

CMSE 346 Computer Networks Fall 2022

Applications

Reading: Peterson and Davie, §9.1, 9.3, and selected topics

07/11/2022

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Application-Layer Protocols

- Network applications run on end systems
 - They depend on the network to provide a service
 - ... but cannot run software on the network elements
- Network applications run on multiple machines
 - Different end systems communicate with each other
 - Software is often written by multiple parties
- Leading to a need to explicitly define a protocol
 - Types of messages (e.g., requests and responses)
 - Message syntax (e.g., fields, and how to delineate)
 - Semantics of the fields (i.e., meaning of the information)
 - Rules for when and how a process sends messages

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Application vs. Application-Layer Protocols

- Application-layer protocol is just one piece
 - Defining how the end hosts communicate
- Example: World Wide Web
 - HyperText Transfer Protocol is the protocol used to retrieve web pages from remote servers
 - But the Web includes other components, such as document formats (HTML), Web browsers, servers,...
- Example: electronic mail {see next slide}
 - Simple Mail Transfer Protocol (SMTP) is the protocol used to exchange electronic mail
 - But e-mail includes other components, such as mail servers, user mailboxes, mail readers,...

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E-mail example

User Interface (Application)	e.g.: Outlook Express
Companion protocol	e.g.: RFC822, MIME
Application protocol	e.g.: SMTP

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Traditional application protocols

- **Name service (DNS)** {not an application that users invoke explicitly, but an application that all other applications depend on}
- **Electronic mail (SMTP, MIME)** {used to exchange electronic mail}
- **World wide web (HTTP)** {used to communicate between web browsers and web servers}
- **Network management (SNMP)** {used to query/modify the state of remote network nodes}

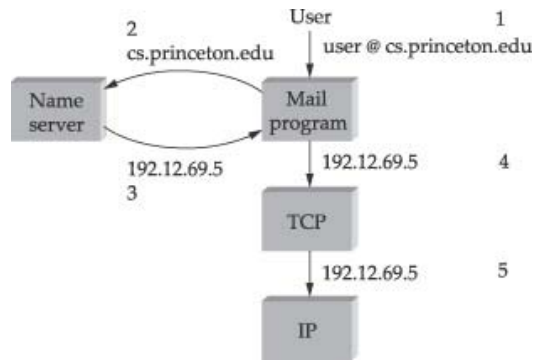
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Name service (DNS)

- Maps user-friendly **names** into router-friendly **addresses**
 - middleware: fills the gap between applications and the underlying network
 - transported using UDP, port number 53
- Host names
 - variable length and mnemonic
 - typically contain no information that helps network to locate the host
- IP addresses
 - fixed-length numeric address
 - may have routing information embedded in them
- Terms:
 - **namespace** = set of possible names, flat or hierarchical
 - naming system maintains a collection of **bindings** of names to values
 - given a name, a **resolution mechanism** returns the corresponding value
 - a **name server** is an implementation of the resolution mechanism
 - DNS (Domain Name System) = name service in Internet

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Example

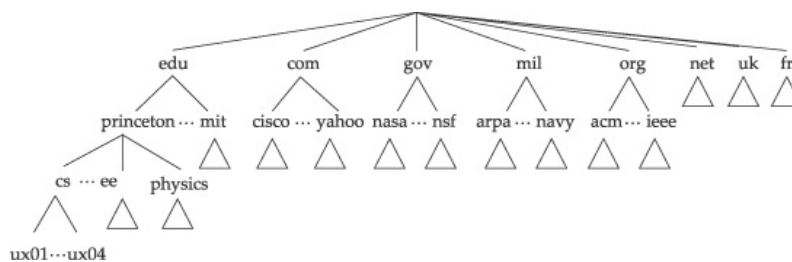


⇒ Application (mail) uses DNS to translate the name into IP address

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DNS domain hierarchy

- First level hierarchy
 - domains for each country + edu, com, gov, mil, org, net
 - DNS first level managed by Internet Corporation for Assigned Names and Numbers (ICANN), also manages address allocations
- Hierarchy is partitioned into subtrees, zones
 - zone corresponds to fundamental implementation unit in DNS (i.e., a name server)



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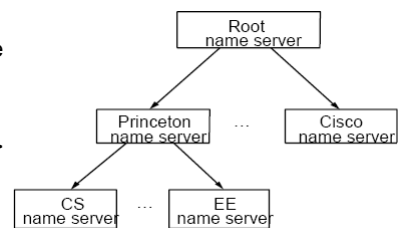
DNS domain hierarchy (cont)

- Zones implemented in two or more name servers (redundancy)
 - clients send queries to name servers
 - servers response with final answer or pointer to another server
- Name binding database consists of resource records
 - format: <Name, Value, Type, Class, TTL>
 - Type: how Value is interpreted,
 - A: means that Value is an IP address, name-address mapping
 - NS: Value contains name for host that knows how to resolve the name
 - CNAME: Value is a canonical name for host, used to define aliases
 - MX: Value gives the domain name for a host running a mail server
 - Class: only widely used class IN (Internet)
 - TTL: how long resource record is valid (used by servers that cache resource records from other servers)
 - can use alias for company web server ⇒ web server to be changed without remote users being affected
 - MX allows administrators to change the mail host without changing user email addresses

DNS domain hierarchy (cont)

- Root name server: NS record for each 2nd level server + A record that translates name into IP address

<princeton.edu, cit.princeton.edu, NS, IN>
 <cit.princeton.edu, 128.196.128.233, A, IN>



- At 2nd level, records contain either final answers or pointer to 3rd level name servers

<cs.princeton.edu, gnat.cs.princeton.edu, NS, IN>
 <gnat.cs.princeton.edu, 192.12.69.5, A, IN> (pair like above)

<jupiter.physics.princeton.edu, 128.196.4.1, A, IN> (final record)

- Lowest level contains final records, aliases for hosts (CNAME) and MX records

Name resolution

- How did the client locate the root server in the first place?
 - name-to-address mapping for one or more name servers is well known (published outside the naming system itself)
 - in practice, client program initialized with the address of a local name server
 - ◊ client makes a query to local server ⇒ local server makes queries further
 - ◊ advantages
 - + only the servers need to know about root name servers
 - + local server gets to see the responses (can cache these)
- Note: Internet has identifiers at 3 levels - domain names, IP addresses, and physical network addresses
 - users give domain names in applications ⇒ applications use DNS to translate these into IP addresses ⇒ IP does forwarding at each router, so it maps IP addresses into another (next hop router) ⇒ IP engages ARP to translate the next hop IP address into a physical address

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Traditional Applications and Protocols

- Traditional = elastic data traffic, without timeliness requirements
- **SMTP**: Simple Mail Transfer Protocol
 - exchange of electronic mail
 - RFC 822 and MIME define the format of email messages
- **HTTP**: HyperText Transport Protocol
 - communication between Web browsers and Web servers
 - HTML specifies the form of the Web pages
- **SNMP**: Simple Network Management Protocol
 - querying (and modifying) the state of remote network nodes
 - MIB (management information base) defines the variables that can be queried

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Electronic mail (SMTP, MIME)

- Mail service consists of
 - a mail reader,
 - a message transfer protocol (SMTP) and
 - ◊ SMTP = Simple Message Transfer Protocol
 - companion protocols RFC 822 (request for comments) & MIME (multipurpose internet mail extensions)
- Mail access protocol: retrieval from server
 - reader programs: Netscape Messenger, Outlook, etc..
 - POP3: Post Office Protocol (RFC 1939)
 - ◊ authorization (agent ↔ server) and download
 - ◊ downloads mails to your own local host
 - IMAP: Internet Mail Access Protocol (RFC 1730)
 - ◊ more features (more complex)
 - ◊ manipulation of inbox and stored messages on server
 - HTTP: Hotmail , Yahoo! Mail, gmail, etc...

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Electronic mail (cont)

- Message format:
 - RFC 822: message has two parts - a header and a body
 - both in ASCII text
 - MIME: extends RFC 822 so that message can contain all sorts of data
 - data still presented as ASCII text
 - ASCII format ⇒ human can pretend to be an smtp client
- Message header:
 - series of <CRLF>-terminated lines (carriage-return + line-feed)
 - separated from message body by blank line
 - each header line contains a Type and a Value separated by a colon
 - To: student@emu.edu.tr
 - Subject: CMPE344

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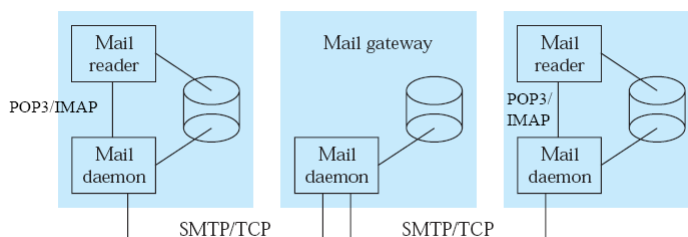
MIME

- Extends RFC 822 to allow email messages to carry audio, video, images, Word documents etc.
- Consists of 3 basic pieces
 - collection of header lines
 - ◇ extend the original set defined in RFC 822
 - ◇ ex. MIME-version, Content-Description, Content-Type, Content-Transfer-Encoding..
 - definitions for a set of content types
 - ◇ ex. image/gif, image/jpeg, text/plain, text/richtext, application/postscript, application/msword
 - a way to encode various data types so that they can be shipped in an ASCII mail message
- base64 coding of binary data into ASCII: map every 3 bytes of the original binary data into 4 ASCII characters

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Message transfer (SMTP)

- E-mail delivery
 - mail reader \Rightarrow message to mail daemon \Rightarrow daemon uses SMTP running over TCP to get message to a daemon in another machine \Rightarrow this daemon puts the message into user's mailbox
 - SMTP uses TCP on port 25
- Mail traverses many mail gateways that store and forward email msgs
 - mail gateway vs. IP router? IP router stores datagrams in memory and tries to retransmit them for a short period of time (fraction of seconds), mail gateway buffer messages on disk and try resending for days



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World Wide Web (HTTP)

- Web is a collection of cooperating clients and servers
 - everyone uses same protocol, HTTP
 - web browser used to open web pages
 - ◊ URL (Uniform Resource Locator) specifies location of object on the web
(e.g., `http://www.emu.edu.tr/index.html`)
 - opening a URL makes the browser open a TCP connection to port 80 to the given location, e.g., `www.emu.edu.tr`, and the file `index.html` would be downloaded to your machine using HTTP over TCP
 - like SMTP, HTTP is a text oriented protocol
- Main ingredients of the Web
 - URL, HTML, and HTTP

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Main Components: URL

- Uniform Resource Identifier (URI)
 - Denotes a resource independent of its location or value
 - A pointer to a “black box” that accepts request methods
- Formatted string
 - Protocol for communicating with server (e.g., `http`)
 - Name of the server (e.g., `www.amazon.com`)
 - Name of the resource (e.g., `textbook.gif`)
- Name (URN), Locator (URL), and Identifier (URI)
 - URN: globally unique name, like an ISBN # for a book
 - URI: identifier representing the contents of the book
 - URL: location of the book

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HTTP and TCP connections

- HTTP version 1.0 made a separate TCP connection for each data item
 - waste of resources, especially when most items are small sized
- HTTP version 1.1 allows persistent connections: client and server can exchange multiple request/response messages over the same TCP connection
 - good:
 - ◇ eliminates the connection setup overhead
 - ◇ client can send multiple request messages \Rightarrow TCP's congestion window mechanism operates more efficiently (not necessary to do slow start for each request)
 - bad:
 - ◇ neither the client nor server knows how long to keep a particular TCP connection open (problem for servers with thousands of connections)
 - ◇ client and server must watch if the other side has elected to close the connection (recall, both sides need to close the TCP connection)

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Caching

- WWW cache = web proxy
- Benefits:
 - pages from nearby cache can be displayed quickly
 - can reduce servers' load
- Implementation at several (hierarchical) layers:
 - in user's browser
 - user's site can support a single sitewide cache (takes advantage of pages previously downloaded by other users)
 - ISPs may have their own caches
- Cache needs to make sure it is not responding with an out-of-date version of the page
 - server may assign an expiration date (Expires header field) to each page
 - HTTP conditional requests by using, i.e., If-Modified-Since message header

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Network Management (SNMP)

- Possible tasks:
 - monitor faulty equipment in the network
 - keep track of the load on various nodes (need for new routers or links?) etc., etc.
- Nodes in the network are distributed \Rightarrow use the network to manage the network
 - need a protocol for reading (and writing) state information on different network nodes
- Simple Network Management Protocol (SNMP)
 - request/reply protocol that supports GET and SET messages
 - runs on top of UDP
 - client program uses SNMP to request information, SNMP server running on a node replies
 - depends on companion specification Management Information Base (MIB) that describes object structure of network elements

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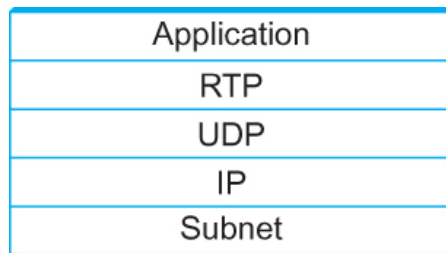
Interactive multimedia applications

- Voice over IP (VOIP)
 - Phone calls over IP
 - Computer to computer
 - Analog phone to/from computer
 - Analog phone to analog phone
- Enabling protocols:
 - RTP: Real-time Transport Protocol
 - RTCP: Real-time Transport Control Protocol
 - SIP: Session Initiation Protocol

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RTP

- An end-to-end protocol used by multimedia applications that have real-time constraints



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SIP

- An application layer protocol
 - Determines the correct device with which to communicate to reach a particular user
 - Determines if the user is willing to or able to take part in a particular communication
 - Determines the choice of media and coding scheme to use
 - Establishes session parameters (e.g., port numbers)

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Streaming multimedia applications

- Streaming applications deliver audio/video streams from a server to a client
- No human-to-human interaction: Less stringent real-time requirements
- Enabling protocols: RTP (and RTCP) and HTTP
- YouTube (streaming stored audio/video)
- Q: Why is UDP not suitable as a transport protocol for streaming applications?
- Q: Why is TCP not suitable for real-time multimedia communications?

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Peer-to-Peer (P2P) applications

- Unlike traditional applications, P2P applications are not based on client-server architecture
- Pairs of intermittently connected hosts, called peers, communicate directly with each other
- File distribution (BitTorrent), file sharing (Gnutella)

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