Networking

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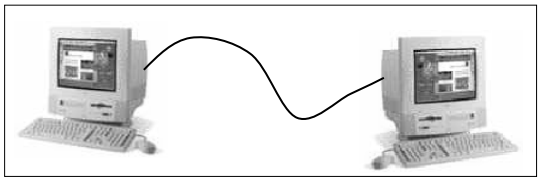
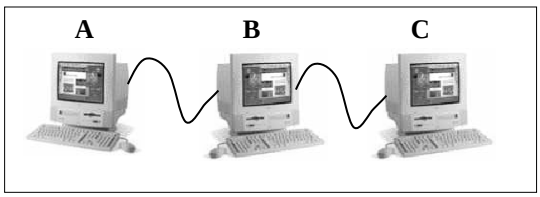
Types of computer networks:

- Point-to-point connection (link) between two computers



e.g. PPP, SLIP

- Store-and-forward transmission: packets



e.g. token ring

- Datagram packet switching: destination address in packet
- also, LAN, WAN, ATM (virtual circuit switching)

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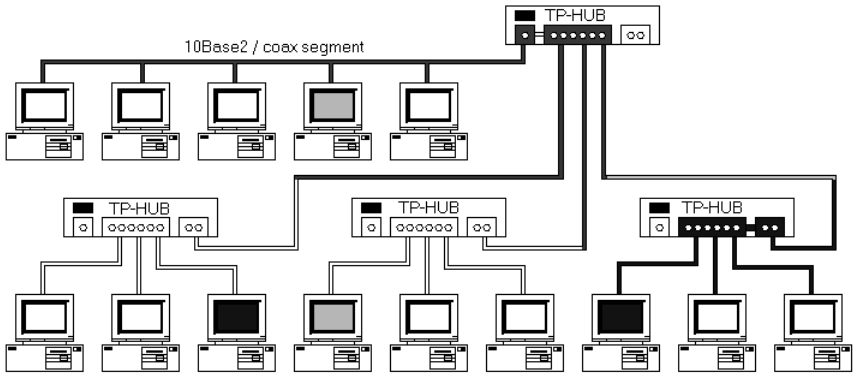
• multiple access networks (e.g. ALOHA, Ethernet)



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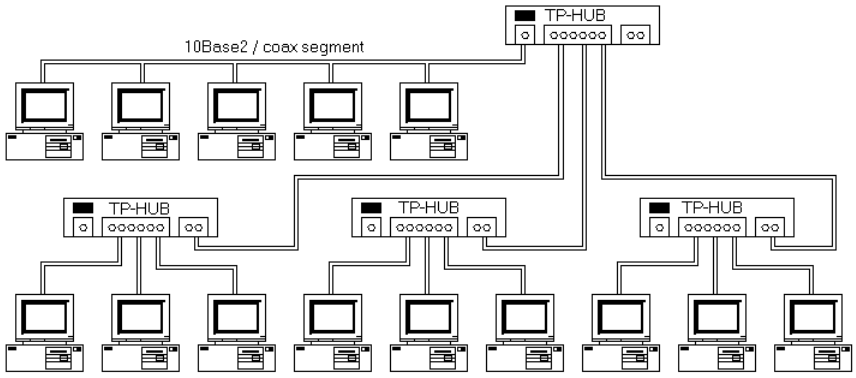

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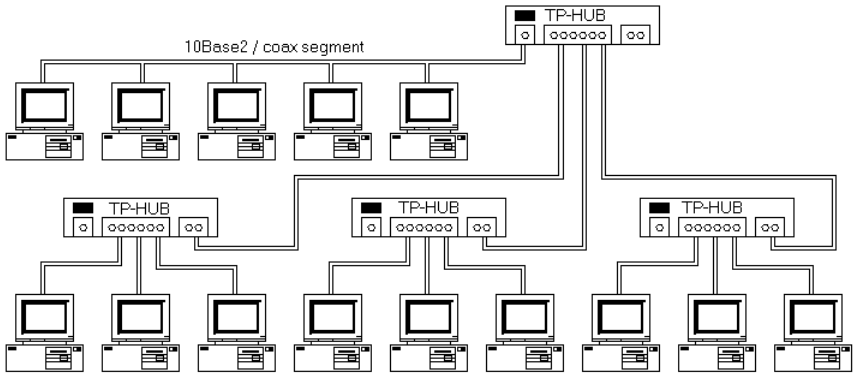
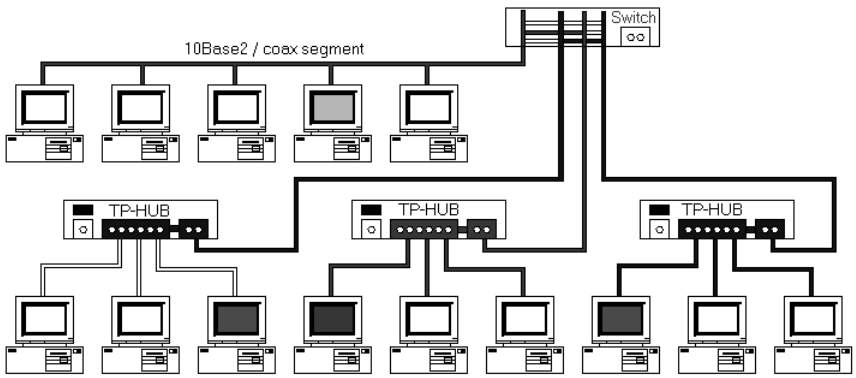
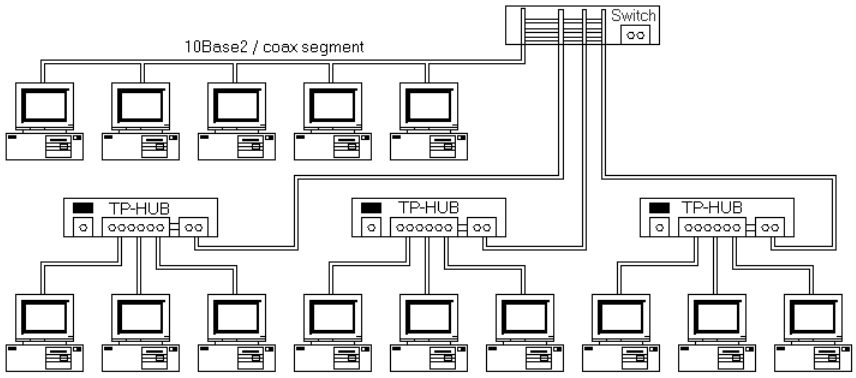

TP-HUB
10Base2 / coax segment
TP-HUB
TP-HUB
TP-HUB

5


Switch
10Base2 / coax segment
TP-HUB
TP-HUB
TP-HUB

6



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Review of components

- Hosts
  - Considered a “node” or “end point” in the network (client/server/printer)
  - Processes all levels of the protocol stack
- Hubs
  - acts as an “extender” - similar in effect to taking all incoming lines and twisting the wires together
  - Does not do any processing - acts only at the physical layer
- Bridges
  - attaches two physically identical LANs together, physical layer processing
  - forwards only traffic which is destined for “the other side”
- Switches
  - depending on level of switch complexity, anywhere from a hub to a router
- Routers
  - Processing at the Network layer
  - Route packets between networks with potentially different lower level protocol stacks (i.e., different physical and data link layers)
- Gateways
  - Processes all levels of the protocol stack
  - Used to connect networks with different protocol stacks

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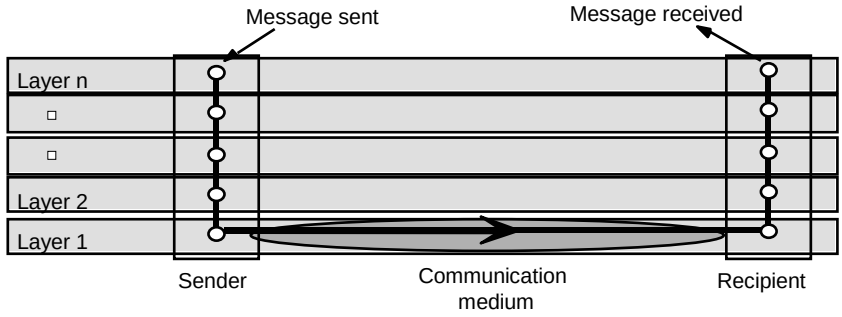
Layered communication model



Coulouris, Dollimore, Kindberg, Distributed Systems, Addison Wesley 2001 (3rd ed)

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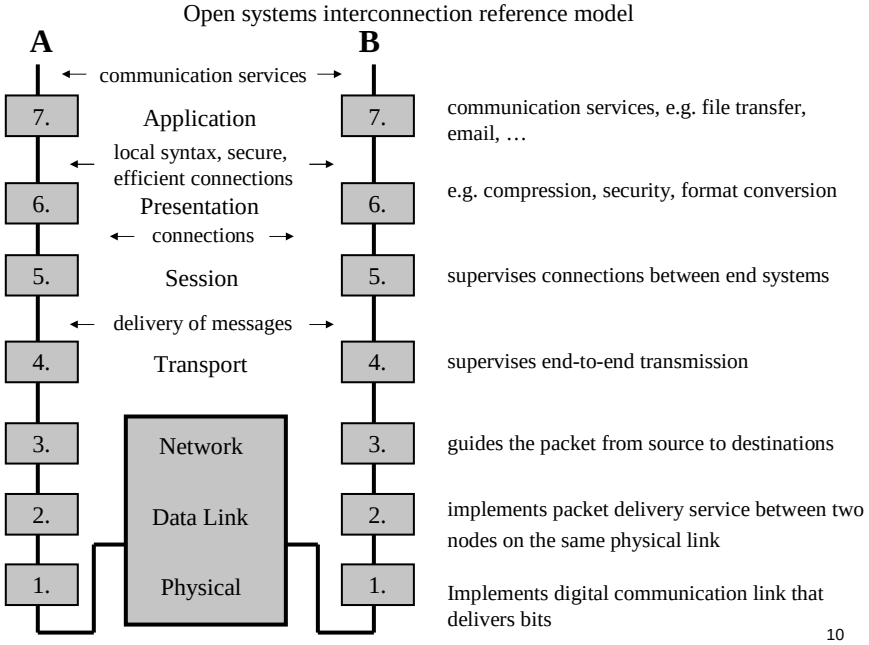
ISO-OSI layer model

Open systems interconnection reference model



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Layer	*Description*	*Examples*
Application	Protocols that are designed to meet the communication requirements of specific applications, often defining the interface to a service.	HTTP,FTP, SMTP, CORBA IIOP
Presentation	Protocols at this level transmit data in a network representation that is independent of the representations used in individual computers, which may differ. Encryption is also performed in this layer, if required.	Secure Sockets (SSL),CORBA Data Rep.
Session	At this level reliability and adaptation are performed, such as detection of failures and automatic recovery.	
Transport	This is the lowest level at which messages (rather than packets) are handled. Messages are addressed to communication ports attached to processes, Protocols in this layer may be connection-oriented or connectionless.	TCP, UDP
Network	Transfers data packets between computers in a specific network. In a WAN or an internetwork this involves the generation of a route passing through routers. In a single LAN no routing is required.	IP, ATM virtual circuits
Data link	Responsible for transmission of packets between nodes that are directly connected by a physical link. In a WAN transmission is between pairs of routers or between routers and hosts. In a LAN it is between any pair of hosts.	Ethernet MAC, ATM cell transfer, PPP
Physical	The circuits and hardware that drive the network. It transmits sequences of binary data by analogue signalling, using amplitude or frequency modulation of electrical signals (on cable circuits), light signals (on fibre optic circuits) or other electromagnetic signals (on radio and microwave circuits).	Ethernet base- band signalling, ISDN

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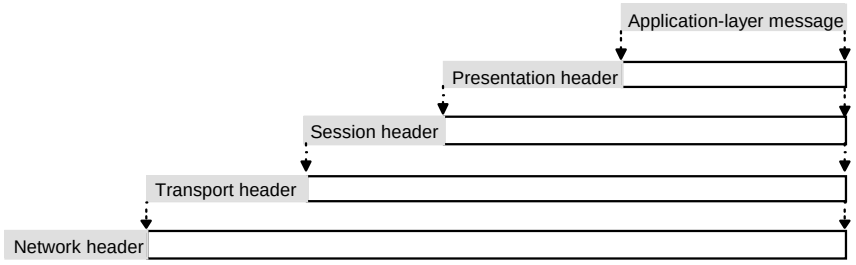

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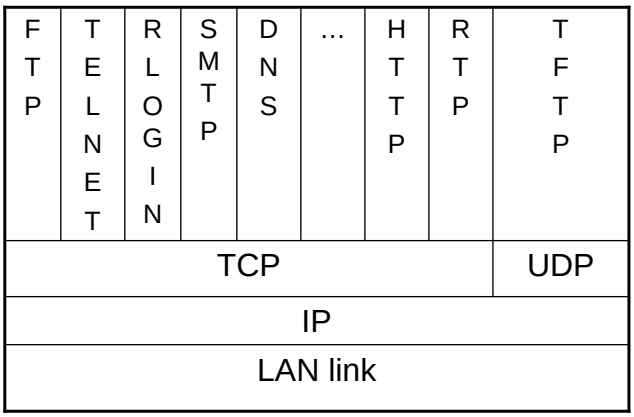
4-layer model of the Internet protocol stack



Other layer models: IEEE 802 (LAN)
ODN (open data network by NRC)
…

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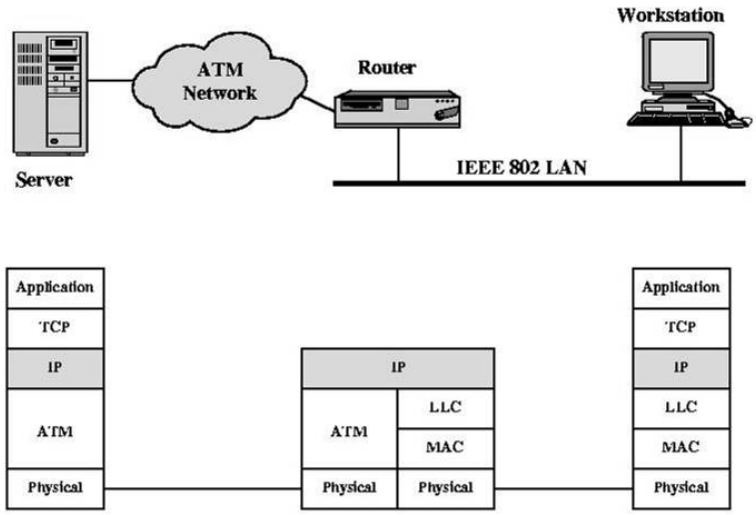

Figure 2.7 Configuration for TCP/IP Example

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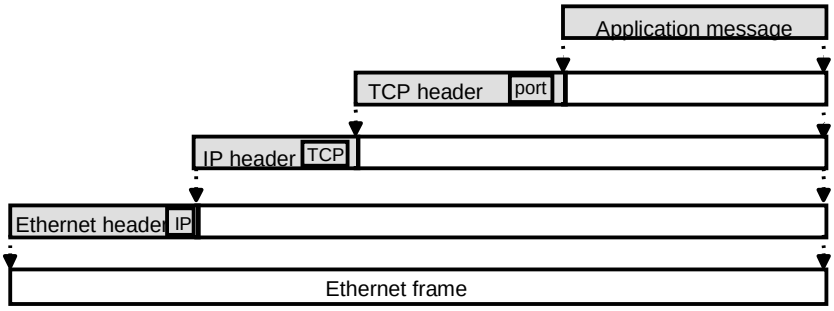

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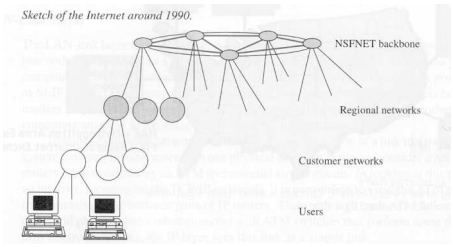

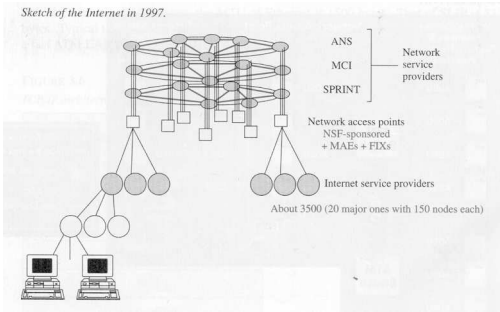

Jean Walrand, *Communication Networks, a first course,* McGraw-Hill 1998 (2nd edition).

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What is a protocol

`**A protocol is a set of rules** governing message interchanges which occur between a number of computers in a distributed system; each of these messages implement functions of the system. A protocol is also used to establish a connection and allow entities to exchange data about themselves, for example the operating system they are using and the format of the data that they intend passing; this is known as a handshake. ‘

D. Ince

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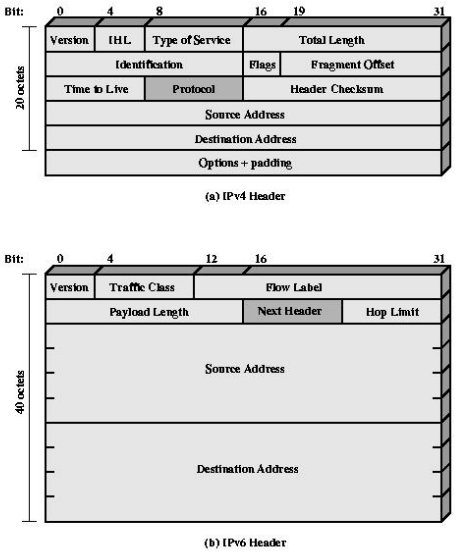
IP Header



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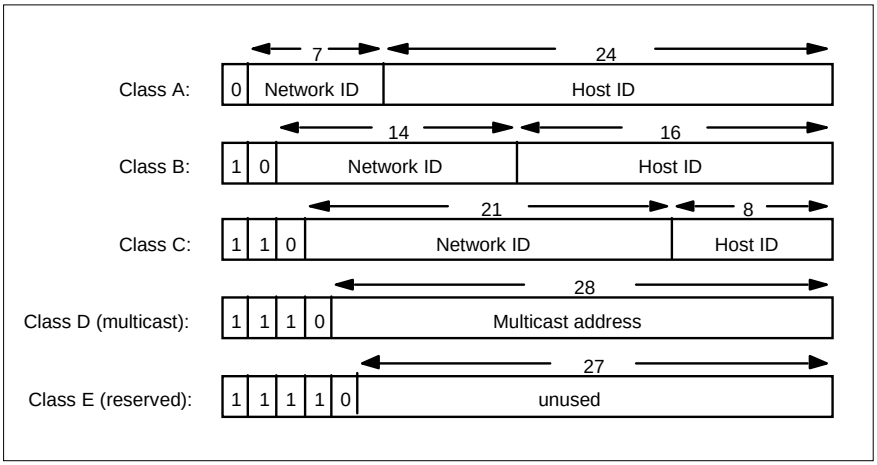

- Around 4 billion IP addresses

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Transport layer protocols

- TCP (Transmission Control Protocol):
  - connection-oriented
  - Reliable packet delivery in sequence
- UDP (User Datagram Protocol):
  - connectionless (datagram)
  - Unreliable packet delivery
  - Packets may arrive out of sequence or duplicated
  - Less overhead
  - Simply adds port addressing to IP
  - Checksum is optional

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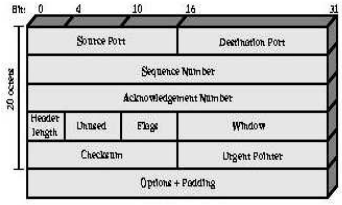
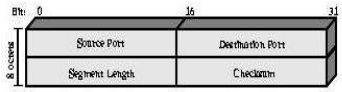
TCP and UDP Header



(a) TCP Header



(b) UDP Header

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ICMP protocol

- Internet Control Message Protocol
- Used by the nodes in the internet to implement IP

Fragmentation

- The IP protocol delivers datagrams of up to 64 kbytes. Links have a maximum size of packets they can transmit (MTU; Maximum Transfer Unit), so that the packets might have to be broken up an reassembled for specific links.

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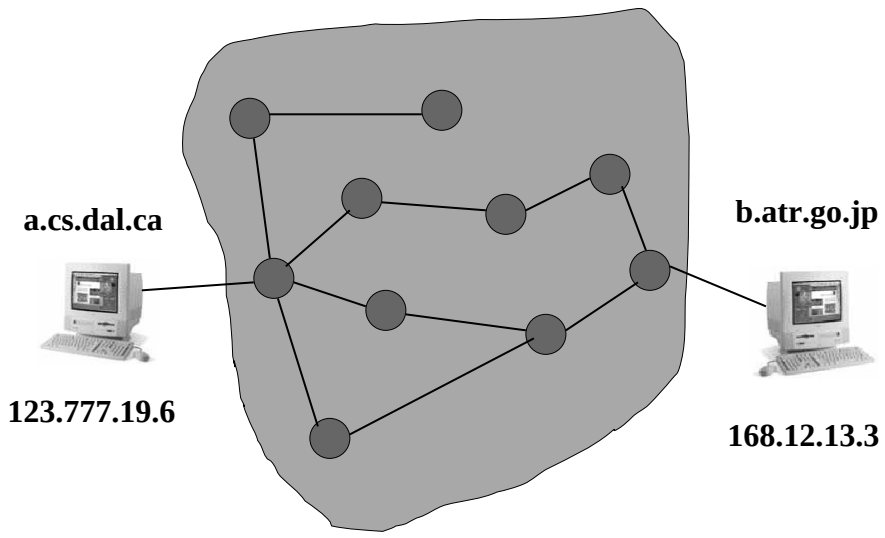

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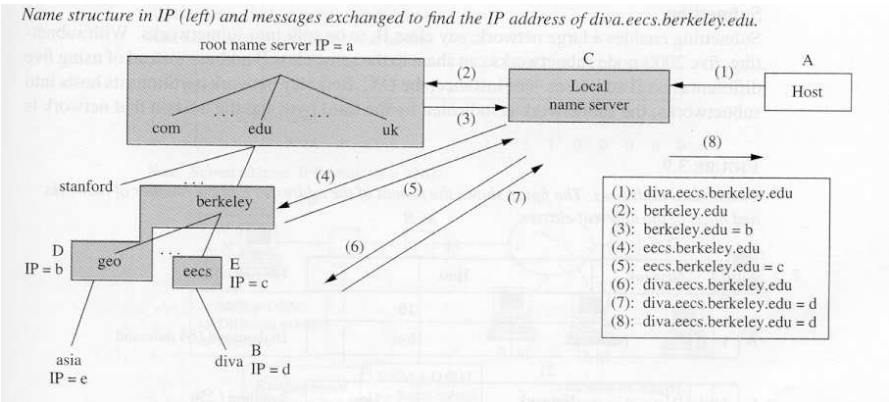
URL: A Global Address



http://www.cs.dal.ca/cs1200/week1/x.html

- **Scheme**
- **Server name**
- **Path**
- File

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Name	Port/Protocol	Comment
ftp-data	20/tcp	
ftp	21/tcp	
telnet	23/tcp	
smtp	25/tcp	mail
bootps	67/udp	# BOOTP/DHCP server
bootpc	68/udp	# BOOTP/DHCP client
hostnames	101/tcp	hostname # usually to sri-nic
sunrpc	111/udp	rpcbind
sunrpc	111/tcp	rpcbind
finger	79/tcp	
pop3	110/tcp	# Post Office
nntp	119/tcp	usenet # Network News Transfer
imap	143/tcp	# Internet Message Access
ssh	22/tcp	# Secure SHell
who	513/udp	whod
kerberos	750/udp	kdc # Kerberos key server
xaudio	1103/tcp	Xaserver # X Audio Server
stel	10005/tcp	# Secure Telnet

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Routing and congestion control

Send information of nodes and links to each node of the network. This might include some physical properties such as maximal size of packets, typical time delays, …

→ Build map of network

→ Use routing algorithm to build routing tables

for example: OSPF (Open Shortest Path First)

if every router uses the same algorithm and maps they build consistent tables

→ Hierarchical Routing:

`use local map to get to the highway, use highway map to get to your destination town, use local map to get to your friends house'.

More sophisticated routine on `highway' (BGP, Border Gateway Protocol)

How is congestion controlled?

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How is congestion controlled?

Flow control → TCP

Destination publishes maximal acceptable window size in reply message

Source destination discovers congestion from unusually long delay times of response

→ additive increase, multiplicative decrease

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ATM (virtual circuit switching)

Quality of Service (QoS)

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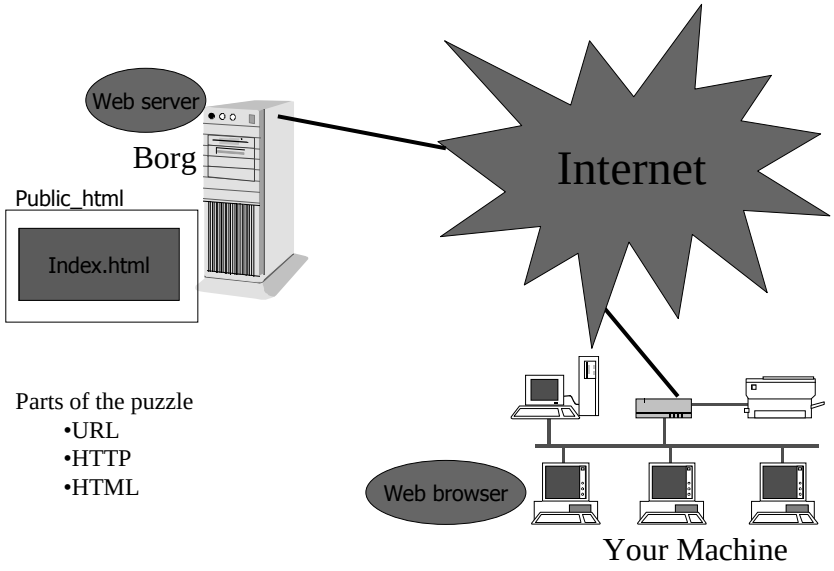
The Internet vs. the WWW



Parts of the puzzle
- •URL
- •HTTP
- •HTML

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HTTP: Hyper Text Transfer Protocol

client request:

```
GET /index.html HTTP/1.1
User-Agent: Lynx/2.4
Connection: Keep-Alive
Host: www.openaccess.com
Accept: text/html
```

Server response:

```
HTTP/1.1 200 OK
Date: Thu, 22 July 1998 18:40:55 GMT
Server: Apache 1.3.5 (Unix) PHP/3.0.6
Last-Modified: Mon, 19 July 1997
16:03:22 GMT
Content-Type: text/html
Content-Length: 12987
...
```

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The World-Wide Web

- The *World-Wide Web* allows many different types of information to be accessed using a common interface
- A *browser* is a program which accesses and presents information: text, graphics, sound, audio, and programs
- A Web document usually contains *links* to other Web documents, creating a *hypermedia* environment
- The term Web comes from the fact that information is not organized in a linear fashion
- Web documents are defined by the *HyperText Markup Language* (HTML)
- Information on the Web is found using a *Uniform Resource Locator* (URL):

  http://www.cs.dal.ca
- A URL may indicate an HTML document, or some other kind of information

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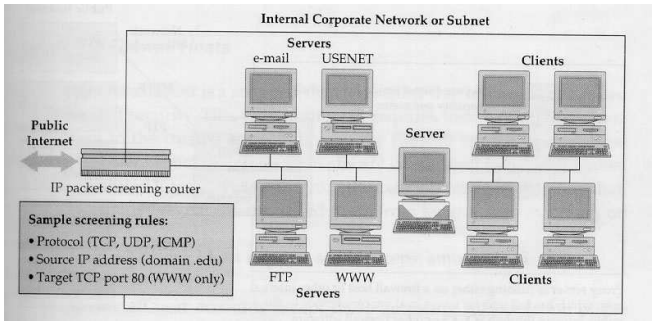
Packet filtering firewalls



–Packet filtering firewalls decide whether or not to forward packets based on their source and destination IP addresses and port numbers

–Rules dictate whether or not packets should be forwarded

–Typically once a connection through the firewall has been established, further packets are passed without scrutiny

–Processes up to the network layer of the protocol stack (one notable exception is for FTP, which requires some application-level support)

–Can perform IP Masquerading

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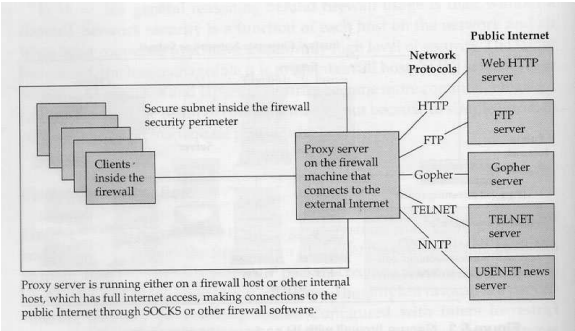
Proxy-based firewalls



- Proxy-based firewalls operate at the application layer of the protocol stack
- Every type of application for which a connection through the firewall is requested requires that a proxy server be running on the firewall for that specific application, or the request will be denied
- Allows for logging of events at the application layer, much more detailed logging than a packet-filtering firewall allows
- Requires that client machines inside the firewall be configured on an application by application basis to use the proxied services of the firewall

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Programming example in Java

The JAVA Socket class

`Socket oldSock = new Socket("penny.open.ac.uk", 1048);`
remote computer `penny` in the domain `open.ac.uk` with communication occurring via port 1048.

→ `InputStream`

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