Networking

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

ISO-OSI layer model
Open systems interconnection reference model

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

**Application**
- Protocols that are designed to meet the communication requirements of specific applications, often defining the interface to a service. Examples: HTTP, FTP, SMTP, CORBA IIOP, Secure Sockets (SSL), CORBA Data Rep.

**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. Examples: 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. Examples: 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. Examples: 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. Examples: 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).

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**Diagram:**
- Application-layer message
- Presentation header
- Session header
- Transport header
- Network header
4-layer model of the Internet protocol stack

<table>
<thead>
<tr>
<th>FTP</th>
<th>TELNET</th>
<th>LOGIN</th>
<th>SMTP</th>
<th>DNS</th>
<th>...</th>
<th>HTTP</th>
<th>RTP</th>
<th>FTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td>UDP</td>
<td>IP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAN link</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Figure 2.7 Configuration for TCP/IP Example
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
### Class A: 0 Network ID Host ID

#### Class B: 1 0 Network ID Host ID

#### Class C: 1 1 0 Network ID Host ID

#### Class D (multicast): 1 1 1 0 Multicast address

#### Class E (reserved): 1 1 1 1 unused

- **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
TCP and UDP Header

![TCP and UDP Header Diagram](image)

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 and reassembled for specific links.
URL: A Global Address

- Scheme
- Server name
- Path
- File

http://www.cs.dal.ca/cs1200/week1/x.html
<table>
<thead>
<tr>
<th>Name</th>
<th>Port/Protocol</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ftp-data</td>
<td>20/tcp</td>
<td></td>
</tr>
<tr>
<td>ftp</td>
<td>21/tcp</td>
<td></td>
</tr>
<tr>
<td>telnet</td>
<td>23/tcp</td>
<td></td>
</tr>
<tr>
<td>smtp</td>
<td>25/tcp</td>
<td>mail</td>
</tr>
<tr>
<td>bootps</td>
<td>67/udp</td>
<td># BOOTP/DHCP server</td>
</tr>
<tr>
<td>bootpc</td>
<td>68/udp</td>
<td># BOOTP/DHCP client</td>
</tr>
<tr>
<td>hostnames</td>
<td>101/tcp</td>
<td>hostname # usually to sri-nic</td>
</tr>
<tr>
<td>sunrpc</td>
<td>111/udp</td>
<td>rpcbind</td>
</tr>
<tr>
<td>sunrpc</td>
<td>111/tcp</td>
<td>rpcbind</td>
</tr>
<tr>
<td>finger</td>
<td>79/tcp</td>
<td></td>
</tr>
<tr>
<td>pop3</td>
<td>110/tcp</td>
<td># Post Office</td>
</tr>
<tr>
<td>nnlp</td>
<td>119/tcp</td>
<td>usenet # Network News</td>
</tr>
<tr>
<td>imap</td>
<td>143/tcp</td>
<td>internet message access # internet</td>
</tr>
<tr>
<td>ssh</td>
<td>22/tcp</td>
<td># Secure SHell</td>
</tr>
<tr>
<td>who</td>
<td>513/udp</td>
<td>whod</td>
</tr>
<tr>
<td>kerberos</td>
<td>750/udp</td>
<td>kdc # Kerberos key server</td>
</tr>
<tr>
<td>xaudio</td>
<td>1103/tcp</td>
<td>Xaserver # X Audio Server</td>
</tr>
<tr>
<td>stel</td>
<td>10005/tcp</td>
<td># Secure Telnet</td>
</tr>
</tbody>
</table>

**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?
How is congestion controlled?

Flow control $\rightarrow$ TCP

Destination publishes maximal acceptable window size in reply message

Source destination discovers congestion from unusually long delay times of response

$\rightarrow$ additive increase, multiplicative decrease

ATM (virtual circuit switching)

Quality of Service (QoS)
The Internet vs. the WWW

Parts of the puzzle
• URL
• HTTP
• HTML

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
...
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

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
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

Programming example in Java

**The JAVA Socket class**

```java
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
```