Network

“... communication system for connecting end-systems”

End-systems a.k.a. “hosts”
PCs, workstations
dedicated computers
network components
Multiaccess vs. Point-to-point

- **Multiaccess** means shared medium.
  - many end-systems share the same physical communication resources (*wire, frequency, ...*)
  - There must be some arbitration mechanism.

- **Point-to-point**
  - only 2 systems involved
  - no doubt about where data came from!
Multiaccess  Point-to-point
LAN - Local Area Network

- connects computers that are physically close together (< 1 mile).
  - high speed
  - multi-access

- Technologies:
  - Ethernet 10 Mbps, 100Mbps
  - Token Ring 16 Mbps
  - FDDI 100 Mbps
  - Myrinet 2 Gbps
WAN - Wide Area Network

- connects computers that are physically far apart. “long-haul network”.
  - typically slower than a LAN.
  - typically less reliable than a LAN.
  - point-to-point

- Technologies:
  - telephone lines
  - Satellite communications
MAN - Metropolitan Area Network

- Larger than a LAN and smaller than a WAN
  - example: campus-wide network
  - multi-access network

- Technologies:
  - coaxial cable
  - microwave
Internetwork

- Connection of 2 or more distinct (possibly dissimilar) networks.
- Requires some kind of network device to facilitate the connection.
OSI Reference Model

Layered model:

- 7. Application
- 6. Presentation
- 5. Session
- 4. Transport
- 3. Network
- 2. Data Link
- 1. Physical
The Physical Layer

- **Responsibility:**
  - transmission of raw bits over a communication channel.

- **Issues:**
  - mechanical and electrical interfaces
  - time per bit
  - distances
The Data Link Layer -
Data Link Control

- **Responsibility:**
  - provide an error-free communication link

- **Issues:**
  - *framing* (dividing data into chunks)
    - » header & trailer bits
  - addressing
The Data Link Layer - The MAC sublayer

- Medium Access Control - needed by multiaccess networks.

- MAC provides DLC with “virtual wires” on multiaccess networks.
The Network Layer

- **Responsibilities:**
  - path selection between end-systems (routing).
  - subnet flow control.
  - fragmentation & reassembly
  - translation between different network types.

- **Issues:**
  - *packet* headers
  - virtual circuits
The Transport Layer

- Responsibilities:
  - provides virtual end-to-end links between peer processes.
  - end-to-end flow control

- Issues:
  - headers
  - error detection
  - reliable communication
The Session Layer

- **Responsibilities:**
  - establishes, manages, and terminates sessions between applications.
  - service location lookup

- Many protocol suites do not include a session layer.
The Presentation Layer

- Responsibilities:
  - data encryption
  - data compression
  - data conversion

- Many protocol suites do not include a Presentation Layer.
The Application Layer

- **Responsibilities:**
  - anything not provided by any of the other layers

- **Issues:**
  - application level protocols
  - appropriate selection of “type of service”
Layering & Headers

- Each layer needs to add some control information to the data in order to do its job.
- This information is typically prepended to the data before being given to the lower layer.
- Once the lower layers deliver the data and control information - the peer layer uses the control information.
What are the headers?

**Physical**: no header - just a bunch of bits.

**Data Link**:  
- address of the receiving endpoints  
- address of the sending endpoint  
- length of the data  
- checksum.
Network layer header - examples

- protocol suite version
- type of service
- length of the data
- packet identifier
- fragment number
- time to live

- protocol
- header checksum
- source network address
- destination network address
Important Summary

- **Data-Link**: communication between machines on the same network.
- **Network**: communication between machines on possibly different networks.
- **Transport**: communication between processes (running on machines on possibly different networks).
Connecting Networks

- **Repeater:** physical layer
- **Bridge:** data link layer
- **Router:** network layer
- **Gateway:** network layer and above.
Repeater

- Copies bits from one network to another
- Does not look at any bits
- Allows the extension of a network beyond physical length limitations
Bridge

- Copies frames from one network to another
- Can operate selectively - does not copy all frames (must look at data-link headers).
- Extends the network beyond physical length limitations.
Router

- Copies packets from one network to another.
- Makes decisions about what route a packet should take (looks at network headers).
Gateway

- Operates as a router
- Data conversions above the network layer.
- Conversions:
  - encapsulation - use an intermediate network
  - translation - connect different application protocols
  - encryption - could be done by a gateway
Encapsulation Example

- Provides service connectivity even though intermediate network does not support protocols.
Translation

- Translate from green protocol to brown protocol
Hardware vs. Software

- Repeaters are typically hardware devices.
- Bridges can be implemented in hardware or software.
- Routers & Gateways are typically implemented in software so that they can be extended to handle new protocols.
- Many workstations can operate as routers or gateways.
Byte Ordering

- Different computer architectures use different byte ordering to represent multibyte values.
- 16 bit integer:

```
Low Byte  Address A  High Byte
High Byte  Address A+1  Low Byte
```
# Byte Ordering

## Little-Endian

<table>
<thead>
<tr>
<th>Low Byte</th>
<th>High Byte</th>
</tr>
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<tbody>
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- IBM 80x86
- DEC VAX
- DEC PDP-11

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- IBM 370
- Motorola 68000
- Sun
Suppose a Big Endian machine sends a 16 bit integer with the value 2:

```
0000000000000010
```

A Little Endian machine will think it got the number 512:

```
000000100000000000
```
Conversion of application-level data is left up to the presentation layer.

But hold on !!! How do lower level layers communicate if they all represent values differently ? (data length fields in headers)

A fixed byte order is used (called network byte order) for all control data.
Multiplexing

- “.. to combine many into one”.
- Many processes sharing a single network interface.
- A single process could use multiple protocols.
- More on this when we look at TCP/IP.
Modes of Service

- connection-oriented vs. connectionless
- sequencing
- error-control
- flow-control
- byte stream vs. message based
- full-duplex vs. half-duplex.
Connection-Oriented vs. Connectionless Service

- A connection-oriented service includes the establishment of a logical connection between 2 processes.
  - establish logical connection
  - transfer data
  - terminate connection.

- Connectionless services involve sending of independent messages.
Sequencing

- Sequencing provides support for an order to communications.
- A service that includes sequencing requires that messages (or bytes) are received in the same order they are sent.
Error Control

- Some services require error detection (it is important to know when a transmission error has occurred).
- Checksums provide a simple error detection mechanism.
- Error control sometimes involves notification and retransmission.
Flow Control

- Flow control prevents the sending process from overwhelming the receiving process.
- Flow control can be handled a variety of ways - this is one of the major research issues in the development of the next generation of networks (ATM).
Byte Stream vs. Message

- Byte stream implies an ordered sequence of bytes with no message boundaries.
- Message oriented services provide communication service to chunks of data called datagrams.
Full- vs. Half-Duplex

- Full-Duplex services support the transfer of data in both directions.

- Half-Duplex services support the transfer of data in a single direction.
End-to-End vs. Hop-to-Hop

- Many service modes/features such as flow control and error control can be done either:
  - between endpoints of the communication.
  - or-
  - between every 2 nodes on the path between the endpoints.
End-to-End

Process A

Process B
Buffering

- Buffering can provide more efficient communications.
- Buffering is most useful for byte stream services.
Addresses

- Each communication endpoint must have an address.
- Consider 2 processes communicating over an internet:
  - the network must be specified
  - the host (end-system) must be specified
  - the process must be specified.
Addresses at Layers

- Physical Layer: no address necessary
- Data Link Layer - address must be able to select any host on the network.
- Network Layer - address must be able to provide information to enable routing.
- Transport Layer - address must identify the destination process.
Broadcasts

- Many networks support the notion of sending a message from one host to all other hosts on the network.
- A special address called the “broadcast address” is often used.
- Some popular network services are based on broadcasting (YP/NIS, rup, rusers)