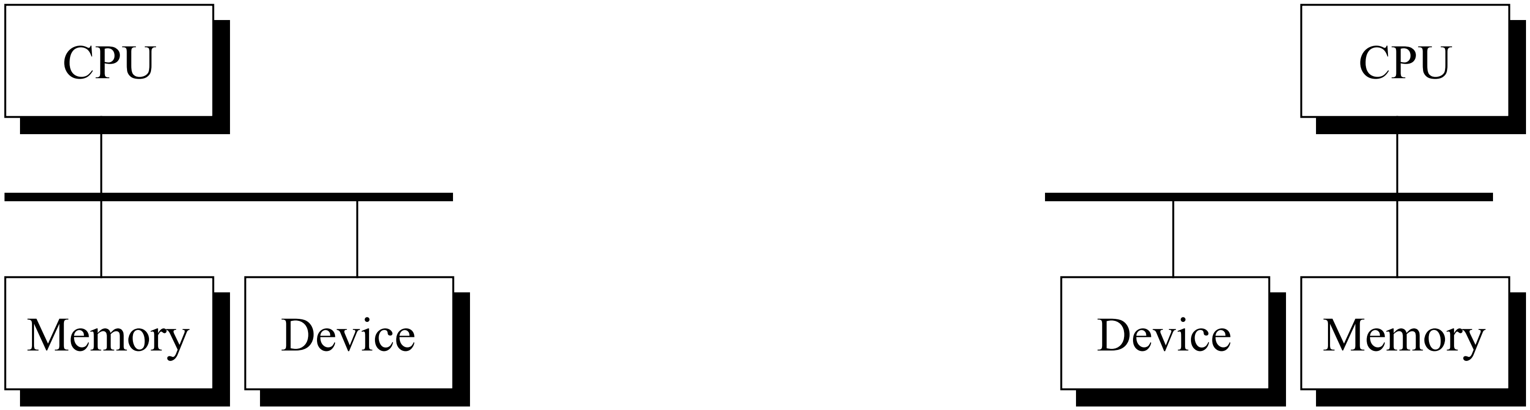
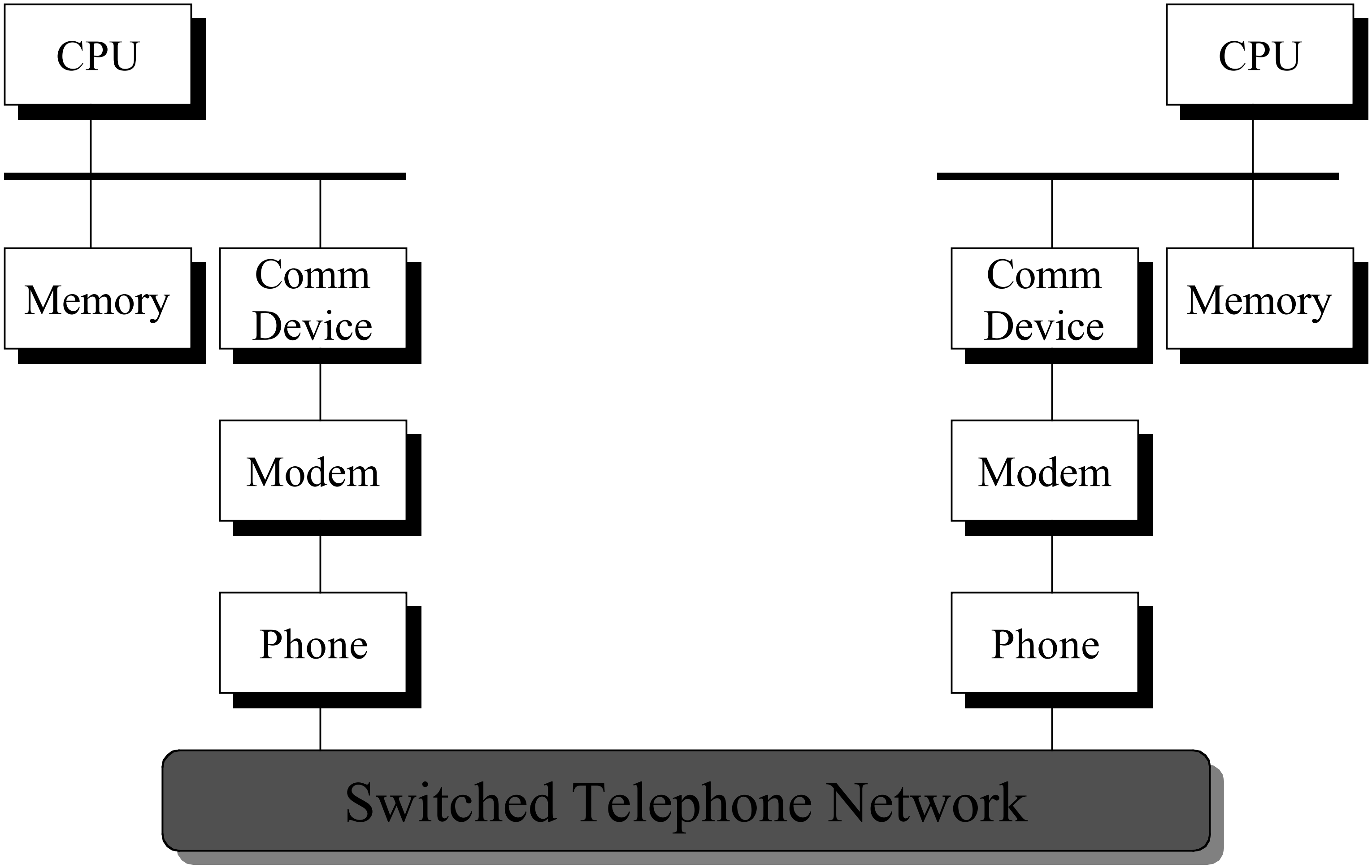
Networks

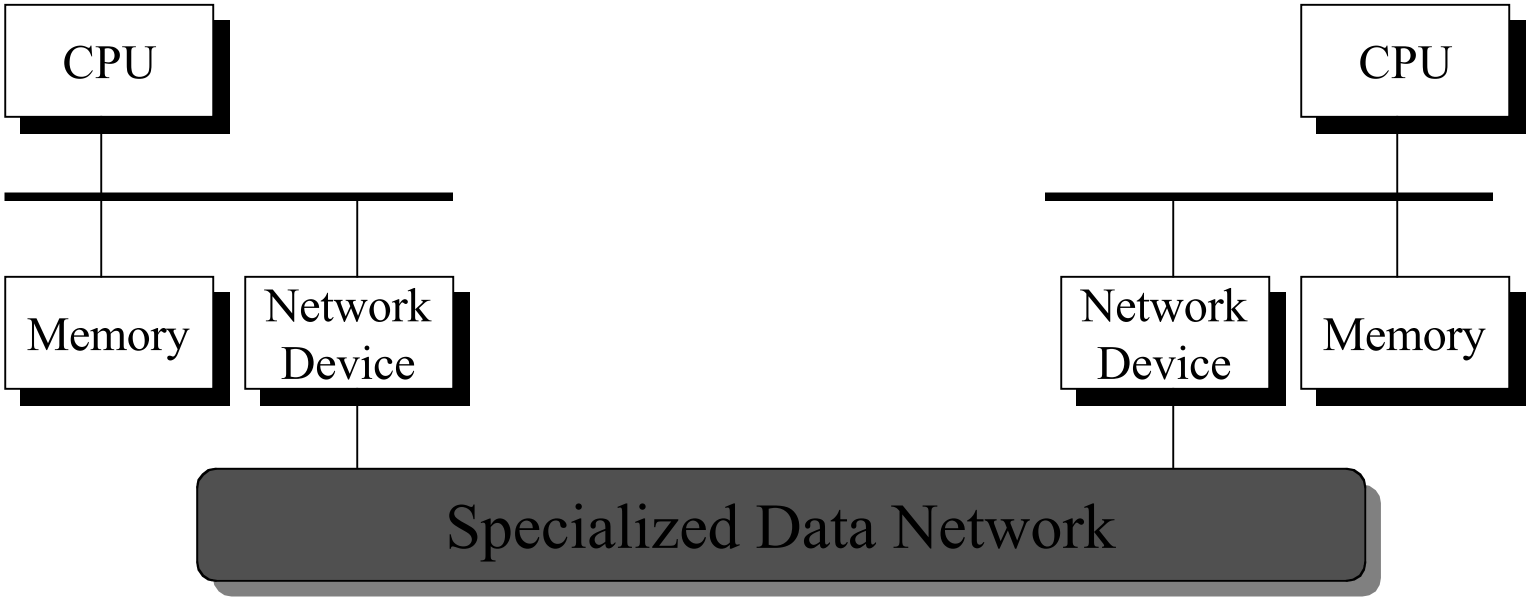
Computer-Computer Comm



Computer-Computer Comm



Data Networks



•WANs, MANs, and LANs
•Specialized communication *protocols*
•Multidrop
•Packet oriented
•Looks like other devices… make it look like a file ...

Multidrop Packet Network

- Need a cost-effective “switch fabric” -- cheaper/better than the telephone network
- To transmit/receive:
    - Sender convert data packet into form suitable for physical transmission
    - Deliver packets to destination host
    - Receiver converts physical signal back into a data packet
- Need a widely-agreed upon set of protocols

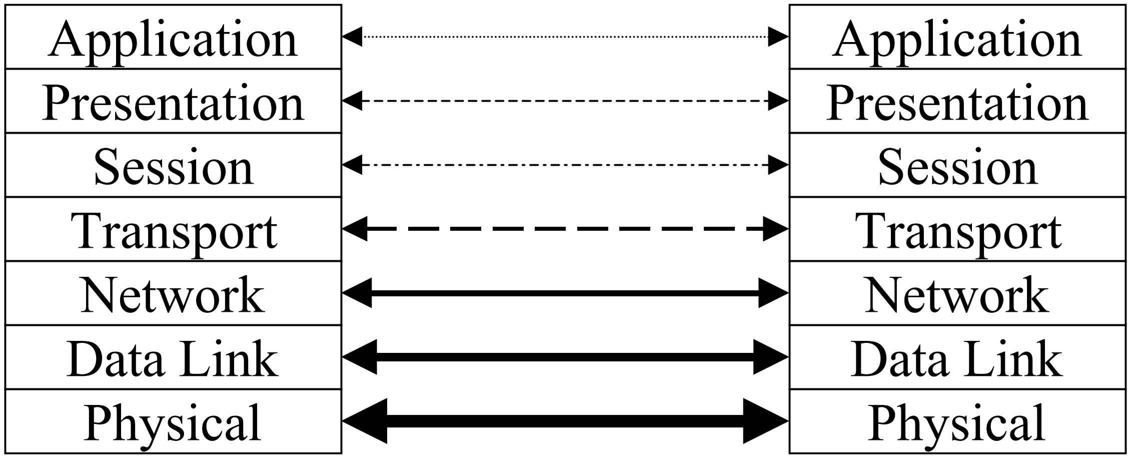
Protocol Tasks

- Control information delivery rates
- Pass info across networks
- Provide fast/reliable IPC-like communication
- Support logical byte streams
- Create other models for communication
  - File transfer
  - Procedure call paradigm
  - Shared memory paradigm
- Translate machine-dependent data representations
- … and more …

Standardizing Protocols

- ANSI X.25
- ARPAnet
- ISO Open Systems Interconnect (OSI) model
  - Now widely used as a reference architecture
  - 7-layer model
  - Provides *framework* for specific protocols (such as IP, TCP, FTP, RPC, RSVP, …)

ISO OSI Model



Application

Presentation

Session

Transport

Network

Data Link

Physical

Application

Presentation

Session

Transport

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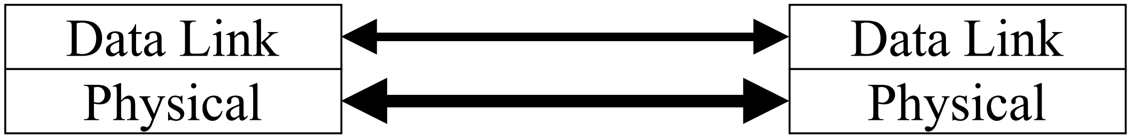
Data Link

Physical

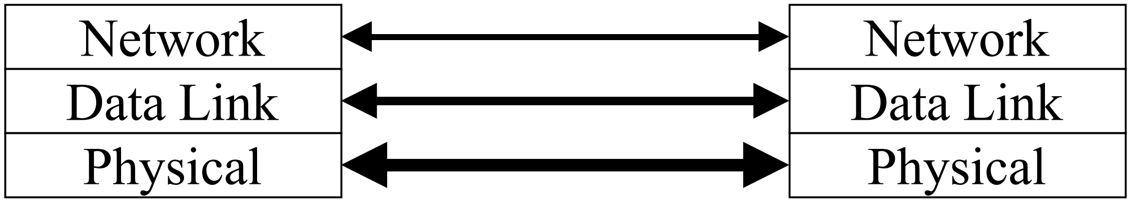
ISO OSI Model



<u>Examples</u>

- Physical/Data Link layer networks: Ethernet, Token Ring, ATM

ISO OSI Model



Network | Network

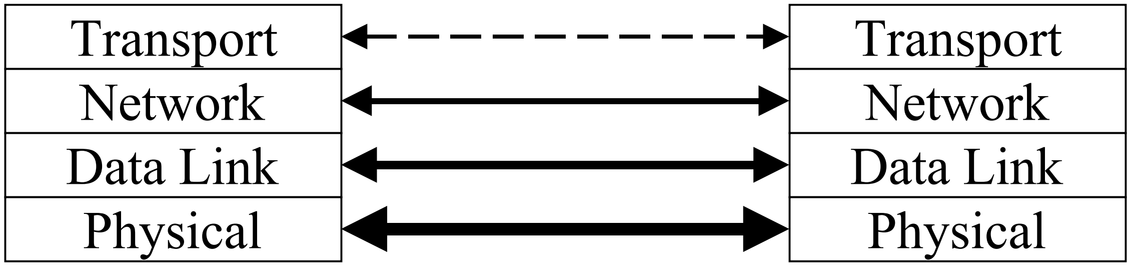
Data Link | Data Link

Physical | Physical

<u>Examples</u>

- Physical/Data Link layer networks: Ethernet, Token Ring, ATM
- Network layer net: The Internet

ISO OSI Model

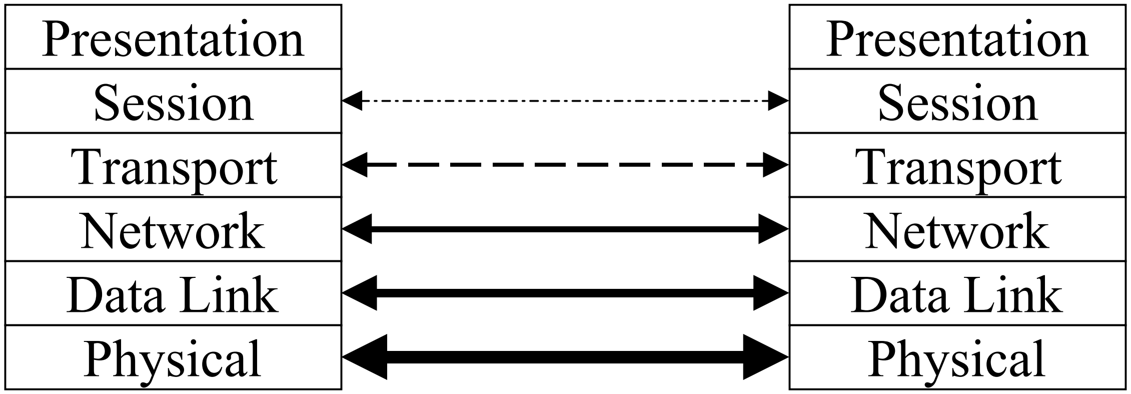


Transport	Transport
Network	Network
Data Link	Data Link
Physical	Physical

<u>Examples</u>

- Physical/Data Link layer networks: Ethernet, Token Ring, ATM
- Network layer net: The Internet
- Transport layer net: TCP-based network

ISO OSI Model



Presentation | Presentation
Session | Session
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Examples

- Physical/Data Link layer networks: Ethernet, Token Ring, ATM
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- Presentation/Session layer net: http/html, RPC, PVM, MPI

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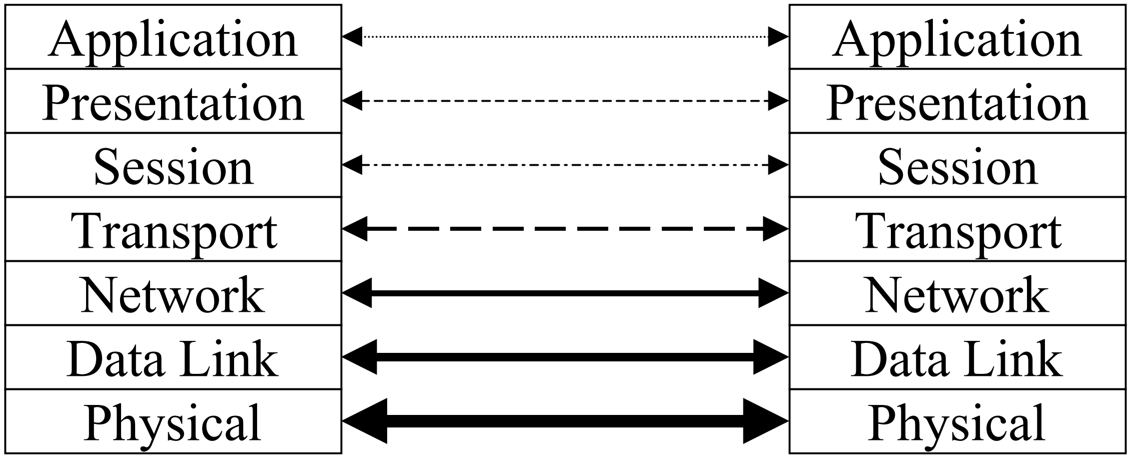

Application

Presentation

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Application

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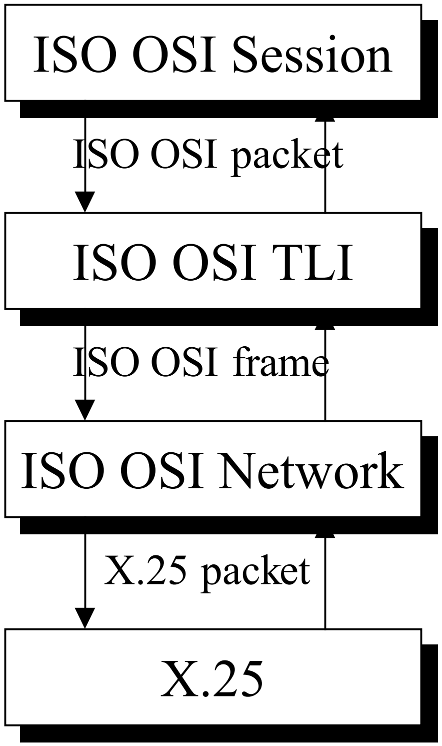
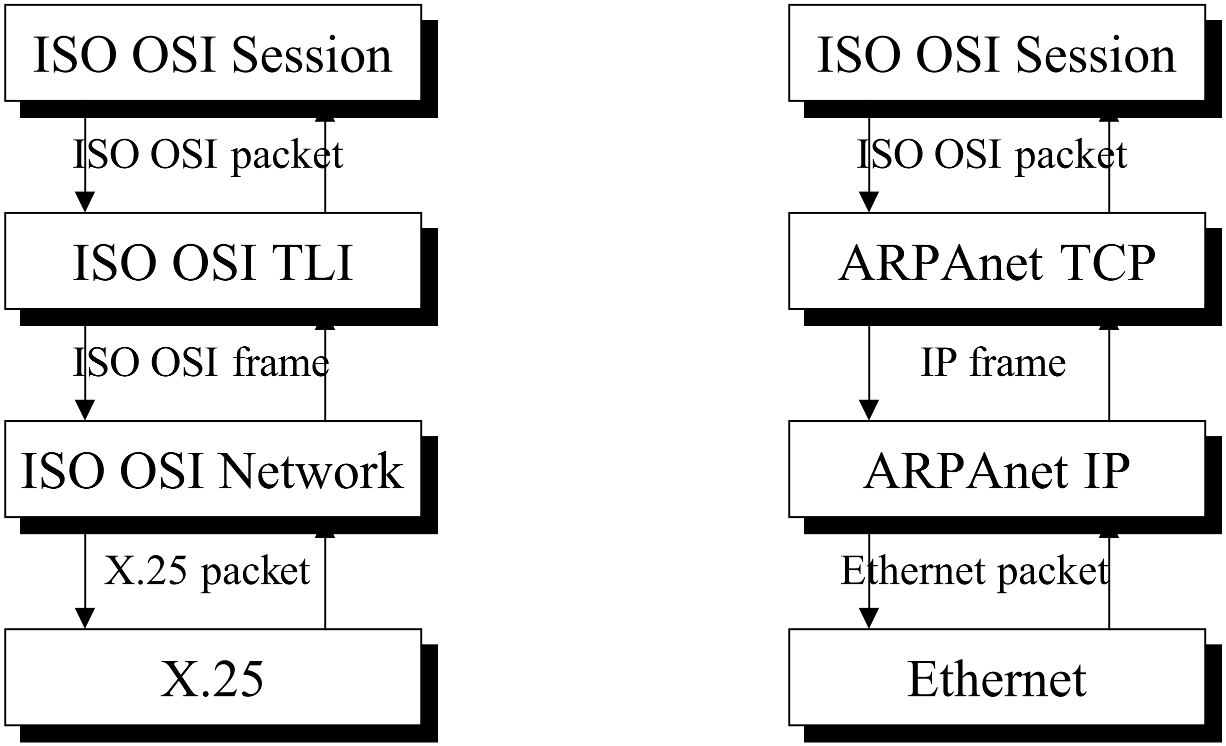
<u>Examples</u>

•Physical/Data Link layer networks: Ethernet, Token Ring, ATM
•Network layer net: The Internet
•Transport layer net: TCP-based network
•Presentation/Session layer net: http/html, RPC, PVM, MPI
•Applications, e.g., WWW, window system, numerical algorithm

ISO OSI & TCP/IP



ISO OSI & TCP/IP

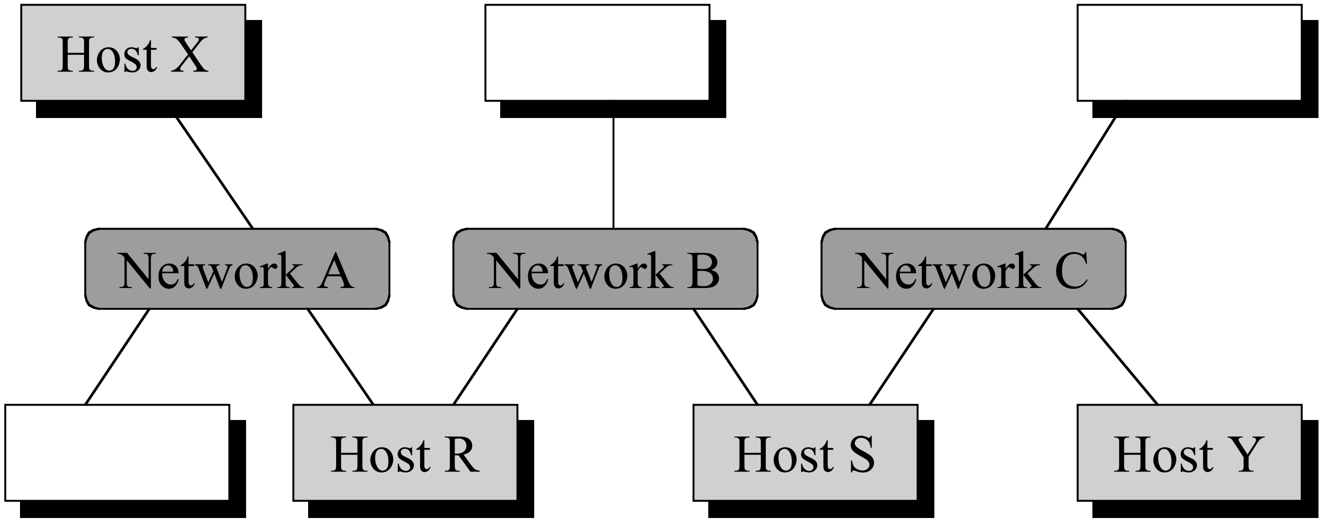


Low Level Protocols

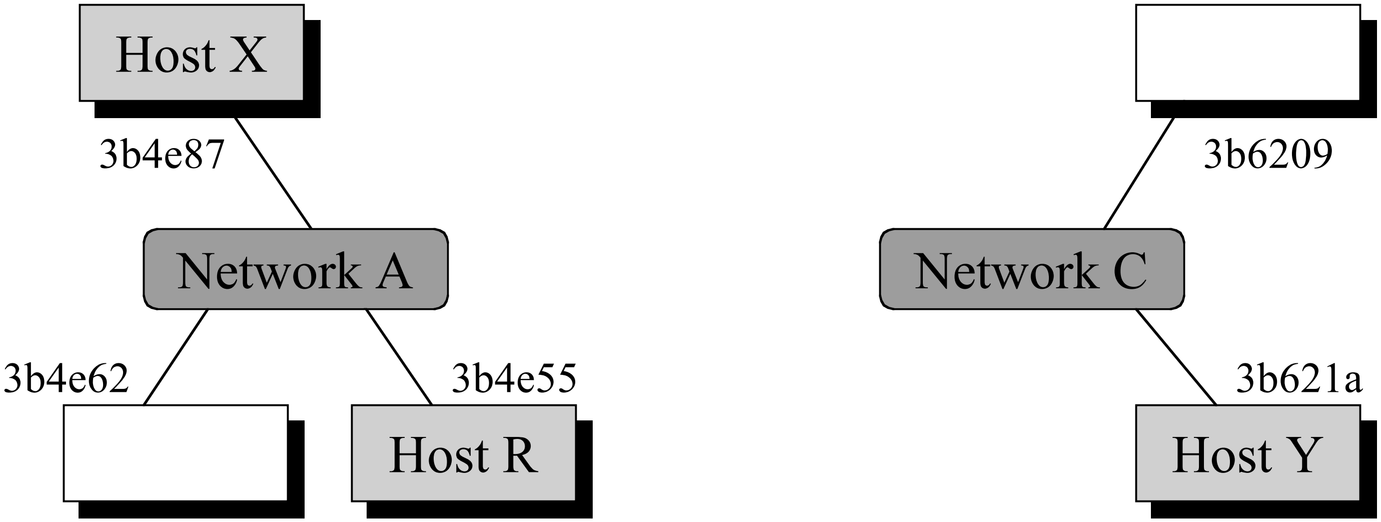
- Physical layer: Signaling technology
- Data link layer: Frame management
- *All done in hardware*
- Examples
  - Ethernet
  - Token ring
  - X.25
  - ATM
- Read pages 463-471

Network Layer

- Primary purpose is to combine networks
- *Internet protocol* (IP) is dominant protocol
- Creates an internet *address space*
- Implements packet *routing* across networks

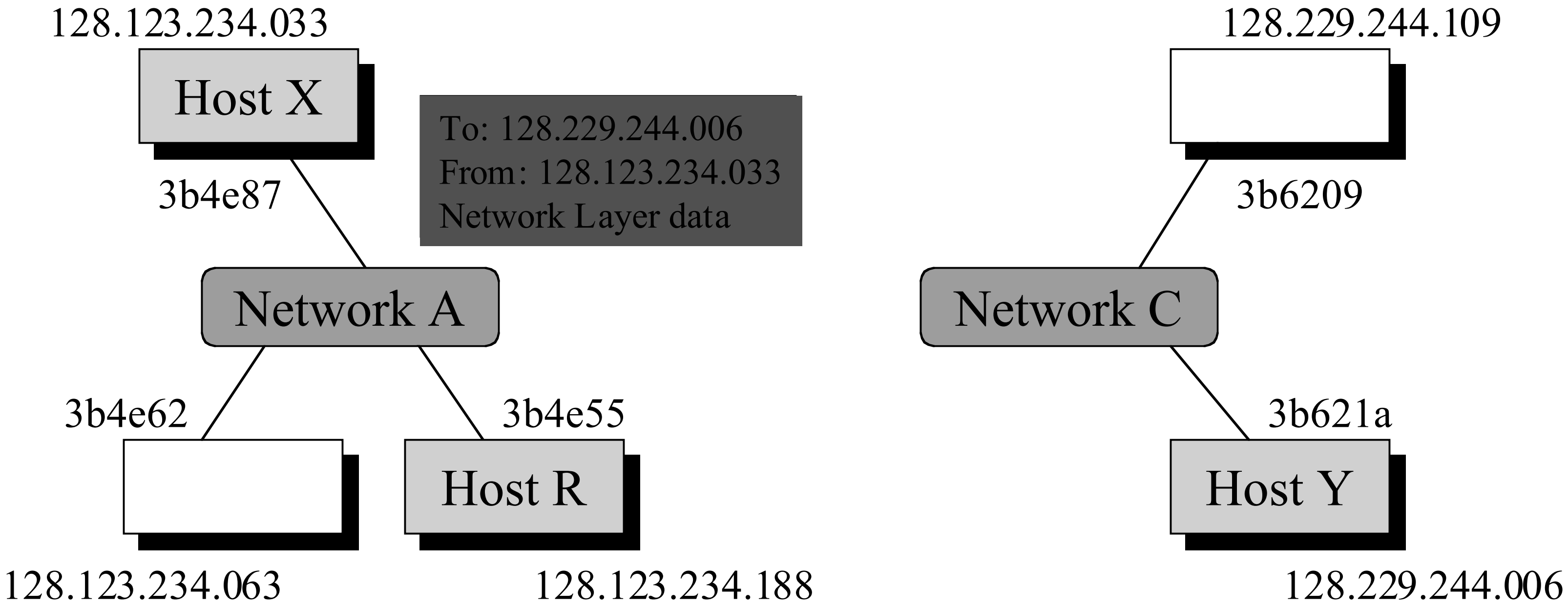


Addressing & Routing



- Host X does not know how to send to Host Y
- Can send a frame to Host R for forwarding
- What should it tell Host R?

Addressing & Routing



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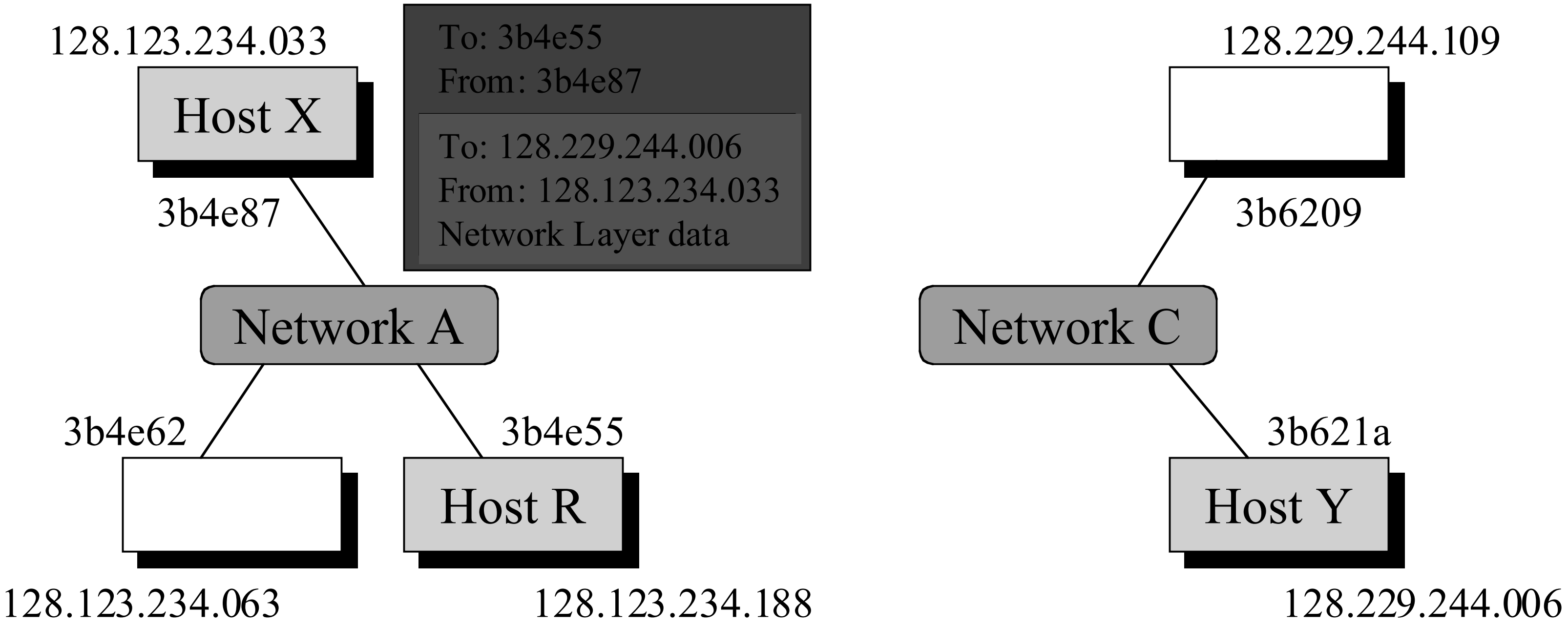
- Internet address spans all machines

Addressing & Routing

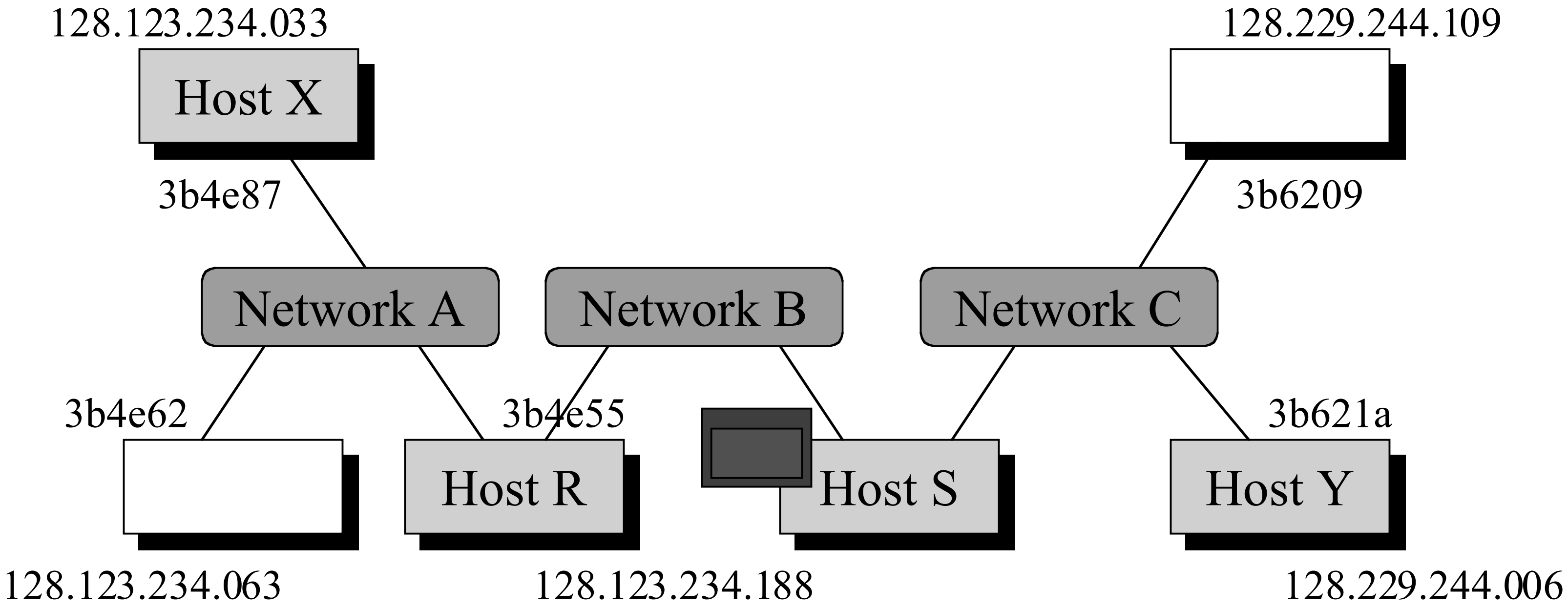


To: 3b4e55
From: 3b4e87

To: 128.229.244.006
From: 128.123.234.033
Network Layer data

- Host X does not know how to send to Host Y
- Can send a frame to Host R for forwarding
- What should it tell Host R?
- Internet address spans all machines
- Send *encapsulated* packet to Host R with Host Y

Addressing & Routing



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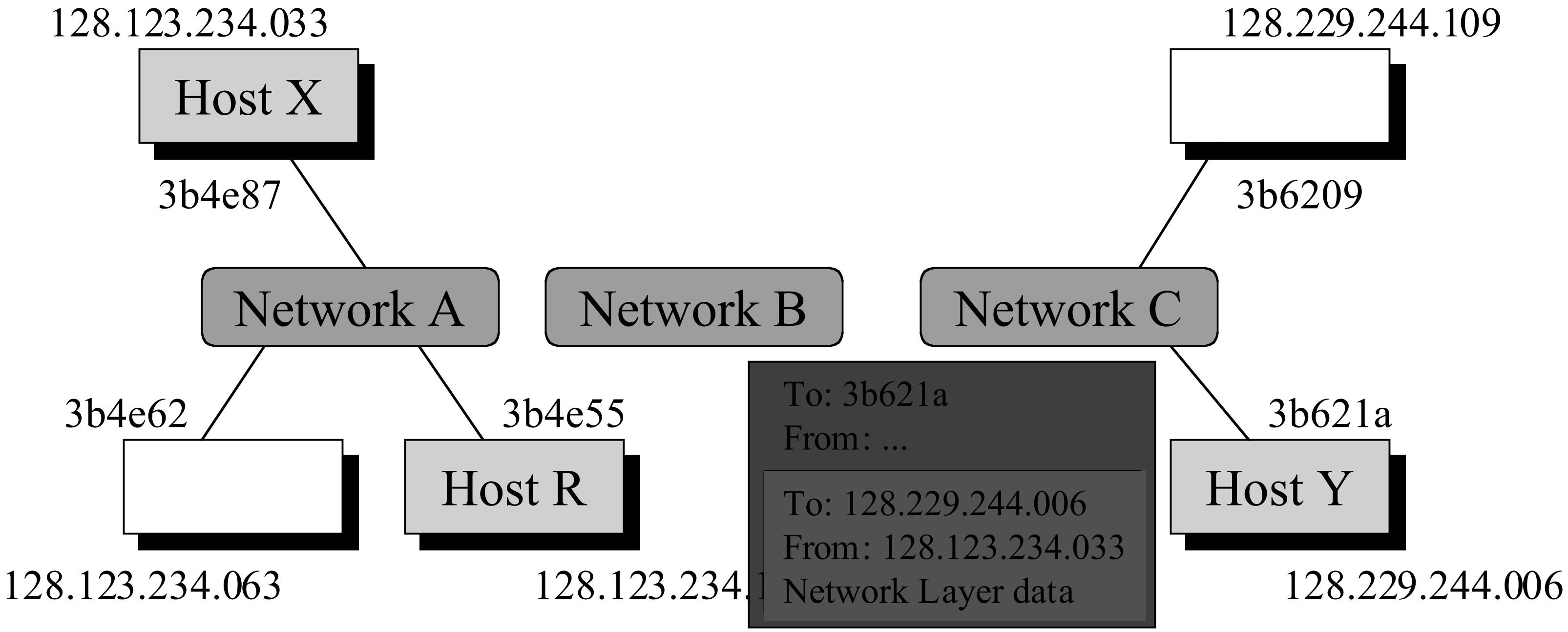
Addressing & Routing



128.123.234.033

Host X

3b4e87

128.229.244.109

3b6209

Network A

Network B

Network C

3b4e62

3b4e55

3b621a

Host R

Host Y

128.123.234.063

128.123.234.1

128.229.244.006

To: 3b621a
From: ...

To: 128.229.244.006
From: 128.123.234.033
Network Layer data

- Host X does not know how to send to Host Y
- Can send a frame to Host R for forwarding
- What should it tell Host R?
- Internet address spans all machines
- Send *encapsulated* packet to Host R with Host Y
- Data Link frame is received by Host Y

More on the Network Layer

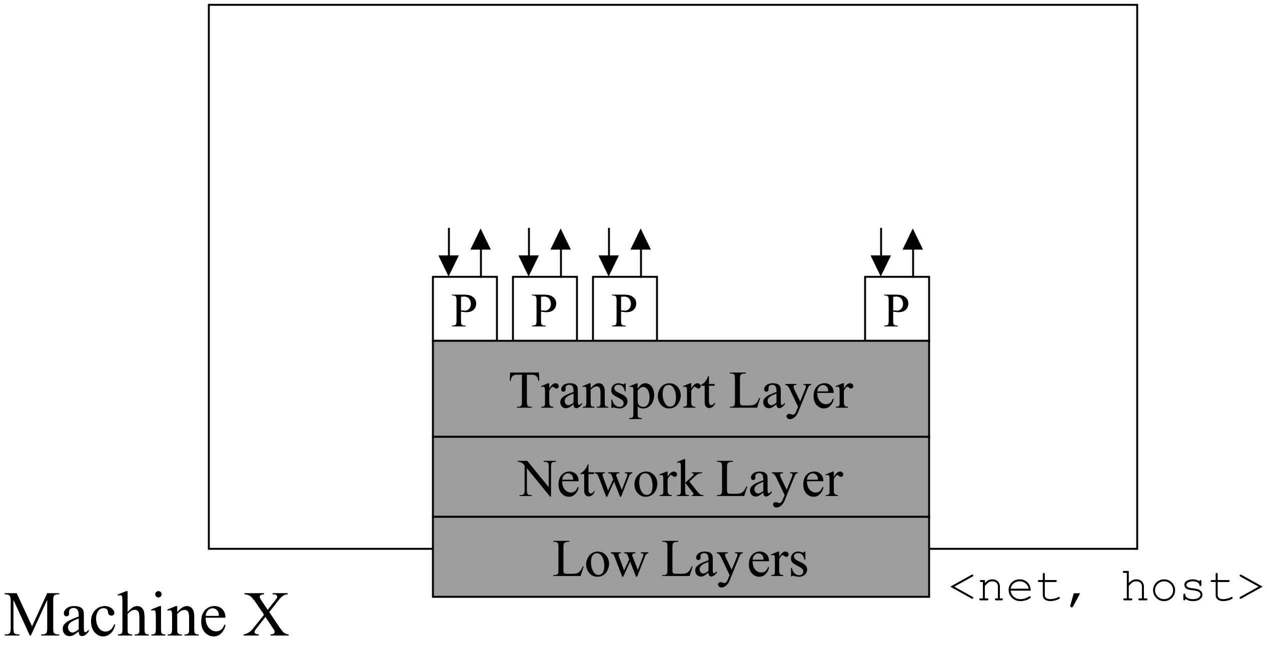
- Implements internet addressing & routing
- ARPAnet IP protocol is dominant -- underlies *the Internet*
- Intermediate hosts are called *gateways*
  - Connected to two or more networks
  - Runs IP routing software
  - `nag` is a gateway for the teaching lab
  - Read pages 471-477

Transport Layer

- Provides yet another address extension
  - IP references onlyu networks and hosts
  - Transport layer adds *ports* -- logical endpoints
  - Address form is `<net, host, port>`
- Two primary protocols (both from ARPAnet)
  - User Datagram Protocol (UDP)
    - User-space interface to IP packets
    - No guarantee that packet will be delivered
  - Transmission Control Protocol (TCP)
    - Provides a stream-oriented interface to the network
    - Reliable delivery

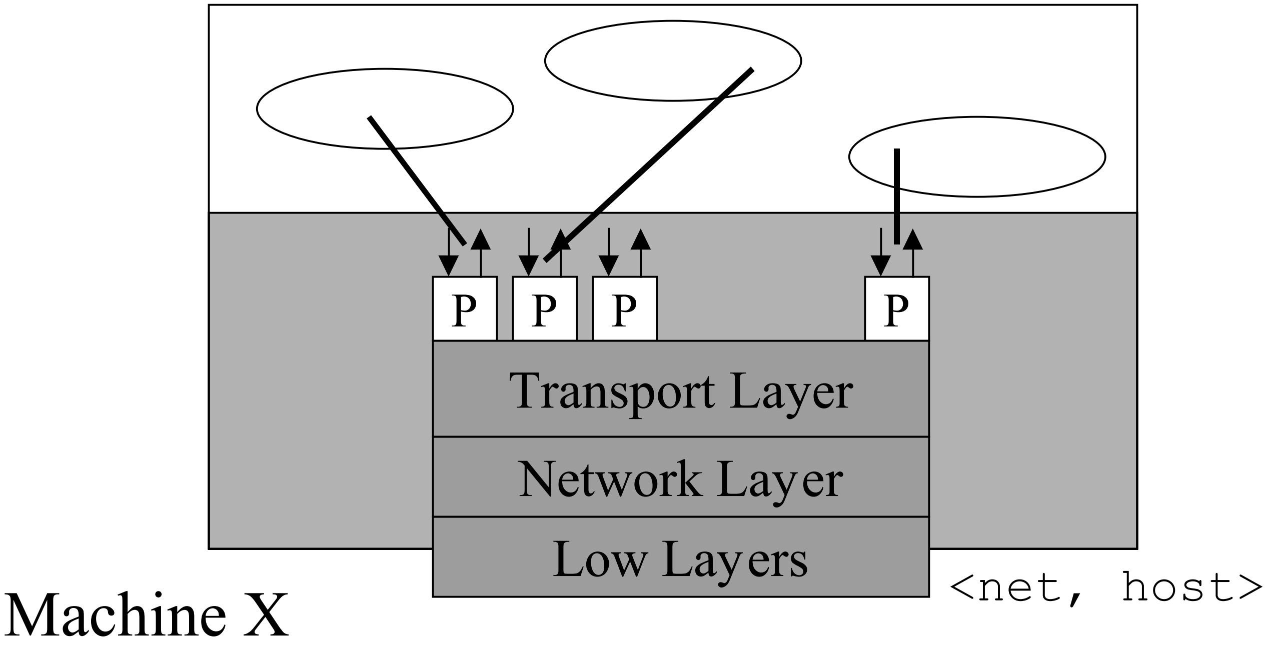
Communication Ports

- Global name for a “mailbox”
- Will be many ports at one <net, host>



Communication Ports

- Global name for a “mailbox”
- Will be many ports at one <net, host>
- Each port can be *bound* to an address



BSD Sockets

- Sockets are comm ports in BSD UNIX
- Semantics resemble pipes (files)
- Bidirectional

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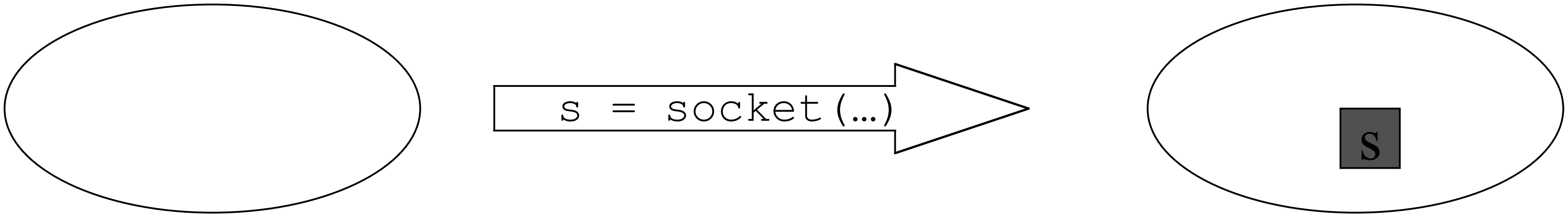
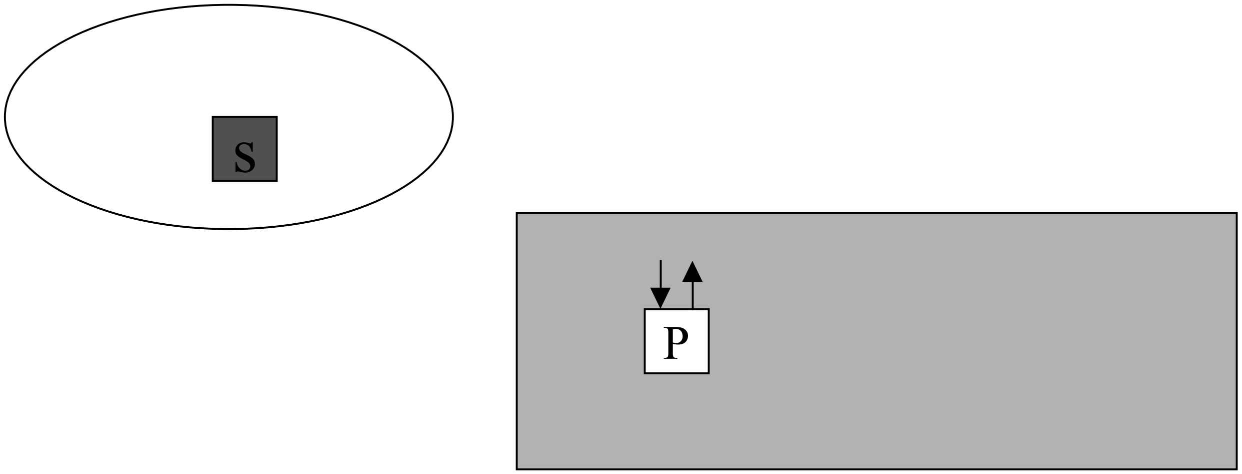
```
int socket(int addressFamily, int socketType, int protocolNo)
```



BSD Sockets (cont)

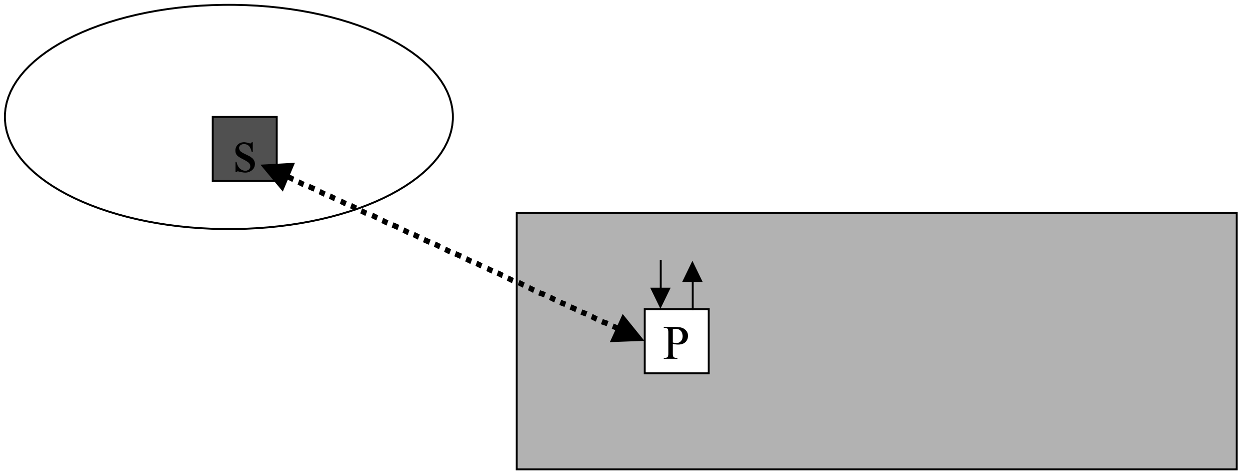
- Once a socket has been created, it can be bound to an internet port



BSD Sockets (cont)

- Once a socket has been created, it can be bound to an internet port

```
int bind(int skt, struct sockadrr *addr, int addrLength)
```



- Example code available on the web page

UDP

- *Datagram* ("*connectionless*") service
  - Similar to disk I/O level of service
- Logically associated with an IP packet & Data Link frame (but not physically)
- Best-effort delivery of datagrams, but:
  - Datagram may be dropped (lost)
  - Datagrams may be delivered out of order
- Efficient, relative to TCP

Using UDP

```
/* Set up a socket to talk to the server */
    skt = socket(AF_INET, SOCK_DGRAM, 0);
    host = gethostbyname(remoteHostName);
    bzero(&remote, sizeof(remote));
    remote.sin_family = host->h_addrtype;
    remote.sin_port = htons(remotePort);
    bcopy(host->h_addr, &remote.sin_addr, host->h_length);
/* Export the socket to a port (and IP address) */
    host = gethostbyname(localHostName);
    bzero(&local, sizeof(local));
    local.sin_family = host->h_addrtype;
    local.sin_port = htons(localPort);
    bcopy(host->h_addr, &local.sin_addr, host->h_length);
    if(bind(skt, &local, sizeof(local))) {
        printf("Bind error ... restart\n");
        exit(1);
    }
    . . .
    sendto(s, outBuf, strlen(outBuf), 0, remote, sizeof(remote));
    if((len = recv(s, inBuf, BUFLEN, 0)) > 0) {. . .}
```

TCP

- *Connected* (or *virtual circuit*) protocol
- Interface allows programmer to read/write a byte stream over the network
- Byte stream is mapped into a series of packets
  - Reliable delivery
  - Each packet must be acknowledged
  - Effectively 2 packets per transmission
- Must open/close a connection before use

Using TCP -- Client

```
skt = socket(AF_INET, SOCK_STREAM, 0);
host = gethostbyname(serverHostName);
bzero(&listener, sizeof(listener));
listener.sin_family = host->h_addrtype;
listener.sin_port = htons(port);
bcopy(host->h_addr, &listener.sin_addr, host->h_length);
if(connect(skt, &listener, sizeof(listener))) {
    printf("Connect error ... restart\n");
    printf("(Must start Server end first)\n");
    exit(1);
};
. . .
write(s, outBuf, BUFLEN);
if((len = read(s, inBuf, BUFLEN)) > 0) {. . .}
```

Using TCP -- Server

```
skt = socket(AF_INET, SOCK_STREAM, 0);  /* Produce an inet address */
host = gethostbyname(serverHostName);
bzero(&listener, sizeof(listener));
listener.sin_family = host->h_addrtype;
listener.sin_port = htons(port);
bcopy(host->h_addr, &listener.sin_addr, host->h_length);
if(bind(skt, &listener, sizeof(listener))) {
    printf("Bind error ... restart\n");
    exit(1);
}
listen(skt, BACKLOG);    /* Listen for a request */
newSkt = accept(skt, &client, &clientLen);
if (fork() == 0) {
    close(skt);     /* Child doesn't need listener socket */
    . . .
}
close(newSkt);          /* Parent doesn't need the new socket */

if((len = read(s, inBuf, BUFLEN)) > 0) { . . .}
write(s, outBuf, BUFLEN);
```

Client-Server Paradigm

- Making a connection in TCP is an example of the *client-server paradigm* for distributed computing
  - Active component is the client
    - Runs autonomously
    - Decides when it wants to use server
  - Passive component is the server
    - Persistent
    - Always waiting for a client to request service
- Not a machine -- just software