Data Communication Networks Application Layer

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Domain Name System

- DNS is a hierarchical distributed database used to map host names to IP addresses

- To map a name an application calls a (local) library procedure called resolver

- The resolver sends a UDP packet to a local DNS server

- This server returns, possibly after consulting with other DNS servers, the IP address to the application

Domain Name System

- **DNS Name Space**
  - Naming scheme is hierarchical e.g. www.sharif.ac.ir
    - ir is top level domain (TLD)
    - sharif is sub domain and represents all the nodes under it
  - Leaves of the tree represent domains which have no sub domain
  - Naming follows organizational boundaries, not physical (network) ones
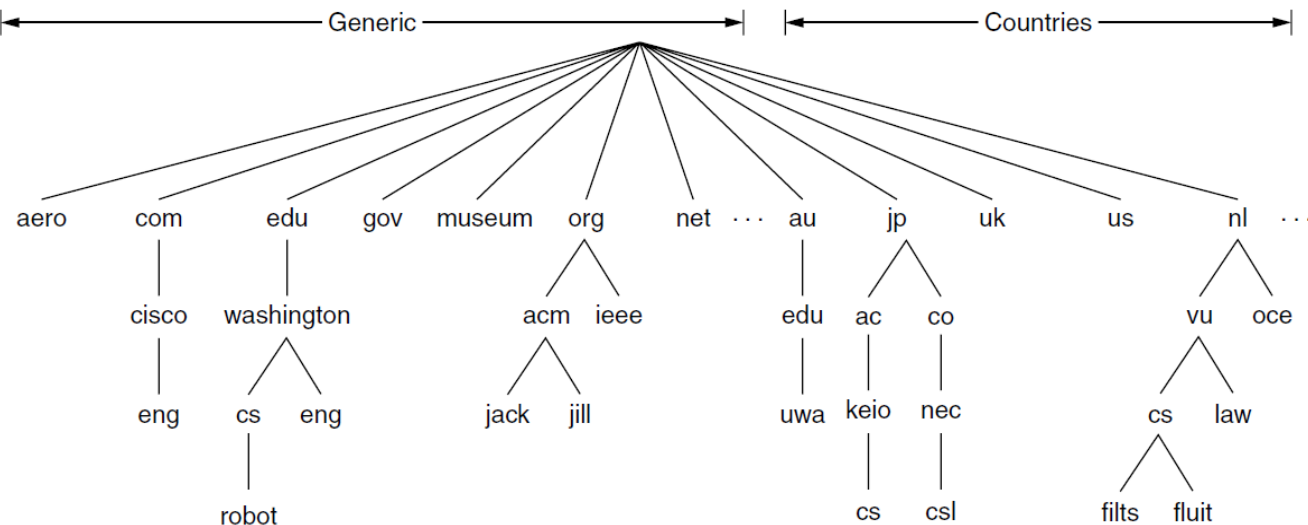
DNS Name Space

- Getting a name like sharif.ac.ir requires registration with the ac.ir *domain manager*

- After that sub domains can be added freely: ee.sharif.ac.ir

- Names are case insensitive

- DNS Database
    - Every domain name has a set of corresponding **resource records** in the database
    - For a single host: just record its IP address, but many other records exist
    - When a resolver gives name to DNS, it gets back the associated resource records

DNS Name Space

- DNS resource record
  - Domain-name: search key
  - Time-to-live: indicates how stable the entry is in terms of seconds (needed for caching) e.g. 86400 seconds (= 1 day)
  - Type: different types of resource records have been defined
  - Class: always IN for internet information
  - Value: Returned value
- Example:
  - relay1.bar.foo.com, static, A, IN, 145.37.93.126
  - This means: IP Address of relay1.bar.foo.com is 145.37.93.126

Domain name	Time to live	Type	Class	Value

DNS Server Types

Root DNS servers

- Root name servers provide the IP addresses of the TLD servers.

## Top-level domain (TLD) servers

- Every top-level Domain has a top-level Domain Server
- TLD servers provide the IP addresses for authoritative DNS servers.

Authoritative DNS servers

- Every organization with publicly accessible hosts (such as Web servers and mail servers) on the Internet must provide publicly accessible DNS records that map the names of those hosts to IP addresses.
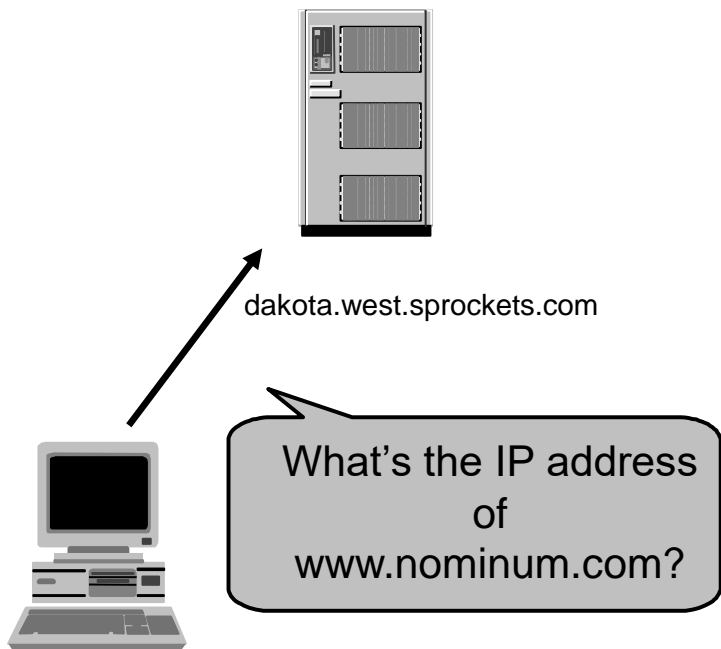
DNS Name Servers

- The DNS name space is split into non overlapping zones.
- A zone usually has 1 primary name server, and multiple secondary ones, which get their information from the primary one.
- Note: cs.yale.edu and yale.edu have separate name servers
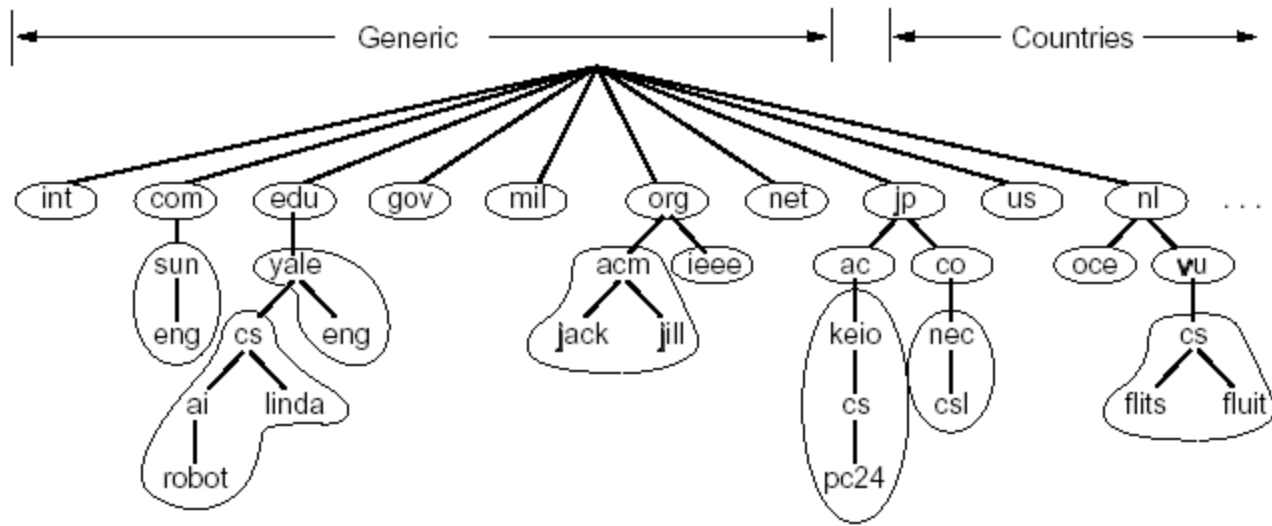
Name Resolution Example

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

dakota.west.sprockets.com
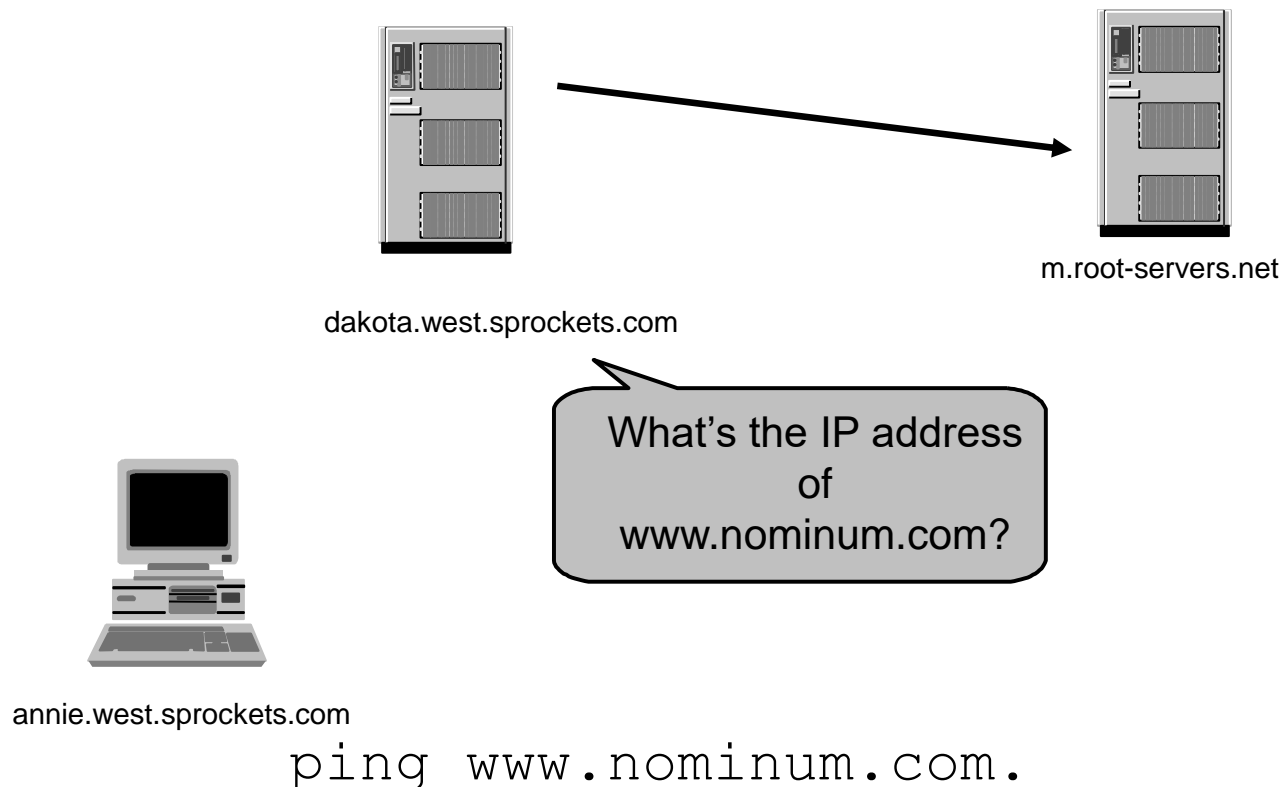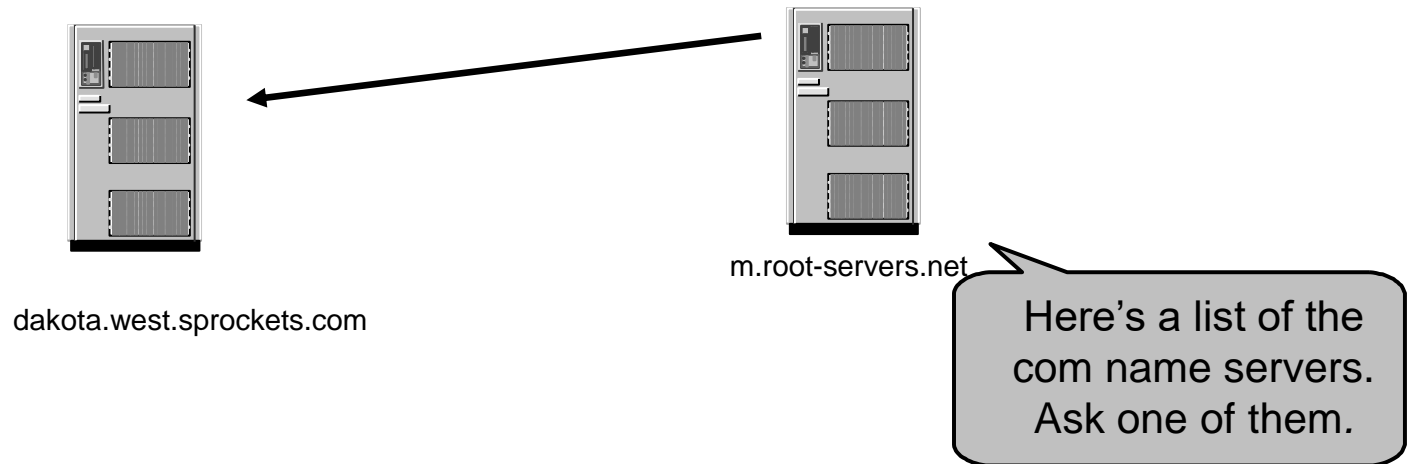
What's the IP address of www.nominum.com?

annie.west.sprockets.com

`ping www.nominum.com.`

Name Resolution Example

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

m.root-servers.net

dakota.west.sprockets.com

What's the IP address of www.nominum.com?

annie.west.sprockets.com

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

Name Resolution Example

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

dakota.west.sprockets.com

m.root-servers.net

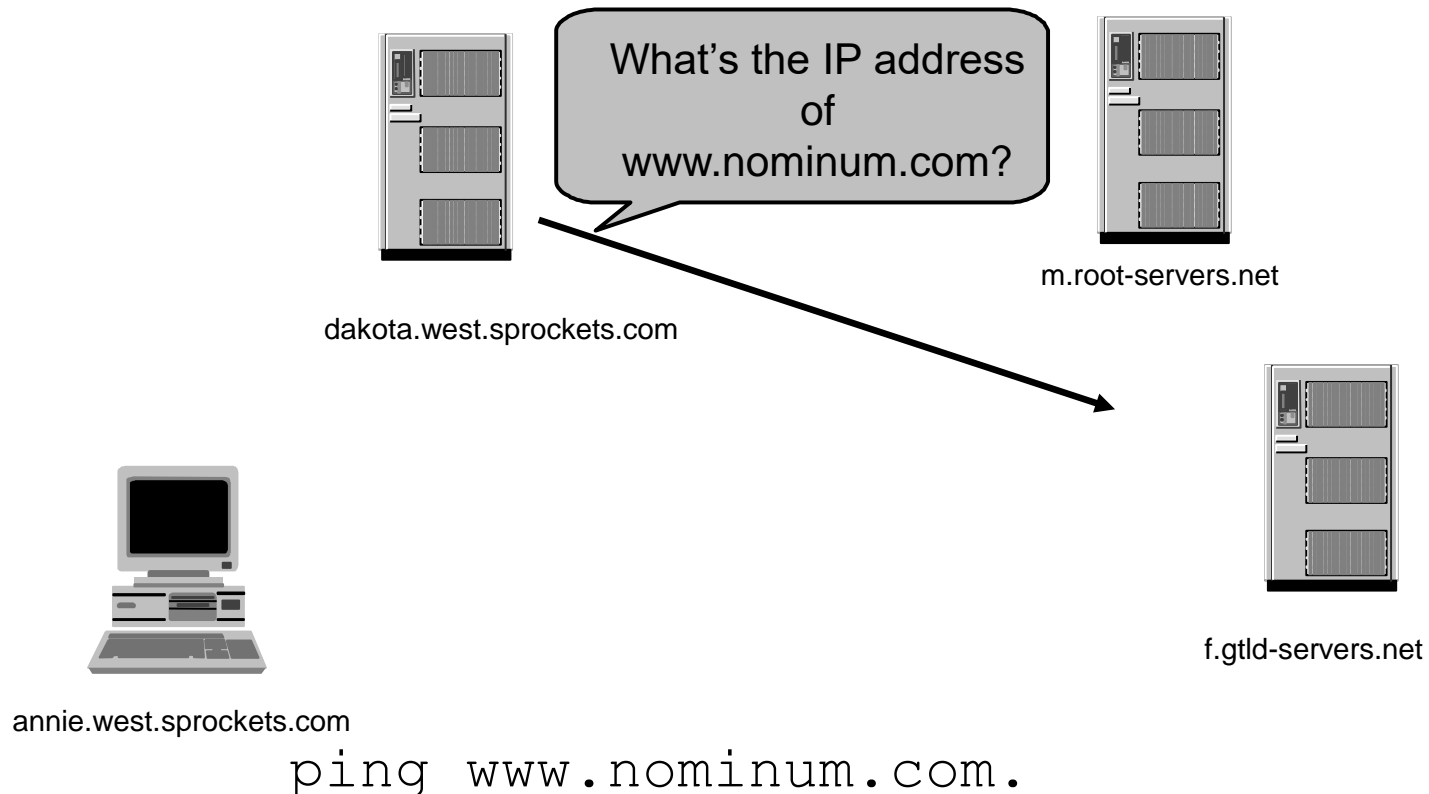Here's a list of the com name servers. Ask one of them.

annie.west.sprockets.com

```
ping www.nominum.com.
```
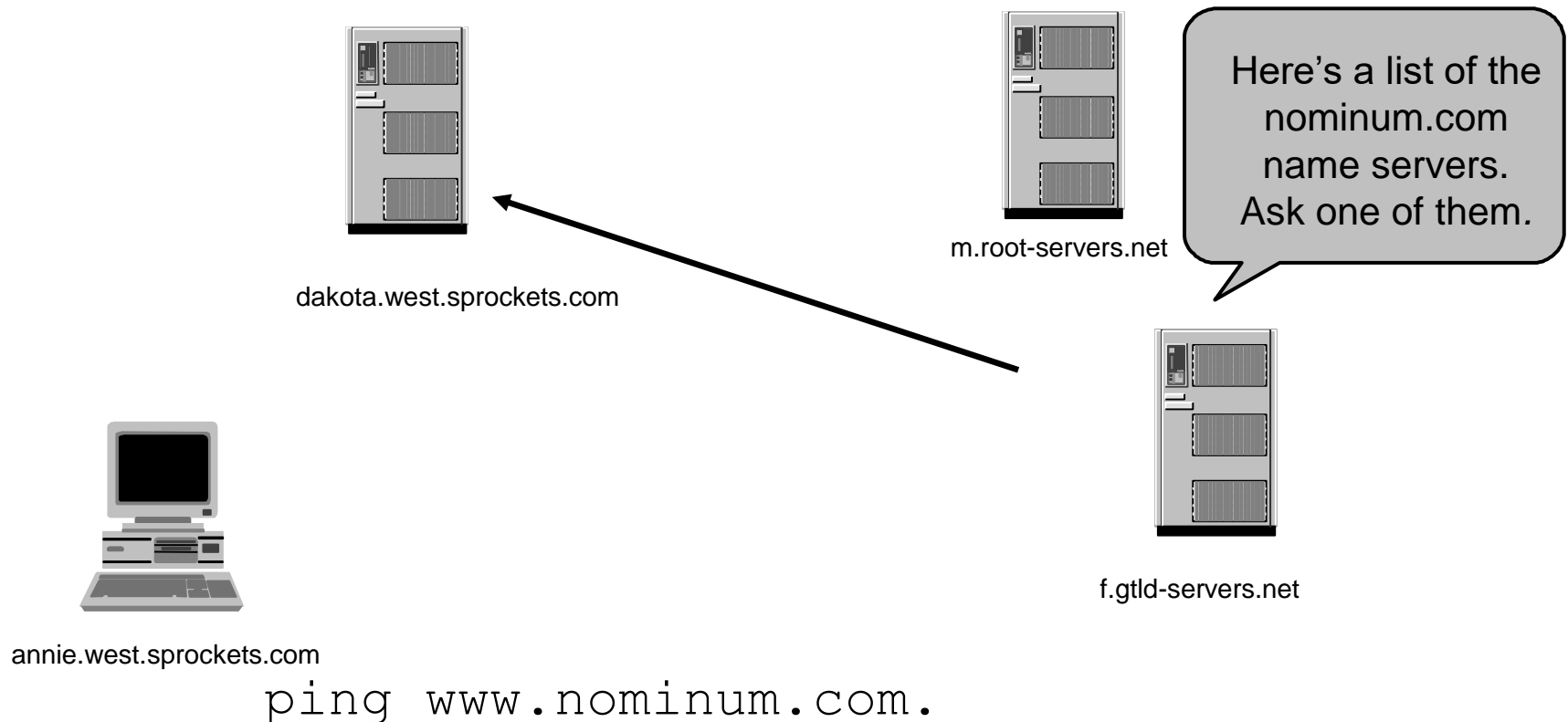
Name Resolution Example

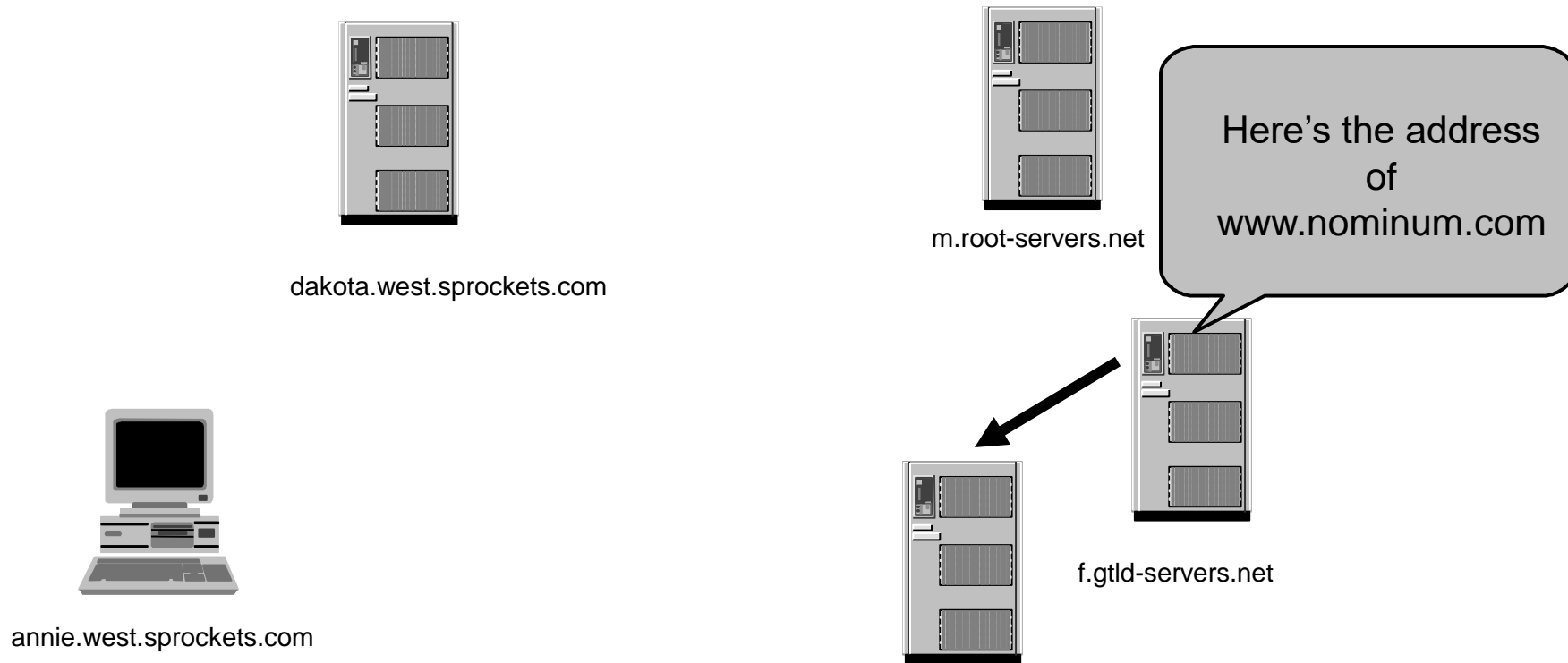- The name server *dakota* asks a *com* name server, *f*, for *www.nominum.com's* address

What's the IP address of www.nominum.com?

m.root-servers.net

dakota.west.sprockets.com

f.gtld-servers.net

annie.west.sprockets.com

`ping www.nominum.com.`

Name Resolution Example

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

dakota.west.sprockets.com

m.root-servers.net

Here's a list of the nominum.com name servers. Ask one of them.

f.gtld-servers.net

annie.west.sprockets.com

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

If the Name doesn't exist

dakota.west.sprockets.com

m.root-servers.net

Here's the address of www.nominum.com

f.gtld-servers.net

annie.west.sprockets.com
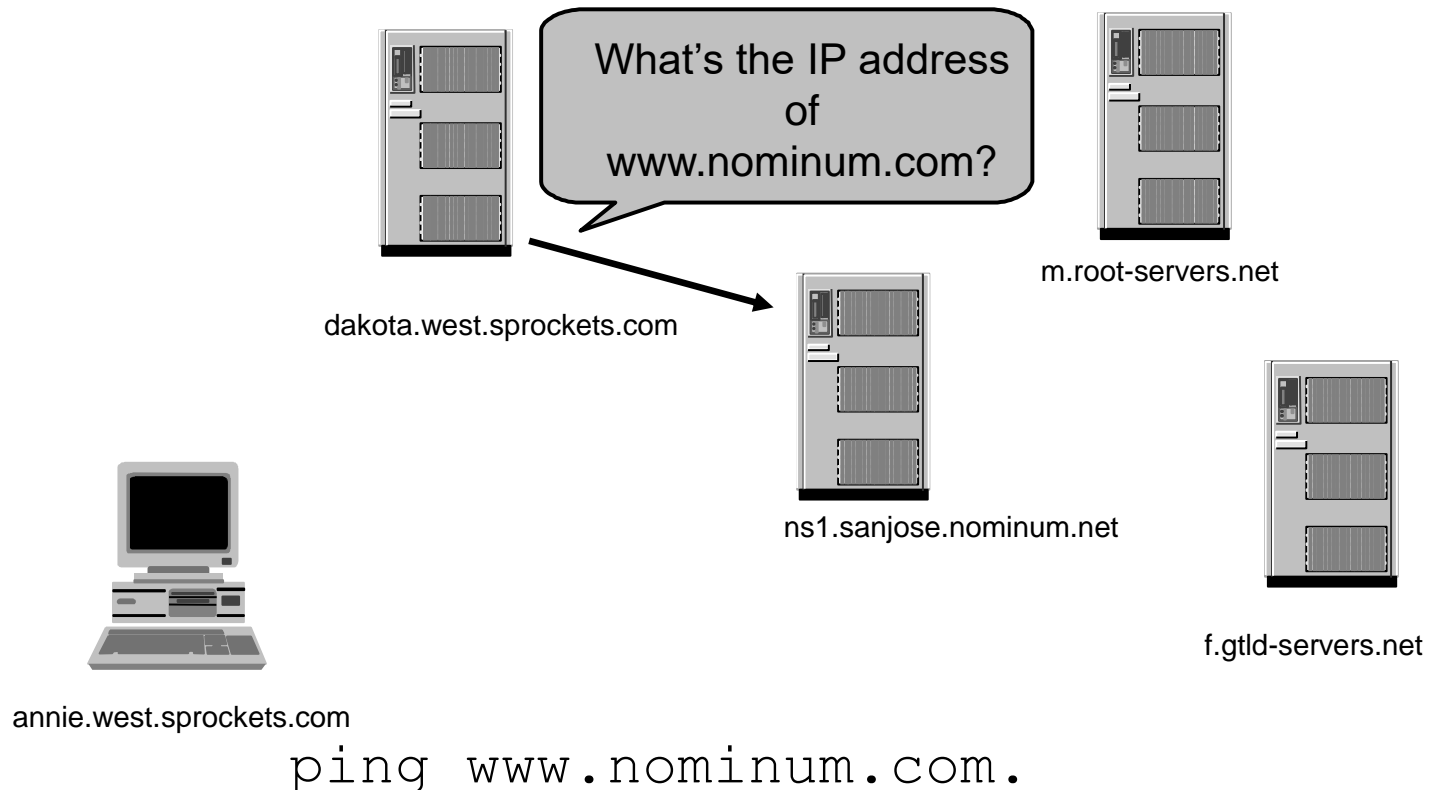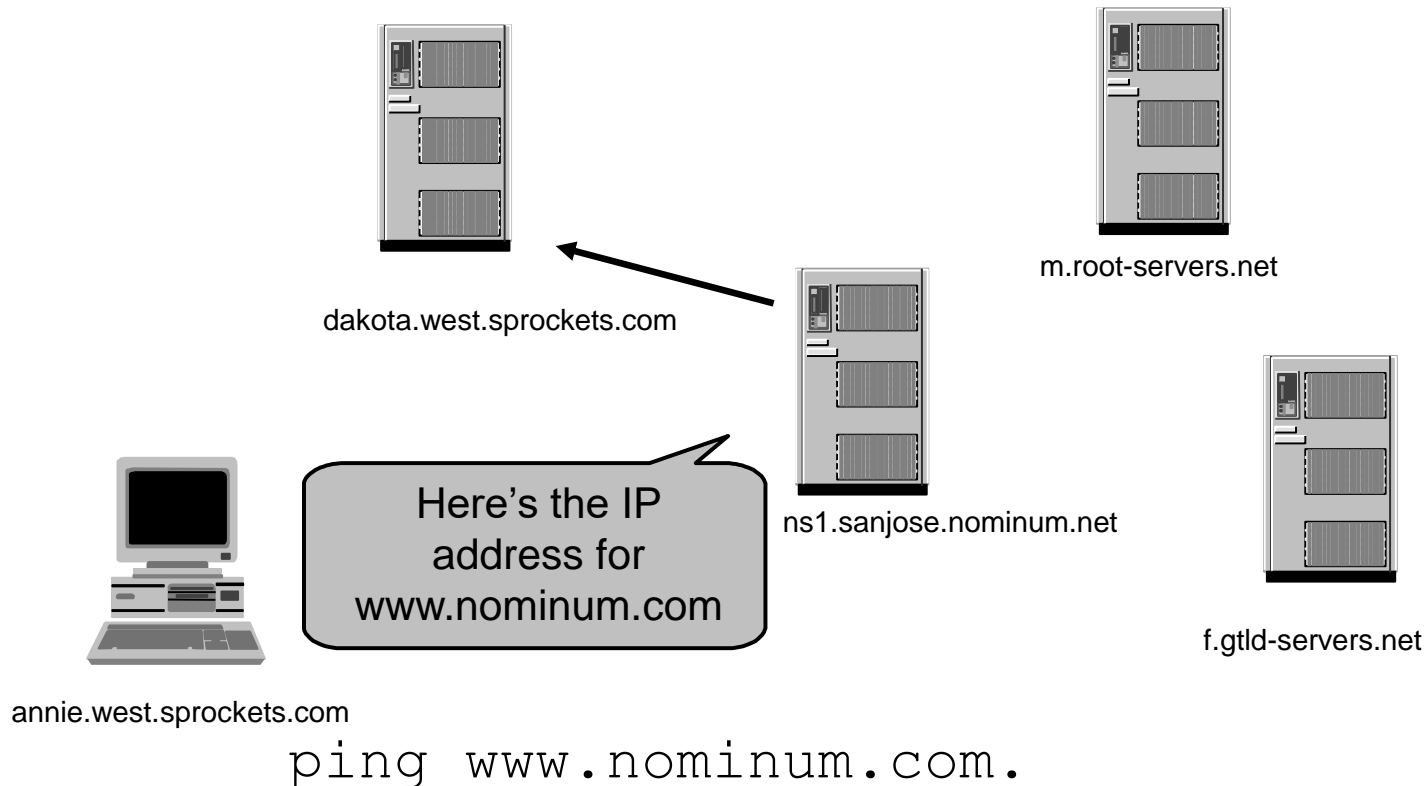
`ping www.nominum.com.`

Name Resolution Example

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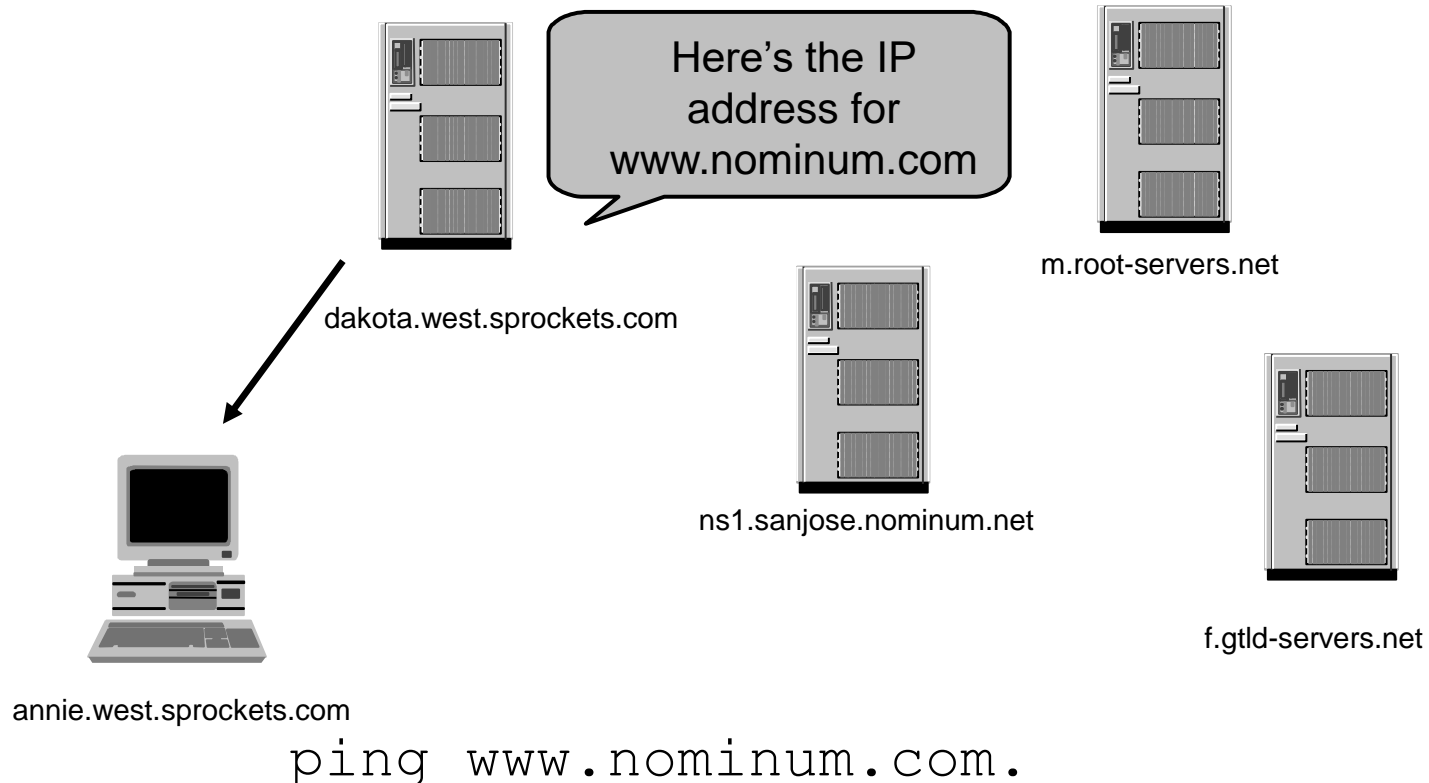

What's the IP address of www.nominum.com?

dakota.west.sprockets.com

m.root-servers.net

ns1.sanjose.nominum.net

f.gtld-servers.net

annie.west.sprockets.com

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

Name Resolution Example

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

dakota.west.sprockets.com

m.root-servers.net

ns1.sanjose.nominum.net

Here's the IP address for www.nominum.com

f.gtld-servers.net

annie.west.sprockets.com

`ping www.nominum.com.`

Name Resolution Example

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

Here's the IP address for www.nominum.com

dakota.west.sprockets.com

m.root-servers.net

ns1.sanjose.nominum.net

f.gtld-servers.net

annie.west.sprockets.com
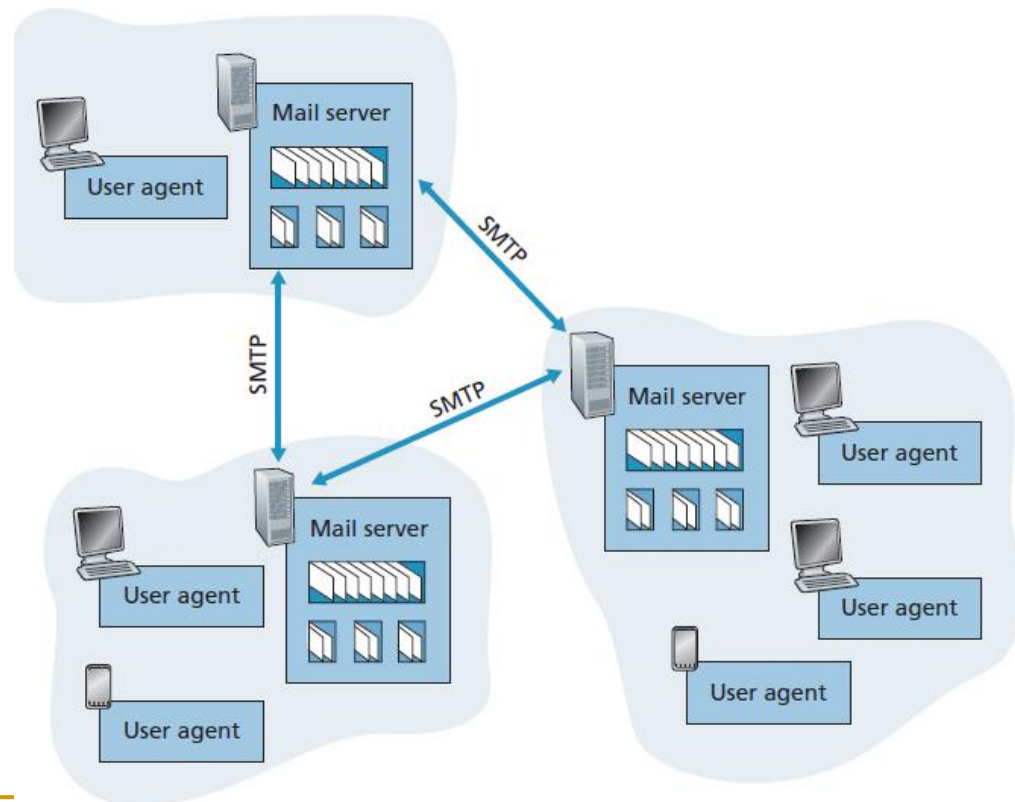
```
ping www.nominum.com.
```

Name Lookup Sequence

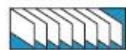- DNS Records are cached in your computer as well as your ISP
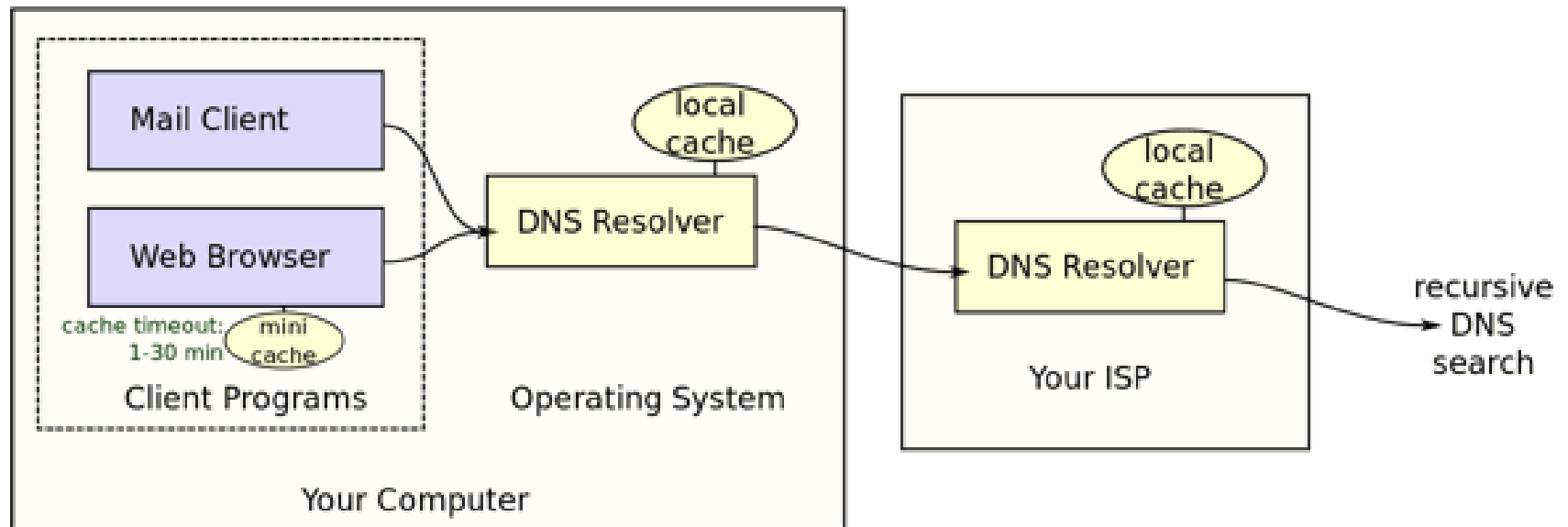
Electronic Mail

- Important E-mail components:
    - Simple Mail Transfer Protocol (SMTP).
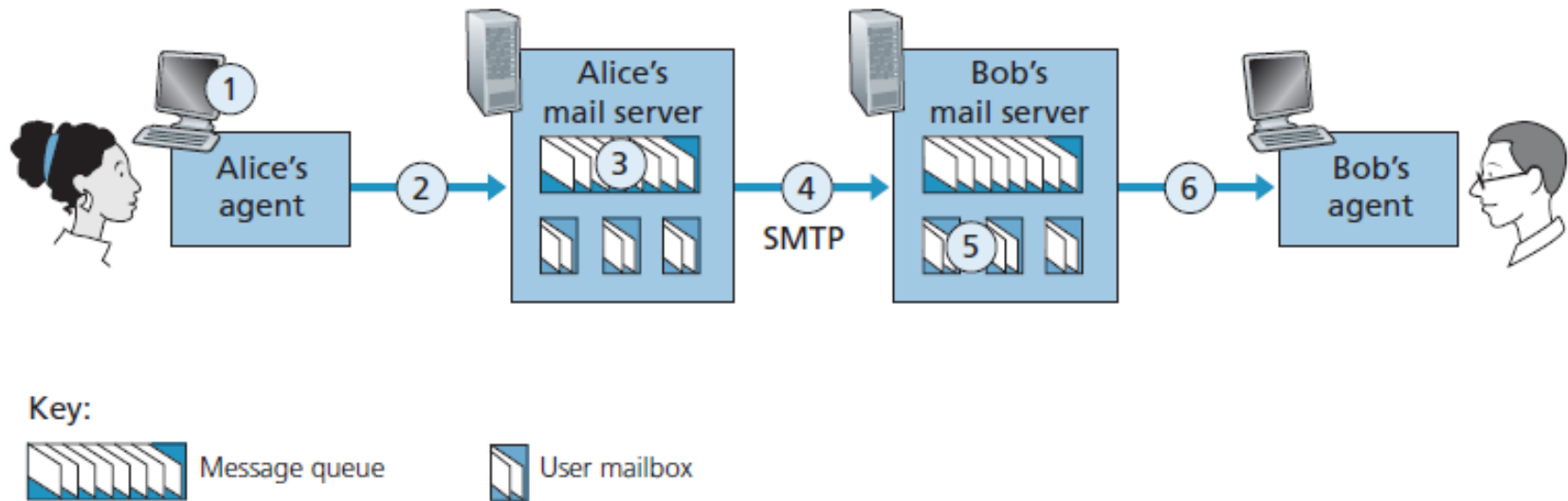   - Main Server
    - User agents

Key:

Outgoing message queue

User mailbox

Simple Mail Transfer Protocol (SMTP)

- SMTP is the principal application-layer protocol for Internet electronic mail.

- It uses the reliable data transfer service of TCP to transfer mail from the sender's mail server to the recipient's mail server.

Mail Access Protocols

## Post Office Protocol (POP)

- The Post Office Protocol provides access for a user client application to a mailbox maintained on a mail server.
- The protocol supports download and delete operations for messages.

Internet Message Access Protocol (IMAP)

- The Internet Message Access Protocol is an application layer Internet protocol that allows an e-mail client to access email on a remote mail server

World Wide Web

- **Web is framework for accessing linked documents**
  - Web servers provide documents (pages)
  - Web browsers view the documents
  - Pages are linked using hypertext techniques
- **Web idea comes from CERN, Geneva (1989)**
- **WWW consortium was set up by CERN and MIT (1994) to organize and standardize**
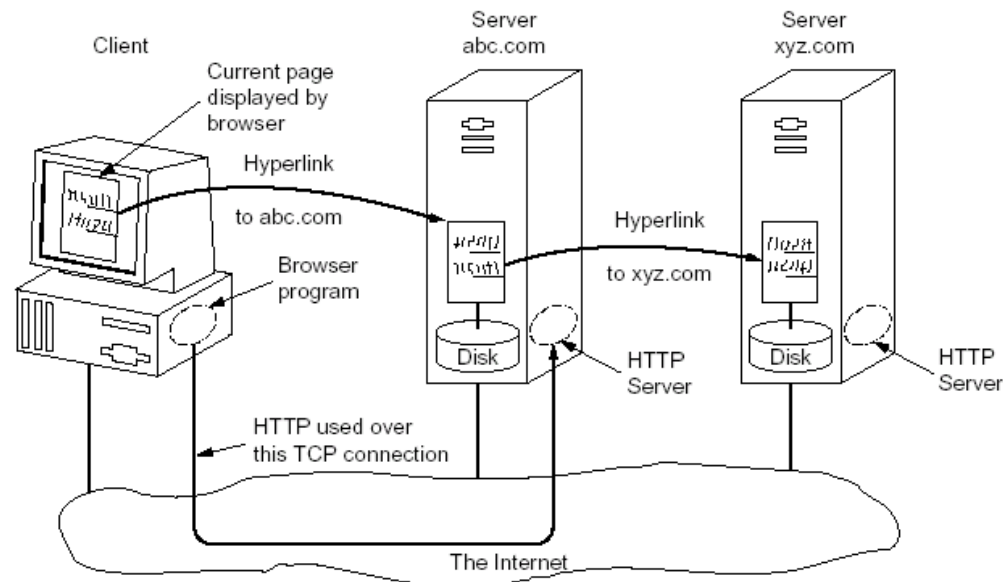
World Wide Web: Architecture

- Web pages are viewed by client-side programs called "browsers" (Chrome, Firefox)
- Browsers key functions:
  - Interact with the web servers using Hyper Text Transfer Protocol (HTTP) to fetch the desired content and data
  - Display the content in a proper format to the user
  - Interact with the user to receive user data (click on the page, typed text, etc)
  - Interact with the helper applications on the user computer to handle the content properly
  - Caching of the contents
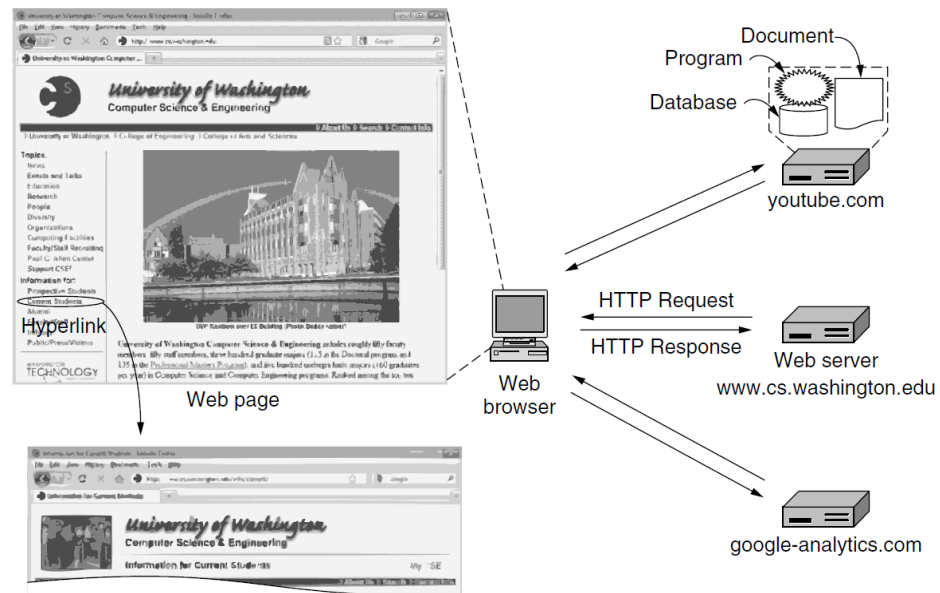
WWW Server Side

- **Hypertext transfer Protocol : HTTP**
  - HTTP is ASCII based protocol
- **Two types of requests:**
  - without or with protocol version
  - e.g.: *GET /hypertext/WWW/pages.html HTTP/1.0*
- **Several built-in HTTP request methods**

Method	Description
GET	Request for resource from server
POST	Submit data to the server
HEAD	Same as GET but does not return the body
PUT	The data within the request must be stored at the URL supplied, replacing any existing data.
DELETE	Delete a resource
OPTIONS	Return the HTTP methods supported by the server
CONNECT	Client requests the HTTP proxy to forward a TCP connection to some destination. Used to create a TCP/IP tunnel for secure connections using HTTP proxies.

WWW Server Side

- **WWW Pages**
  - Pages are written in HTML: HyperText Markup Language
  - Markup commands are not hidden
  - HTML editors are usually used to create and edit HTML pages
  - Multiple versions of HTML have been developed with new features added on over time.

Item	HTML 1.0	HTML 2.0	HTML 3.0	HTML 4.0	HTML 5.0
Hyperlinks	x	x	x	x	x
Images	x	x	x	x	x
Lists	x	x	x	x	x
Active maps & images		x	x	x	x
Forms		x	x	x	x
Equations			x	x	x
Toolbars			x	x	x
Tables			x	x	x
Accessibility features				x	x
Object embedding				x	x
Style sheets				x	x
Scripting				x	x
Video and audio					x
Inline vector graphics					x
XML representation					x
Background threads					x
Browser storage					x
Drawing canvas					x

Figure 7-24. Some differences between HTML versions.

Example of HTML page

```html
<html>
<head> <title> AMALGAMATED WIDGET, INC. </title> </head>
<body> <h1> Welcome to AWI's Home Page </h1>
<img src="http://www.widget.com/images/logo.gif" ALT="AWI Logo"> <br>
We are so happy that you have chosen to visit <b> Amalgamated Widget's</b>
home page. We hope <i> you </i> will find all the information you need here.
<p>Below we have links to information about our many fine products.
You can order electronically (by WWW), by telephone, or by email. </p>
<hr>
<h2> Product information </h2>
<ul>
   <li> <a href="http://widget.com/products/big"> Big widgets </a> </li>
   <li> <a href="http://widget.com/products/little"> Little widgets </a> </li>
</ul>
<h2> Contact information </h2>
<ul>
   <li> By telephone: 1-800-WIDGETS </li>
   <li> By email: info@amalgamated-widget.com </li>
</ul>
</body>
</html>
```

Example of HTML page

Welcome to AWI's Home Page

We are so happy that you have chosen to visit **Amalgamated Widget's** home page. We hope *you* will find all the information you need here.

Below we have links to information about our many fine products. You can order electronically (by WWW), by telephone, or by email.

Product Information

- Big widgets
- Little widgets

Contact information

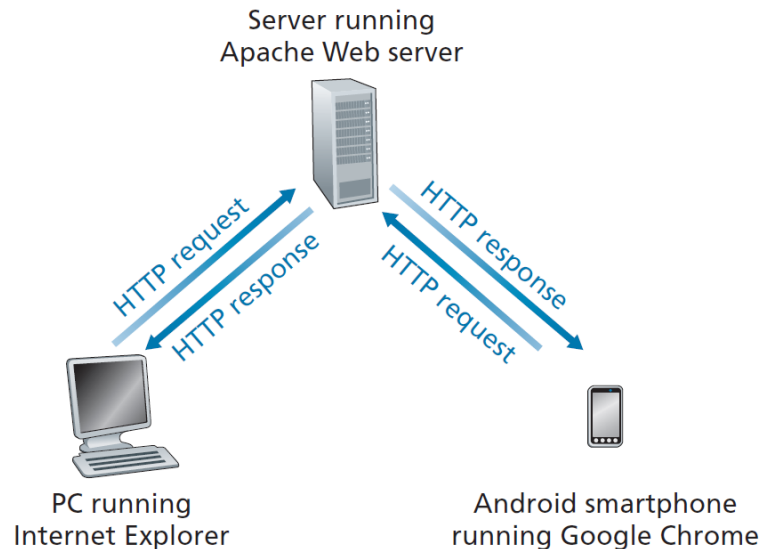- By telephone: 1-800-WIDGETS
- By email: info@amalgamated-widget.com

Uniform Resource Locator: URL

- WWW uses ULRs to locate pages
- Example: http://sina.sharif.ac.ir/index.html
- URL contains 3 parts:
  - protocol name:
    - HTTP, FTP, news, mailto, or file
  - server name: sina.sharif.ac.ir
  - page (file) name: Index.html

Name	Used for	Example
http	Hypertext (HTML)	http://www.ee.uwa.edu/~rob/
https	Hypertext with security	https://www.bank.com/accounts/
ftp	FTP	ftp://ftp.cs.vu.nl/pub/minix/README
file	Local file	file:///usr/suzanne/prog.c
mailto	Sending email	mailto:JohnUser@acm.org
rtsp	Streaming media	rtsp://youtube.com/montypython.mpg
sip	Multimedia calls	sip:eve@adversary.com
about	Browser information	about:plugins

Browsing the Web

- Protocol steps:
  - Browser determines URL
  - Browser asks DNS to map server name to IP address
  - Browser makes TCP connection to server IP address, port 80
  - Browser sends GET 'URL' command
  - Server sends page (file) index.html

Server running
Apache Web server

HTTP request
HTTP response
HTTP response
HTTP request

PC running
Internet Explorer

Android smartphone
running Google Chrome

Server Side

- Functions of the web server:
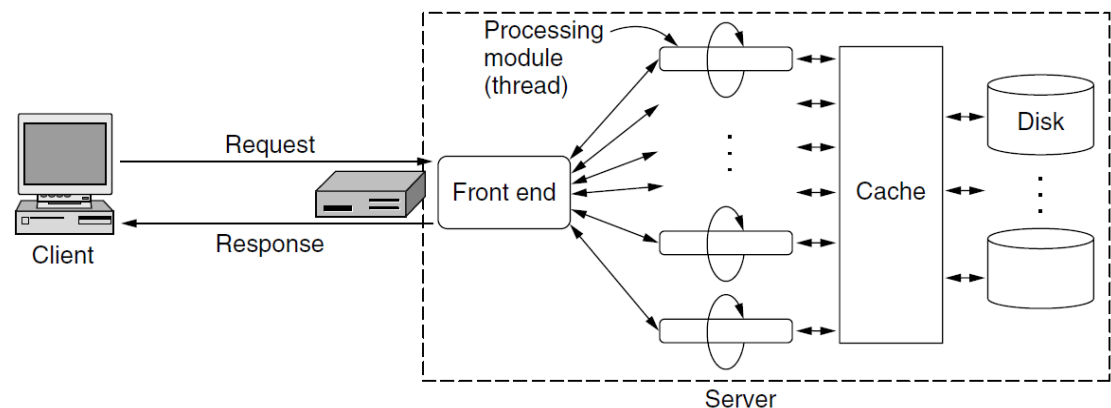   - Resolve the name of the Web page requested.
    - Perform access control on the Web page.
    - Check the cache.
    - Fetch the requested page from disk or run a program to build it.
    - Determine the rest of the response (e.g., the MIME type to send).
    - Return the response to the client.
    - Make an entry in the server log.
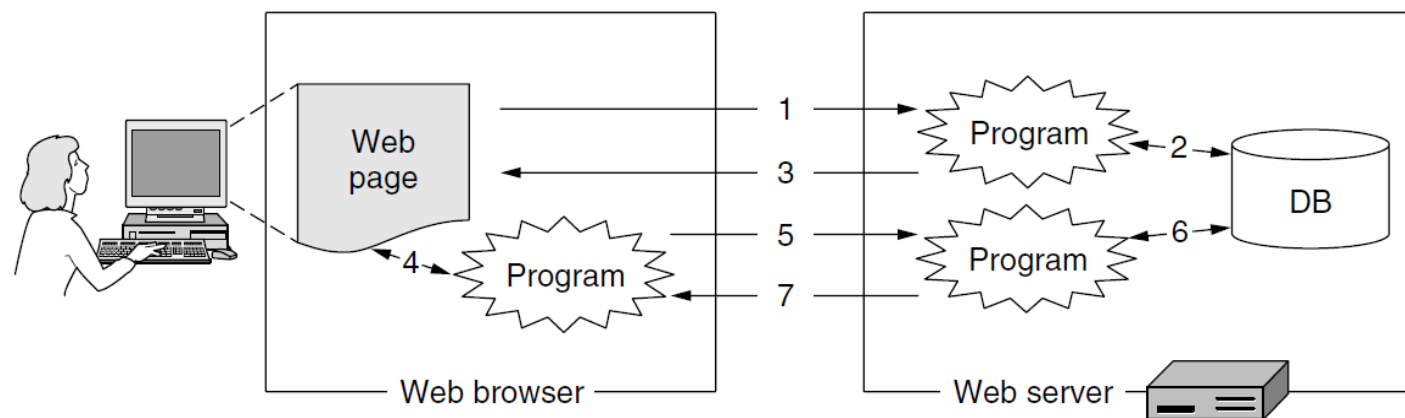- Key challenges:
    - Speed
    - Scalability
- Solutions:
    - Cache
    - Load Balancing

Server-Side Dynamic Web Pages

- Many web interactions such as web search requires a program to generate the content based on user data.

- A program should run on the server side that interacts with user generated data.

- Example: Search Engines such as google.com

Server-Side Programming Languages

- Programming languages oriented toward interfacing between the web and the server database
- Run on the server and generates dynamic web pages on the request of the client
- Examples:
    - PHP
    - Python
    - Java Script

Client-Side Dynamic web Pages

- Idea: Download a code that runs on the client side and interacts with user locally
- Java Script
  - A scripting language with some similarities to Java
- Java applets:
  - Applets are downloaded and then run locally
  - Applets are written in JAVA bytecode and interpreted by a Java Virtual Machine (JVM)
  - Interpreter has to guarantee security
  - The objective has been to allow JAVA bytecodes to run on all machines that have a JVM