Structured Naming

Internet Naming Service: DNS*

*referred to slides by David Conrad at nominum.com

Overview

- Introduction to the DNS
- DNS Components
- DNS Structure and Hierarchy
- The DNS in Context

DNS History (1)

- ARPANET utilized a central file HOSTS.TXT
  - Contains names to addresses mapping
  - Maintained by SRI’s NIC (*Stanford-Research-Institute: Network-Information-Center)*
- Administrators email changes to NIC
  - NIC updates HOSTS.TXT periodically
- Administrators FTP (download) HOSTS.TXT

DNS History (2)

- As the system grew, HOSTS.TXT had problems with:
  - Scalability (traffic and load)
  - Name collisions
  - Consistency

- In 1984, Paul Mockapetris released the first version (RFCs 882 and 883, superseded by 1034 and 1035 …)

The DNS is…

- The “Domain Name System”
- What Internet users use to reference anything by name on the Internet
- The mechanism by which Internet software translates names to attributes such as addresses

The DNS is also…

- A globally distributed, scalable, reliable database
- Comprised of three components
  - A “name space”
  - Servers making that name space available
  - Resolvers (clients) which query the servers about the name space

DNS as a Lookup Mechanism

- Users generally prefer names to numbers
- Computers prefer numbers to names
- DNS provides the mapping between the two
  - I have “x”, give me “y”

DNS as a Database

- Keys to the database are “domain names”
  - www.foo.com, 18.in-addr.arpa, 6.4.e164.arpa
- Over 200,000,000 domain names stored
- Each domain name contains one or more attributes
  - Known as “resource records”
- Each attribute individually retrievable

Global Distribution

- Data is maintained locally, but retrievable globally
  - No single computer has all DNS data
- DNS lookups can be performed by any device
- Remote DNS data is locally cachable to improve performance

Loose Coherency

- Each version of a subset of the database (a zone) has a serial number
  - The serial number is incremented on each database change
- Changes to the master copy of the database are propagated to replicas according to timing set by the zone administrator
- Cached data expires according to timeout set by zone administrator

Scalability

- No limit to the size of the database
- No limit to the number of queries
  - Tens of thousands of queries handled easily every second
- Queries distributed among masters, slaves, and caches

Reliability

- Data is replicated
  - Data from master is copied to multiple slaves
- Clients can query
  - Master server
  - Any of the copies at slave servers
- Clients will typically query local caches
- DNS protocols can use either UDP or TCP
  - If UDP, DNS protocol handles retransmission, sequencing, etc.

Dynamicity

- Database can be updated dynamically
  - Add/delete/modify of any record
  - Only master can be dynamically updated
- Modification of the master database triggers replication

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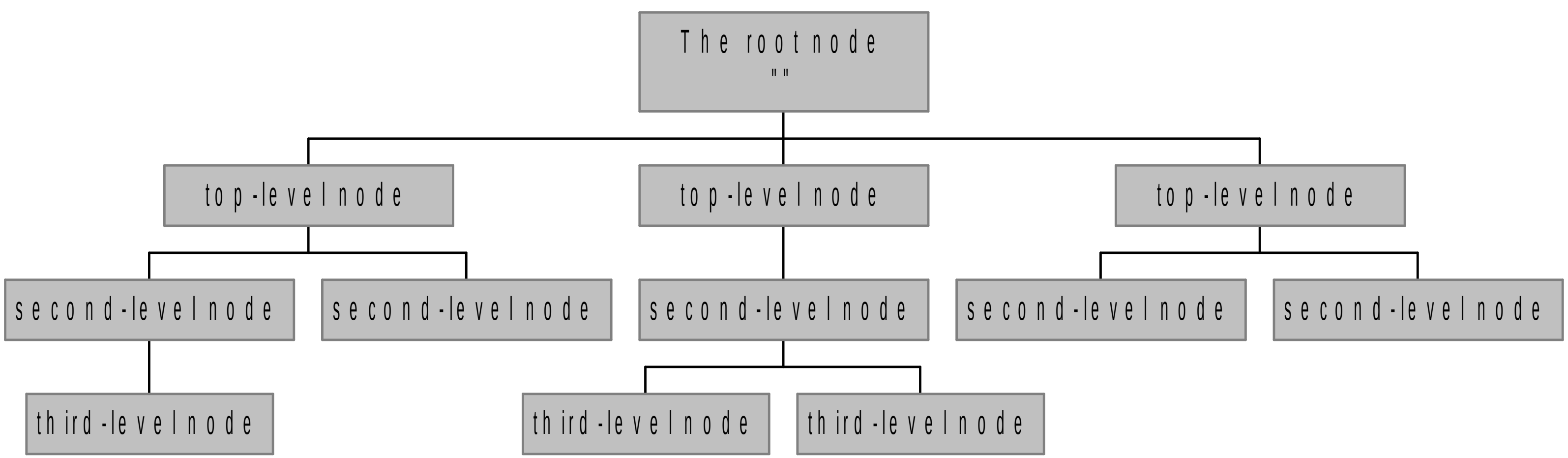
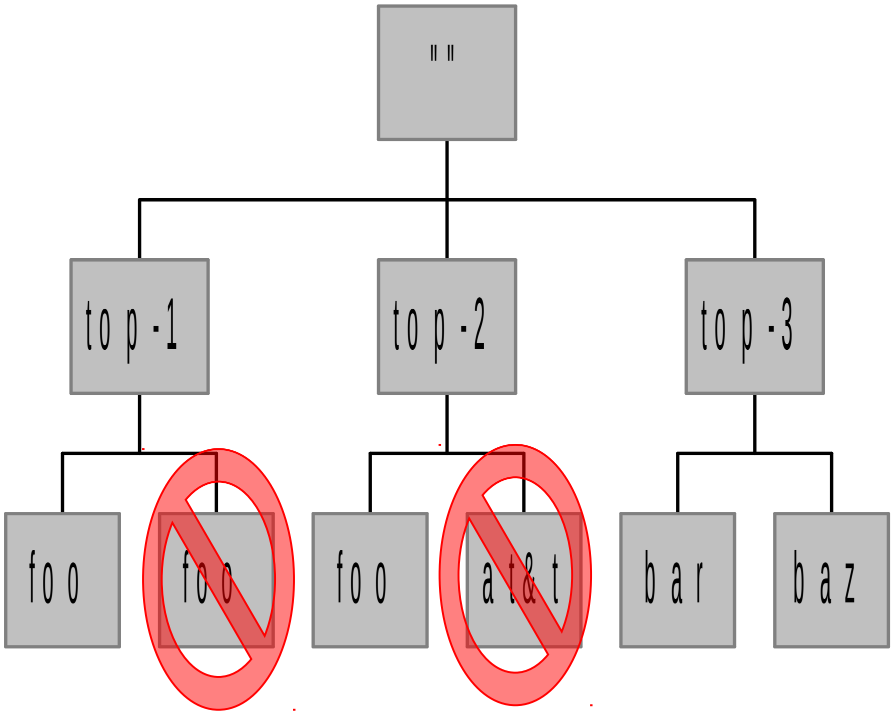
The Name Space

- The *name space* is the structure of the DNS database
  - An inverted tree with the root node at the top
- Each node has a label
  - The root node has a null label, written as “”



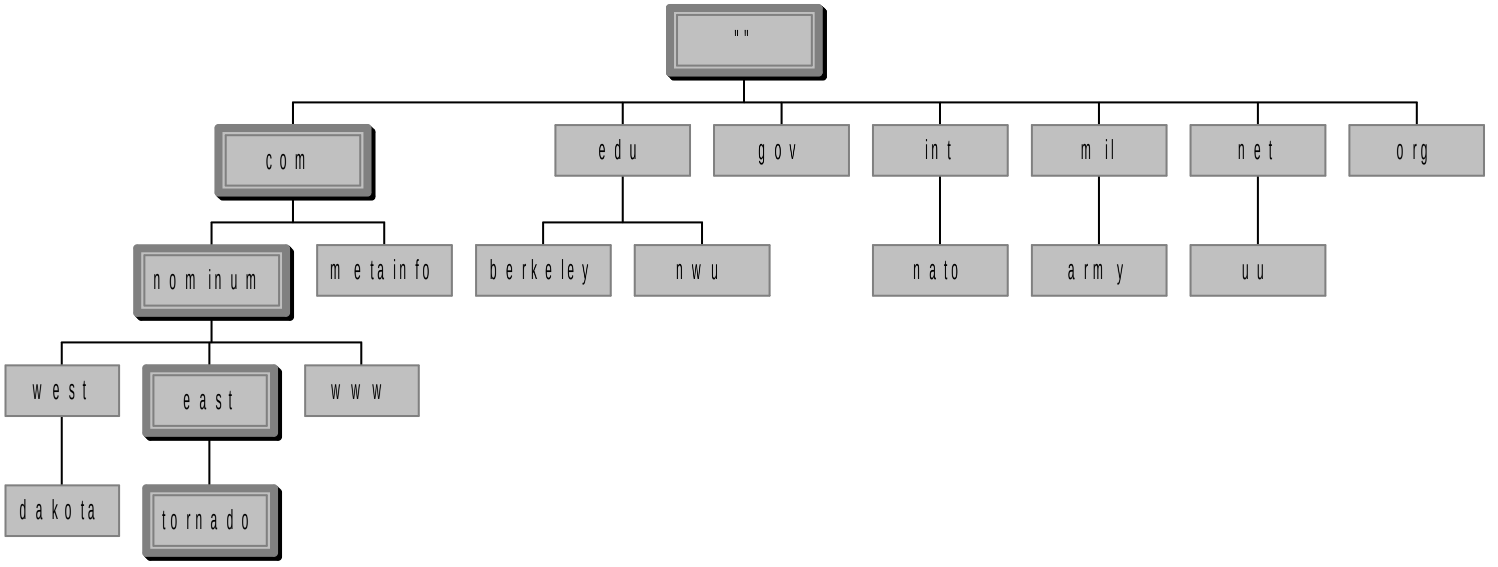
Labels

- Each node in the tree must have a label
  - A string of up to 63 bytes
  - RFCs 852 and 1123 define legal characters for “hostnames”
    - A-Z, 0-9, and “-” only with a-z and A-Z treated as the same
- Sibling nodes must have unique labels
- The null label is reserved for the root node



Domain Names

- A *domain name* is the sequence of labels from a node to the root, separated by dots (“.”s), read left to right
  - The name space has a maximum depth of 127 levels
  - Domain names are limited to 255 characters in length
- A node’s domain name identifies its position in the name space



Subdomains

- One domain is a subdomain of another if its domain name ends in the other's domain name
  - So *sales.nominum.com* is a subdomain of
    - *nominum.com & com*
  - *nominum.com* is a subdomain of *com*

Delegation

- Administrators can create subdomains to group hosts
  - According to geography, organizational affiliation etc.

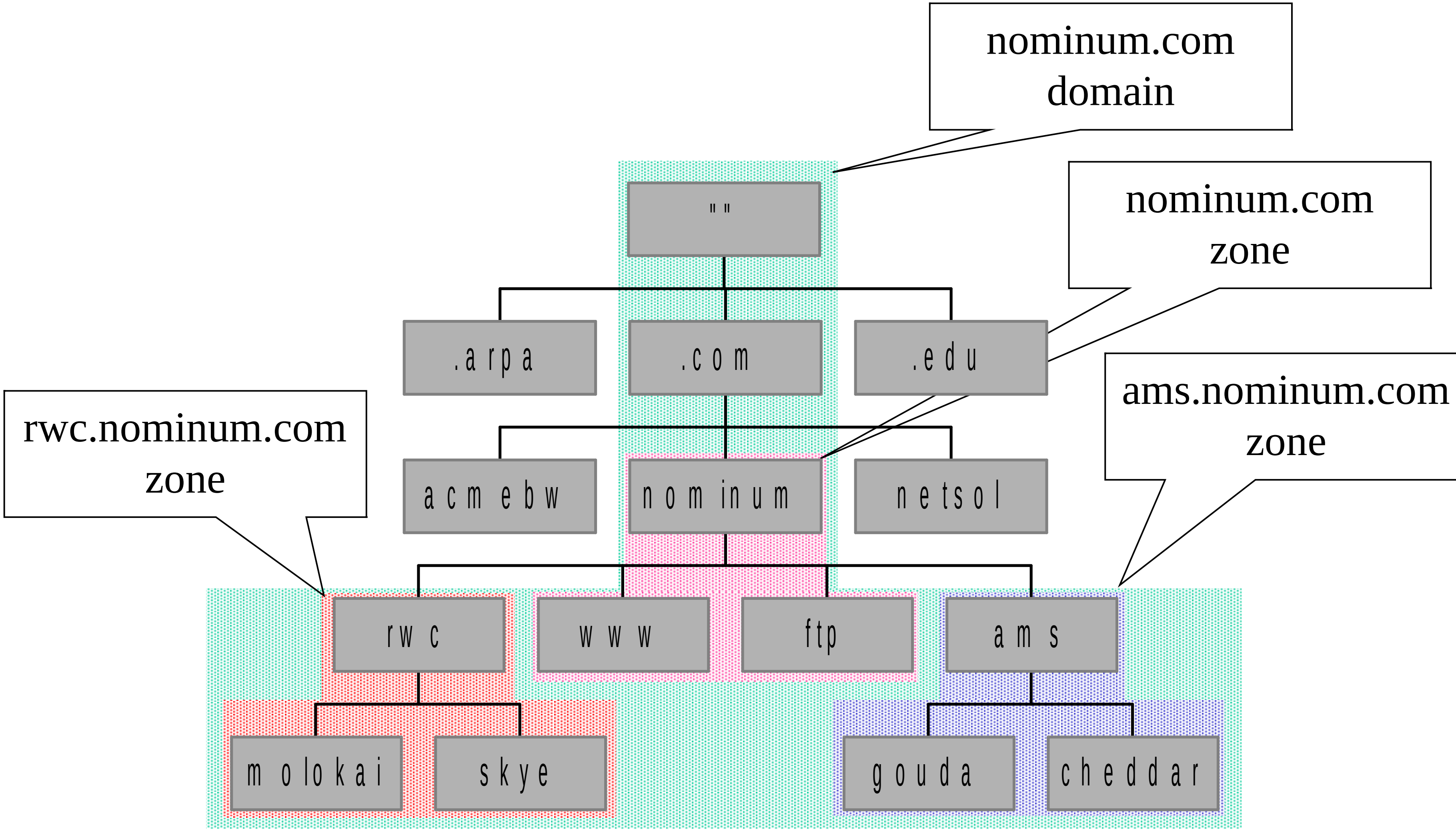
- An administrator of a domain can delegate responsibility for managing a subdomain to someone else

- The parent domain retains links to the delegated subdomains

Delegation Creates Zones

- Each time an administrator delegates a subdomain, a new unit of administration is created
  - The subdomain and its parent domain can now be administered independently
  - These units are called *zones*
  - The boundary between zones is a point of delegation in the name space
- Delegation is good: it is the key to scalability

Dividing a Domain into Zones



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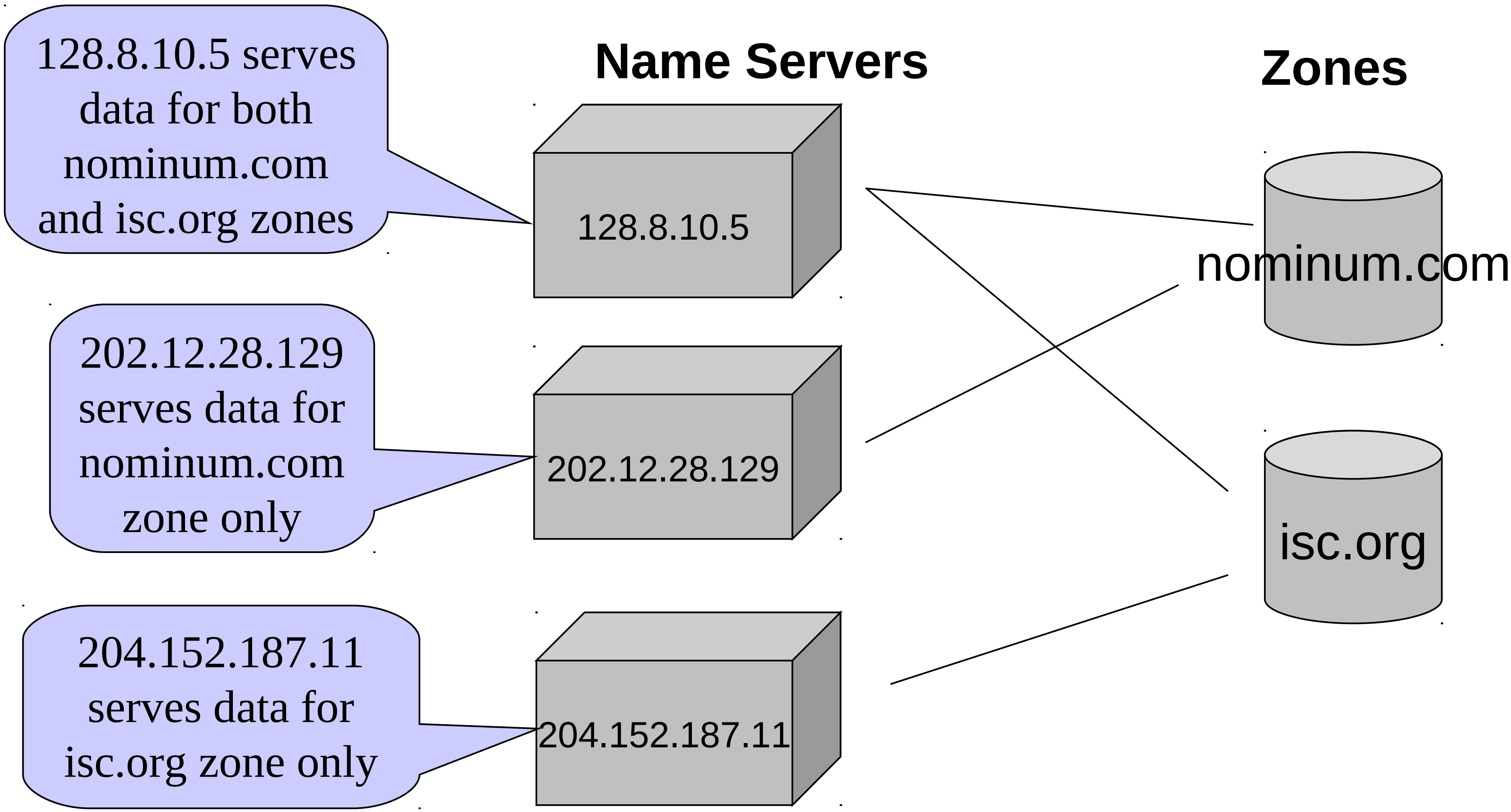
Name Servers

- Name servers store information about the name space in units called “zones”
  - The name servers that load a complete zone are said to “have authority for” or “be authoritative for” the zone
- Usually, more than one name server are authoritative for the same zone
  - This ensures redundancy and spreads the load
- Also, a single name server may be authoritative for many zones

Name Servers and Zones



Types of Name Servers

- Two main types of servers
  - Authoritative – maintains the data
    - Master – where the data is edited
    - Slave – where data is replicated to
  - Caching – stores data obtained from an authoritative server
- No special hardware necessary

Name Server Architecture

- You can think of a name server as part of:
  - *database server*, answering queries about the parts of the name space it knows about (i.e., is authoritative for),
  - *cache*, temporarily storing data it learns from other name servers, and
  - *agent*, helping resolvers and other name servers find data

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Name Resolution

- *Name resolution* is the process by which resolvers and name servers cooperate to find data in the name space
- Closure mechanism for DNS?
  - Starting point: the names and IP addresses of the name servers for the root zone (the “root name servers”)
  - The root name servers know about the top-level zones and can tell name servers whom to contact for all TLDs

Name Resolution

- A DNS query has three parameters:
  - A domain name (e.g., *www.nominum.com*),
    - Remember, every node has a domain name!
  - A class (e.g., *IN*), and
  - A type (e.g., *A*)
  - http://network-tools.com/nslook/
- Upon receiving a query from a resolver, a name server
  - 1) looks for the answer in its authoritative data and its cache
  - 2) If step 1 fails, the answer must be looked up

The Resolution Process

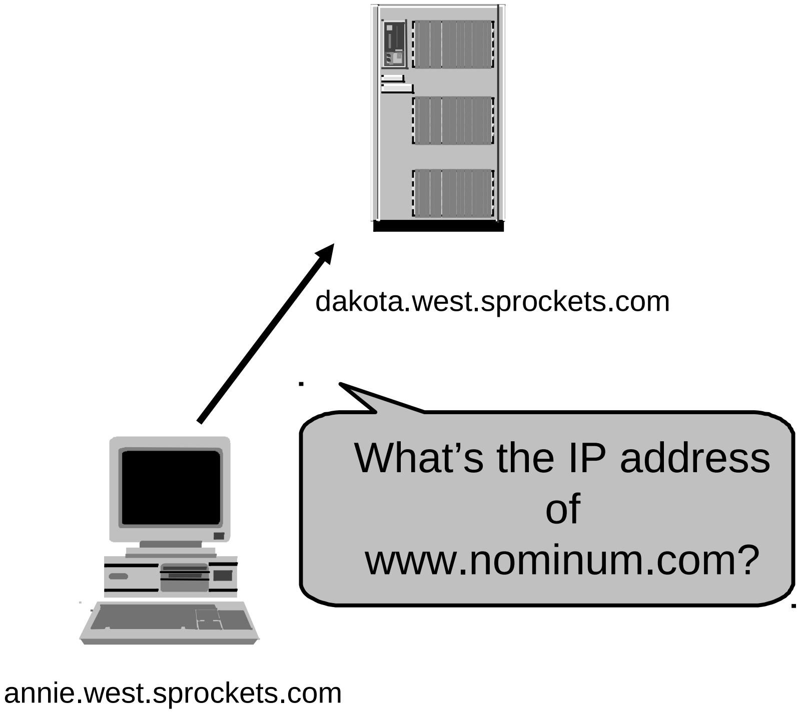
- Let’s look at the resolution process step-by-step:

annie.west.sprockets.com

```
ping www.nominum.com.
```

The Resolution Process

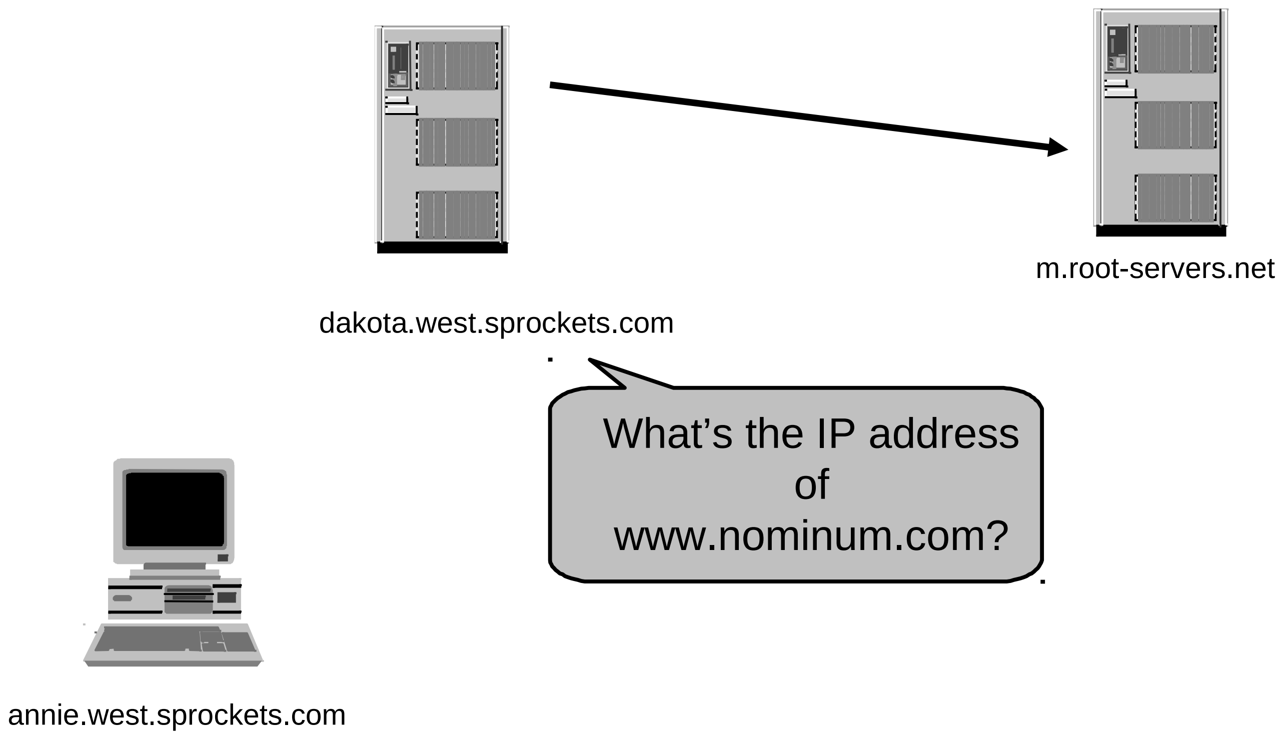
- The workstation *annie* asks its configured name server, *dakota*, for *www.nominum.com's* address




```
ping www.nominum.com.
```

The Resolution Process

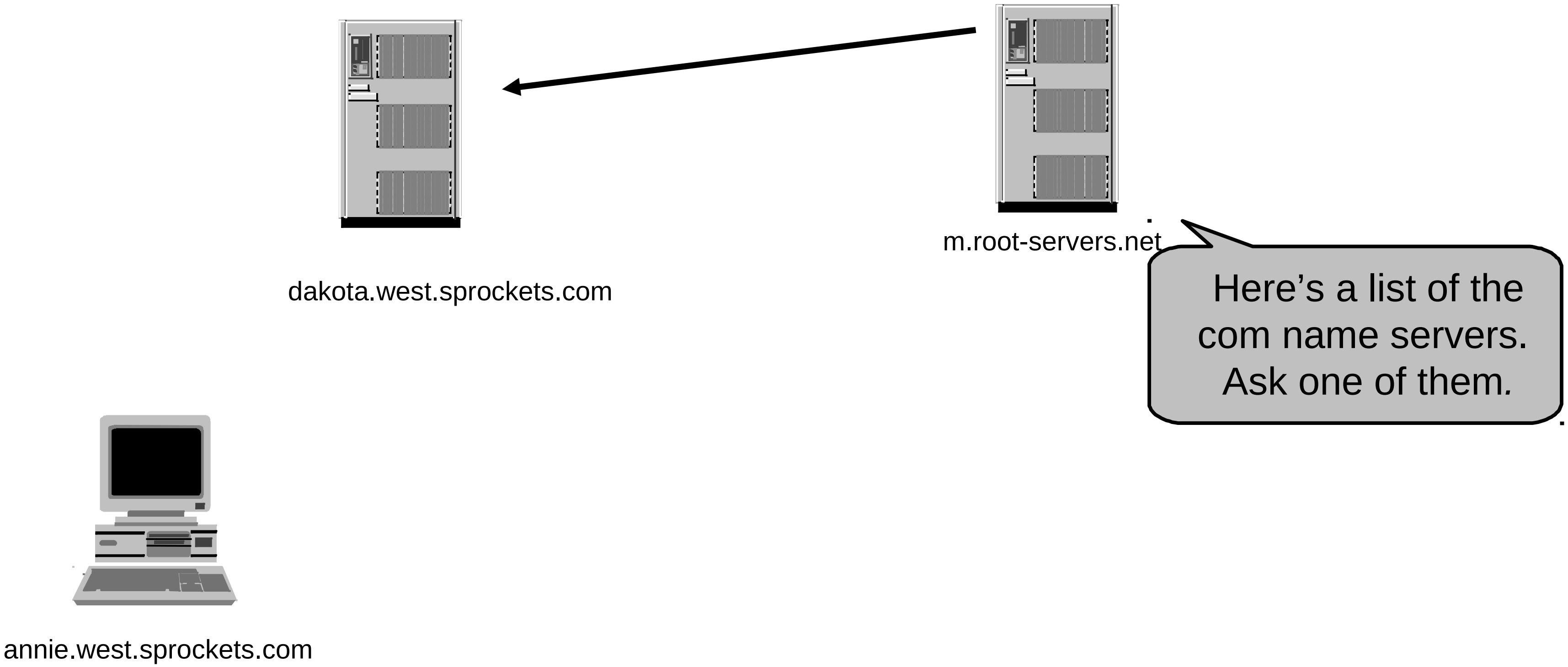
- The name server *dakota* asks a root name server, *m*, for *www.nominum.com's* address




```
ping www.nominum.com.
```

The Resolution Process

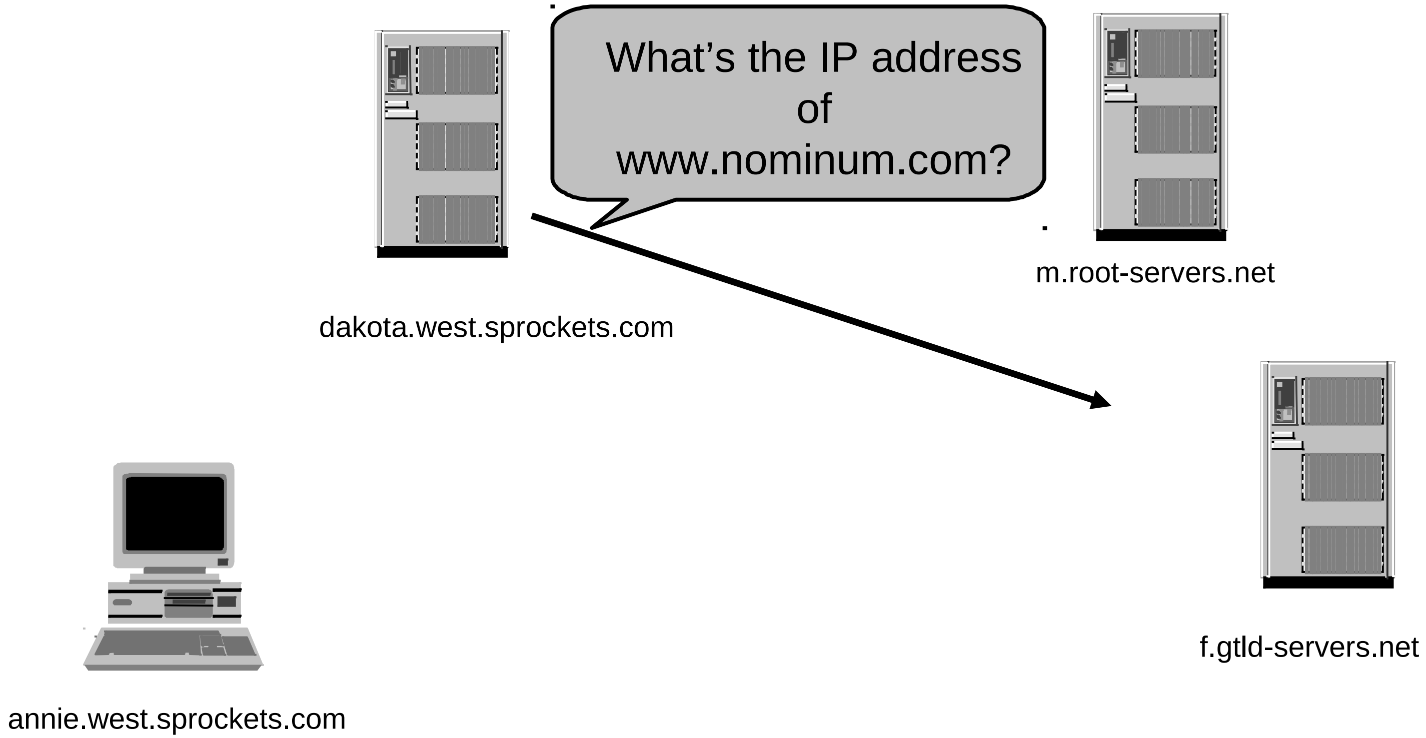
- The root server *m* refers *dakota* to the *com* name servers
- This type of response is called a "referral"



`ping www.nominum.com.`

The Resolution Process

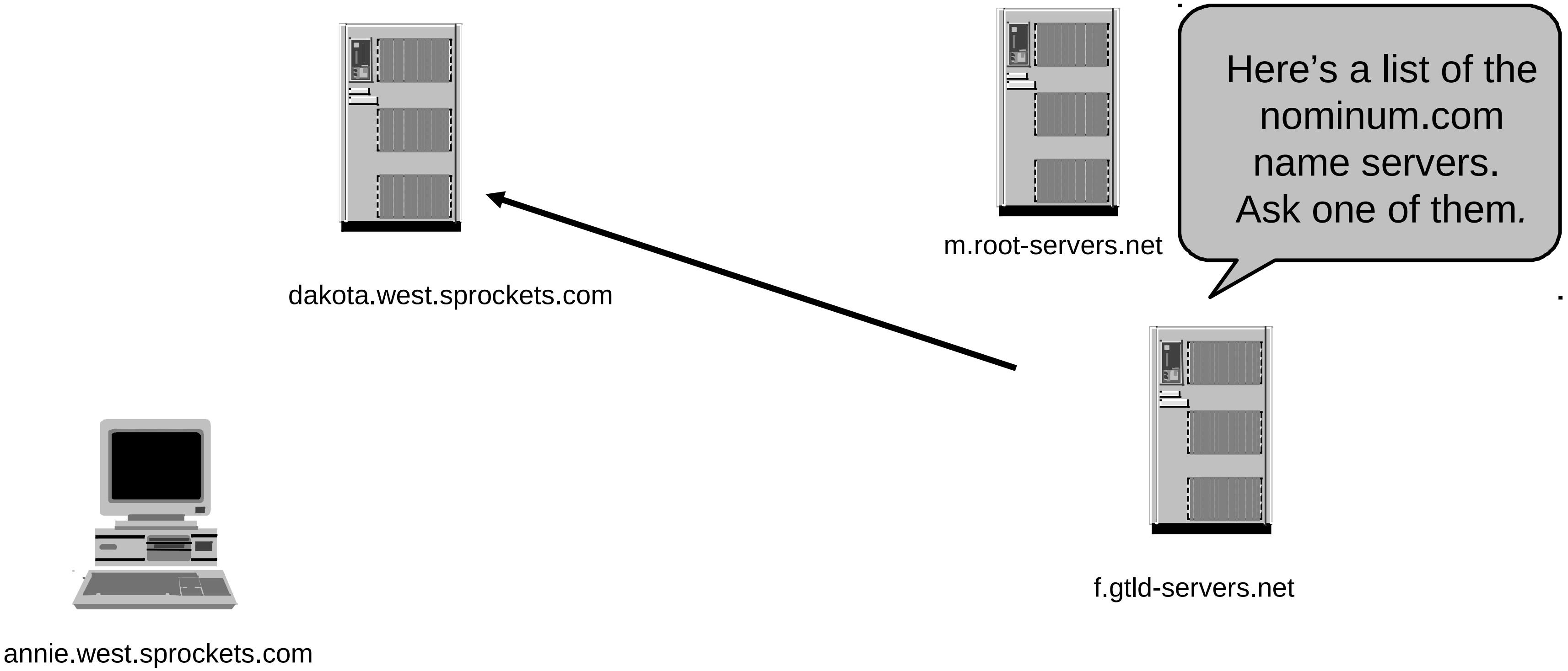
- The name server *dakota* asks a *com* name server, *f*, for *www.nominum.com's* address



`ping www.nominum.com.`

The Resolution Process

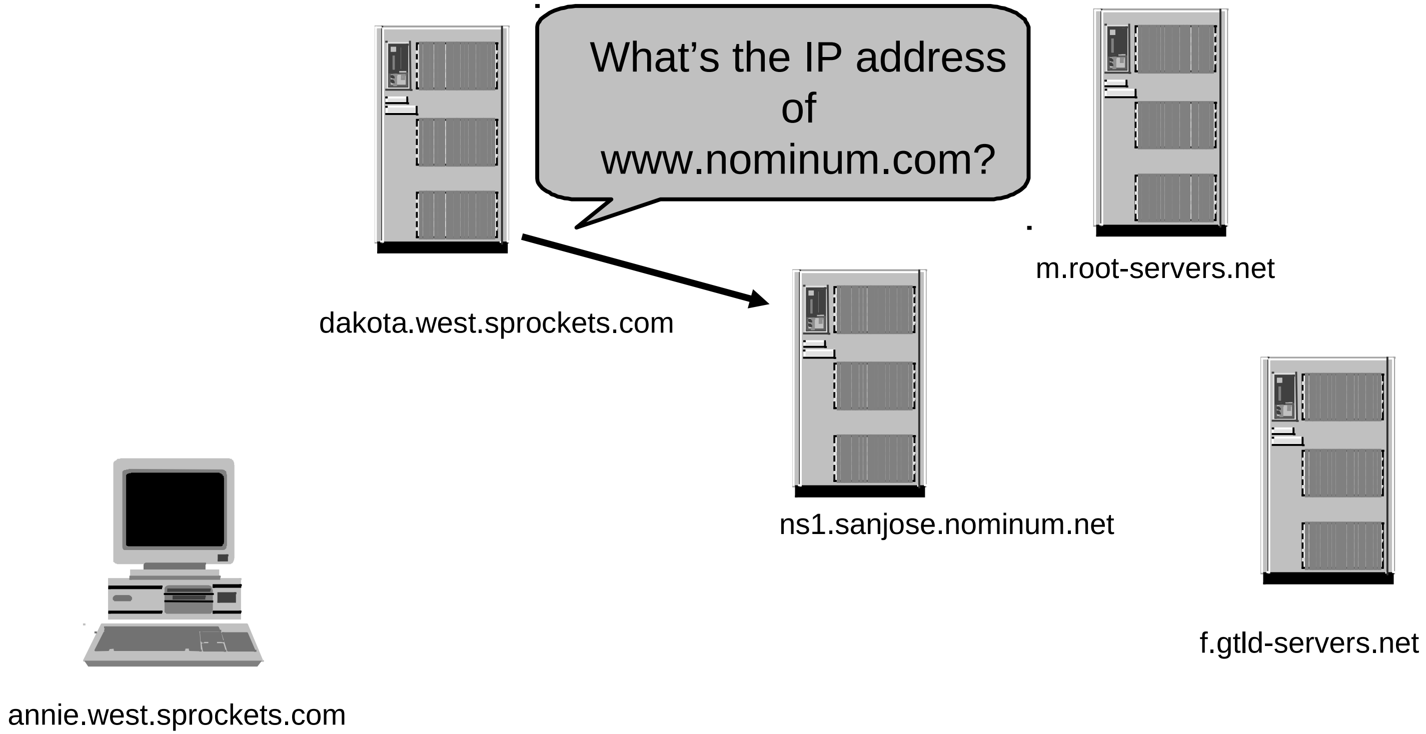
- The *com* name server *f* refers *dakota* to the *nominum.com* name servers




```
ping www.nominum.com.
```

The Resolution Process

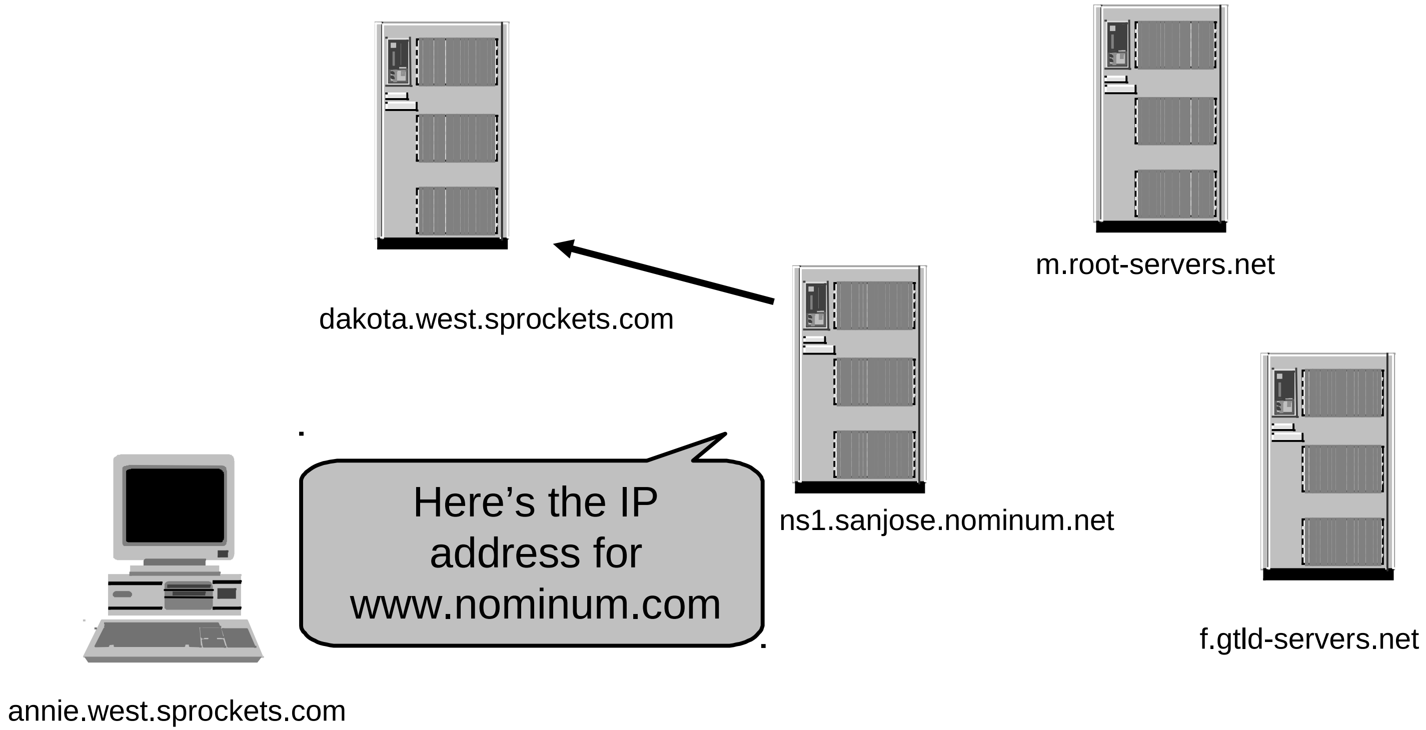
- The name server *dakota* asks a *nominum.com* name server, *ns1.sanjose*, for *www.nominum.com’s* address



`ping www.nominum.com.`

The Resolution Process

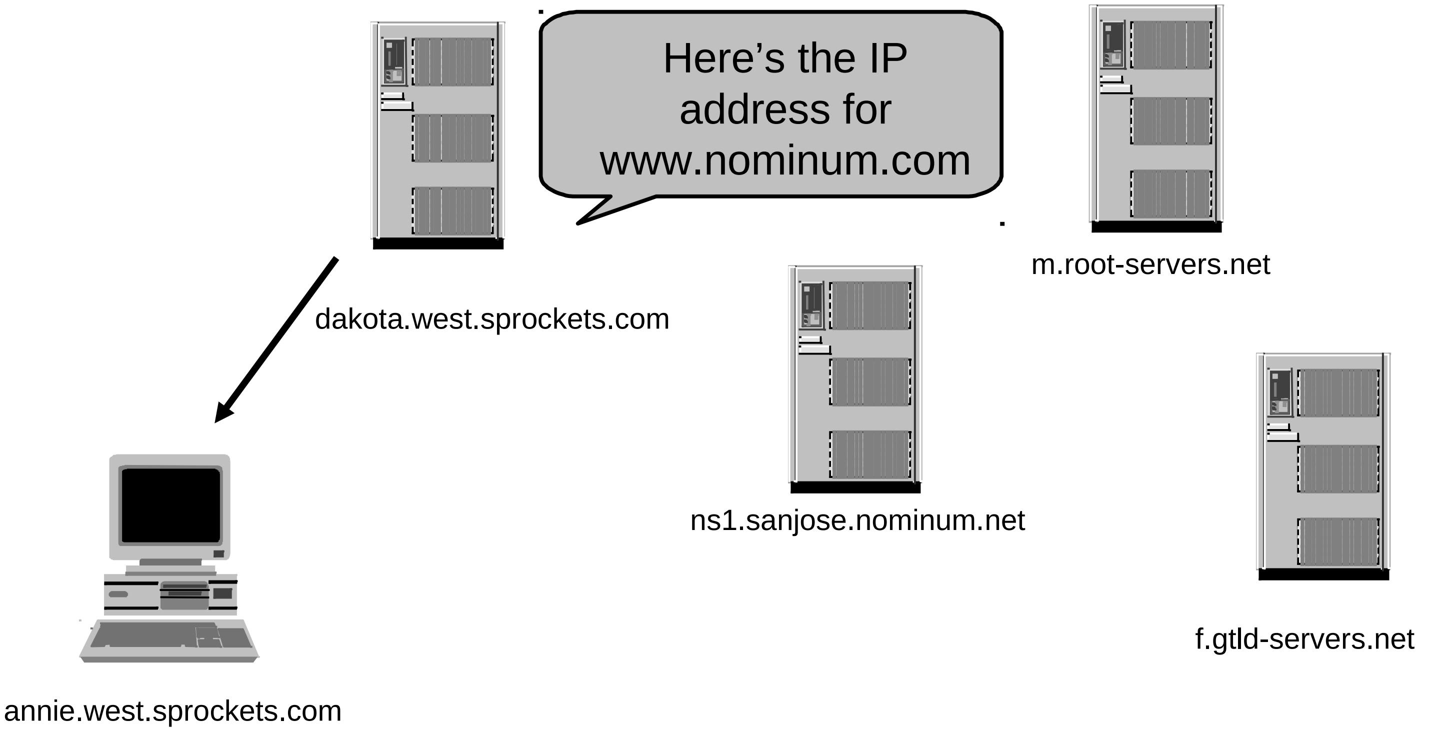
- The *nominum.com* name server *ns1.sanjose* responds with *www.nominum.com's* address




```
ping www.nominum.com.
```

The Resolution Process

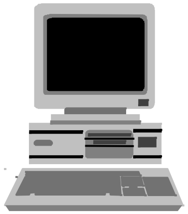
- The name server *dakota* responds to *annie* with *www.nominum.com's* address



`ping www.nominum.com.`

Resolution Process (Caching)

- After the previous query, the name server *dakota* now knows:
  - The names and IP addresses of the *com* name servers
  - The names and IP addresses of the *nominum.com* name servers
  - The IP address of *www.nominum.com*
- Let's look at the resolution process again

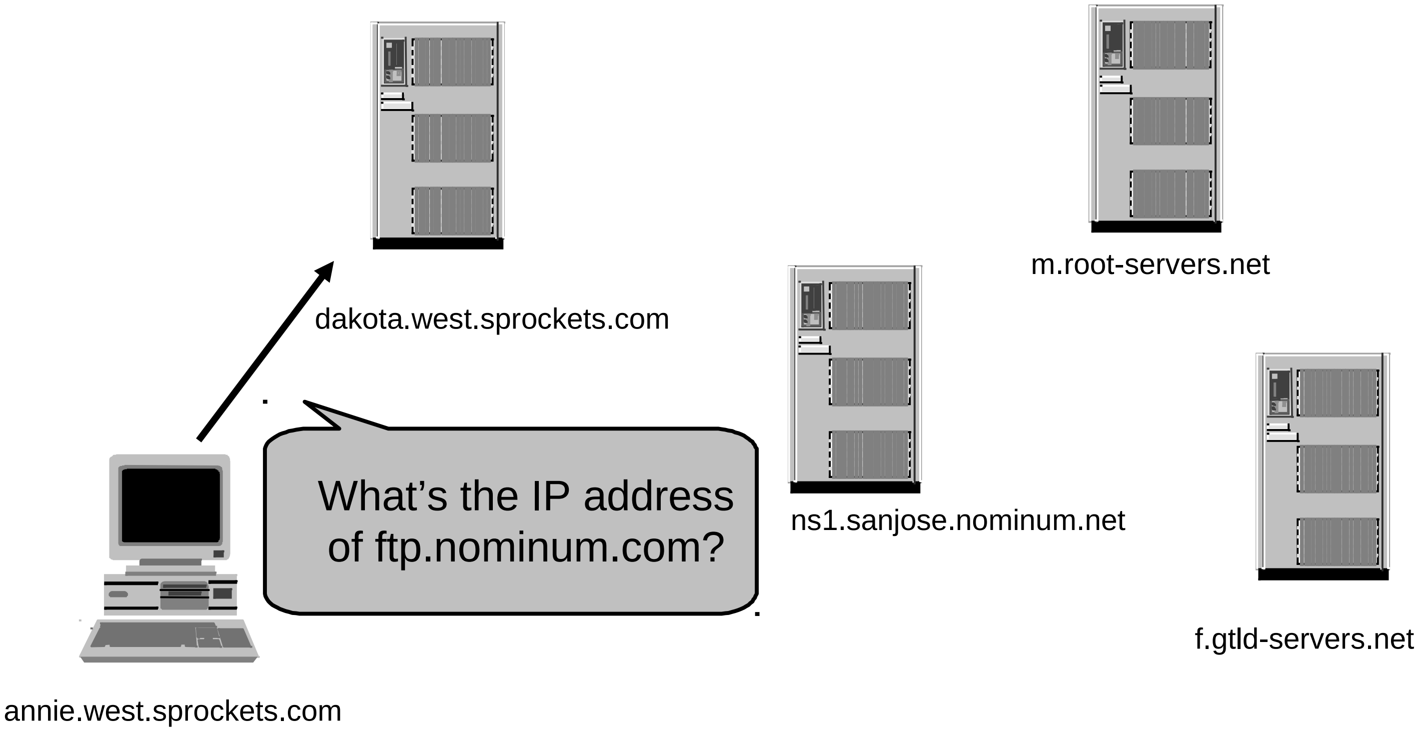


annie.west.sprockets.com

`ping` **`ftp`**`.nominum.com.`

Resolution Process (Caching)

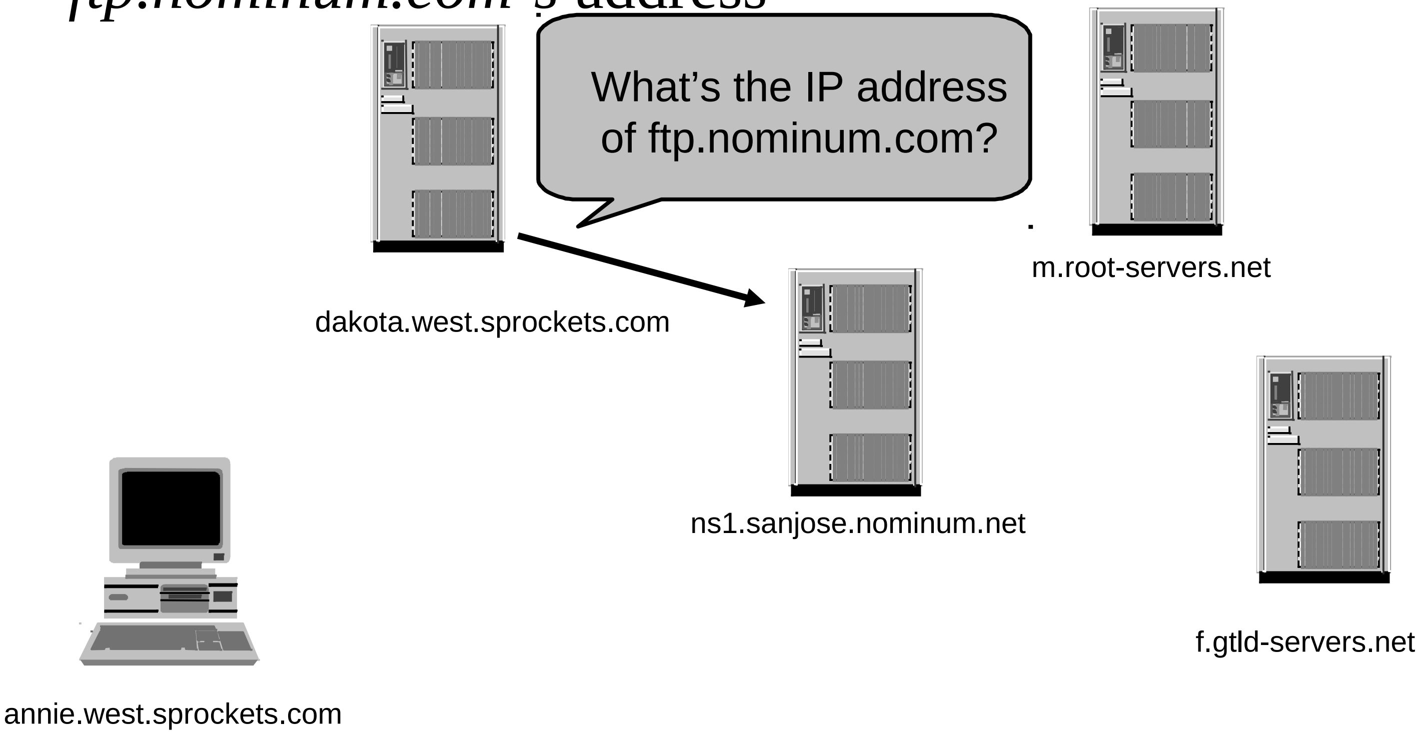
- The workstation *annie* asks its configured name server, *dakota*, for *ftp.nominum.com's* address




```
ping ftp.nominum.com.
```

Resolution Process (Caching)

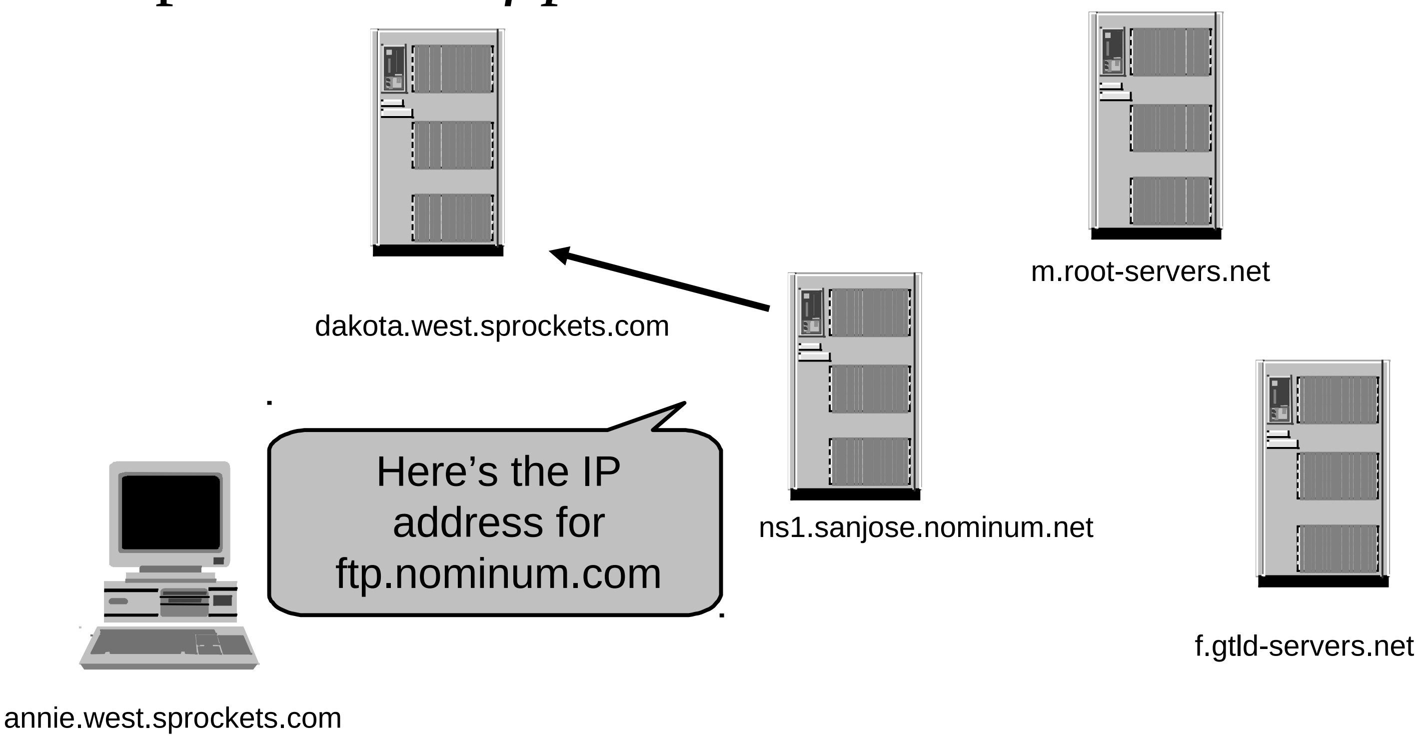
- *dakota* has cached a NS record indicating *ns1.sanjose* is an *nominum.com* name server, so it asks it for *ftp.nominum.com's* address



`ping ftp.nominum.com.`

Resolution Process (Caching)

- The *nominum.com* name server *ns1.sanjose* responds with *ftp.nominum.com's* address

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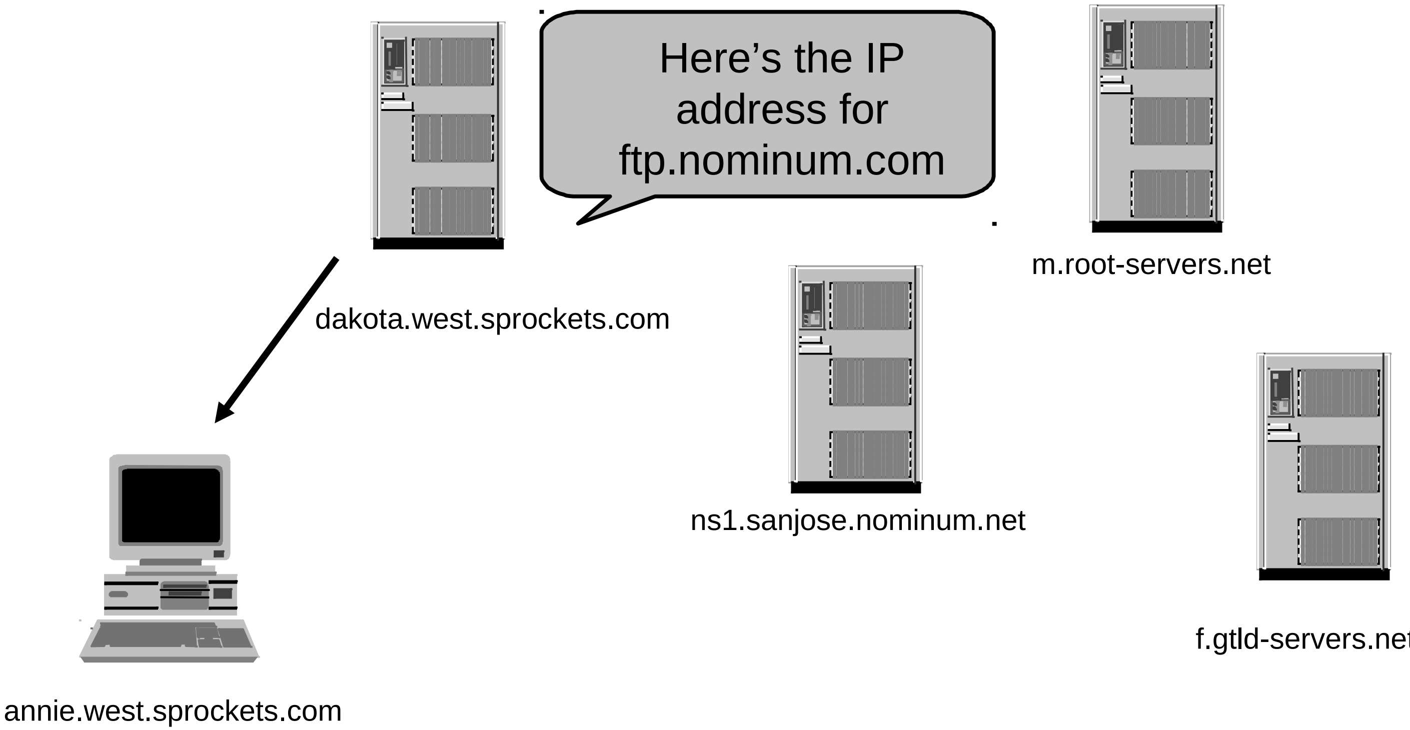
Resolution Process (Caching)

- The name server *dakota* responds to *annie* with *ftp.nominum.com's* address



`ping ftp.nominum.com.`

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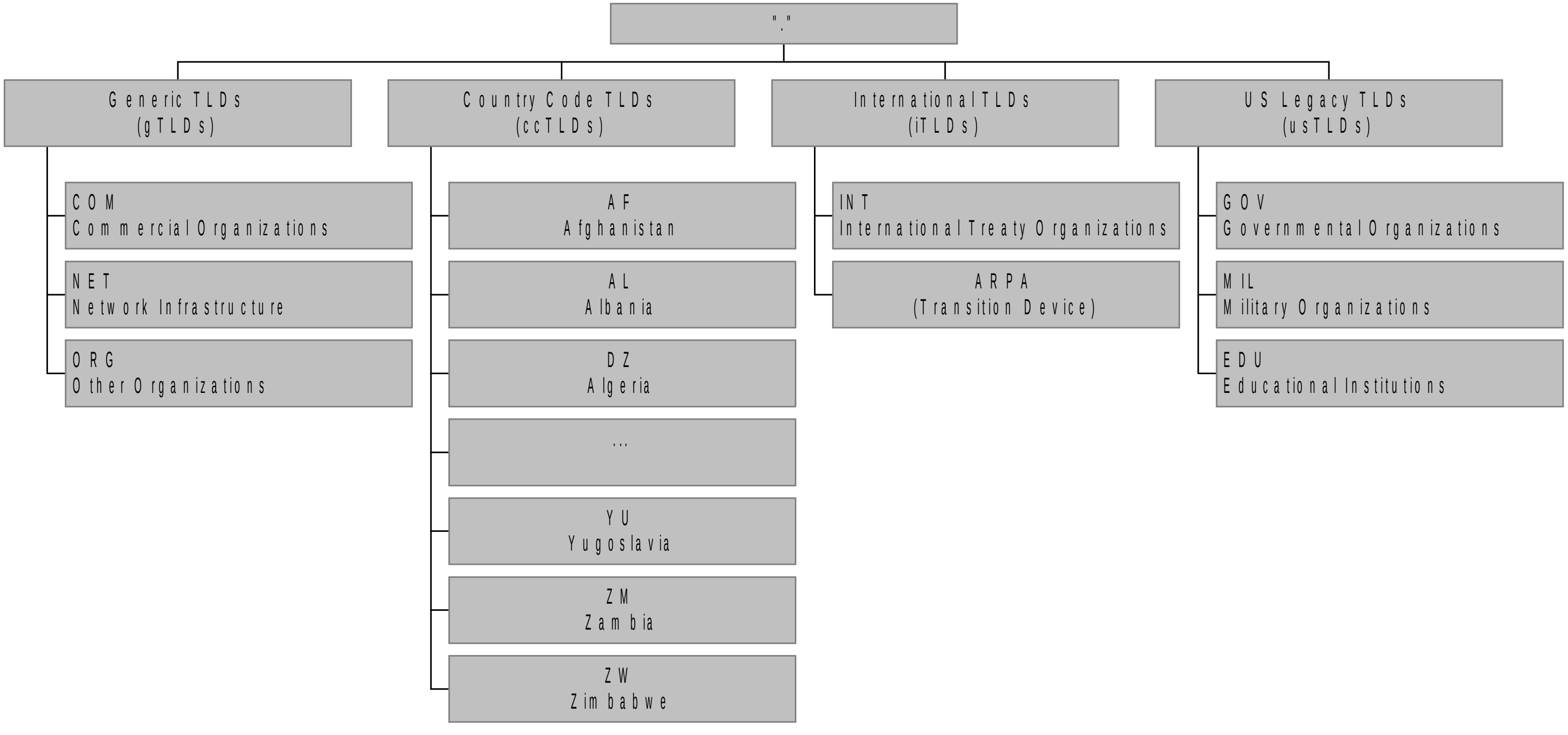
DNS Structure and Hierarchy

- The DNS imposes no constraints on how the DNS hierarchy is implemented except:
  - A single root
  - The label restrictions
  - So, can we create a host with a name *a.wonderful.world*?
- If a site is not connected to the Internet, it can use any domain hierarchy it chooses
  - Can make up whatever TLDs (top level domains) you want
- Connecting to the Internet implies use of the existing DNS hierarchy

Top-level Domain (TLD) Structure

- In 1983 (RFC 881), the idea was to have TLDs correspond to network service providers
  - e.g., ARPA, DDN, CSNET, etc.
    - Bad idea: if your network changes, your name changes
- By 1984 (RFC 920), functional domains was established
  - e.g., GOV for Government, COM for commercial, EDU for education, etc.
- RFC 920 also
  - Provided country domains
  - Provided "Multiorganizations"
    - Large, composed of other (particularly international) organizations
  - Provided a stable TLD structure until 1996 or so

The Current TLDs



Internet Corporation for Assigned Names and Numbers (ICANN)

- ICANN’s role: to oversee the management of Internet resources including
  - Addresses
    - Delegating blocks of addresses to the regional registries
  - Protocol identifiers and parameters
    - Allocating port numbers, etc.
  - Names
    - Administration of the root zone file
    - Oversee the operation of the root name servers

The Root Nameservers

- The root zone file lists the names and IP addresses of the authoritative DNS servers for all top-level domains (TLDs)
- The root zone file is published on 13 servers, “A” through “M”, around the Internet
- Root name server operations currently provided by volunteer efforts by a very diverse set of organizations

Root Name Server Operators

Nameserver	Operated by:
A	Verisign (US East Coast)
B	University of S. California –Information Sciences Institute (US West Coast)
C	Cogent Communications (US East Coast)
D	University of Maryland (US East Coast)
E	NASA (Ames) (US West Coast)
F	Internet Software Consortium (US West Coast)
G	U. S. Dept. of Defense (ARL) (US East Coast)
H	U. S. Dept. of Defense (DISA) (US East Coast)
I	Autonomica (SE)
J	Verisign (US East Coast)
K	RIPE-NCC (UK)
L	ICANN (US West Coast)
M	WIDE (JP)

Registries, Registrars, and Registrants

- A classification of roles in the operation of a domain name space
- Registry
  - the name space's database
  - the organization which has edit control of that database
  - the organization which runs the authoritative name servers for that name space
- Registrar
  - the agent which submits change requests to the registry on behalf of the registrant
- Registrant
  - the entity which makes use of the domain name

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Load Concerns

- DNS can handle the load
  - DNS root servers get approximately 3000 queries per second
    - Empirical proofs (DDoS attacks) show root name servers can handle 50,000 queries per second
      - Limitation is network bandwidth, not the DNS protocol
  - in-addr.arpa zone, which translates numbers to names, gets about 2000 queries per second

Performance Concerns

- DNS is a very lightweight protocol
  - Simple query – response
- Any performance limitations are the result of network limitations
  - Speed of light
  - Network congestion
  - Switching/forwarding latencies

Security Concerns

- Base DNS protocol (RFC 1034, 1035) is insecure
  - DNS spoofing (cache poisoning) attacks are possible
- DNS Security Enhancements (DNSSEC, RFC 2565) remedies this flaw
  - But creates new ones
    - DoS attacks
    - Amplification attacks
- DNSSEC strongly discourages large flat zones
  - Hierarchy (delegation) is good

Questions?