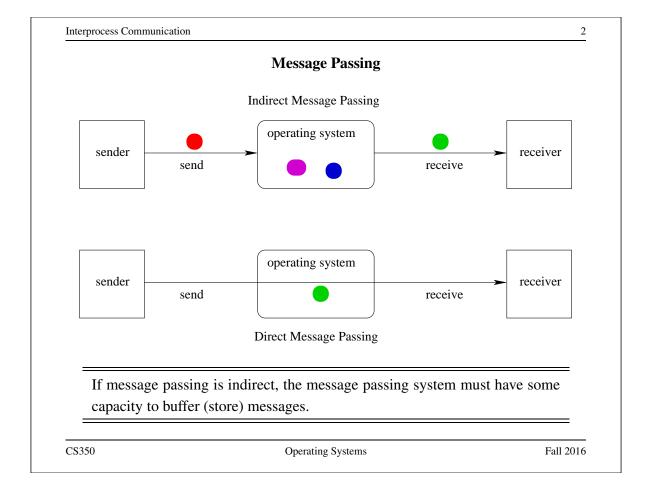
Interprocess Communication Mechanisms

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



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?

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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

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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.

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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)

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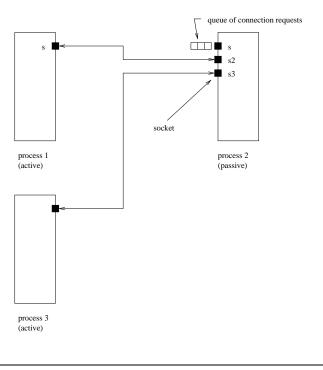
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Using Stream Sockets (Active Process)

```
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



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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

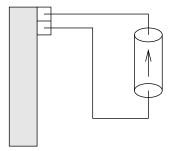
```
int fd[2];
char m[] = "message for parent";
char y[100];
pipe(fd); // create pipe
pid = fork(); // create child process
if (pid == 0) {
    // child executes this
    close(fd[0]); // close read end of pipe
    write(fd[1],m,19);
    ...
} else {
    // parent executes this
    close(fd[1]); // close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

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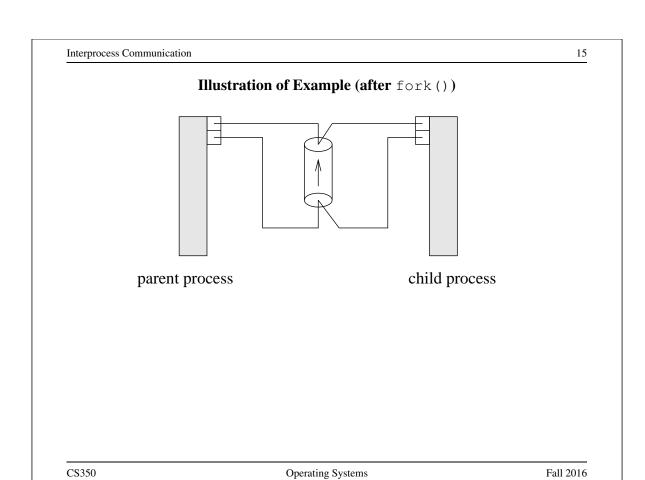
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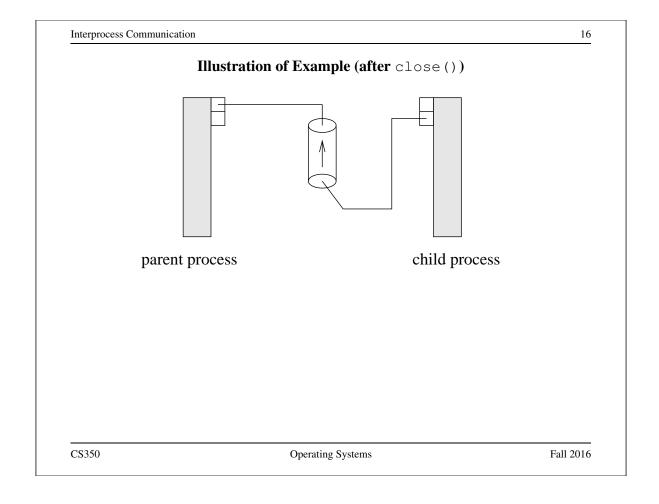
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Illustration of Example (after pipe ())



parent 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

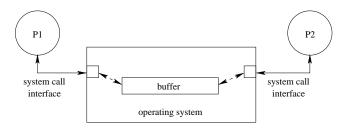
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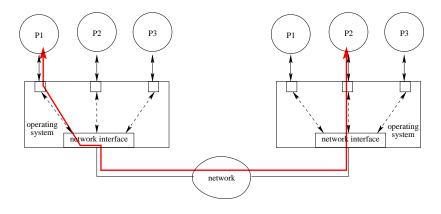
Implementing IPC

- 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



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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

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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