CSci 4061
Introduction to Operating Systems

Module 4: Communication
IPC: Basics, Pipes
Chap 6-6.2

Communication

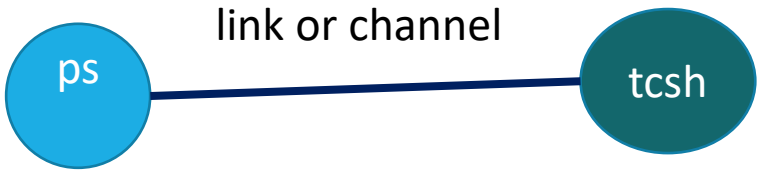
- Abstraction: conduit for data exchange between two or more processes (or threads)

IPC in Unix

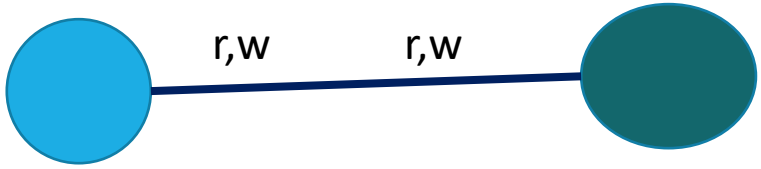
- Pipes: most basic form of IPC in Unix
  - process-process
  - `ps -u weiss039 | grep tcsh` // what happens?

- Pipe has a "read-end" (receive) and a "write-end" (send) : think of this actually as a 
  - FIFO communication
    - (write A, write B, read->A, read->B)
  - "Bi-directional"

IPC in Unix (cont'd)



- Pipe allows communication between a parent and child or related processes



Pipes

```
#include <unistd.h>
int pipe (int ends[2]); // returns -1 on failure
```

output parameter

`ends` is a 2-integer `fd` array that represents the ends of the pipe

`ends[0]` is the "read-end" (receive) and

`ends[1]` is the "write-end" (send)

Integrated into filesystem

Link is "named" by the pipe but we do not name the reader/writer processes

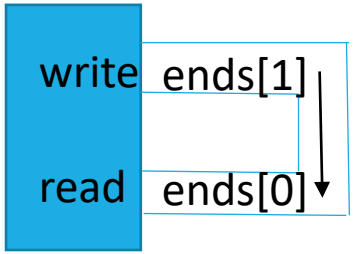
How can `pipe` fail?

Pipes and FD

Simple pipe example: single process

```
#include <unistd.h>
#include <stdio.h>
#define MSGSIZE 16
char *msg1 = "hello, world #1";
char *msg2 = "hello, world #2";
void main () {
      char inbuf [MSGSIZE];
      int ends[2];

      if (pipe(ends) == -1)  {
            perror ("pipe error");
            exit (1);
      }
…
```

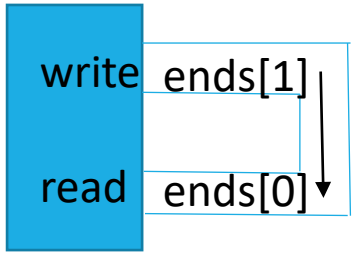


Simple pipe example (cont'd)

```
// write (send) down pipe
write (ends[1], msg1, MSGSIZE);
write (ends[1], msg2, MSGSIZE);
// read (receive) from pipe
read (ends[0], inbuf, MSGSIZE);
fprintf (stderr, "%s\n", inbuf);
read (ends[0], inbuf, MSGSIZE);
fprintf (stderr, "%s\n", inbuf);
```

Output is:

hello, world #1
hello, world #2



Read and write

```
write (ends[1], msg, MSGSIZE);
read (ends[0], inbuf, MSGSIZE);
```

Read may not get everything but it “usually does” up to *max* (MSGSIZE, and pipe contents)

- blocks if pipe if empty

Pipe have finite size (e.g. 4K/8K)

- write blocks if not enough space
- why is there a limit?

Simple pipe example: multi process

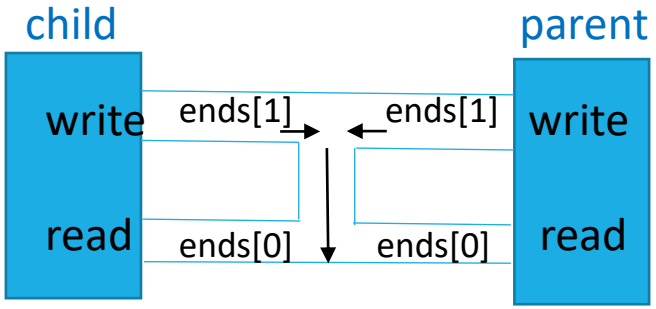
```
void main () {
    char inbuf [MSGSIZE];
    int ends[2], j;
    pid_t pid;

    if (pipe(ends) == -1)  {
        perror (“pipe error”);
        exit (1);
    }
```

Multi process (cont'd)

```
pid = fork ();
if (pid == 0) {                          // child sends into pipe
        write (ends[1], msg1, MSGSIZE);
        write (ends[1], msg2, MSGSIZE);
}
else if (pid > 0) {                      // parent receives from pipe
        read (ends[0], inbuf, MSGSIZE);
        fprintf (stderr, "%s\n", inbuf);
        read (ends[0], inbuf, MSGSIZE);
        fprintf (stderr, "%s\n", inbuf);
        wait (NULL);
}
```

why does this work across these processes?



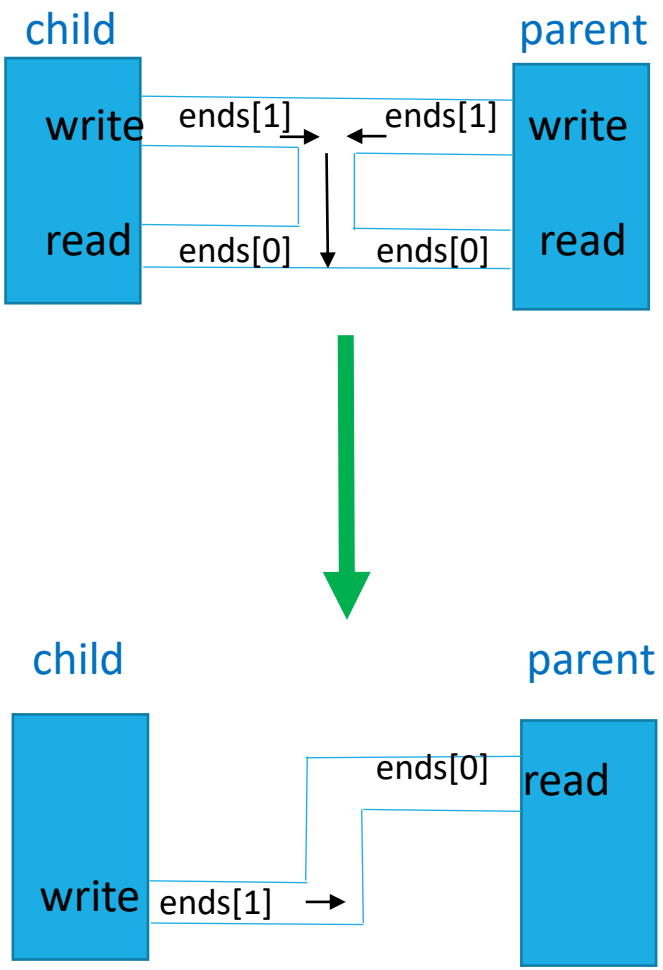
Issues

- Potential problem
  - If both processes write into the pipe, what would happen?
  - Usually, one writes and other reads
  - Either way, writes would likely be serialized

Resolving

```
if (pid == 0) {                    // child sends into pipe
     close (ends[0]);
     write (ends[1], msg1, MSGSIZE);
     write (ends[1], msg2, MSGSIZE);
}
else if (pid > 0) {                // parent receives from pipe
     close (ends[1]);
     read (ends[0], inbuf, MSGSIZE);
     fprintf (stderr, "%s\n", inbuf);
     read (ends[0], inbuf, MSGSIZE);
     fprintf (stderr, "%s\n", inbuf);
     wait (NULL);
}
```

New picture


child
parent
write
ends[1]
ends[1]
write
read
ends[0]
ends[0]
read
child
parent
ends[0]
read
write
ends[1]

Typical Pipe Use Case

- Near infinite stream of data from producer to consumer
  - consumer (reader) had better keep up with producer (writer) and vice-versa
  - why?
  - `cat * | wc`
- You cannot `fseek/seek` a pipe `fd`

More on pipes

- `close` write-end (and no processes have pipe open for write) and pipe is empty:
  - `read` returns a 0
- `close` read-end and write-end is open:
  - `write` kills the process!
  - "broken pipe"
- Pipes are limited to parent-child siblings, related process relationships must share `fd`s

Example: Knock-Knock

- https://www.youtube.com/watch?v=uky0JpQzDNI

Example: Knock-Knock

- Protocol: sequence of messages

P: “k-k” “orange” “aren’t you glad this isn’t Java?”

C: “w-t?” “orange-who?”

P: w, r, w, r, ..

C: r, w, r, w, …

Solution

Sol 1:

```
pipe (ends);
fork ();
```

// parent

```
write (ends[1], "k-k", …)
read (ends[0], buf, …);
write (ends[1], "orange", …);
read (ends [0], buf, …);
write (ends[1], "aren't …", …);
```

// child

```
read (ends[0], buf, …);
write (ends[1], "w-t?", …);
read (ends [0], buf, …);
write (ends[1], "orange-who?", …);
read (ends [0], buf, …);
```

Issues?

Better one?

Solution

Sol 2:

```
int P_C[2], C_P[2];
pipe (P_C);
pipe (C_P);
fork ();
```

```
// parent
close (P_C[0]);
close (C_P[1]);
write (P_C[1], …)
read (C_P[0], …);
…
```

```
// child
close (P_C[1]);
close (C_P[0]);
read (P_C[0], …);
write (C_P[1], …);
…
```

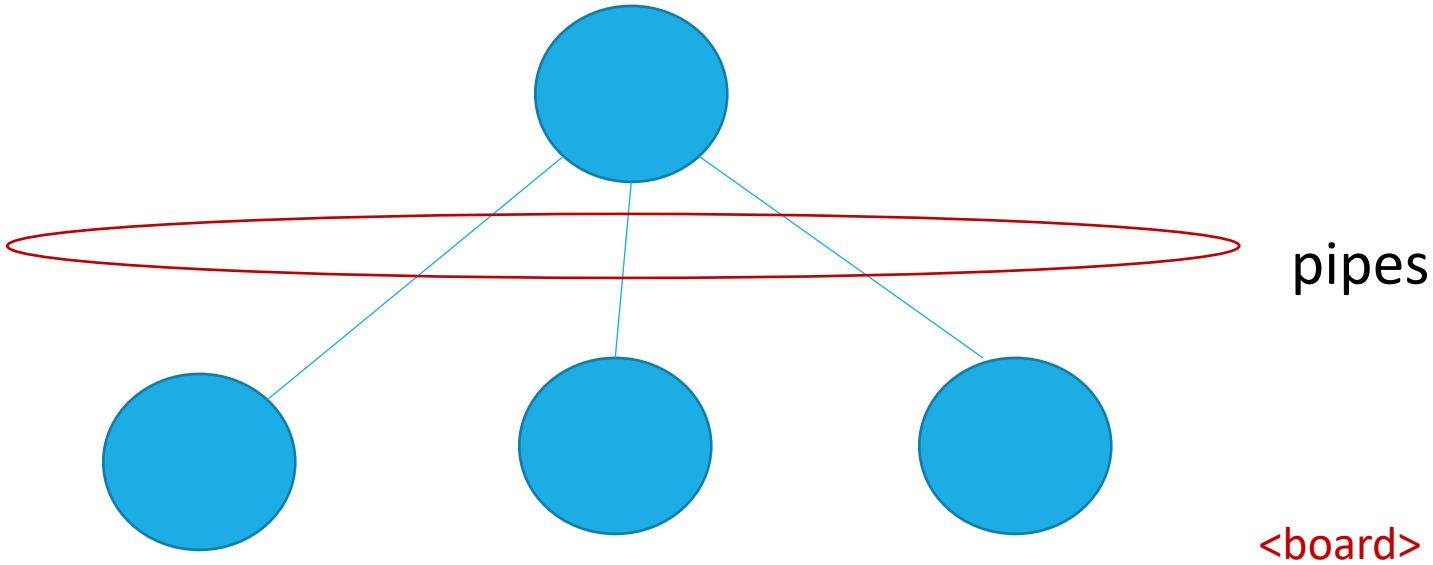
Takeaway Lesson

- Knock-knock example …
- Need two-way communication
- Most likely will need a pair of pipes

Non-blocking pipes: example

- Children may inform the parents of various events or ask for things to do … BUT this is unpredictable …

- Suppose we do blocking I/O?



Non-blocking pipes

- Default I/O behavior is blocking
- Non-blocking I/O can be handy
- Since pipe is a file … can control attributes

```
#include <fcntl.h>
int fcntl (int fd, int cmd, …);
int ends[2], flags, nread;

pipe (ends);
flags = fcntl (fd, F_GETFL, 0);
fcntl (ends[0], F_SETFL, flags | O_NONBLOCK);
…
nread = read (ends[0], buf, size);
```

// if nothing to `read`, returns -1, `errno` set to `EAGAIN`

Pipes in the shell

- `ps -u weiss039 | grep tcsh`
- How does the shell do it?

```
pipe (ends);
if (childpid = fork ()) == 0) {
      dup2(ends[1], 1);
      close (ends[0]);
      execl("/bin/ps", ….);
}
else {
      dup2(ends[0], 0);
      close (ends[1]);
      execl("/bin/grep", …);
}
```

Sending Discrete “Data”

- Sending a message into a pipe or any fd

```
typedef struct {
        int x;
        int y;
        char str[20];
} message_t;

message_t m1, m2;
int ends[2];

pipe (ends); // check for error!

// send m1 into the pipe
write (ends[1], &m1, sizeof (message_t));

// pull data into m2 from the pipe
read (ends[0], &m2, sizeof (message_t));
```

Must be contiguous data