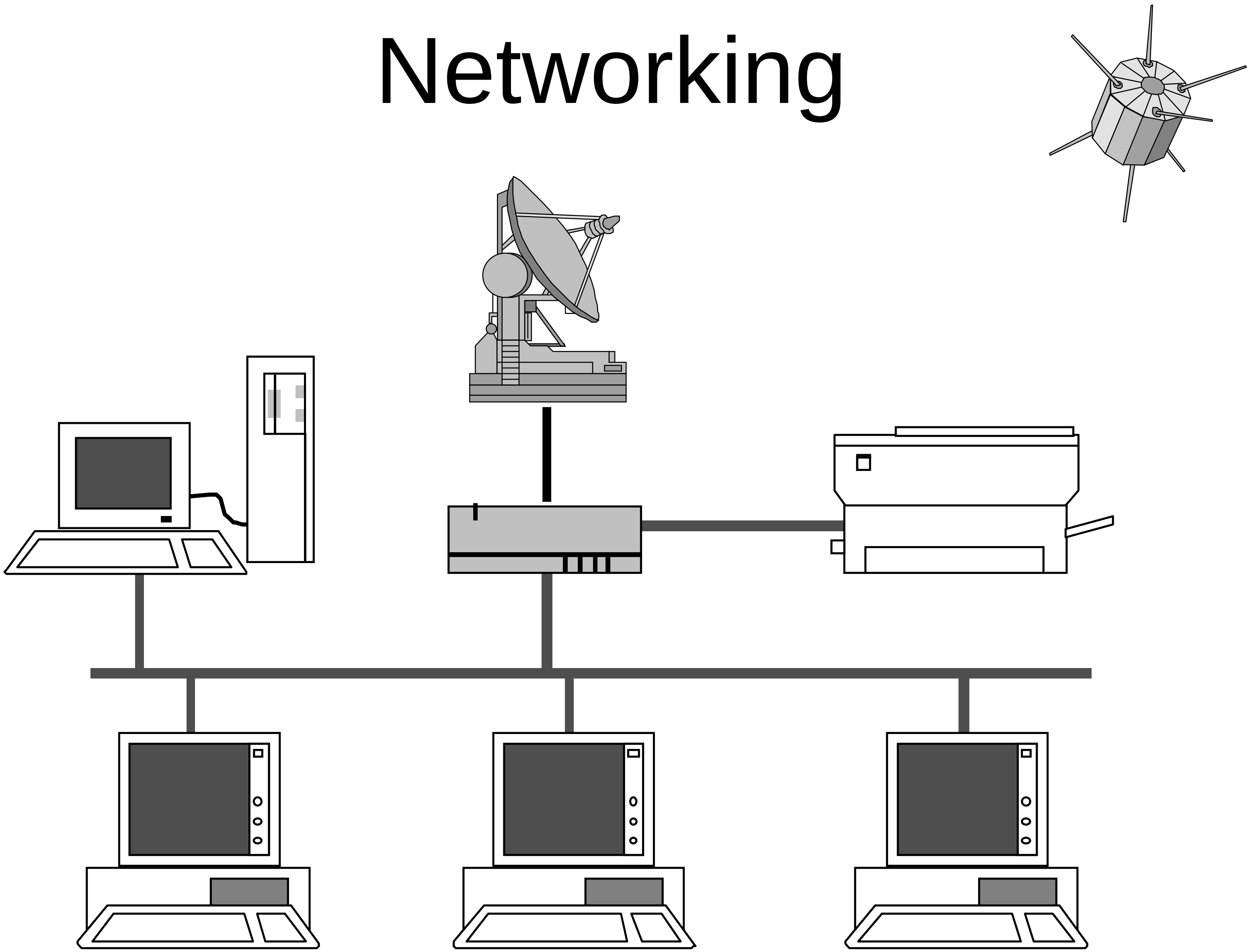
Networking



Network

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

End-systems a.k.a. “hosts”

PCs, workstations

dedicated computers

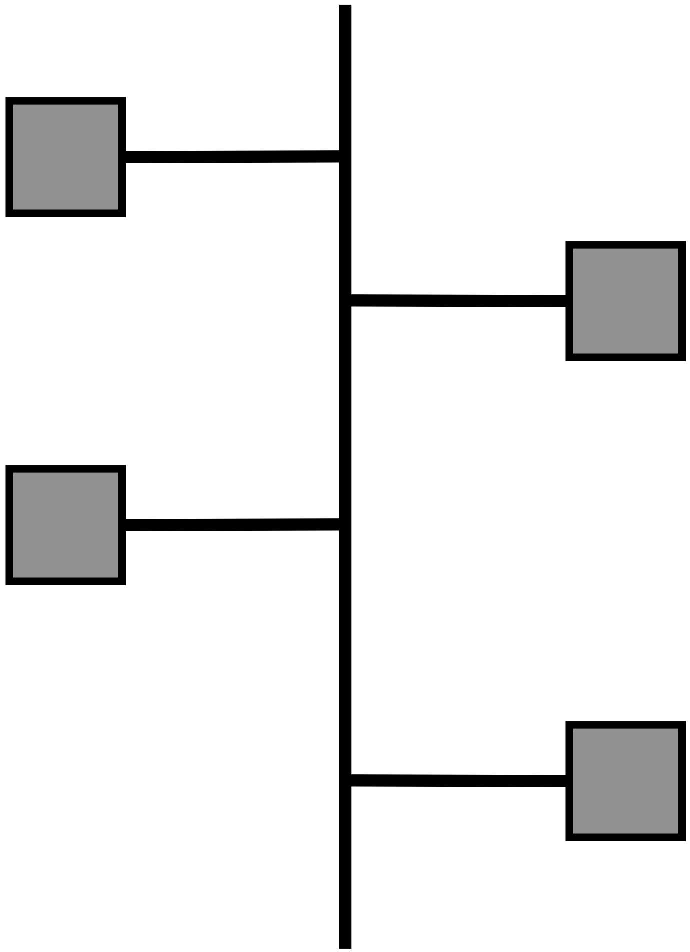
network components

Multiaccess vs. Point-to-point

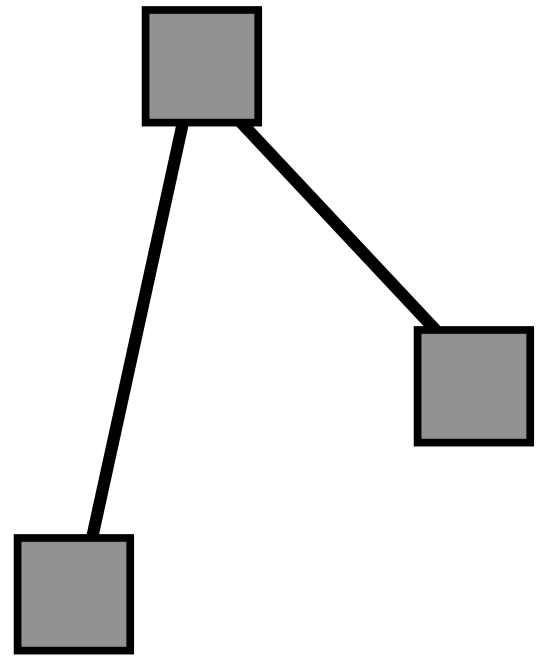
- Multiaccess means shared medium.
  - many end-systems share the same physical communication resources (*wire, frequency, ...)*
  - There must be some arbitration mechanism.

- 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

WAN - Wide Area Network

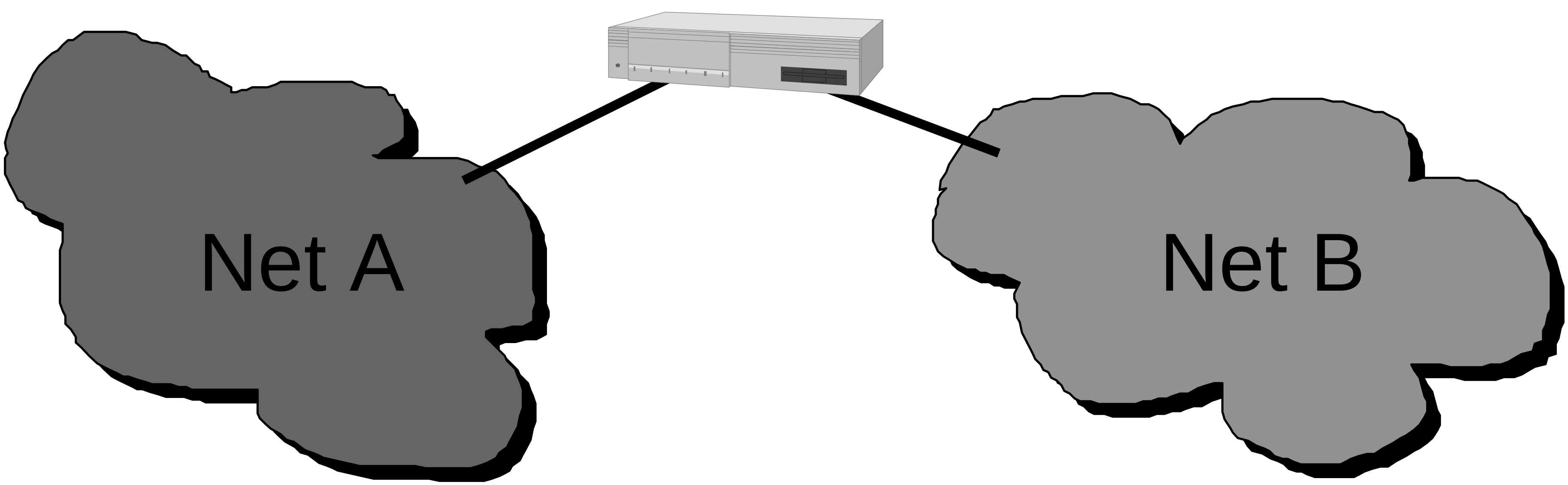
- connects computers that are physically far apart. “long-haul network”.
  - typically slower than a LAN.
  - typically less reliable than a LAN.
  - point-to-point
- Technologies:
  - telephone lines
  - Satellite communications

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.

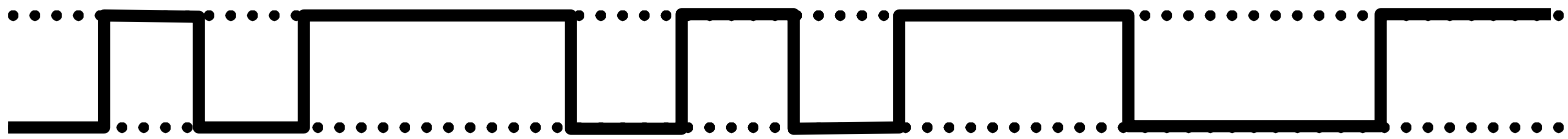


OSI Reference Model

- Layered model:
  7. Application
  6. Presentation
  5. Session
  4. Transport
  3. Network
  2. Data Link
  1. Physical

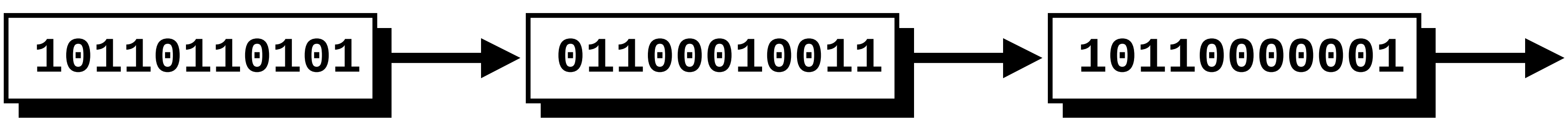
The Physical Layer

- 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 mutiaccess 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.

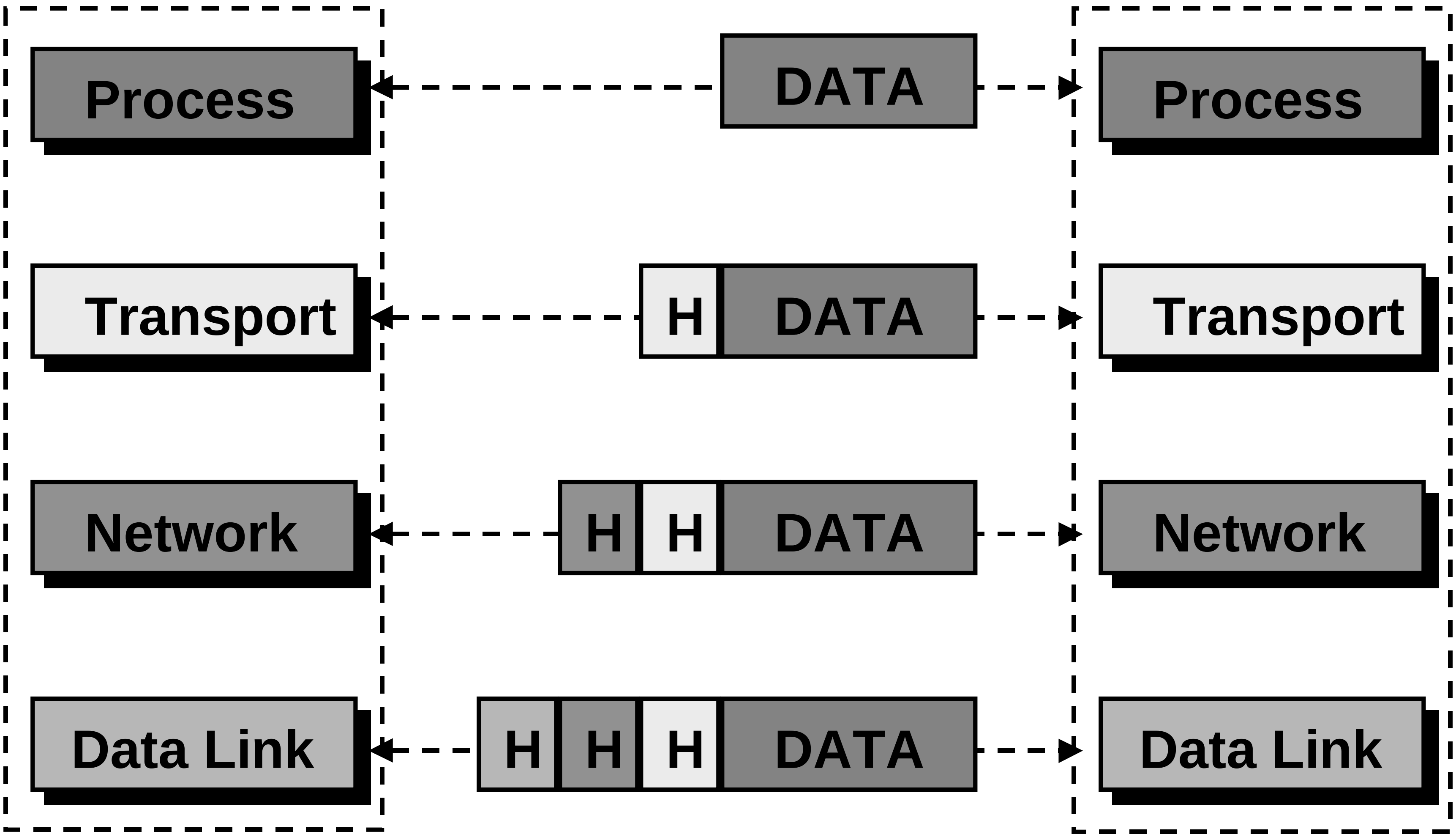
The Application Layer

- 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 it's job.
- This information is typically prepended to the data before being given to the lower layer.
- Once the lower layers deliver the the data and control information - the peer layer uses the control information.

Headers



Process
DATA
Process
Transport
H
DATA
Transport
Network
H
H
DATA
Network
Data Link
H
H
H
DATA
Data Link

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

Connecting Networks

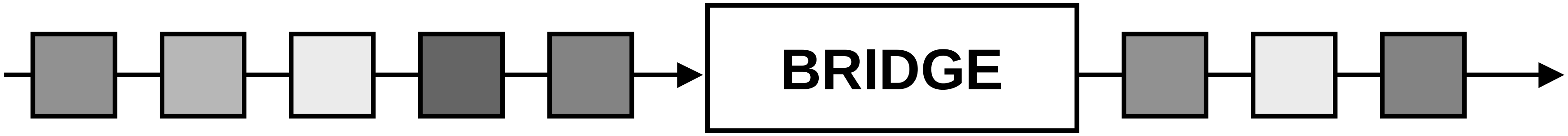
- Repeater: physical layer
- Bridge: data link layer
- Router: network layer
- Gateway: network layer and above.

Repeater

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

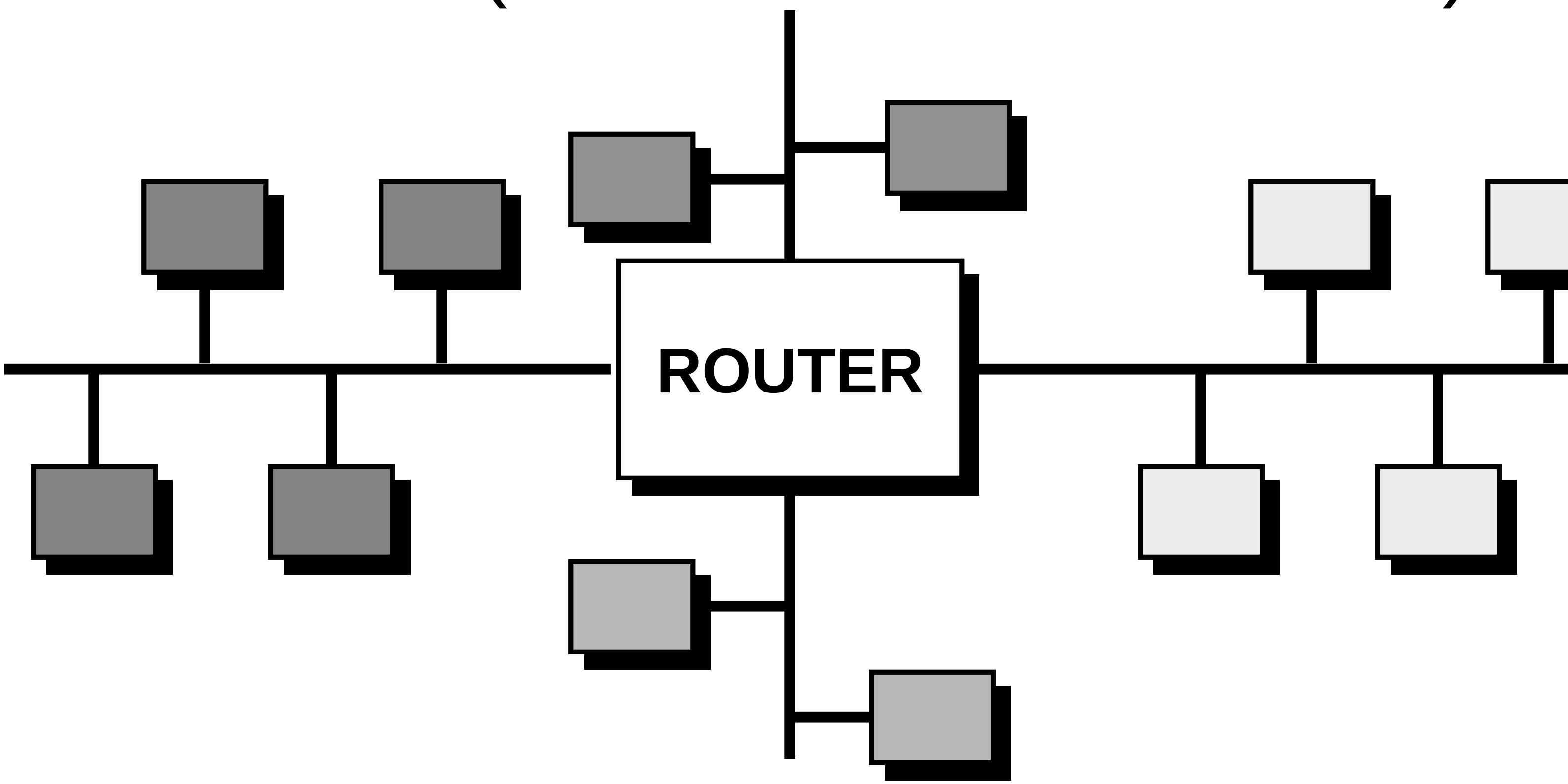
Bridge

- 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

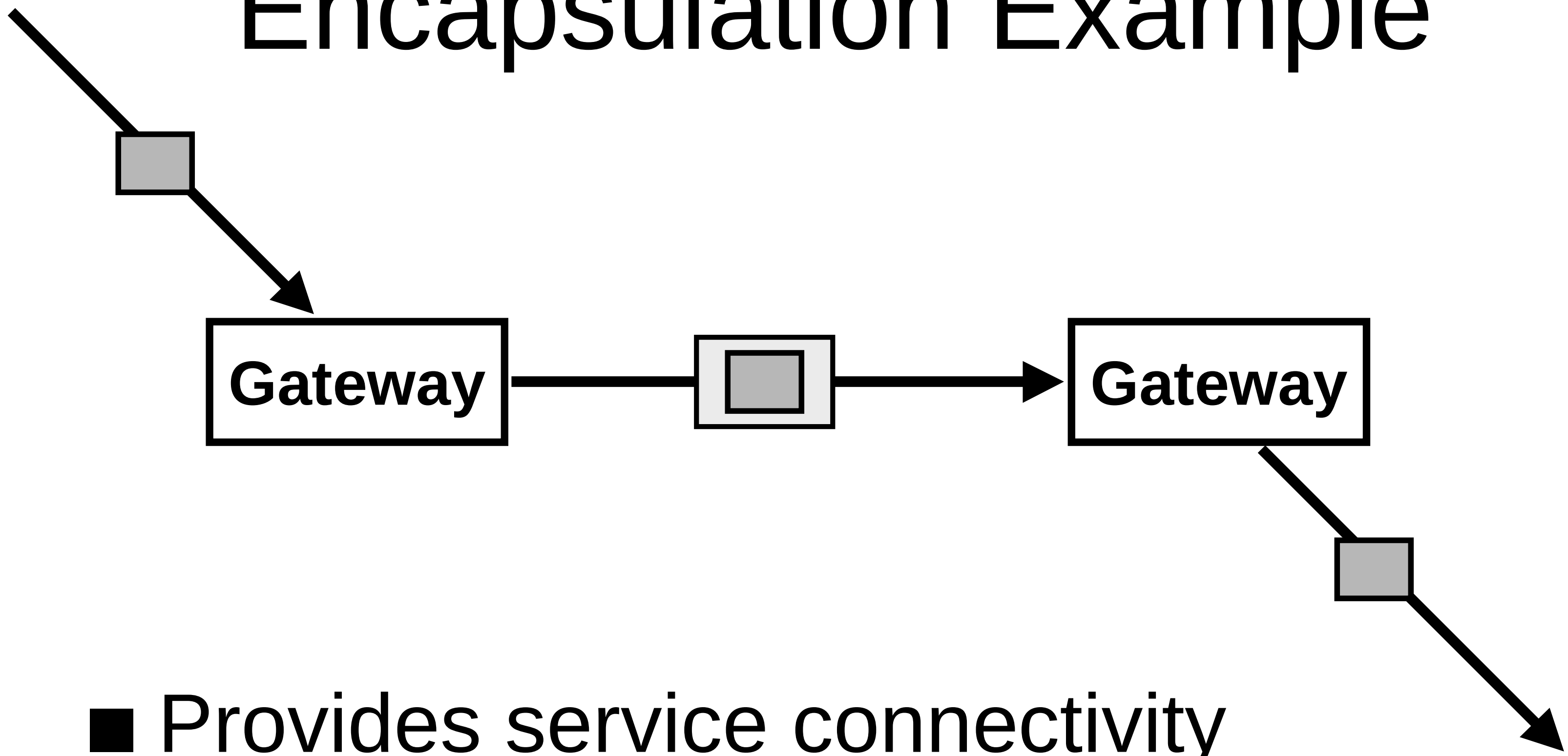
- Copies packets from one network to another.
- Makes decisions about what *route* a packet should take (looks at network headers).



Gateway

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

Encapsulation Example

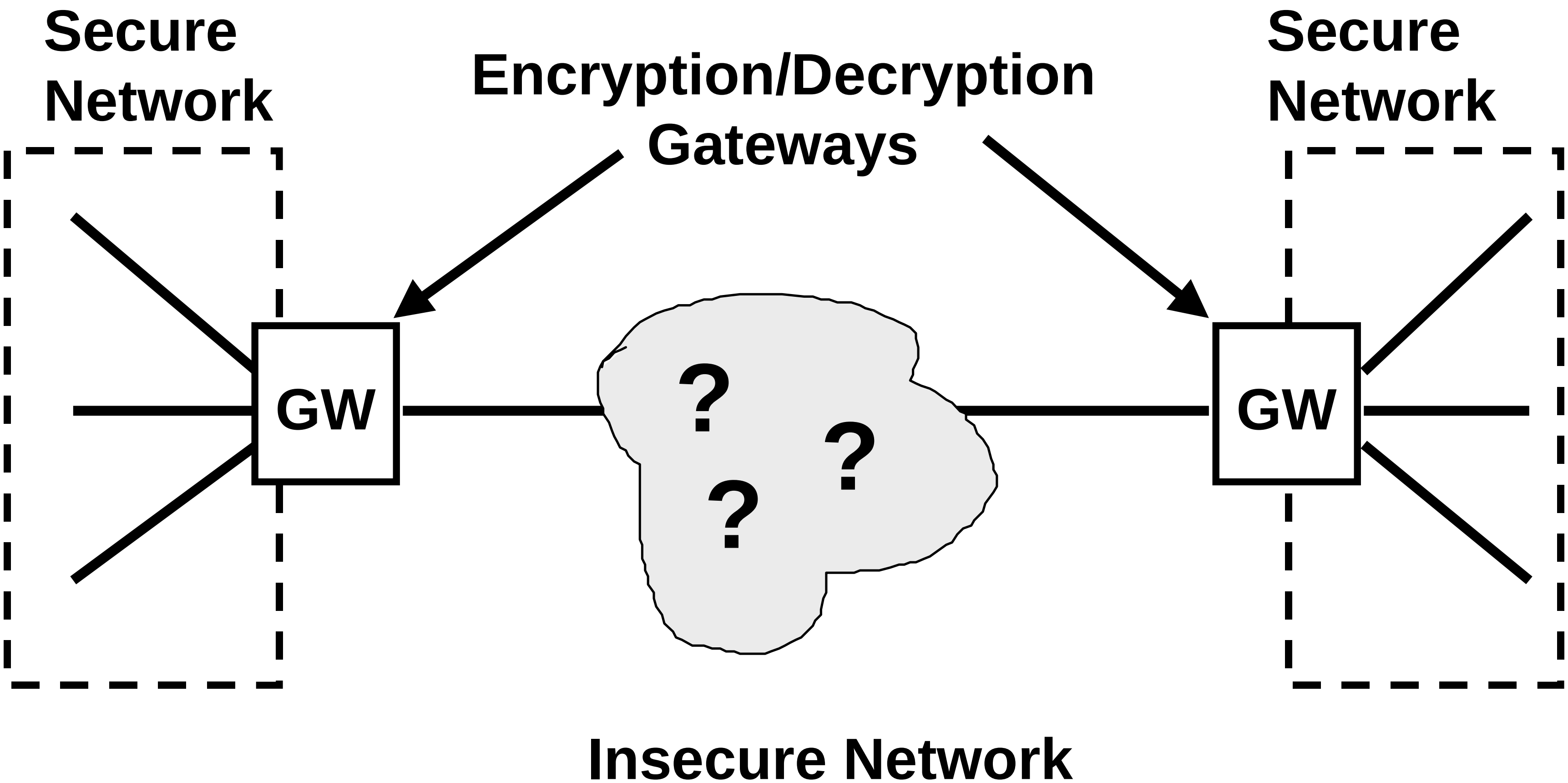


- Provides service connectivity even though intermediate network does not support protocols.

Translation

- Translate from green protocol to brown protocol

Encryption gateway

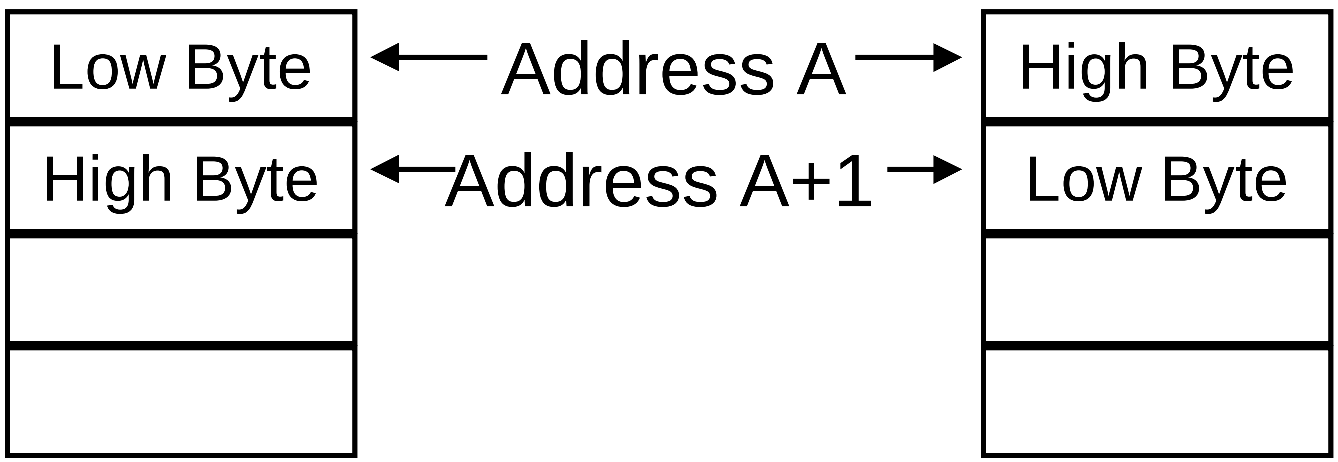


Hardware vs. Software

- 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:



Byte Ordering

Little-Endian

Low Byte	High Byte
Addr A	**Addr A+1**

IBM 80x86

DEC VAX

DEC PDP-11

Big-Endian

High Byte	Low Byte
Addr A	**Addr A+1**

IBM 370

Motorola 68000

Sun

Byte Order and Networking

- Suspose 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 occured).
- 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

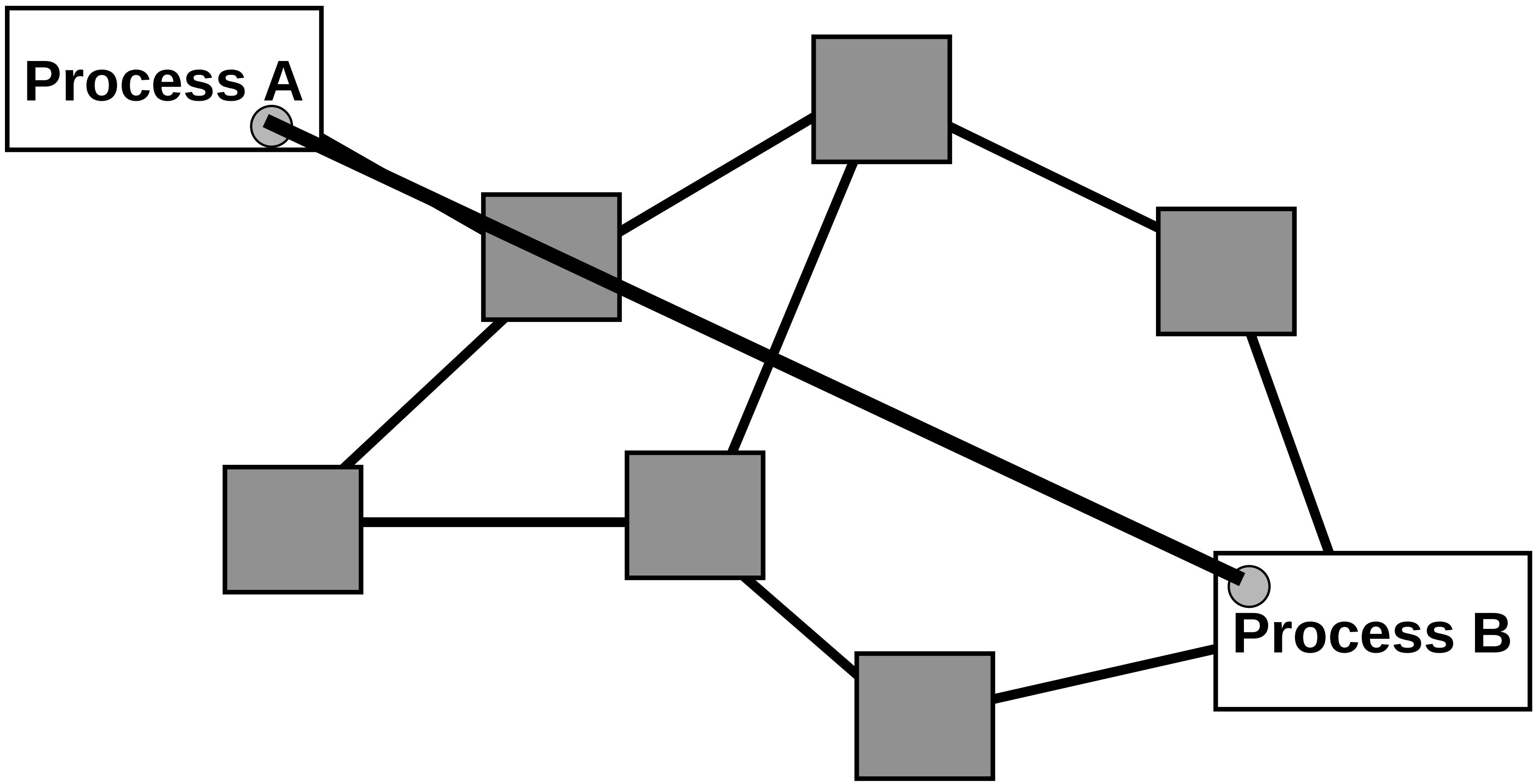
- Many service modes/features such as flow control and error control can be done either:

  between endpoints of the communication.

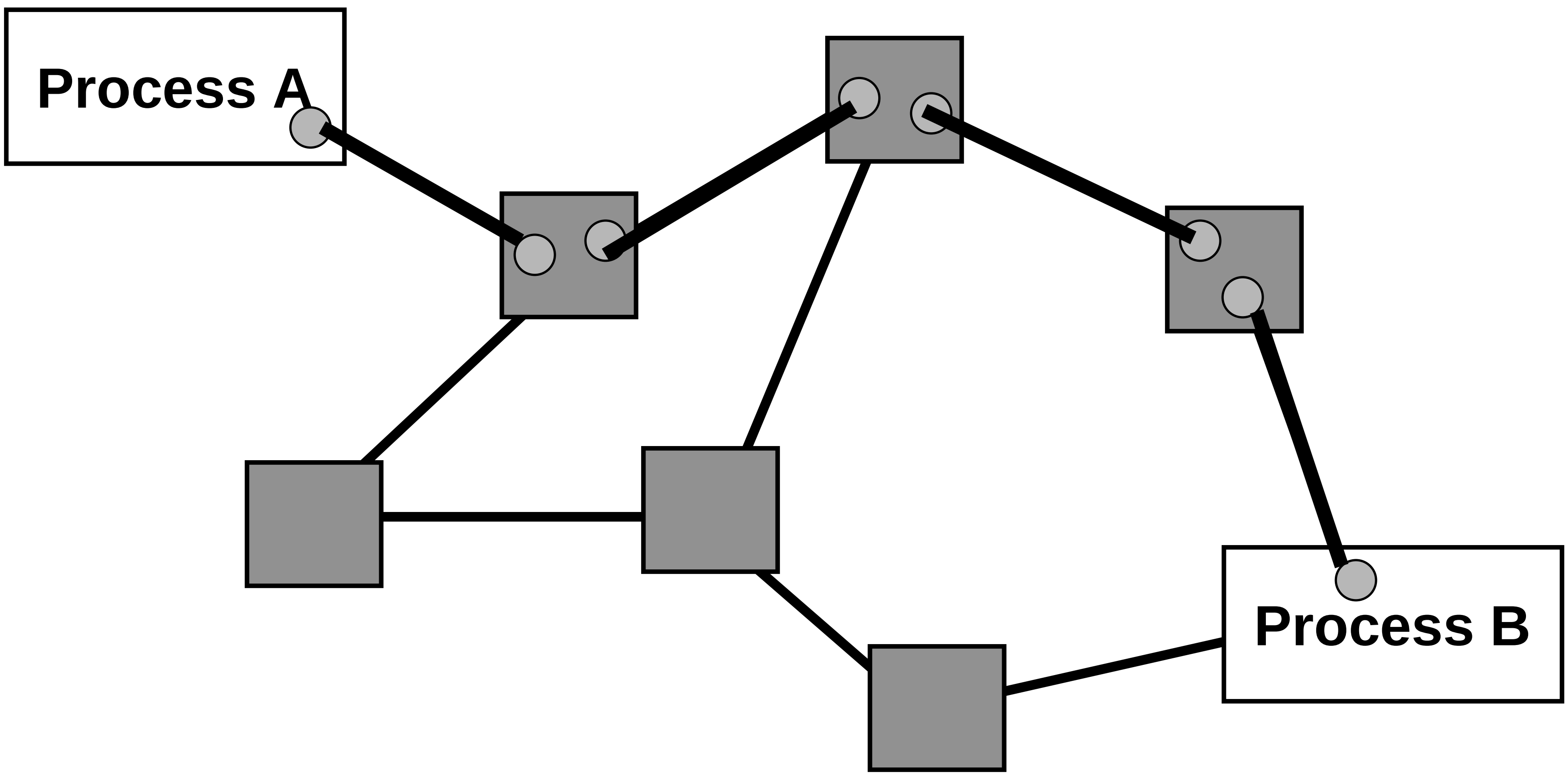
  -or-

  between every 2 nodes on the path between the endpoints.

End-to-End



Hop-by-Hop



Buffering

- Bufferring 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)