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Tiered Computing Styles

- A tiered system is considered to contain a number of tiers of computation which combine to offer service to an ultimate consumer.
- Each tier acts as a server for its caller and as a client for the next tier in the architecture. A key principle is that a tier can communicate in this way only with the tiers immediately on either side of it and is not aware of the existence of other tiers.

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Common Tiers in Enterprise Information Systems

- Presentation Layer (user interface)
- Business Process (combining a sequence of business transactions into a service)
- Business Transactions (The fundamental business operations in the system that act on the business entities)
- Data Access (Providing governed access to business entities)
- Data Storage (The databases in which the enterprises data resides)

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Common Tiers in Enterprise Information Systems

- Advantages: This style allows clear separation of concerns between tiers and provides the potential for reusability of the simpler tiers (data storage, data access and business transactions) across a number of systems
- Disadvantages: include the overhead of communication between the tiers and additional development complexity arising from the number of system elements that need to be developed and integrated across tiers

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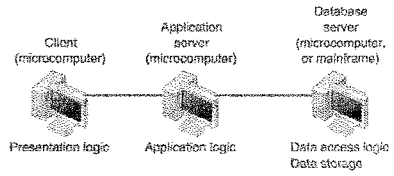
Examples of Client Server Styles

Client Based Computing (3-Tier)



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Multi-Processor Architecture

- Involve more than two computers in distributing application program logic
  - 2-processor architecture
    - Uses clients and servers in a balance, very popular approach in simple LANs
  - 3-processor architecture
    - 3 sets of computers involved
  - N-tier architecture
    - More than three sets of computers used, more typical across complex organizations
    - Allows load balancing across servers

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Multi-Processor Architectures

- Advantages
  - Better load balancing:
    - More evenly distributed processing. (e.g., application logic distributed between several servers.)
  - More scalable:
    - Only servers experiencing high demand need be upgraded
- Disadvantages
  - Heavily loaded network:
    - More distributed processing necessitates more data exchanges
  - Difficult to program and test due to increased complexity

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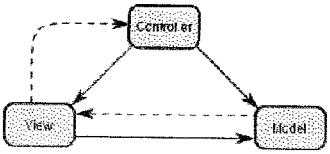
Other Architectural Styles

- Model – View – Controller:



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Model – View – Controller Architecture:

The Model is used to manage information and notify observers when that information changes. The model is the domain-specific representation of the data upon which the application operates.

The View renders the model into a form suitable for interaction, typically a user interface element. Multiple views can exist for a single model for different purposes. A viewport typically has a one to one correspondence with a display surface and knows how to render to it.

The **Controller** receives input and initiates a response by making calls on model objects. A controller accepts input from the user and instructs the model and viewport to perform actions based on that input.

An MVC application may be a collection of model/view/controller triads, each responsible for a different UI element.

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Other Architectural Styles

- Layered Implementation: The style organizes a system's implementation into a stack of layers with each layer providing a service to the layer above it and requesting services from the one below it. The layers are ordered by the degree of abstraction they represent.
- The top of the stack is the most abstract (organization-specific operations) and the bottom of the stack is the least abstract (operating system-specific libraries).

Communication stacks are classic examples of layered organization.

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Criteria for Choosing Architecture

- Infrastructure Cost
  - Cost of servers, clients, and circuits
  - Mainframes: very expensive; terminals, PCs: inexpensive
- Development Cost
  - Mainly cost of software development
  - Software: expensive to develop; off-the-shelf software: inexpensive
- Scalability
  - Ability to increase (or decrease) in computing capacity as *network demand changes*
  - Mainframes: not scalable?; PCs: highly scalable?

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Lecture 4

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Application Layer Examples

- Web Browser
- E-mail
- File Transfer
- Videoconferencing
- Instant Messaging

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Web Browser

- Web began with two innovative ideas:
  - Hypertext
    - A document containing links to other documents
  - Uniform Resource Locators (URLs)
    - A formal way of identifying links to other documents
- Invention of WWW (1989)
  - By Tim Berners-Lee at CERN in Switzerland
- First graphical browser, Mosaic, (1993)
  - By Marc Andressen at NCSA in USA; later founded Netscape

CERN - Conseil Européen pour la Recherche Nucléaire (Berners-Lee, T. (2000) Weaving the Web. New York: HarperCollins. P. 4)
NCSA - National Center for Supercomputing Applications

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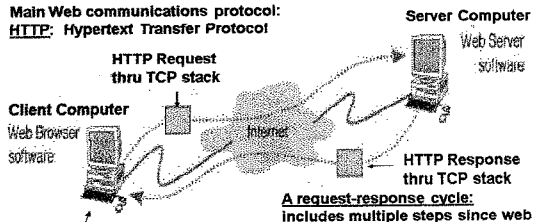
How the Web Works



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HTTP Characteristics

- HTTP is a networking protocol for distributed, collaborat hypermedia information systems.
- HTTP functions as a request-response protocol in the cl computing model.

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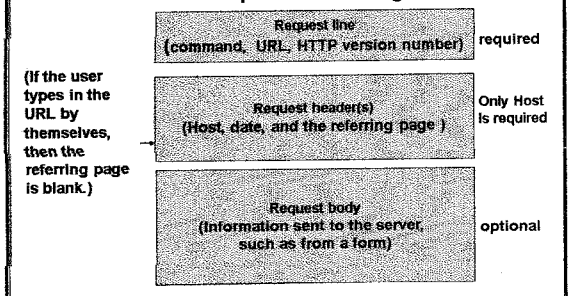
HTTP/1.1 Request Message



RFC 2616 from working group of IETF has 1.1 spe

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Example of Request Commands

- HEAD
  Asks for the response identical to the one that would correspond to a GET request, but without the response body. This is useful for retrieving meta-information written in response headers, without having to transport the entire content.
- GET
  Requests a representation of the specified resource. Note that GET should not be used for operations that cause side-effects, such as using it for taking actions in web applications. One reason for this is that GET may be used arbitrarily by robots or crawlers, which should not need to consider the side effects that a request should cause.
- POST
  Submits data to be processed (e.g., from an HTML form) to the identified resource. The data is included in the body of the request. This may result in the creation of a new resource or the updates of existing resources or both.
- PUT
  Uploads a representation of the specified resource.
- DELETE
  Deletes the specified resource.
- TRACE
  Echoes back the received request, so that a client can see what (if any) changes or additions have been made by intermediate servers.
- OPTIONS
  Returns the HTTP methods that the server supports for specified URL. This can be used to check the functionality of a web server by requesting '*' instead of a specific resource.
- CONNECT
  Converts the request connection to a transparent TCP/IP tunnel, usually to facilitate SSL-encrypted communication (HTTPS) through an unencrypted HTTP proxy.
- PATCH
  Is used to apply partial modifications to a resource.

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Example of an HTTP Request

GET /default.htm HTTP/1.1\r\n	Request Line
Host: rhynoru\r\n	Mandatory header line
Accept: */*\r\n \r\n	Optional Header Info
	Optional body Info

Note that this HTTP Request message has no "Body" part.

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HTTP/1.1 Response Message

Response status (http version number, status code, reason)	**required**
Response header (Date, information on the server, URL of the page retrieved, format used)	**Date is mandatory**
Response body (requested web page)	**optional**

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HTTP/1.1 200 OK\r\n	Response line Mandatory
Content-Length: 50\r\n Content-Type: text/html\r\n Last-Modified: Sun, 20 Oct 2002 22:52:16 GMT\r\n Accept-Ranges: bytes\r\n ETag: "255591568b78c21:5cd"\r\n Server: Microsoft-IIS/6.0\r\n MicrosoftOfficeWebServer: 5.0_Pub\r\n X-Powered-By: ASP.NET\r\n Date: Sun, 20 Oct 2002 22:52:35 GMT\r\n \r\n	Response Header Mandatory
<HTML>\r\n <BODY>\r\n \r\n Hello World.\r\n \r\n </BODY>\r\n </HTML>	Response Body

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HTTP Response Status Codes

- Success 2XX
  eg: OK 200, Created 201,
- Redirection 3XX
  eg: Moved 301
- Error 4XX, 5XX
  eg: Bad request 400, Unauthorized 401, Not Found 40
  Internal Error 500, Service temporarily overloaded

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HTML - Hypertext Markup Language

- A protocol used to format Web pages
- Also developed at CERN (initially for text files)
- *Tags are embedded in HTML documents*
  - include information on how to format the file
- Extensions to HTML needed to format multimedia files
- XML - Extensible Markup Language
  - A new markup language becoming popular

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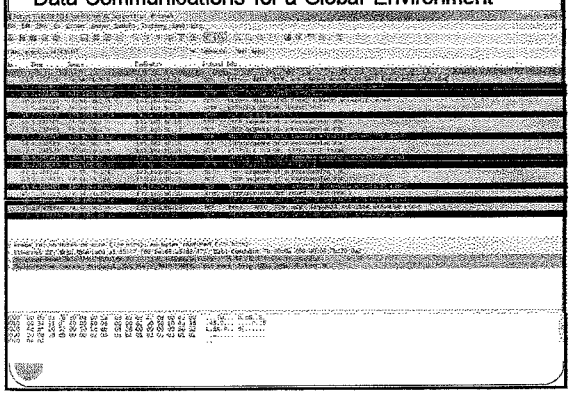

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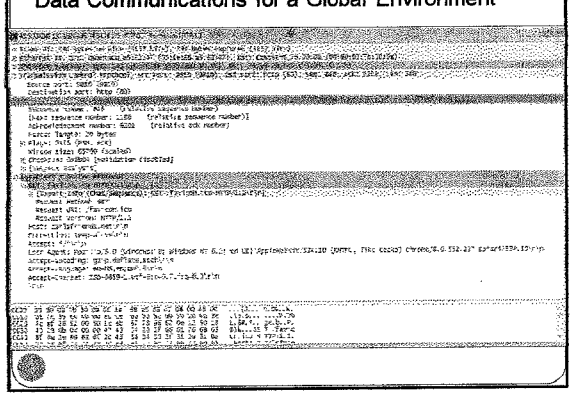

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E-mail Standards

- SMTP - Simple Mail Transfer Protocol (push protocol)
  - Main e-mail standard for
    - Originating user agent and the mail transfer agent
    - Between mail transfer agents
  - Originally written to handle only text files
  - Usually used in two-tier client-server architectures
- Post Office Protocol (POP) and Internet Mail Access Protocol (IMAP)
  - Main protocols used between the **receiver** user agent and mail transfer agent
  - Main difference: with IMAP, messages can be left at the server after downloading them to the client

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Two-Tier E-mail Architecture

- *User agent* is another word for an e-mail client application
  - Run on client computers
  - Send e-mail to e-mail servers
  - Download e-mail from mailboxes on those servers
  - Examples: Eudora, Outlook, Netscape Messenger
- *Mail transfer agent* is another word for the mail server application
  - Used by e-mail servers
  - Send e-mail between e-mail servers
  - Maintain individual *mailboxes*.

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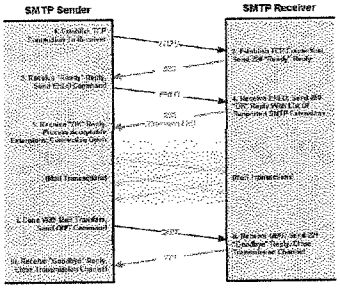
SMTP Transaction Session Establishment and Termination



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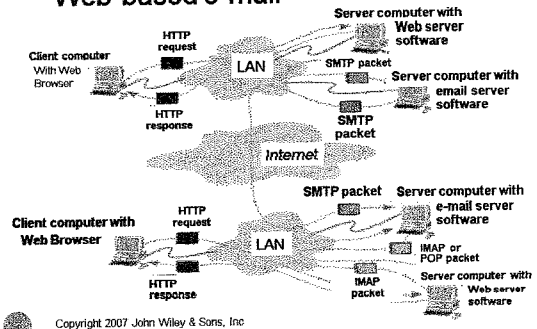
Web-based e-mail



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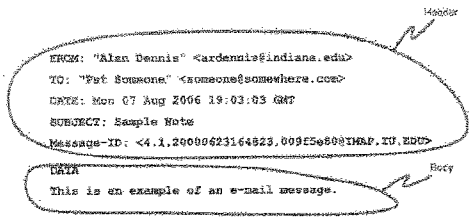
Sample SMTP Message



Note that this SMTP message has no attachments.

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MIME

- Multipurpose Internet Mail Extension
  - A graphics capable mail transfer agent protocol (to send graphical information in addition to text)
    - SMPT was designed years ago for text transfer only
  - MIME software is included as part of an e-mail client
  - Translates graphical information into text allowing the graphic to be sent as part of an SMTP message (as a special attachment)
  - Receiver's e-mail client then translates the MIME attachment from text back into graphical format

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Electronic Mailing Lists/eg: Listserv

- Mailing lists of users who join to discuss some special topic (e.g., cooking, typing, networking)
- Some permit any member to post messages, some are more restricted
- Parts of listserv
  - Listserv Processor
    - Process commands (subscriptions, etc,)
  - Listserv Mailer
    - Receive a message and resend it to everyone
- To subscribe
  - Send an email to Listserv processor (address of the processor is different than the address of mailer)

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File Transfer Protocol (FTP)

- Enables sending and receiving files over the Internet
- Requires an application program on the client computer and a FTP server program on a server
- Commonly used today for uploading web pages
- Many packages available using FTP
  - WS-FTP (a graphical FTP software)
- FTP sites
  - Closed sites
    - Requires account name and password
  - Anonymous sites
    - Account name: *anonymous*; password: *email address*

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Telnet

- Allows one computer to log into another computer
  - Remote login enabling full control of the host
- Requires an application program on the client computer and a Telnet server program on the server
  - Client program emulates a "dumb" terminal off the server
- Many packages available conforming Telnet
  - EWAN
- Requires account name and password
  - Anonymous sites similar to FTP approach
    - Account name: *anonymous*; password: *email address*

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Internet Protocol Suite

Application Layer

BGP · DHCP · DNS · FTP · HTTP · IMAP · IRC · LDAP · MGCP · NNTP · NTP · POP · RIP · RPC · RTP · SIP · SMTP · SNMP · SSH · Telnet · TLS/SSL · XMPP · (more)

Transport Layer

TCP · UDP · DCCP · SCTP · RSVP · ECN · (more)

Internet Layer

IP (IPv4, IPv6) · ICMP · ICMPv6 · IGMP · IPsec · (more)

Link Layer

ARP/InARP · NDP · OSPF · Tunnels (L2TP) · PPP · Media Access Control (Ethernet, DSL, ISDN, FDDI) · (more)

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Instant Messaging (IM)

- A client-server program that allows real-time typed messages to be exchanged
  - Client needs an IM client software
  - Server needs an IM server package
- Some types allow voice and video packets to be sent
  - Like a telephone
- Examples include AOL and ICQ
- Two step process:
  - Telling IM server that you are online
  - Chatting

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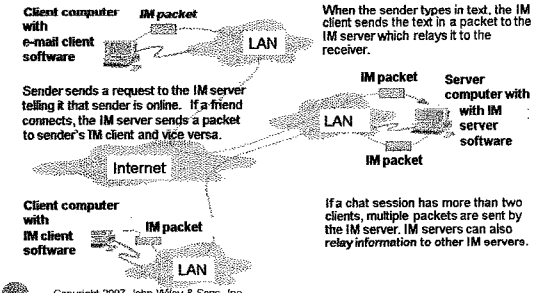
How Instant Messaging Works



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Videoconferencing

- Provides real time transmission of video and audio signals between two or more locations
  - Allows people to meet at the same time in different locations
  - Saves money and time by not having to move people around
  - Typically involves matched special purpose rooms with cameras and displays
- Desktop videoconferencing
  - Low cost application linking small video cameras and microphones together over the Internet
  - No need for special rooms
  - Example: Net Meeting software on clients communicating through a common videoconference server

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Videoconferencing Standards

- Proprietary early systems
- Common standards in use today
  - H.320
    - Designed for room-to-room videoconferencing over high-speed phone lines
  - H.323
    - Family of standards designed for desktop videoconferencing and just simple audio conferencing over Internet
  - MPEG-2
    - Designed for faster connections such as LAN or privately owned WANs

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Webcasting

- Special type of uni-directional videoconferencing
  - Content is sent from the server to users
- Process
  - Content created by developer
  - Downloaded as needed by the user
  - Played by a plug-in to a Web browser
- No standards for webcasting yet
  - Defacto standards: products by RealNetworks

Data Communications for a Global Environment

Implications for Management

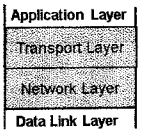
- Network may be used to provide a worry-free environment for applications
  - Network is the critical infrastructure over which the wide variety of strategic applications enable an organization to compete in its environment
  - The applications running on the network have the potential for changing the organization
- Dramatic increase in number and type of applications
  - Rapid growth in amount and type of networking traffic over time
    - Different implication on network design and management
    - *Increased operating cost for the network function*
    - Security

Data Communications for a Global Environment

Lecture 6

Data Communications for a Global Environment

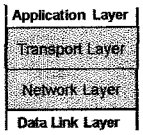
Introduction



- Transport and Network layers
  - Responsible for moving messages from end-to-end in a network
  - Closely tied together
  - TCP/IP: most commonly used protocol
    - Used in Internet
    - Compatible with a variety of Application Layer protocols as well as with many Data Link Layer protocols

Data Communications for a Global Environment

Introduction



TCP/IP is often used in a variety of contexts. It does not imply that TCP and IP are the only protocols functioning in the Transport and Network layers

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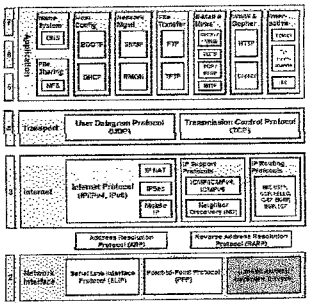
Other Protocols associated with the TCP/IP stack



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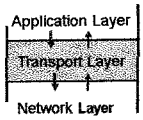
Introduction - Transport layer



- **Multiplexing and Demultiplexing:** transport layer protocols on a sending device *multiplex* the data received from many application programs for transport, combining them into a single stream of data to be sent.
- **Segmentation, Packaging and Reassembly:** The transport layer segments the large amounts of data it sends over the network into smaller pieces on the source machine, and then reassemble them on the destination machine.
- **Connection Establishment, Management and Termination:** Transport layer connection-oriented protocols are responsible for the series of communications required to establish a connection, maintain it as data is sent over it, and then terminate the connection when it is no longer required.

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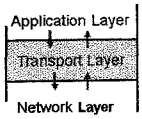
Introduction - Transport layer



- **Acknowledgments and Retransmissions:** The transport layer is where many protocols are implemented that guarantee reliable delivery of data. This is done using a variety of techniques, most commonly the combination of *acknowledgments* and *retransmission timers*.
- **Flow Control:** Transport layer protocols that offer reliable delivery also often implement *flow control* features. These features allow one device in a communication to specify to another that it must "throttle back" the rate at which it is sending data, to avoid bogging down the receiver with data.

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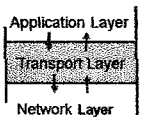

- Identifying the Applications
  - Software Applications are identified by the assignment of Port Numbers.
  - The assignment of Port Numbers is managed by the Internet Assigned Numbers Authority (IANA) and they periodically publish updated lists of common TCP/IP applications and assigned well known and registered Port numbers.

note: the server always uses the standardized port number while the client uses ephemeral or (temporary) port numbers.

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- TCP/IP Applications and common Port numbers

Port #	TCP/UDP	Protocol Abbreviation	Application or Protocol Name
7	TCP/UDP	n/a	Echo Protocol
9	TCP/UDP	n/a	Discard Protocol
11	TCP/UDP	n/a	Active Users Protocol
20	TCP	FTP (data)	File Transfer Protocol – data
21	TCP	FTP (control)	File Transfer Protocol – control
23	TCP	n/a	Telnet Protocol
25	TCP	SMTP	Simple Mail Transport Protocol
53	TCP/UDP	DNS	Domain Name Server
80	TCP	HTTP	Hypertext Transfer Protocol
110	TCP	POP3	Post Office Protocol
143	TCP	IMAP	Internet Access Message Protocol
161	UDP	SNMP	Simple Network Management Protocol
443	TCP	HTTP over SSL	Hypertext Transfer Protocol

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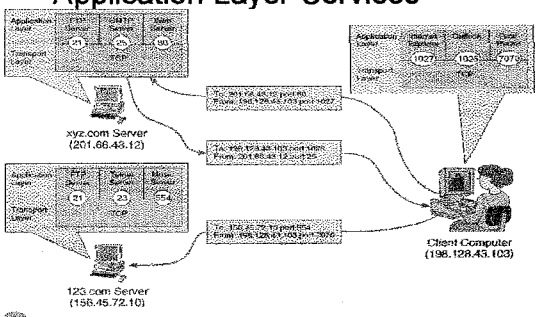
Application Layer Services



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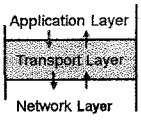
Introduction - Transport layer



•TCP Characteristics

Connection-Oriented: TCP requires that devices first establish a connection with each other before they send data. The connection creates the equivalent of a circuit between the units, and is analogous to a telephone call. A process *of negotiation occurs to establish the connection, ensuring that both devices* agree on how data is to be exchanged.

Bidirectional: Once a connection is established, TCP devices send data bidirectionally. Both devices on the connection can send and receive, regardless of which of them initiated the connection.

Multiply-Connected and Endpoint-Identified: TCP connections are identified by the pair of sockets used by the two devices in the connection. This allows each device to have multiple connections opened, either to the same IP device or different IP devices, and to handle each connection

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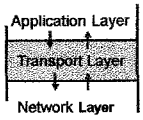
Introduction - Transport layer



•TCP Characteristics (cont'd)

Reliable: Communication using TCP is said to be *reliable* because TCP keeps track of data that has been sent and received to ensure it all gets to its destination. As we saw in the previous topic, TCP can't really "guarantee" that data will always be received. However, it *can* guarantee that all data sent will be checked for reception, and checked for data integrity, and then retransmitted when needed. So, while IP uses "best effort" transmissions, you could say TCP *tries harder*, as the old rent-a-car commercial goes.

Acknowledged: A key to providing reliability is that all transmissions in TCP are acknowledged (at the TCP layer—TCP cannot guarantee that all such transmissions are received by the remote application). The recipient must tell the sender "yes, I got that" for each piece of data transferred. This is in stark contrast to typical messaging protocols where the sender never knows what happened to its transmission. As we will see, this is fundamental to the operation of TCP as a whole.

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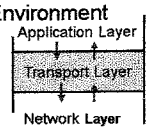
Introduction - Transport layer



•TCP Characteristics (cont'd)

Stream-Oriented: Most lower-layer protocols are designed so that to use them, higher-layer protocols must send them data in blocks. IP is the best example of this; you send it a message to be formatted and it puts that message into a datagram. UDP is the same. In contrast, TCP allows applications to send it a continuous stream of data for transmission. Applications don't need to worry about making this into chunks for transmission; TCP does it.

Data-Unstructured: An important consequence of TCP's stream orientation is that there are no natural divisions between data elements in the application's data stream. When multiple messages are sent over TCP, applications must provide a way of differentiating one message (data element, record, etc.) from the next.

Data-Flow-Managed: TCP does more than just package data and send it as fast as possible. A TCP connection is *managed* to ensure that data flows evenly and smoothly, with means included to deal with problems that arise along the way.

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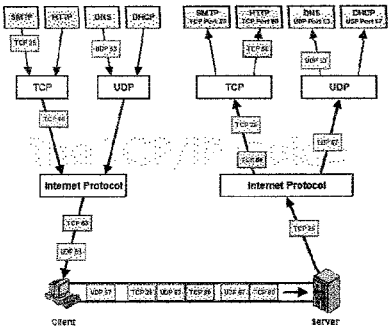
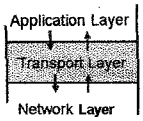
TCP/IP multiplexing using TCP/UDP ports



Data Communications for a Global Environment

Introduction - Transport layer



- Establishing the connection to a remote Host
  ***Connection Oriented* is provided by TCP**
  Setting up a virtual circuit, or a TCP connection
  TCP asks IP to route all packets in a message by using the same path (from source to destination)
  Packet deliveries are acknowledged
  Used by HTTP, SMTP, FTP
  This is also know as a reliable protocol. With TCP the Transport layer can ensure that all pieces reach their destination by having the source device to retransmit any data that is lost.

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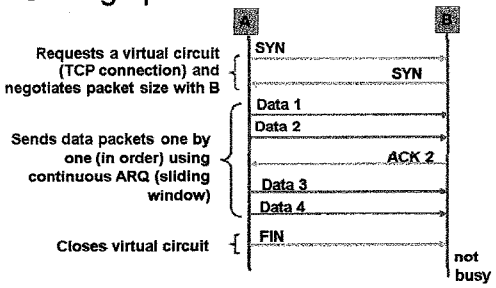
Setting up Virtual Connections



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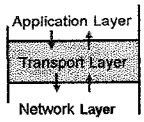
Introduction - Transport layer



- Establishing the connection to a remote Host
  ***Connectionless communication* is provided by UDP**

  Sending packets individually without a virtual circuit
  Each packet is sent independently of one another, and will be routed separately, following different routes and arriving at different times

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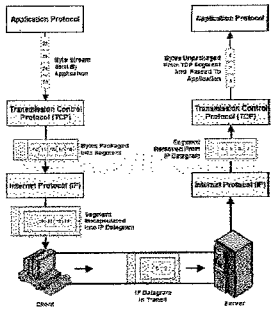
TCP/IP a more realistic model



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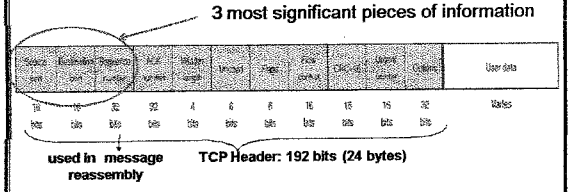
TCP Message Header



Routing Connectivity by Transport Layer

- *Connection Oriented* is provided by TCP
  - Setting up a virtual circuit, or a TCP connection
    - TCP asks IP to route all packets in a message by using the same path (from source to destination)
    - Packet deliveries are acknowledged
    - Used by HTTP, SMTP, FTP
- *Connectionless Routing* is provided by UDP
  - Sending packets individually without a virtual circuit
  - Each packet is sent independently of one another, and will be routed separately, following different routes and arriving at different times
- QoS Routing (provided by RTP)
  - A special kind connection oriented routing with priorities

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UDP - User Datagram Protocol

- Protocol used for connectionless routing in TCP/IP suite that uses no acks, no flow control
- Uses only a small packet header
  - Only 8 bytes containing only 4 fields:
    - Source port
    - Destination port
    - Message length
    - Header checksum
- Commonly used for control messages that are usually small, such as DNS, DHCP, RIP and SNMP.
- Can also be used for applications where a packet can be lost, such as information rich video

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QoS - Quality of Service

- QoS parameters - Bandwidth, End to End delay, Jitter and Packet Loss.
- Bandwidth – is the avg numbers of bits per second that travel successfully through the network measured in Kbps or Mbps.
- End to End delay – is the avg time it takes for a network packet to traverse the network from one endpoint to another.
- Jitter - is the variation in E to E delay of sequential packets
- Packet Loss - % of transmitted packets that never reach the the destination.

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QoS - Quality of Service

The three fundamental QoS enablers are:

- Network Provisioning – providing more bandwidth than required.
- Queuing – pertains to transmission buffers in network switches and routers.
- Classifying – is a packet classifying or prioritization scheme
  - Resource Reservation (RSVP)
  - IP Precedence, Differentiated Services (DiffServ)
  - Multiple Protocol Label Switching (MLPS)

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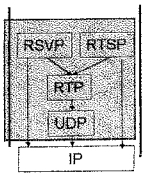
Protocols Supporting QoS



- Asynchronous Transfer Mode (ATM)
  - A high-speed data link layer protocol
- TCP/IP protocol suite
  - Resource Reservation Protocol (RSVP)
    - Sets up virtual circuits for general purpose real-time applications
  - Real-Time Streaming Protocol (RTSP)
    - Sets up virtual circuits for audio-video applications
  - Real-Time Transport Protocol (RTP)
    - Used after a virtual connection setup by RSVP or RTSP
    - Adds a sequence number and a timestamp for helping applications to synchronize delivery
    - Uses UDP (because of its small header) as transport

Lecture 8

Two Primary Network Layer Functions

- Addressing
  - Each piece of equipment on the path between source and destination must have a unique address
  - Assignment of addresses
  - Translation between network layer addresses and other addresses (address resolution)
- Routing
  - Process of deciding what path a packet must take to reach destination
  - Routing protocols

Internet Protocol (IP)

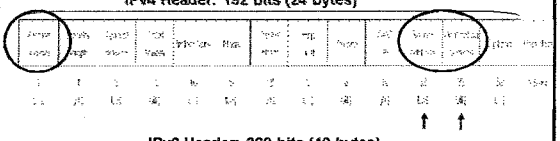
- Two versions of Addressing in current in use
  - IPv4: a 192 bit (24 byte) header, uses 32 bit addresses.
  - IPv6: Mainly to increase IP address space due to the huge growth in Internet usage (128 bit addresses)
- Both versions have a variable length data field
  - Max size depends on the data link layer protocol.
  - e.g., Ethernet's max message size is 1,492 bytes, so max size of TCP message field:

1492 – 24 – 24 = 1444 bytes

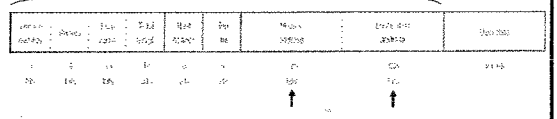
TCP header IPv4 header

IP Packet Formats

IPv4 Header: 192 bits (24 bytes)



IPv6 Header: 320 bits (40 bytes)



Types of Addresses used in the Internet

Address Type	Example	Example Address	Analogy
Application Layer	URL	www.manhattan.edu	Name
Network Layer	IP address	149.61.10.22 (4 bytes)	Street #
Data Link Layer	MAC address	00-0C-00-F5-03-5A (6 bytes)	Apt #

- These addresses must be translated from one type to another for a message to travel from sender to receiver.
- This translation process is called address resolution.
- It is like knowing that you want to talk to John Smith, but you have to use the phone book to find his address and phone number.

Address Resolution

- Server Name Resolution
  - Translating destination host's domain name to its corresponding IP address
    - is resolved to → 204.71.200.74
  - Uses one or more Domain Name Service (DNS) servers to resolve the address
- Data Link Layer Address Resolution
  - Identifying the MAC address of the next node (that packet must be forwarded to)
  - Uses Address Resolution Protocol (ARP)

Assignment of Addresses within a Network or Organization

- Application Layer address (URL)
  - For servers only (clients don't need it)
  - Assigned by network managers and placed in configuration files.
  - Some servers may have several application layer addresses
- Network Layer Address (IP address)
  - Assigned by network managers, or by programs such as DHCP, and placed in configuration files
  - Every network on the Internet is assigned a range of possible IP addresses for use on its network
- Data Link Layer Address (MAC address)
  - Unique hardware addresses placed on network interface cards by their manufacturers (based on a standardized scheme)
- Servers have permanent addresses, clients usually do not

Dynamic Addressing

- **Giving addresses to clients (automatically) only when they are logged in to a network**
  - Eliminates permanent addresses to clients
  - When the computer is moved to another location, its new IP address is assigned automatically
  - Makes efficient use of IP address space
  - Example:
    - A small ISP with several thousands subscribers
    - Might only need to assign 500 IP addresses to clients at any one time
- **Uses a server to supply IP addresses to computers whenever the computers connect to network**

Programs for Dynamic Addressing

- Bootstrap Protocol (bootp)
- Dynamic Host Control Protocol (DHCP)
- Different approaches, but same basic operations:
  - A program residing in a client establishes connection to bootp or DHCP server
  - A client broadcasts a message requesting an IP address (when it is turned on and connected)
  - Server (maintaining IP address pool) responds with a message containing IP address (and its subnet mask)
  - IP addresses can also be assigned with a time limit (leased IP addresses)
    - When expires, client must send a new request

Programs for Dynamic Addressing

- Dynamic Host Control Protocol (DHCP) operates in four steps:
  - Discovery (Broadcast)
  - Offers (Lease duration, IP address, subnet mask, Client MAC address, IP address of DHCP that issued the message)
  - Requests (Broadcast)(If the information is received and accepted)
  - Acknowledgements (The server acknowledges the receipt of the request and sends back lease info and other data client may have requested

IPv4 Addresses

- 4 byte (32 bit) addresses
  - Strings of 32 binary bits
- Dotted decimal notation
  - Used to make IP addresses easier to understand for human readers
  - Breaks the address into four bytes and writes the digital equivalent for each byte

IPv6 Addressing

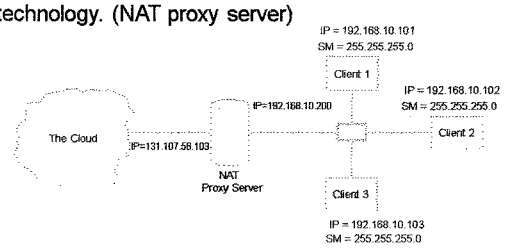
IPv6 uses 16 byte addresses:

- 3.2×10^{38} addresses, a very large number
- Little chance this address space will ever be used up

For IPv4, this pool is 32-bits (232) in size and contains 4,294,967,296 IPv4 addresses.

The IPv6 address space is 128-bits (2128) in size, containing 340,282,366,920,938,463,463,374,607,431,768,211,456 IPv6 addresses.

Private IP addressing can provide additional IP addresses by using Network Address Translation technology. (NAT proxy server)



Other IP Exceptions

The first Octet cannot be 127. This is reserved for Diagnostics
127.0.0.1 is the loopback address.

The Host ID's cannot be all 0's or all 255's
All 0's is the Network ID
All 255's is the Broadcast ID

How do we know what part is which?

32 Bit Address

130.160.86.246

Network ID Host ID

The Subnet Mask

A subnet mask is a way to tell which portion of the IP address defines the Network ID and which portion defines the Host ID.

The IP address is always paired with its Subnet mask.

The Subnet Mask shows where the separation line is.

130.160.86.246

Network ID 255.255.255.0 Host ID

Every IP address will have a subnet mask it is not an option.

Subnetting

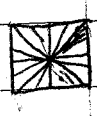
Subnetting is the process of taking a large network and dividing it into a smaller network.

- Performance
- Common shared resources or data

Test 1 Post-Review 2/17/2011

3) communicating with adjacent layers

- Command, Host, Body (optional)
- thin client email sending — HTTP (Gmail)
  - fat " " " — SMTP (Outlook)
- UDP — User Datagram Protocol
- connectionless
  - link state takes into account traffic congestion and the number of hops



standard
~~client~~ on server end
ephemeral " application end