

Network

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

End-systems a.k.a. “hosts”

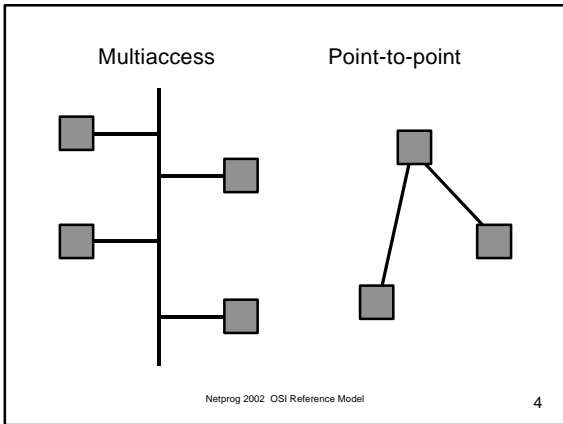
- PCs, workstations
- dedicated computers
- network components

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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 !

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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

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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

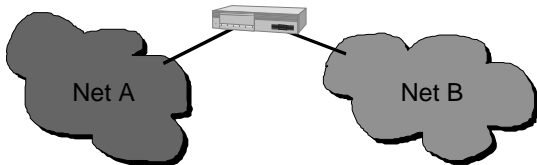
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MAN - Metropolitan Area Network

- 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.

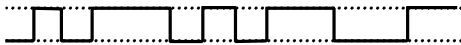


OSI Reference Model

- 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

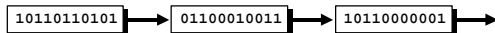


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The Data Link Layer - Data Link Control

- Responsibility:
 - provide an error-free communication link
- Issues:
 - framing (dividing data into chunks)
 - » header & trailer bits
 - addressing



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The Data Link Layer - The MAC sublayer

- Medium Access Control - needed by multiaccess networks.
- MAC provides DLC with "virtual wires" on multiaccess networks.

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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

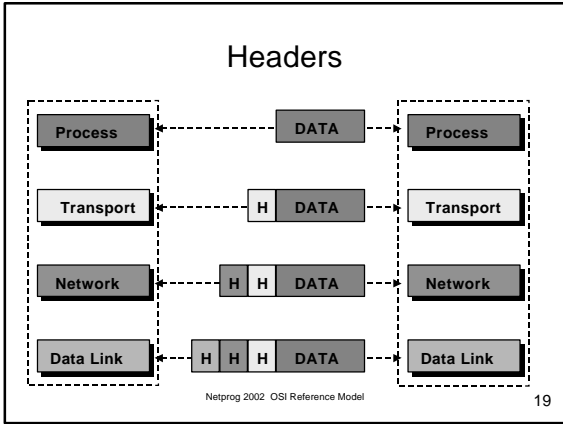
- Responsibilities:
 - data encryption
 - data compression
 - data conversion
- Many protocol suites do not include a Presentation Layer.

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 endpoint(s)
- address of the sending endpoint
- length of the data
- checksum

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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

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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.

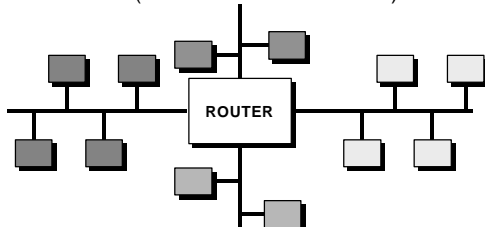


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Router

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



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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

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Encapsulation Example

Gateway → □ → Gateway

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

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Translation

□ → Gateway → □

- Translate from green protocol to brown protocol

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Encryption gateway

Secure Network ← GW → Encryption/Decryption Gateways → GW → Secure Network

? ?
?

Insecure Network

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Hardware vs. Software

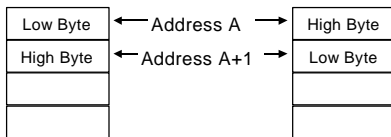
- Repeaters are typically hardware devices.
- Bridges can be implemented in hardware or software.
- Routers & Gateways are typically implemented in software so that they can be extended to handle new protocols.
- Many workstations can operate as routers or gateways.

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Byte Ordering

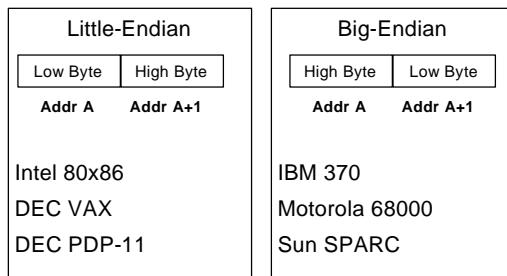
- Different computer architectures use different byte ordering to represent multibyte values.
- 16 bit integer:



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Byte Ordering



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Byte Order and Networking

- 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:

0000001000000000

Network Byte Order

- 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.



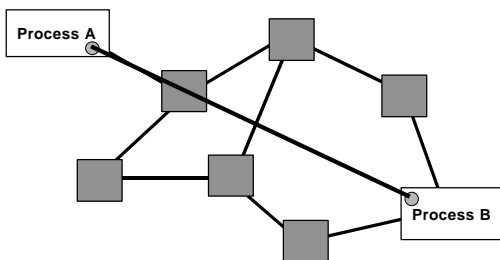
- Half-Duplex services support the transfer of data in a single direction.

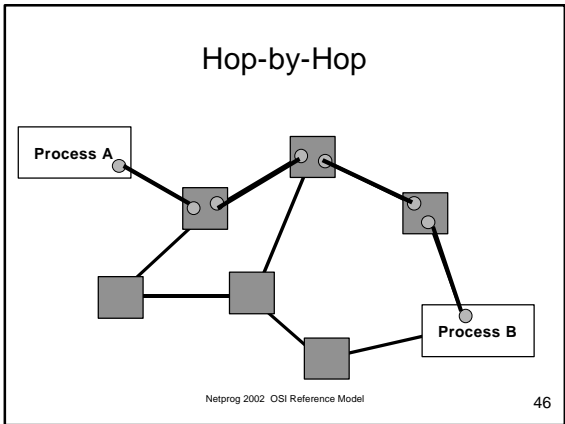


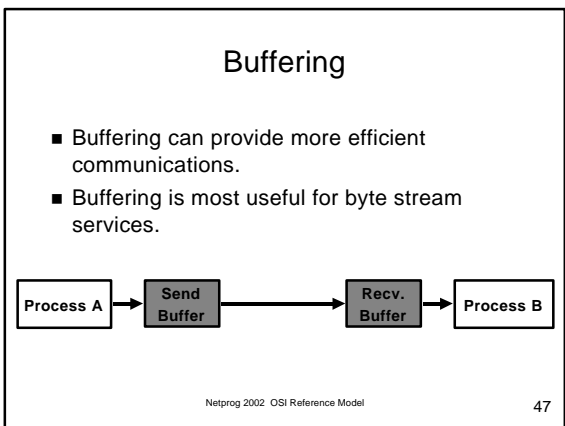
End-to-End vs. Hop-toHop

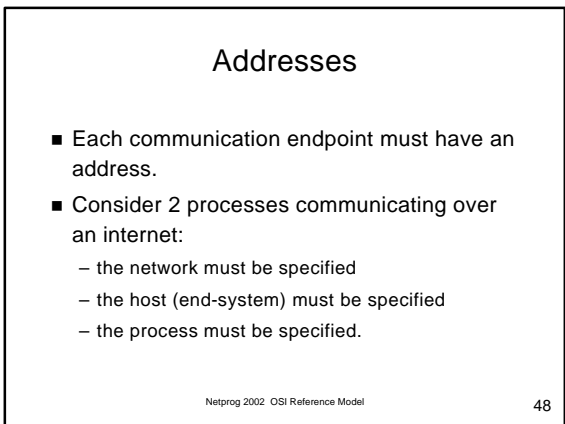
- Many service modes/features such as flow control and error control can be done either:
 - between endpoints of the communication.
 - or-
 - between every 2 nodes on the path between the endpoints.

End-to-End









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, rcp, rusers)
