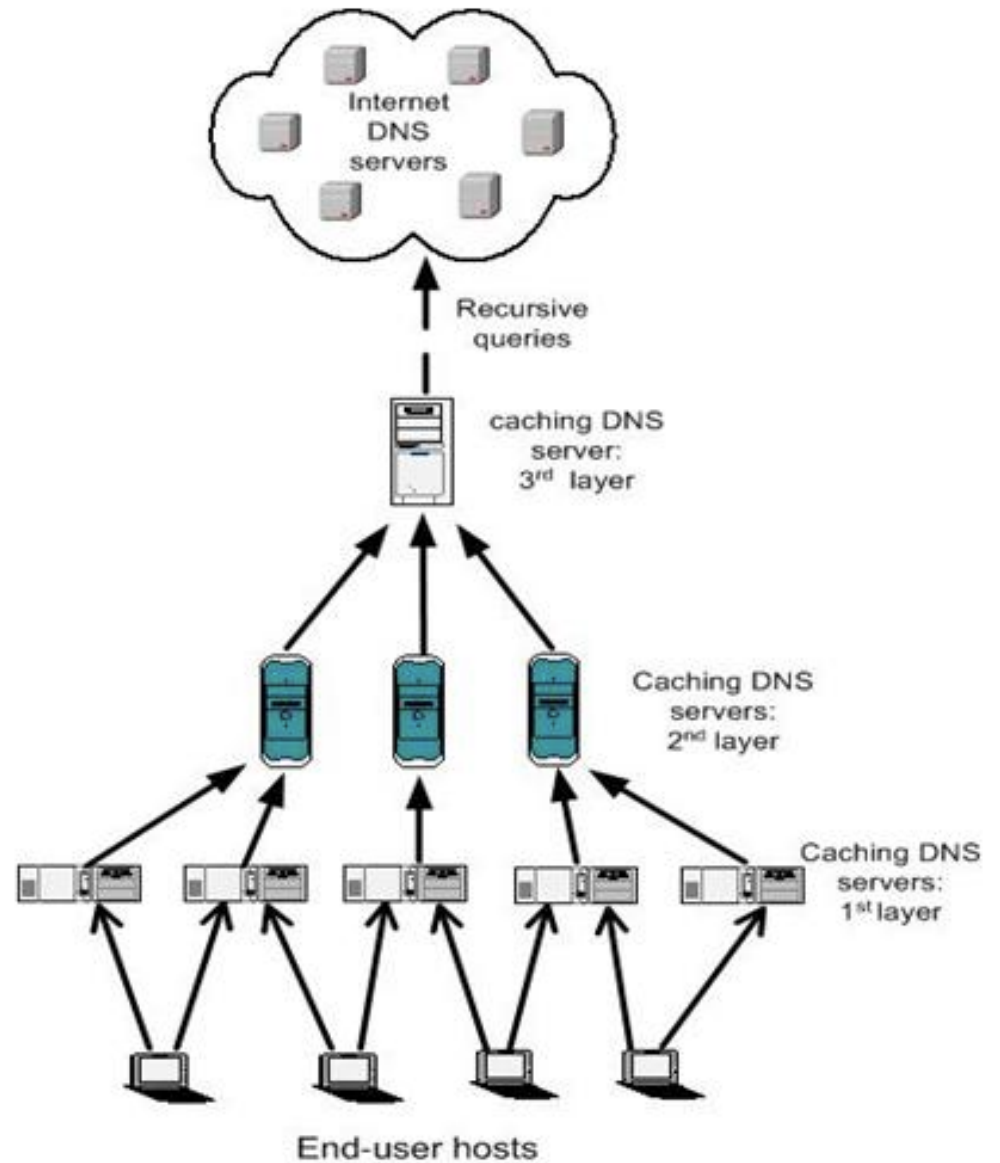
Medium Company

- Internal and external DNS servers
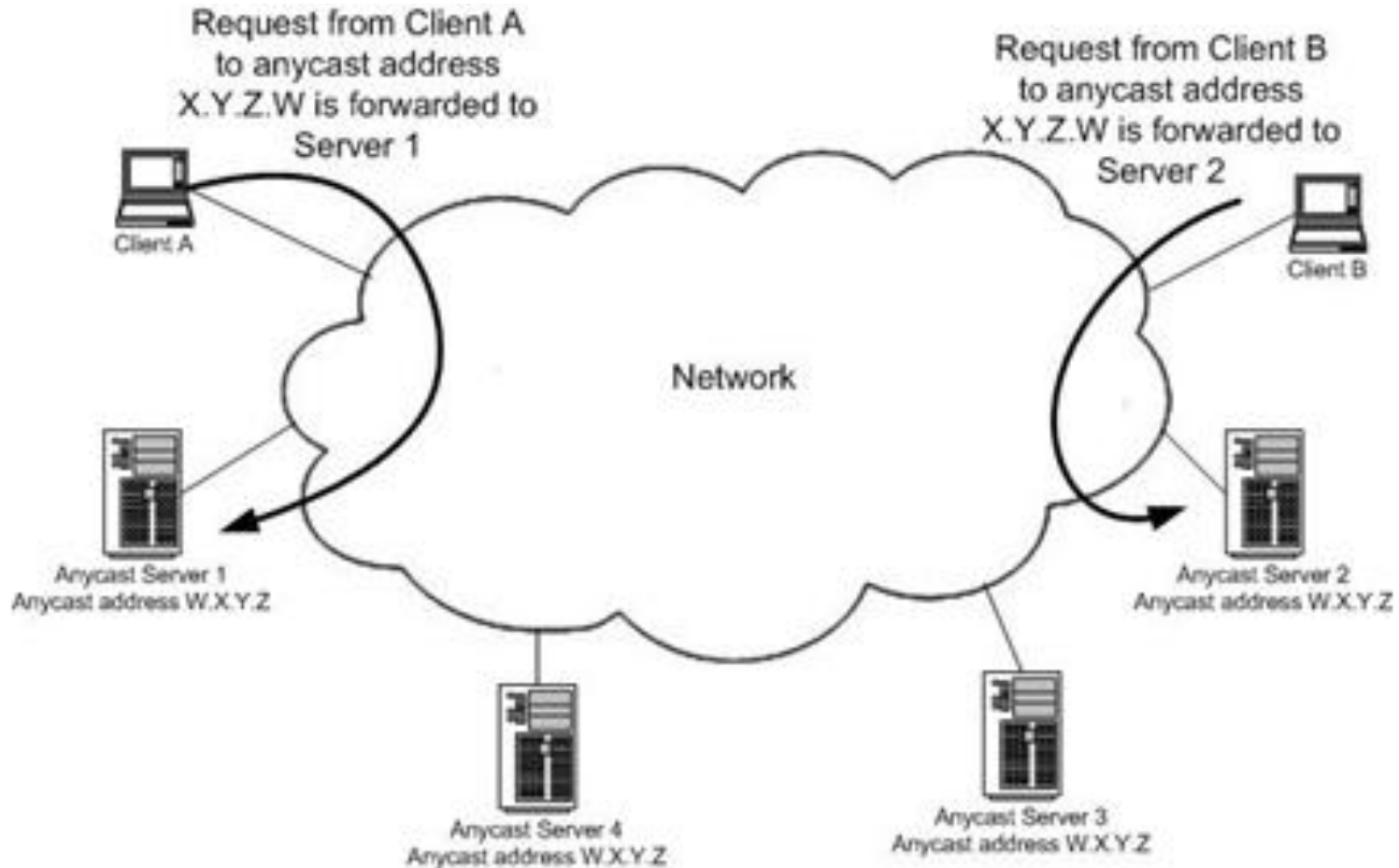- Only public servers like www and mx on external DNS servers

Large Company

Hierarchical Caching Architecture

Anycast