WEB TECHNOLOGIES
A COMPUTER SCIENCE PERSPECTIVE

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Chapter 1
Web Essentials: Clients, Servers, and Communication

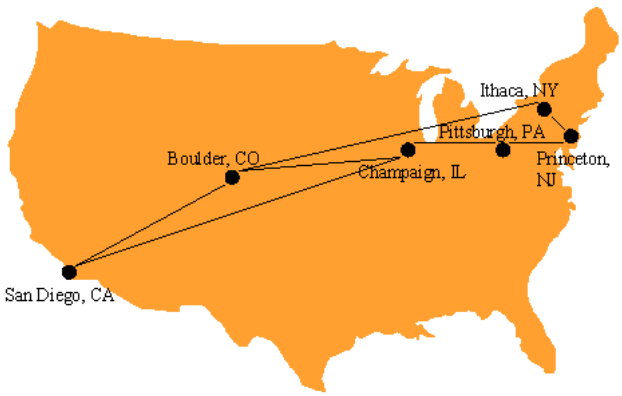
The Internet

- Technical origin: ARPANET (late 1960's)
  - One of earliest attempts to network heterogeneous, geographically dispersed computers
  - Email first available on ARPANET in 1972 (and quickly very popular!)
- ARPANET access was limited to select DoD-funded organizations

The Internet

- Internet: the network of networks connected via the public backbone and communicating using TCP/IP communication protocol

NSFNET in 1985
The first Internet backbone



Internet Protocols

  - Cf. telephone “protocol”: how you answer and end call, what language you speak, etc.
- Internet protocols developed as part of ARPANET research
  - ARPANET began using TCP/IP in 1982
- Designed for use both within local area networks (LAN’s) and between networks

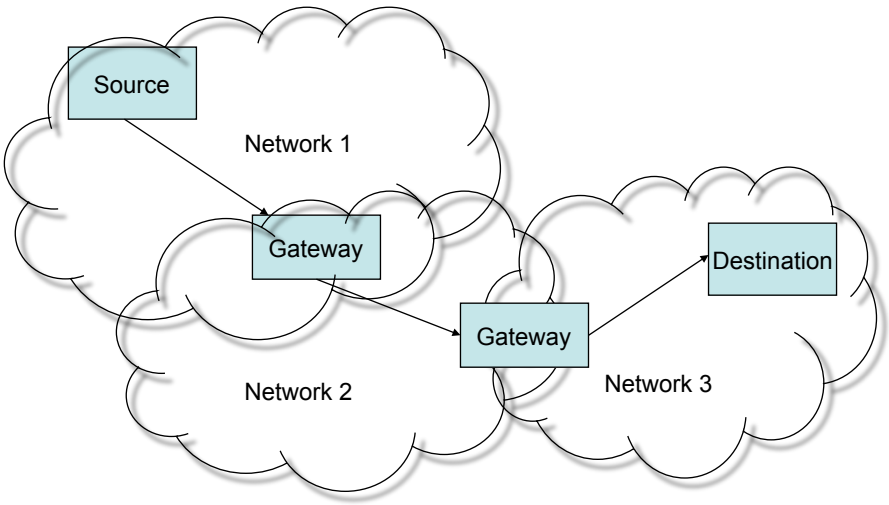
Internet Protocols

- Communication protocol: how computers talk
- IP is the fundamental protocol defining the Internet (as the name implies!)
- IP address:
  - 32-bit number (in IPv4)
  - Associated with at most one device at a time (although device may have more than one)
  - Written as four dot-separated bytes, e.g. 192.0.34.166

IP

- IP function: transfer data from source device to destination device
- IP source software creates a packet representing the data
  - Header: source and destination IP addresses, length of data, etc.
  - Data itself
- If destination is on another LAN, packet is sent to a gateway that connects to more than one network

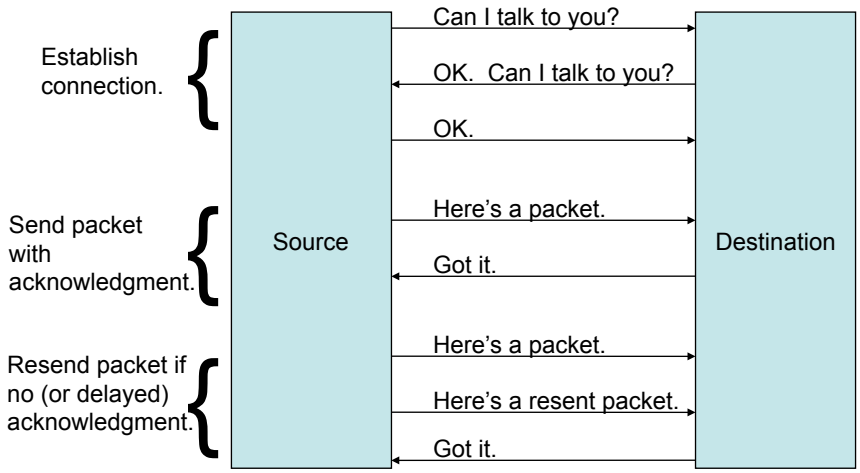
IP



Transmission Control Protocol (TCP)

- Limitations of IP:
  - No guarantee of packet delivery (packets can be dropped)
  - Communication is one-way (source to destination)
- TCP adds concept of a connection on top of IP
  - Provides guarantee that packets delivered
  - Provide two-way (full duplex) communication

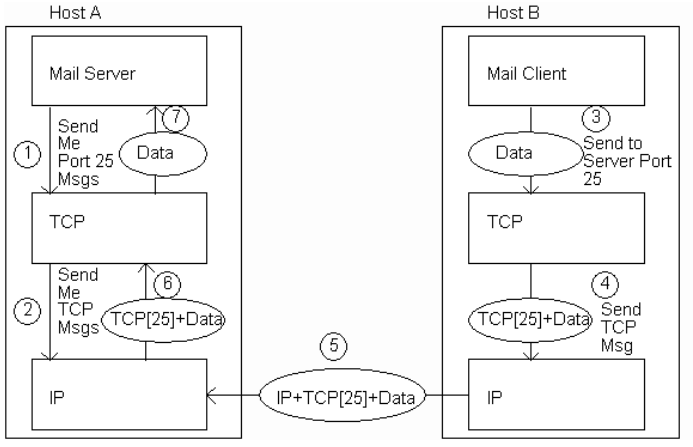
TCP



TCP

- TCP also adds concept of a port
  - TCP header contains port number representing an application program on the destination computer
  - Some port numbers have standard meanings
    - Example: port 25 is normally used for email transmitted using the Simple Mail Transfer Protocol (SMTP)
  - Other port numbers are available first-come-first served to any application

TCP



User Datagram Protocol (UDP)

- Like TCP in that:
  - Builds on IP
  - Provides port concept
- Unlike TCP in that:
  - No connection concept
  - No transmission guarantee
- Advantage of UDP vs. TCP:
  - Lightweight, so faster for one-time messages

Domain Name Service (DNS)

- DNS is the “phone book” for the Internet
  - Map between host names and IP addresses
  - DNS often uses UDP for communication
- Host names
  - Labels separated by dots, e.g., `www.example.org`
  - Final label is *top-level domain*
    - Generic: .com, .org, etc.
    - Country-code: .us, .il, etc.

DNS

- Domains are divided into second-level domains, which can be further divided into subdomains, etc.
  - E.g., in `www.example.com`, `example` is a second-level domain
- A host name plus domain name information is called the fully qualified domain name of the computer
  - Above, www is the host name, `www.example.com` is the FQDN

DNS

- `nslookup` program provides command-line access to DNS (on most systems)
- looking up a host name given an IP address is known as a reverse lookup

Analogy to Telephone Network

- IP ~ the telephone network
- TCP ~ calling someone who answers, having a conversation, and hanging up
- UDP ~ calling someone and leaving a message
- DNS ~ directory assistance

Higher-level Protocols

- Many protocols build on TCP
  - Telephone analogy: TCP specifies how we initiate and terminate the phone call, but some other protocol specifies how we carry on the actual conversation
- Some examples:
  - SMTP (email)
  - FTP (file transfer)
  - HTTP (transfer of Web documents)

World Wide Web

- Originally, one of several systems for organizing Internet-based information
  - Competitors: WAIS, Gopher, ARCHIE
- Distinctive feature of Web: support for hypertext (text containing links)
  - Communication via Hypertext Transport Protocol (HTTP)
  - Document representation using Hypertext Markup Language (HTML)

World Wide Web

- The Web is the collection of machines (Web servers) on the Internet that provide information, particularly HTML documents, via HTTP.
- Machines that access information on the Web are known as Web clients. A Web browser is software used by an end user to access the Web.

Hypertext Transport Protocol (HTTP)

- HTTP is based on the request-response communication model:
  - Client sends a request
  - Server sends a response
- HTTP is a stateless protocol:
  - The protocol does not require the server to remember anything about the client between requests.

HTTP

- Normally implemented over a TCP connection (80 is standard port number for HTTP)
- Typical browser-server interaction:
  - User enters Web address in browser
  - Browser uses DNS to locate IP address
  - Browser opens TCP connection to server
  - Browser sends HTTP request over connection
  - Server sends HTTP response to browser over connection
  - Browser displays body of response in the client area of the browser window

HTTP

Send Request {

```
GET / HTTP/1.1
Host: www.example.org
…
```

Receive Response {

```
HTTP/1.1 200 OK
Date: Thu, 09 Oct 2003 20:30:49 GMT
…
```


HTTP Request

- Structure of the request:
  - start line
  - header field(s)
  - blank line
  - optional body

HTTP Request

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HTTP Request

- Start line
  - Example: `GET / HTTP/1.1`
- Three space-separated parts:
  - HTTP request method
  - Request-URI
  - HTTP version

HTTP Request

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  - Example: `GET / HTTP/1.1`
- Three space-separated parts:
  - HTTP request method
  - Request-URI
  - **HTTP version**
    - We will cover 1.1, in which version part of start line must be exactly as shown

HTTP Request

- Start line
  - Example: `GET / HTTP/1.1`
- Three space-separated parts:
  - HTTP request method
  - **Request-URI**
  - HTTP version

HTTP Request

- Uniform Resource Identifier (URI)
  - Syntax: *scheme* : *scheme-depend-part*
    - Ex: In http://www.example.com/ the scheme is `http`
  - Request-URI is the portion of the requested URI that follows the host name (which is supplied by the required Host header field)
    - Ex: `/` is Request-URI portion of `http://www.example.com/`

URI

- URI's are of two types:
  - Uniform Resource Name (URN)
    - Can be used to identify resources with unique names, such as books (which have unique ISBN's)
    - Scheme is `urn`
  - Uniform Resource Locator (URL)
    - Specifies location at which a resource can be found
    - In addition to `http`, some other URL schemes are `https`, `ftp`, `mailto`, and `file`

HTTP Request

- Start line
  - Example: `GET / HTTP/1.1`
- Three space-separated parts:
  - **HTTP request method**
  - Request-URI
  - HTTP version

HTTP Request

- Common request methods:
  - GET
    - Used if link is clicked or address typed in browser
    - No body in request with GET method
  - POST
    - Used when submit button is clicked on a form
    - Form information contained in body of request
  - HEAD
    - Requests that only header fields (no body) be returned in the response

HTTP Request

- Structure of the request:
  - start line
  - **header field(s)**
  - blank line
  - optional body

HTTP Request

- Header field structure:
  - *field name* : *field value*
- Syntax
  - Field name is not case sensitive
  - Field value may continue on multiple lines by starting continuation lines with white space
  - Field values may contain MIME types, quality values, and wildcard characters (*'s)

Multipurpose Internet Mail Extensions (MIME)

- Convention for specifying content type of a message
  - In HTTP, typically used to specify content type of the body of the response
- MIME content type syntax:
  - *top-level type / subtype*
- Examples: text/html, image/jpeg

HTTP Quality Values and Wildcards

- Example header field with quality values:

```
accept:
        text/xml,text/html;q=0.9,
        text/plain;q=0.8,
    image/jpeg,image/gif;q=0.2,
*/*;q=0.1
```

- Quality value applies to all preceding items
- Higher the value, higher the preference
- Note use of wildcards to specify quality 0.1 for any MIME type not specified earlier

HTTP Request

- Common header fields:
  - Host: host name from URL (required)
  - User-Agent: type of browser sending request
  - Accept: MIME types of acceptable documents
  - Connection: value `close` tells server to close connection after single request/response
  - Content-Type: MIME type of (POST) body, normally application/x-www-form-urlencoded
  - Content-Length: bytes in body
  - Referer: URL of document containing link that supplied URI for this HTTP request

HTTP Response

- Structure of the response:
  - status line
  - header field(s)
  - blank line
  - optional body

HTTP Response

- Structure of the response:
  - **status line**
  - header field(s)
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  - optional body

HTTP Response

- Status line
  - Example: HTTP/1.1 200 OK
- Three space-separated parts:
  - HTTP version
  - status code
  - reason phrase (intended for human use)

HTTP Response

- Status code
  - Three-digit number
  - First digit is class of the status code:
    - 1=Informational
    - 2=Success
    - 3=Redirection (alternate URL is supplied)
    - 4=Client Error
    - 5=Server Error
  - Other two digits provide additional information

HTTP Response

- Structure of the response:
  - status line
  - **header field(s)**
  - blank line
  - optional body

HTTP Response

- Common header fields:
  - Connection, Content-Type, Content-Length
  - Date: date and time at which response was generated (required)
  - Location: alternate URI if status is redirection
  - Last-Modified: date and time the requested resource was last modified on the server
  - Expires: date and time after which the client's copy of the resource will be out-of-date
  - ETag: a unique identifier for this version of the requested resource (changes if resource changes)

Client Caching

- A cache is a local copy of information obtained from some other source
- Most web browsers use cache to store requested resources so that subsequent requests to the same resource will not necessarily require an HTTP request/ response
  - Ex: icon appearing multiple times in a Web page

Client Caching

- Validating cached resource:
  - Send HTTP HEAD request and check Last-Modified or ETag header in response
  - Compare current date/time with Expires header sent in response containing resource
  - If no Expires header was sent, use heuristic algorithm to estimate value for Expires

Character Sets

- Every document is represented by a string of integer values (code points)
- The mapping from code points to characters is defined by a character set
- Some header fields have character set values:
  - Accept-Charset: request header listing character sets that the client can recognize
    - Ex: accept-charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
  - Content-Type: can include character set used to represent the body of the HTTP message
    - Ex: Content-Type: text/html; charset=UTF-8

Character Sets

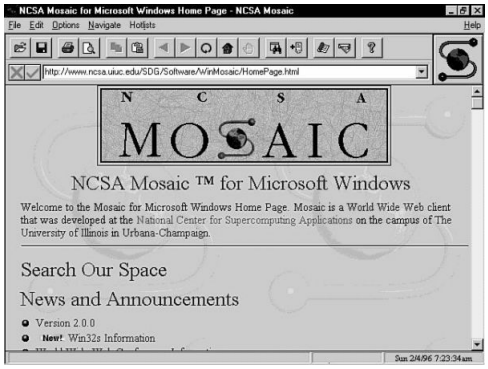
- Technically, many “character sets” are actually character encodings
  - An encoding represents code points using variable-length byte strings
  - Most common examples are Unicode-based encodings UTF-8 and UTF-16
- IANA maintains complete list of Internet-recognized character sets/encodings

Web Clients

- Many possible web clients:
  - Text-only “browser” (lynx)
  - Mobile phones
  - Robots (software-only clients, e.g., search engine “crawlers”)
  - etc.
- We will focus on traditional web browsers

Web Browsers

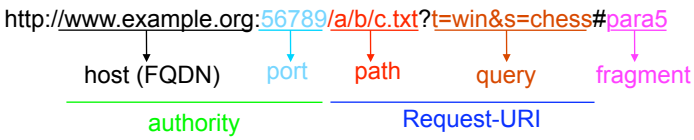
- First graphical browser running on general-purpose platforms: Mosaic (1993)



Web Browsers

- Primary tasks:
  - Convert web addresses (URL's) to HTTP requests
  - Communicate with web servers via HTTP
  - Render (appropriately display) documents returned by a server

HTTP URL's



- Browser uses authority to connect via TCP
- Request-URI included in start line (/ used for path if none supplied)
- Fragment identifier not sent to server (used to scroll browser client area)

Web Browsers

- Additional functionality:
  - Execution of scripts (e.g., drop-down menus)
  - Event handling (e.g., mouse clicks)
  - GUI for controls (e.g., buttons)
  - Secure communication with servers
  - Display of non-HTML documents (e.g., PDF) via plug-ins

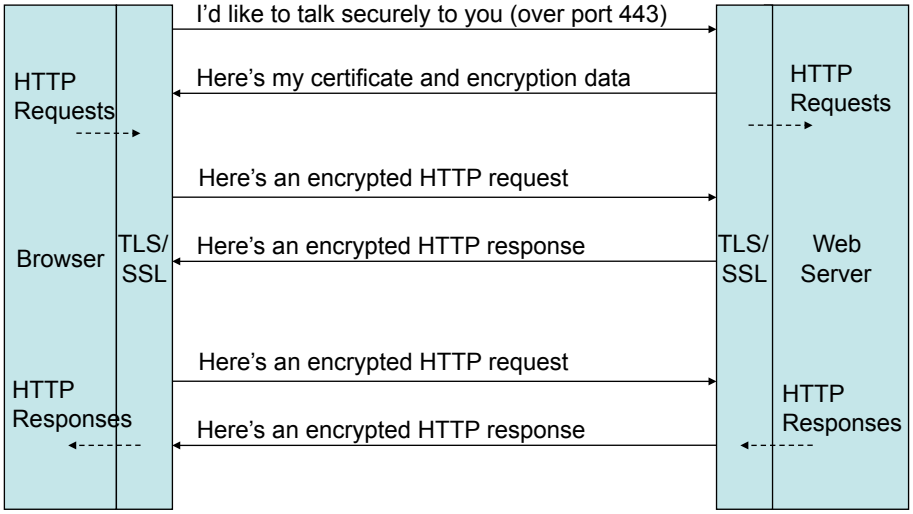
Web Servers

- Basic functionality:
  - Receive HTTP request via TCP
  - Map Host header to specific virtual host (one of many host names sharing an IP address)
  - Map Request-URI to specific resource associated with the virtual host
    - File: Return file in HTTP response
    - Program: Run program and return output in HTTP response
  - Map type of resource to appropriate MIME type and use to set Content-Type header in HTTP response
  - Log information about the request and response

Secure Servers

- Since HTTP messages typically travel over a public network, private information (such as credit card numbers) should be encrypted to prevent eavesdropping
- https URL scheme tells browser to use encryption
- Common encryption standards:
  - Secure Socket Layer (SSL)
  - Transport Layer Security (TLS)

Secure Servers



Explore this material yourself

- Background material via Blackboard
- Lab questions