# The Domain Name System

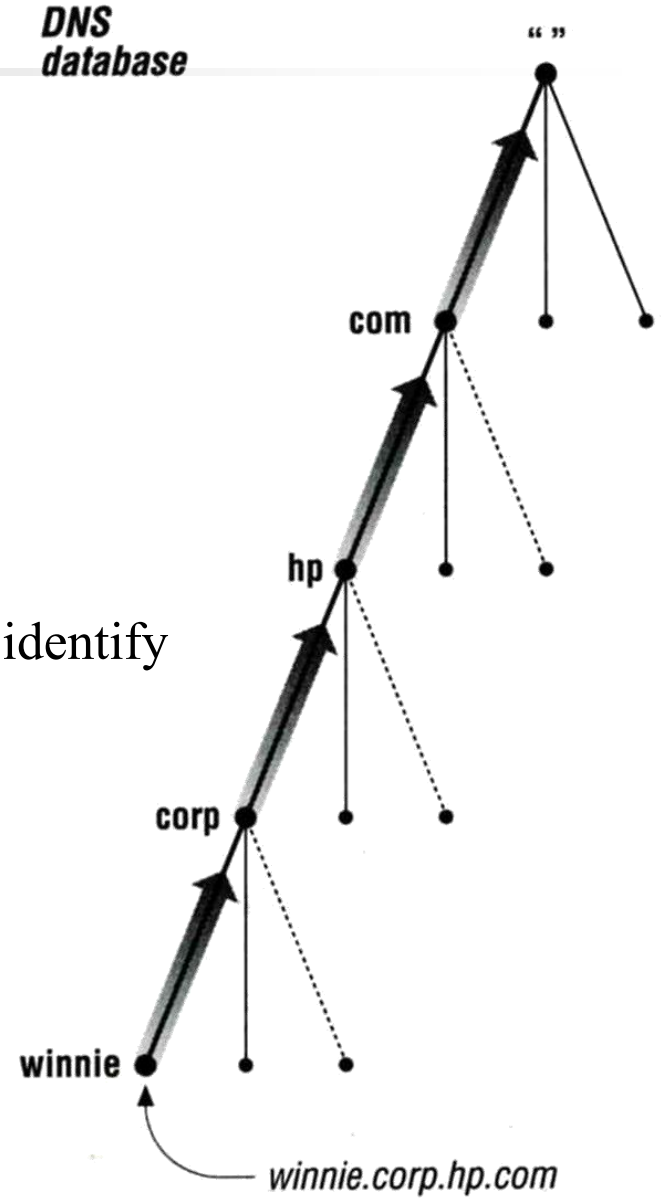
# History of DNS

- What and Why is DNS?
  - IP is not easy to remember
  - Domain Name ↔ IP Address(es)
- Before DNS
  - ARPANET
    - *HOSTS.txt* contains all the hosts' information (/etc/hosts)
    - Maintained by SRI's Network Information Center
      - Register → Distribute DB
  - Problems: Not scalable!
    - Traffic and Load
    - Name Collision
    - Consistency
- Domain Name System
  - Administration decentralization
  - Paul Mockapetris (University of Southern California)
    - RFC 882, 883 (1983) → 1034, 1035 (1984)

# DNS Specification

- Tree architecture – "***domain***" and "***subdomain***"
  - Divide into categories
    - Solve name collision
- Distributed database
  - Each site maintains segment of DB
  - Each site open self information via network
- Client-Server architecture
  - Name servers provide information (Name Server)
  - Clients make queries to server (Resolver)

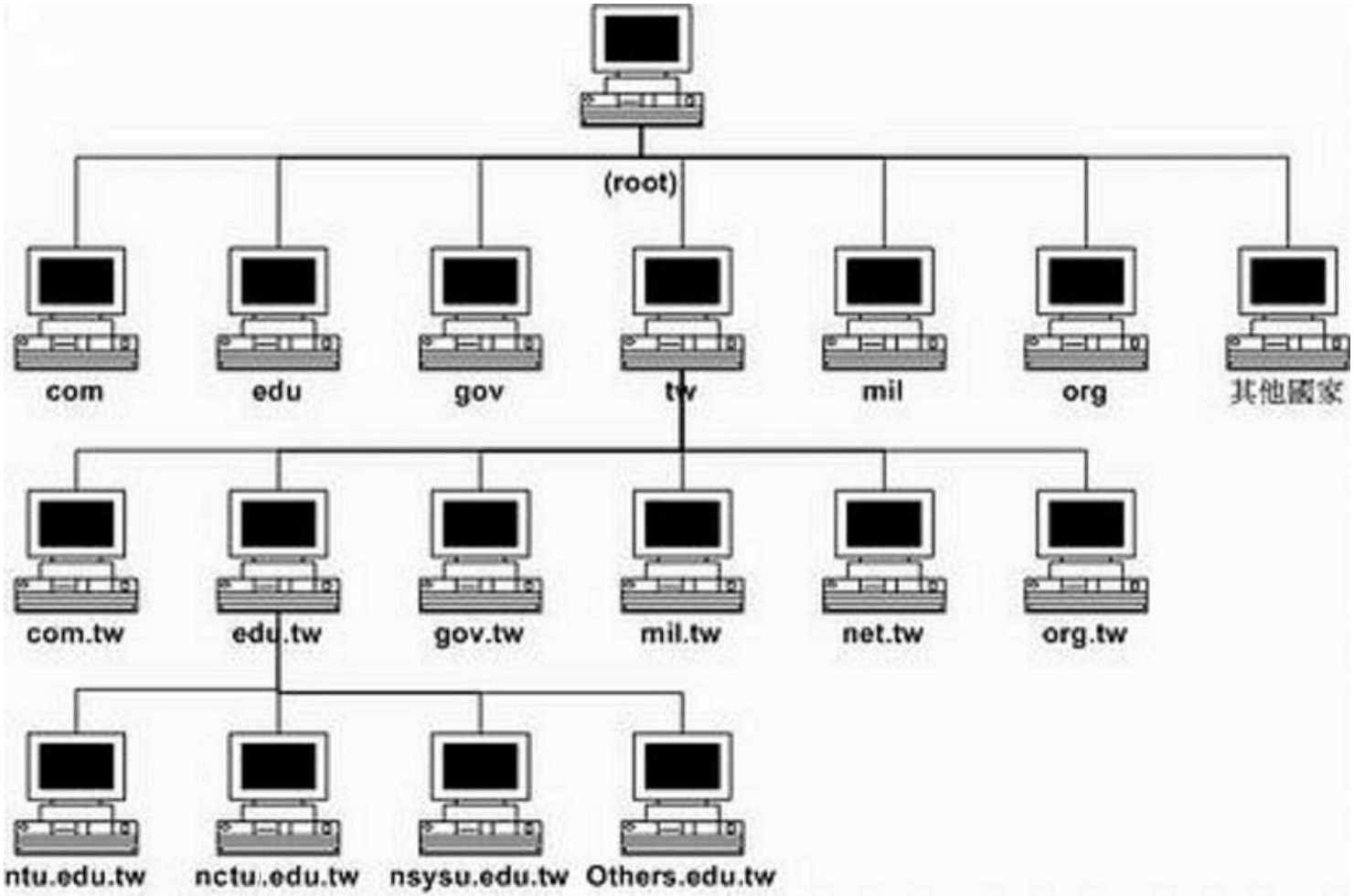
# The DNS Namespace – (1)




- Domain name is
  - A inverted tree (Rooted tree)
    - Root with label "."
    - Root with label "" (Null)

- Domain and subdomain
  - Each domain has a "domain name" to identify its position in database
    - domain: nctu.edu.tw
    - subdomain: cs.nctu.edu.tw

# The DNS Namespace – (2)



# The DNS Namespace – (3)

- Domain level
  - Top-level / First level
    - Child of “root”
    - Maintained by ICANN
  - Second-level
    - Child of a Top-level domain

- Domain name limitation
  - 63-characters in each component
  - Up to 255-characters in a complete name

# The DNS Namespace – (4)

- gTLDs (3 alphabets)
  - generic Top-Level Domains, including:
  - com: commercial organization, such as ibm.com
  - edu: educational organization, such as purdue.edu
  - gov: government organization, such as nasa.gov
  - mil: military organization, such as navy.mil
  - net: network infrastructure providing organization, such as hinet.net
  - org: noncommercial organization, such as x11.org
  - int: International organization, such as nato.int

# The DNS Namespace – (5)

- New gTLDs launched in year 2000:
  - aero: for air-transport industry
  - biz: for business
  - coop: for cooperatives
  - info: for all uses
  - museum: for museum
  - name: for individuals
  - pro: for professionals

  - xxx: for adult entertainment industry (sTLD)
    - On March 31st , 2011

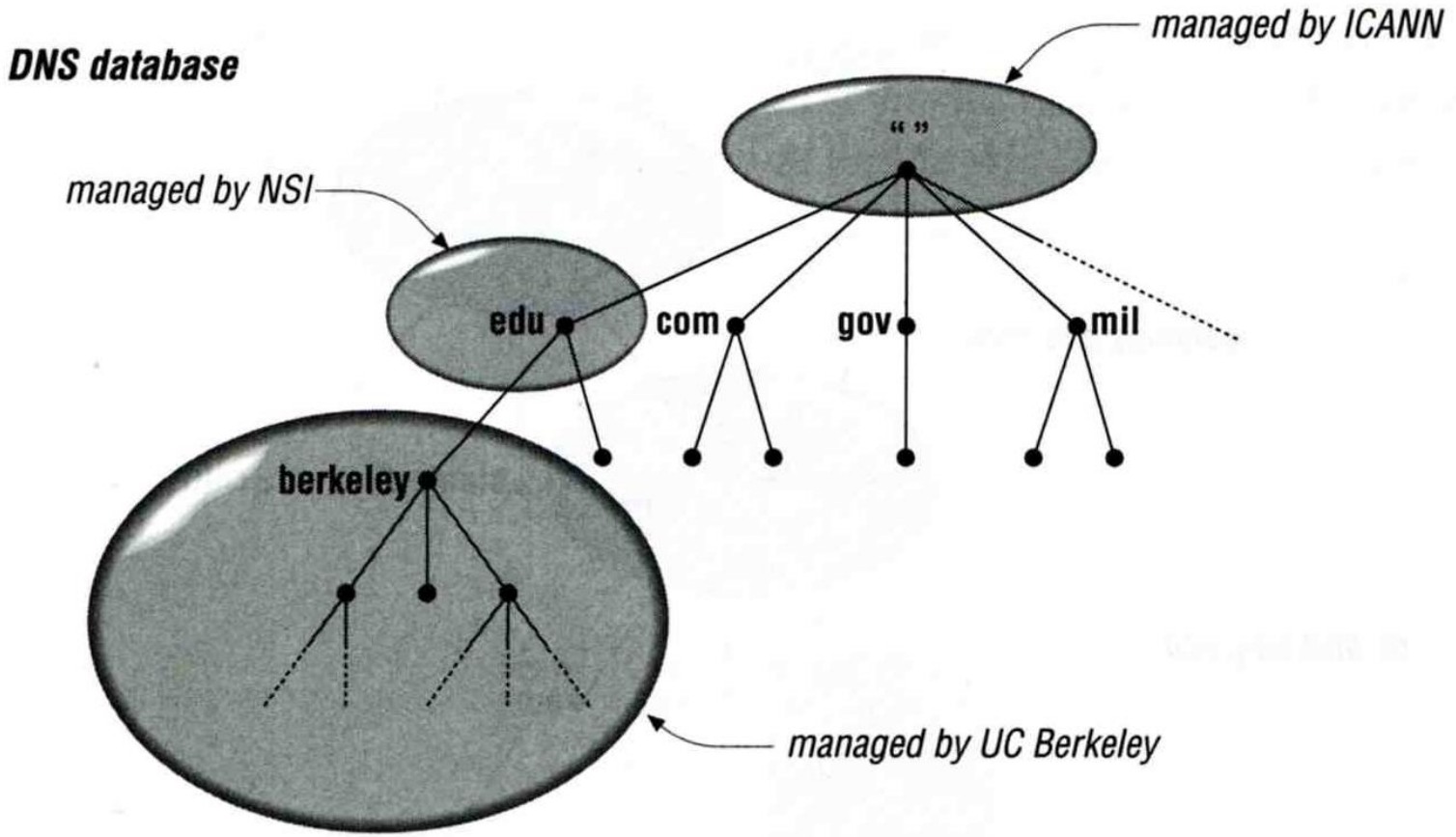
  - https://www.iana.org/domains/root/db

# The DNS Namespace – (6)

- Other than US, ccTLD
  - country code TLD (ISO 3166)
    - Taiwan → tw
    - Japan → jp
    - United States → us
  - Follow or not follow US-like scheme
    - US-like scheme example
      - edu.tw, com.tw, gov.tw
    - Other scheme
      - ac.jp, co.jp

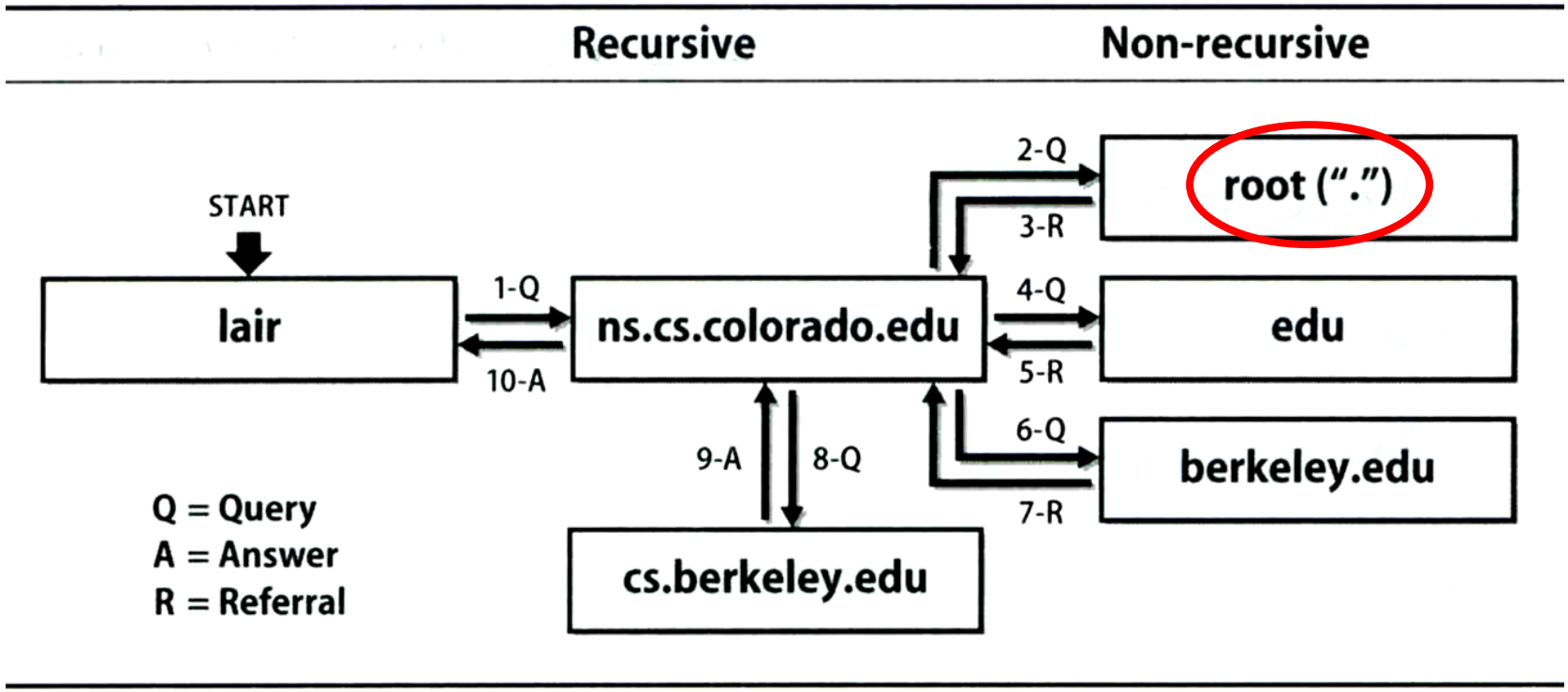
# How DNS Works – DNS Delegation

- Administration delegation
  - Each domain can delegate responsibility to subdomain
    - Specify name servers of subdomain



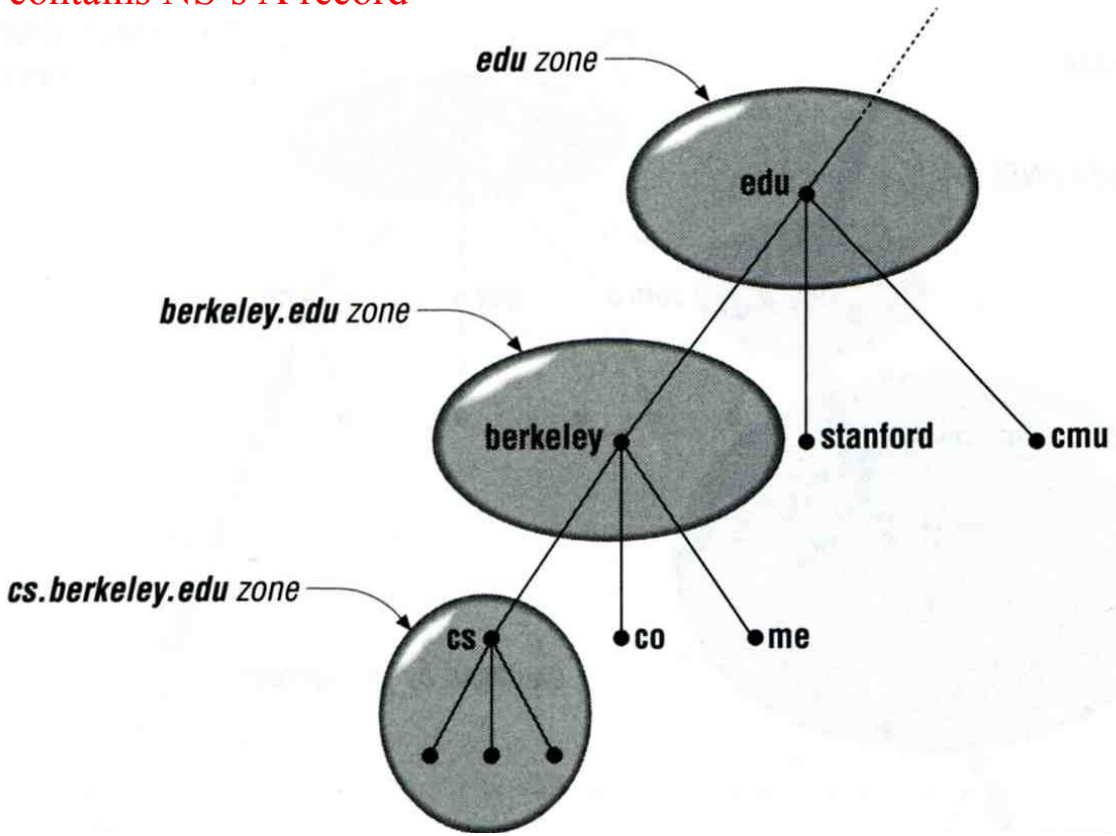
# How DNS Works – DNS query process

- Recursive query process
  - Ex: query lair.cs.colorado.edu → vangogh.cs.berkeley.edu,
    name server "ns.cs.colorado.edu" has no cache data



# DNS Delegation – Administrated Zone

- Zone
  - Autonomously administered piece of namespace
    - Once the subdomain becomes a zone, it is independent to it's parent
      - Even parent contains NS's A record



# DNS Delegation – Administrated Zone

- Two kinds of zone files
  - Forward Zone files
    - Hostname-to-Address mapping
    - Ex:
      - bsd1.cs.nctu.edu.tw. IN A 140.113.235.131
  - Reverse Zone files
    - Address-to-Hostname mapping
    - Ex:
      - 131.235.113.140.in-addr.arpa. IN PTR bsd1.cs.nctu.edu.tw.

# The Name Server Taxonomy (1)

- Categories of name servers
  - Based on the source of name server's data
    - Authoritative: official representative of a zone (master/slave)
      - Master: get zone data from disk
      - Slave: copy zone data from master
    - Nonauthoritative: answer a query from cache
      - caching: caches data from previous queries
  - Based on the type of answers handed out
    - Recursive: do query for you until it return an answer or error
    - Nonrecursive: refer you to the authoritative server
  - Based on the query path
    - Forwarder: performs queries on behalf of many clients with large cache
    - Caching: performs queries as a recursive name server

# The Name Server Taxonomy (2)

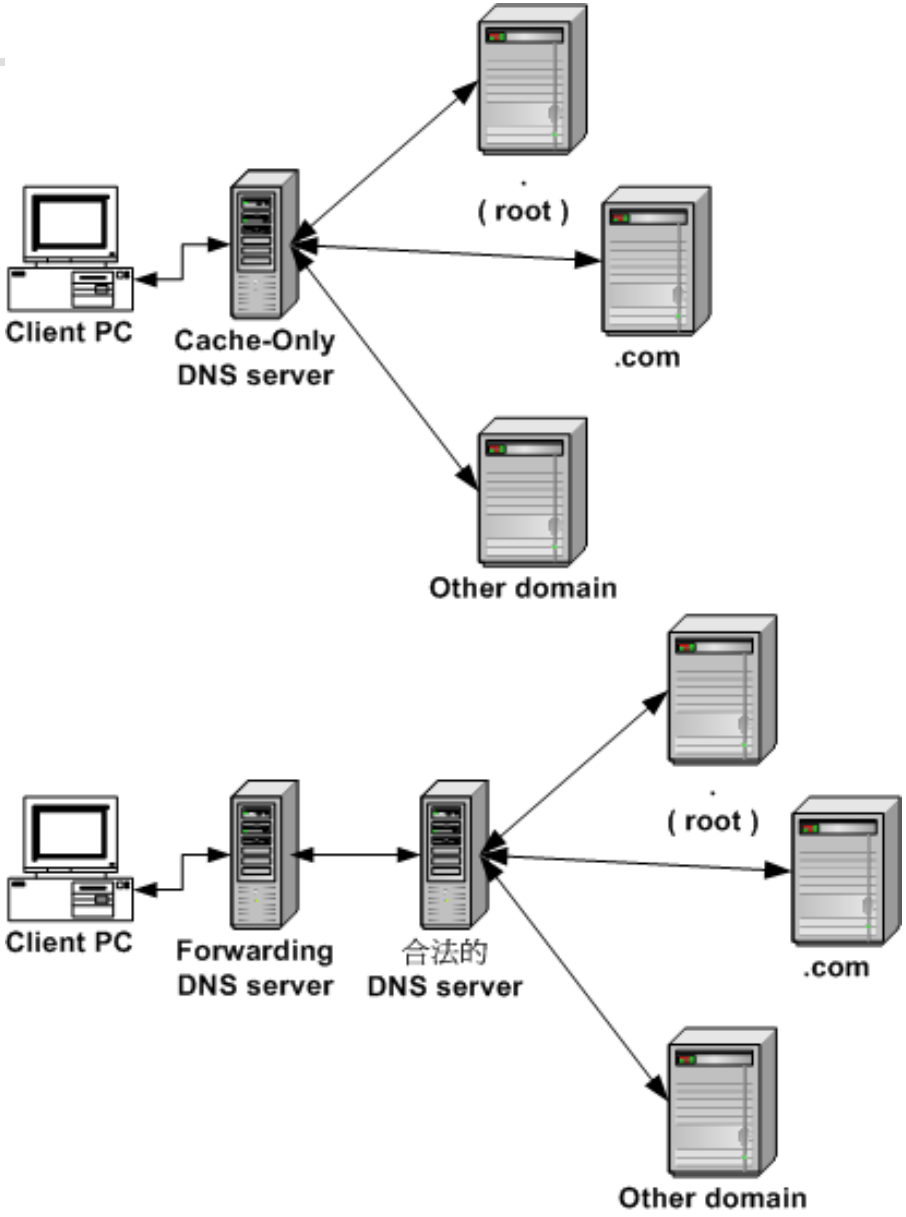
- Nonrecursive referral
  - Hierarchical and longest known domain referral with cache data of other zone's name servers' addresses
  - Ex:
    - Query lair.cs.colorado.edu from a nonrecursive server
    - Whether cache has
      - IP of lair.cs.colorado.edu
      - Name servers of cs.colorado.edu
      - Name servers of colorado.edu
      - Name servers of edu
      - Name servers of root
  - The resolver libraries do not understand referrals mostly. They expect the local name server to be recursive

# The Name Server Taxonomy (3)

- Caching
  - Positive cache (Long TTL)
  - Negative cache (Short TTL)
    - No host or domain matches the name queried
    - The type of data requested does not exist for this host
    - The server to ask is not responding
    - The server is unreachable of network problem
- Negative cache
  - 60% DNS queries are failed
  - To reduce the load of root servers, the authoritative negative answers must be cached

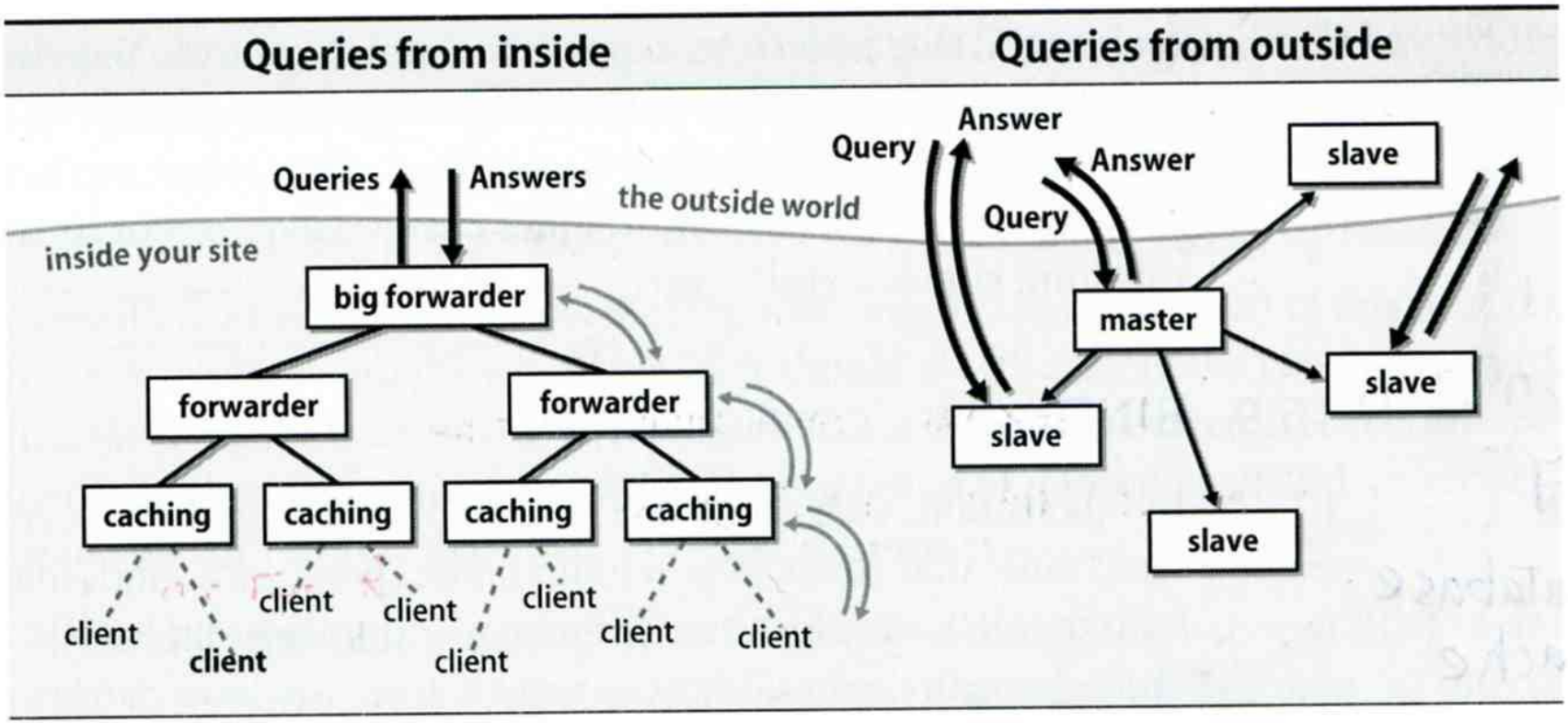
# The Name Server Taxonomy (4)

- Caching and forwarder DNS server



# The Name Server Taxonomy (5)

- How to arrange your DNS servers?
  - Ex:



# The Name Server Taxonomy (6)

- Root name servers
  - In named.root file of BIND

```
.                       3600000  IN  NS    A.ROOT-SERVERS.NET.
A.ROOT-SERVERS.NET.     3600000      A     198.41.0.4
A.ROOT-SERVERS.NET.     3600000      AAAA  2001:503:BA3E::2:30
.                       3600000      NS    B.ROOT-SERVERS.NET.
B.ROOT-SERVERS.NET.     3600000      A     199.9.14.201
B.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:200::b
.                       3600000      NS    C.ROOT-SERVERS.NET.
C.ROOT-SERVERS.NET.     3600000      A     192.33.4.12
C.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:2::c
.                       3600000      NS    D.ROOT-SERVERS.NET.
D.ROOT-SERVERS.NET.     3600000      A     199.7.91.13
D.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:2d::d
.                       3600000      NS    E.ROOT-SERVERS.NET.
E.ROOT-SERVERS.NET.     3600000      A     192.203.230.10
E.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:a8::e
.                       3600000      NS    F.ROOT-SERVERS.NET.
F.ROOT-SERVERS.NET.     3600000      A     192.5.5.241
F.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:2F::F
.                       3600000      NS    G.ROOT-SERVERS.NET.
G.ROOT-SERVERS.NET.     3600000      A     192.112.36.4
G.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:12::d0d
.                       3600000      NS    H.ROOT-SERVERS.NET.
H.ROOT-SERVERS.NET.     3600000      A     198.97.190.53
H.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:1::53
.                       3600000      NS    I.ROOT-SERVERS.NET.
I.ROOT-SERVERS.NET.     3600000      A     192.36.148.17
I.ROOT-SERVERS.NET.     3600000      AAAA  2001:7FE::53
.                       3600000      NS    J.ROOT-SERVERS.NET.
J.ROOT-SERVERS.NET.     3600000      A     192.58.128.30
J.ROOT-SERVERS.NET.     3600000      AAAA  2001:503:C27::2:30
.                       3600000      NS    K.ROOT-SERVERS.NET.
K.ROOT-SERVERS.NET.     3600000      A     193.0.14.129
K.ROOT-SERVERS.NET.     3600000      AAAA  2001:7FD::1
.                       3600000      NS    L.ROOT-SERVERS.NET.
L.ROOT-SERVERS.NET.     3600000      A     199.7.83.42
L.ROOT-SERVERS.NET.     3600000      AAAA  2001:500:3::42
.                       3600000      NS    M.ROOT-SERVERS.NET.
M.ROOT-SERVERS.NET.     3600000      A     202.12.27.33
M.ROOT-SERVERS.NET.     3600000      AAAA  2001:DC3::35
```



https://www.iana.org/domains/root/files

# DNS Client Configurations

- /etc/resolv.conf
  - nameserver: max 3 default name servers
  - domain
  - search
- /etc/hosts
  - IP FQDN Aliases
  - C:\Windows\system32\drivers\etc\hosts
- /etc/nsswitch.conf
  - hosts: files (nis) (ldap) dns

# DNS Client Commands – host

- $ host nasa.cs.nctu.edu.tw
  - nasa.cs.nctu.edu.tw has address 140.113.17.225
- $ host 140.113.17.225
  - 225.17.113.140.in-addr.arpa domain name pointer nasa.cs.nctu.edu.tw.

# DNS Client Commands – nslookup

- $ nslookup nasa.cs.nctu.edu.tw
  - Server: 140.113.235.1
    Address: 140.113.235.1#53

    Name: nasa.cs.nctu.edu.tw
    Address: 140.113.17.225
- $ nslookup 140.113.17.225
  - Server: 140.113.235.1
    Address: 140.113.235.1#53

    225.17.113.140.in-addr.arpa name = nasa.cs.nctu.edu.tw.

# DNS Client Commands – dig (1)

- $ dig nasa.cs.nctu.edu.tw
  - ;; Got answer:
    ;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 47883
    ;; flags: qr aa rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 3, ADDITIONAL: 3

    ;; QUESTION SECTION:
    ;nasa.cs.nctu.edu.tw. IN A

    ;; ANSWER SECTION:
    nasa.cs.nctu.edu.tw. 3600 IN A 140.113.17.225

    ……

# DNS Client Commands – dig (2)

- $ dig -x 140.113.17.225
  - ;; Got answer:
    ;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 5514
    ;; flags: qr aa rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 3, ADDITIONAL: 3

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

    ;; ANSWER SECTION:
    225.17.113.140.in-addr.arpa. 86400 IN PTR nasa.cs.nctu.edu.tw.

    ……

# DNS Security

## DNSSEC

- Provide
  - Origin authentication of DNS data
  - Data integrity
  - Authenticated denial of existence
- Not provide
  - Confidentiality
  - Availability

- $ dig +dnssec bsd1.cs.nctu.edu.tw
  - ;; ANSWER SECTION:

```
bsd1.cs.nctu.edu.tw.   3600   IN   A       140.113.235.131
bsd1.cs.nctu.edu.tw.   3600   IN   RRSIG   A 7 5 3600 …
```

RRSIG: Resource Record Signature