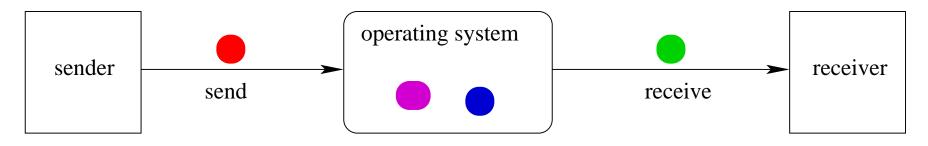
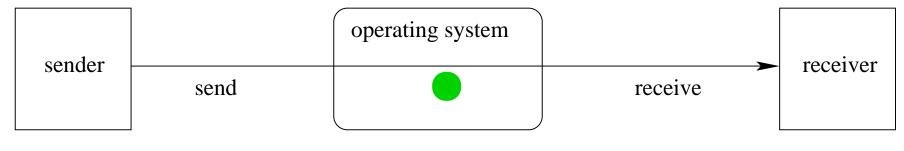
# **Interprocess Communication Mechanisms**

- shared storage
  - shared virtual memory
  - shared files
- message-based
  - sockets
  - pipes
  - signals
  - **–** . . .

# **Message Passing**

#### **Indirect Message Passing**





Direct Message Passing

If message passing is indirect, the message passing system must have some capacity to buffer (store) messages.

# **Properties of Message Passing Mechanisms**

# **Directionality:**

- simplex (one-way), duplex (two-way)
- half-duplex (two-way, but only one way at a time)

#### **Message Boundaries:**

datagram model: message boundaries

stream model: no boundaries

**Connections:** need to connect before communicating?

- in connection-oriented models, recipient is specified at time of connection, not by individual send operations. All messages sent over a connection have the same recipient.
- in connectionless models, recipient is specified as a parameter to each send operation.

#### **Reliability:**

• can messages get lost? reordered? damaged?

#### **Sockets**

- a socket is a communication *end-point*
- if two processes are to communicate, each process must create its own socket
- two common types of sockets
  - **stream sockets:** support connection-oriented, reliable, duplex communication under the stream model (no message boundaries)
  - **datagram sockets:** support connectionless, best-effort (unreliable), duplex communication under the datagram model (message boundaries)
- both types of sockets also support a variety of address domains, e.g.,
  - **Unix domain:** useful for communication between processes running on the same machine
  - **INET domain:** useful for communication between process running on different machines that can communicate using IP protocols.

# **Using Datagram Sockets (Receiver)**

```
s = socket(addressType, SOCK_DGRAM);
bind(s,address);
recvfrom(s,buf,bufLength,sourceAddress);
...
close(s);
```

- socket creates a socket
- bind assigns an address to the socket
- recvfrom receives a message from the socket
  - buf is a buffer to hold the incoming message
  - sourceAddress is a buffer to hold the address of the message sender
- both buf and sourceAddress are filled by the recvfrom call

# **Using Datagram Sockets (Sender)**

```
s = socket(addressType, SOCK_DGRAM);
sendto(s,buf,msgLength,targetAddress)
...
close(s);
```

- socket creates a socket
- sendto sends a message using the socket
  - buf is a buffer that contains the message to be sent
  - msgLength indicates the length of the message in the buffer
  - targetAddress is the address of the socket to which the message is to be delivered

# **More on Datagram Sockets**

- sendto and recvfrom calls may block
  - recvfrom blocks if there are no messages to be received from the specified socket
  - sendto blocks if the system has no more room to buffer undelivered messages
- datagram socket communications are (in general) unreliable
  - messages (datagrams) may be lost
  - messages may be reordered
- The sending process must know the address of the receive process's socket.

#### **Using Stream Sockets (Passive Process)**

```
s = socket(addressType, SOCK_STREAM);
bind(s,address);
listen(s,backlog);
ns = accept(s,sourceAddress);
recv(ns,buf,bufLength);
send(ns,buf,bufLength);
...
close(ns); // close accepted connection
close(s); // don't accept more connections
```

- listen specifies the number of connection requests for this socket that will be queued by the kernel
- accept accepts a connection request and creates a new socket (ns)
- recv receives up to bufLength bytes of data from the connection
- send sends bufLength bytes of data over the connection.

#### **Notes on Using Stream Sockets (Passive Process)**

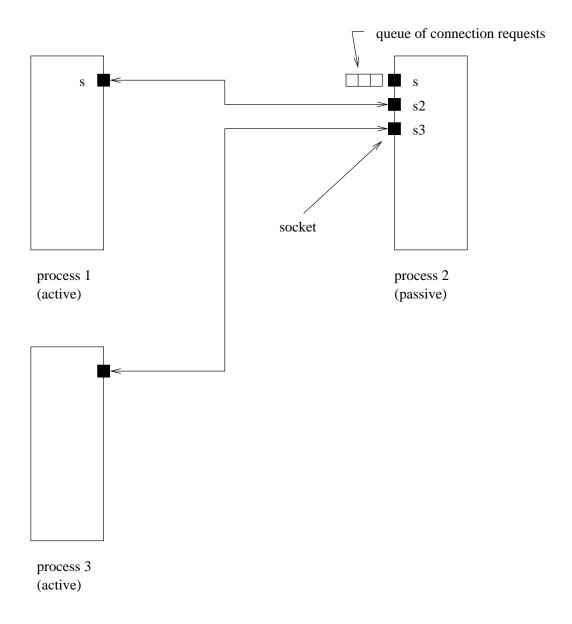
- accept creates a new socket (ns) for the new connection
- sourceAddress is an address buffer. accept fills it with the address of the socket that has made the connection request
- additional connection requests can be accepted using more accept calls on the original socket (s)
- accept blocks if there are no pending connection requests
- connection is duplex (both send and recy can be used)

#### **Using Stream Sockets (Active Process)**

```
s = socket(addressType, SOCK_STREAM);
connect(s,targetAddress);
send(s,buf,bufLength);
recv(s,buf,bufLength);
...
close(s);
```

- connect sends a connection request to the socket with the specified address
  - connect blocks until the connection request has been accepted
- active process may (optionally) bind an address to the socket (using bind) before connecting. This is the address that will be returned by the accept call in the passive process
- if the active process does not choose an address, the system will choose one

#### **Illustration of Stream Socket Connections**



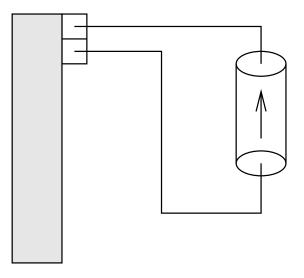
### **Pipes**

- pipes are communication objects (not end-points)
- pipes use the stream model and are connection-oriented and reliable
- some pipes are simplex, some are duplex
- pipes use an implicit addressing mechanism that limits their use to communication between *related* processes, typically a child process and its parent
- a pipe () system call creates a pipe and returns two descriptors, one for each end of the pipe
  - for a simplex pipe, one descriptor is for reading, the other is for writing
  - for a duplex pipe, both descriptors can be used for reading and writing

# **One-way Child/Parent Communication Using a Simplex Pipe**

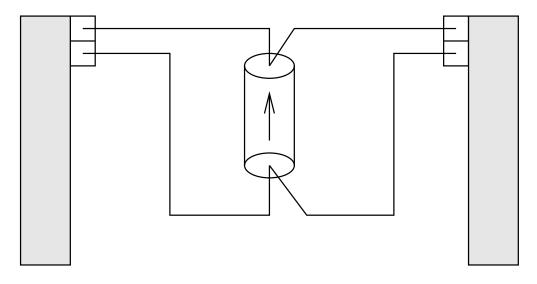
```
int fd[2];
char m[] = "message for parent";
char y[100];
pipe(fd); // create pipe
pid = fork(); // create child process
if (pid == 0) {
  // child executes this
  close(fd[0]); // close read end of pipe
  write(fd[1],m,19);
  . . .
} else {
  // parent executes this
  close(fd[1]); // close write end of pipe
  read(fd[0],y,19);
  . . .
```

# Illustration of Example (after pipe ())



parent process

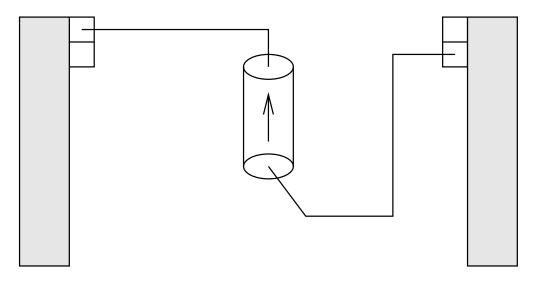
# Illustration of Example (after fork ())



parent process

child process

# **Illustration of Example (after close())**



parent process child process

# **Examples of Other Interprocess Communication Mechanisms**

### named pipe:

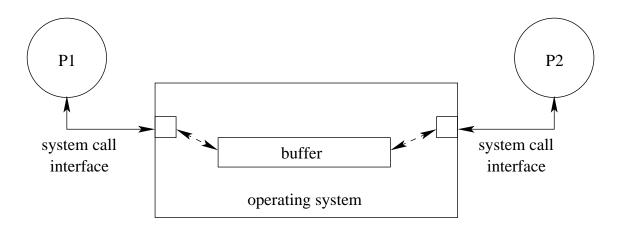
- similar to pipes, but with an associated name (usually a file name)
- name allows arbitrary processes to communicate by opening the same named pipe
- must be explicitly deleted, unlike an unnamed pipe

#### message queue:

- like a named pipe, except that there are message boundaries
- msgsend call sends a message into the queue, msgrecv call receives the next message from the queue

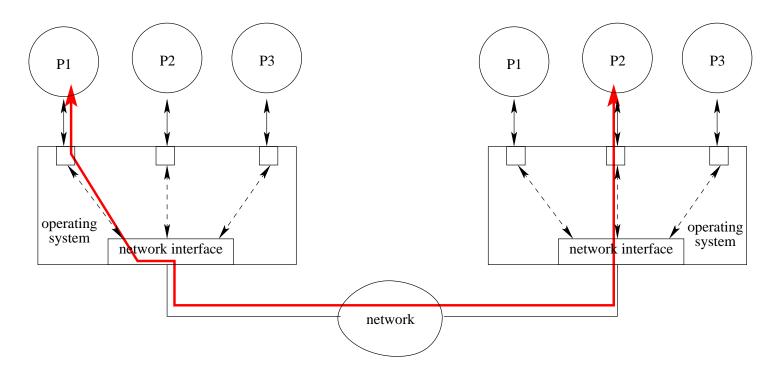
# **Implementing IPC**

- application processes use descriptors (identifiers) provided by the kernel to refer to specific sockets and pipes, as well as files and other objects
- kernel *descriptor tables* (or other similar mechanism) are used to associate descriptors with kernel data structures that implement IPC objects
- kernel provides bounded buffer space for data that has been sent using an IPC mechanism, but that has not yet been received
  - for IPC objects, like pipes, buffering is usually on a per object basis
  - IPC end points, like sockets, buffering is associated with each endpoint



# **Network Interprocess Communication**

- some sockets can be used to connect processes that are running on different machines
- the kernel:
  - controls access to network interfaces
  - multiplexes socket connections across the network



# **Signals**

- signals permit asynchronous one-way communication
  - from a process to another process, or to a group of processes, via the kernel
  - from the kernel to a process, or to a group of processes
- there are many types of signals
- the arrival of a signal may cause the execution of a *signal handler* in the receiving process
- there may be a different handler for each type of signal

# **Examples of Signal Types**

Signal	Value	Action	Comment
SIGINT	2	Term	Interrupt from keyboard
SIGILL	4	Core	Illegal Instruction
SIGKILL	9	Term	Kill signal
SIGCHLD	20,17,18	Ign	Child stopped or terminated
SIGBUS	10,7,10	Core	Bus error
SIGXCPU	24,24,30	Core	CPU time limit exceeded
SIGSTOP	17,19,23	Stop	Stop process

# **Signal Handling**

- operating system determines default signal handling for each new process
- example default actions:
  - ignore (do nothing)
  - kill (terminate the process)
  - stop (block the process)
- a running process can change the default for some types of signals
- signal-related system calls
  - calls to set non-default signal handlers, e.g., Unix signal, sigaction
  - calls to send signals, e.g., Unix kill