Pipes

pipes

- Pipes

  interprocess communication

  system provided facilities

  passing information

  read/write

  "special file" with limited capacity

  PIPE_SIZE

  `<linux/limits.h>`

  FIFO

pipes

- Pipes

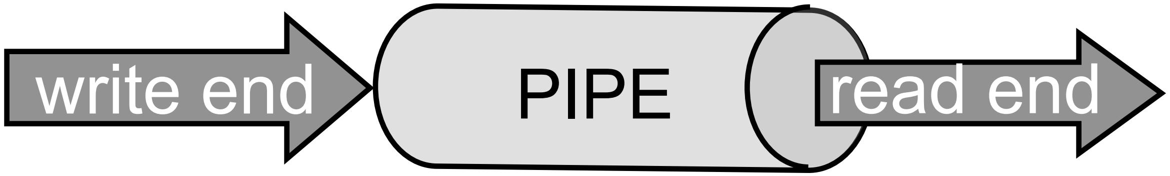
write end

read end

system maintains pointer to current location

system manages current location

no seek permitted



pipes

- Synchronization
  - done by operating system system
  - atomic read/write
  - no seek
  - blocks on
    - write full
    - empty read
    - open for read with no open for write
  - use `read/write` system call
    - unbuffered I/O

pipes

- Synchronization

```
ssize_t write (int fd, const void *buf, size_t count);
```

write `count` bytes from `buffer` to file descriptor `fd`

returns number of bytes written

-1 on error

sets `errno`

pipes

- errors
  - i/o error
  - bad file pointer
  - resource temporarily unavailable
  - bad address
  - file too large
  - no space left on device
  - numerical result out of range count value

pipes

- write
  - always appends to end of pipe
  - writes of `PIPE_BUF` size or less are guaranteed to **not** be interleaved with other write requests to same pipe
  - write to a pipe not opened for read generates a `SIGPIPE` signal (default action is to terminate)
  - if both `ON_NONBLOCK` and `O_NDELAY` flags are clear, `write` blocks if device is busy
    - set in `fcntl` system call
  - if both `ON_NONBLOCK` and `O_NDELAY` flags are not clear `write` will not block

pipes

- read

```
ssize_t read (int fd, void *buf, size_t count);
```

reads `count` bytes

unbuffered I/O `read` system call

returns

actual number of bytes read

zero if at end of pipe

-1 on error

sets `errno`

pipes

- possible errors
  - I/O error
  - No such file or address (file descriptor)
  - Bad file descriptor (not opened for reading)
  - Bad address (buffer references an illegal address)

pipes

- read
  - initiated from current position
    - no seeks
  - If both `ON_NONBLOCK` and `O_NDELAY` flags are clear `read` blocks on empty until data is written or pipe is closed
  - if pipe is not opened for writing returns a 0

pipes

- unnamed pipes
  - used only by related processes
    - parent/child
    - child/child
  - exists as long as they are in use
- named pipes
  - exists as directory entries
  - have file access permissions
  - can be used by unrelated processes

pipes

- **unnamed pipes**
  - pipe system call

```
int pipe( int filedes[2]);
```

  - Returns a pair of integer file descriptors
    - filedes[0]
    - filedes[1]
    - they reference two data streams
      - Linux
        - half duplex: unidirectional
      - Solaris
        - full duplex: bidirectional

pipes

- unnamed pipes
  - half duplex
    - `filedes[0]`
      - reading
    - `filedes[1]`
      - writing
  - full duplex
    - agree on use of read/write ends
    - both opened for reading and writing

pipes

- possible errors
  - file table overflow
  - too many opened files
  - bad address (invalid file descriptor)

pipes

```
int main(int argc, char *argv[ ]) {
  int             f_des[2];
  static char     message[BUFSIZ];
  if (argc != 2) {
   cerr << "Usage: " << *argv << " message\n";
   return 1;
 }
  if (pipe(f_des) == -1) {                  // generate the pipe
    perror("Pipe");      return 2;
  }
  switch (fork( )) {
  case -1:
   perror("Fork");      return 3;
  case 0:                                   // In the child
    close(f_des[1]);         // close write end of pipe
    if (read(f_des[0], message, BUFSIZ) != -1) {
      printf(“Message received by child: [%s]\n”, message);
      fflush(stdout);
    } else {
     perror("Read");     return 4;
  }
    break;
  default:                                  // In the Parent
    close(f_des[0]);         // close read end of pipe
    if (write(f_des[1], argv[1], strlen(argv[1])) != -1) {
      printf(“Message sent by parent    : [%s]\n”,argv[1]);
      fflush(stdout);
    } else {
     perror("Write");   return 5;
   }
  }
 return 0;
}
```

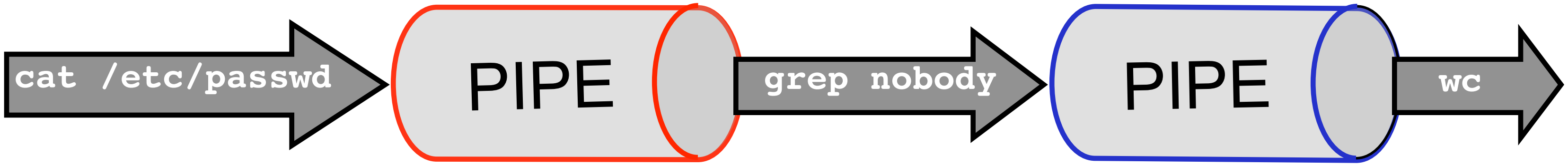
```
$ ./a.out Hello
Message sent by parent    : [Hello]
Message received by child: [Hello]
```

pipe to send first argument from parent to child

pipes

- I/O redirection
  - associate standard input/output to pipe

```
cat /etc/passwd | grep nobody | wc
```



pipes

- dup and dup2

```
int dup ( int oldfd );
```

  - *duplicates* an opened file descriptor
  - new descriptor
    - references file system table entry for ***next available nonnegative file descriptor***
      - always returns next lowest available file descriptor
    - share the same file pointer (offset) as original
    - same access control as original
    - share locks
    - remain open across `exec`
    - do not share *close-on_exec* flag

pipes

- dup

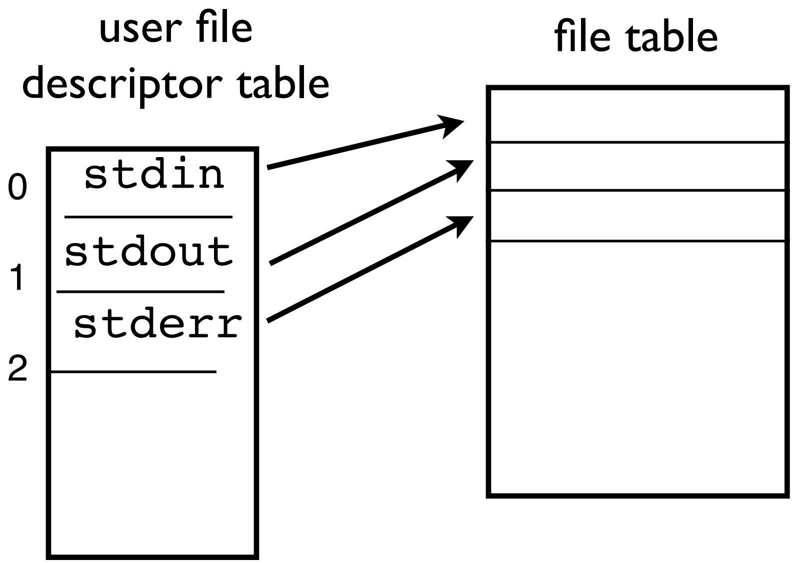
*always return the next lowest available descriptor

```
int f_des_[2];

pipe(f_des);

close(fileno(stdout) );  // close standard output

dup(f_des[1]);           // duplicate 1st free descriptor
                   // as write end of pipe

// any write to stdout will go to write end of pipe
```

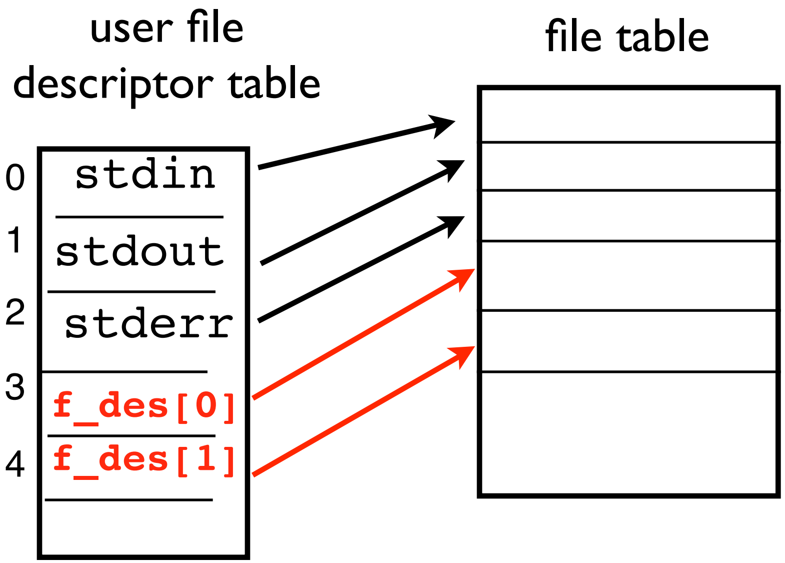
race condition between `close` and `dup`

for example a signal-catcher that closes a file

pipes

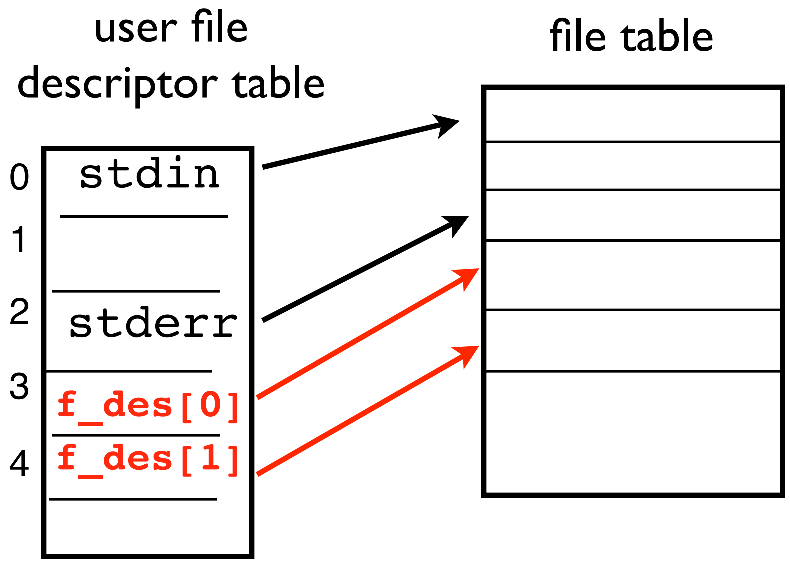

user file descriptor table
file table
0
1
2
stdin
stdout
stderr

pipes



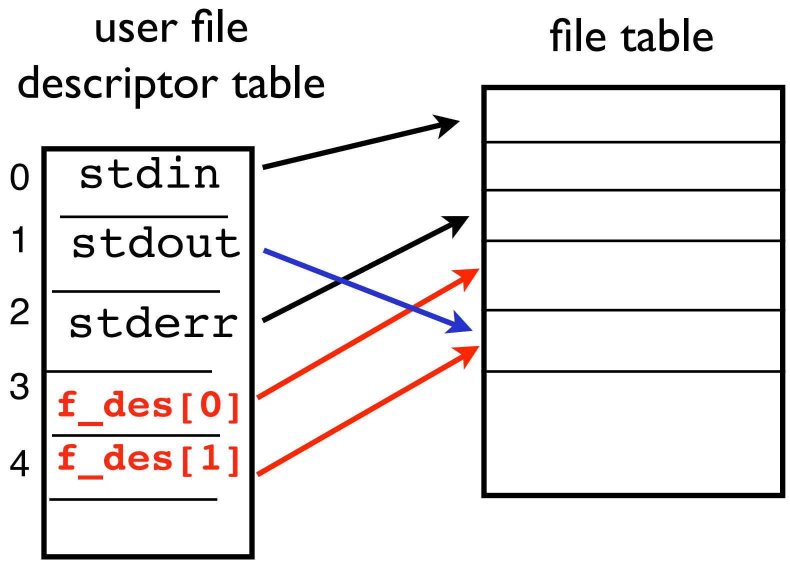
```
int f_des_[2];

pipe(f_des);
```

pipes



```
int f_des_[2];

pipe(f_des);

close(fileno(stdout) );  // close standard output
```

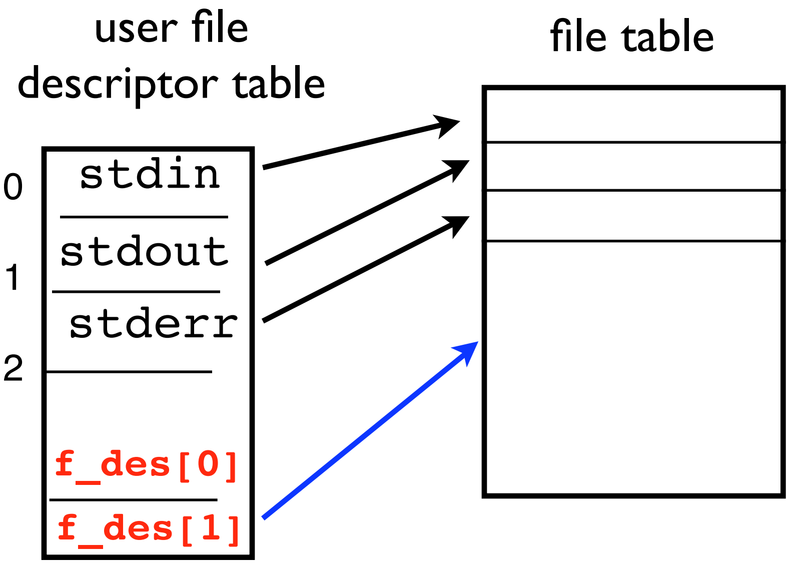
pipes

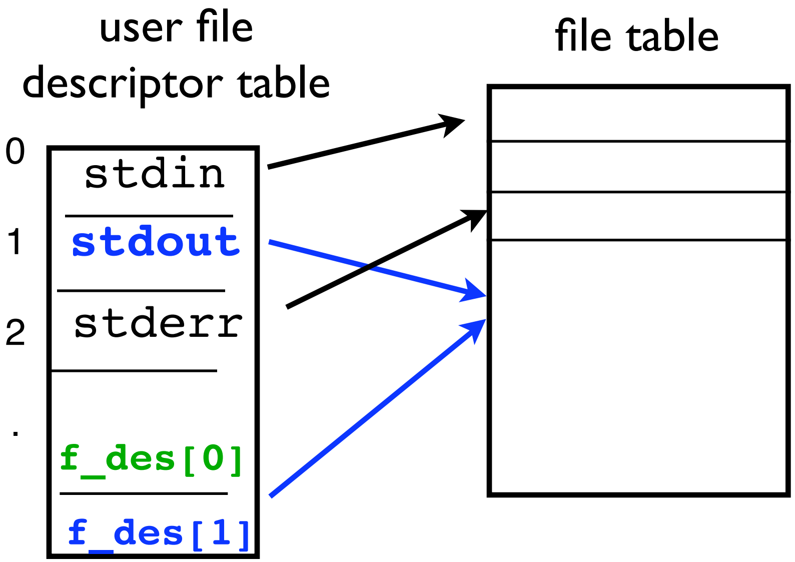


stdout is still entry 1 in file descriptor table

```
int f_des_[2];

pipe(f_des);

close(fileno(stdout) );  // close standard output

dup(f_des[1]);           // duplicate 1st free descriptor
                // as write end of pipe
```

pipes





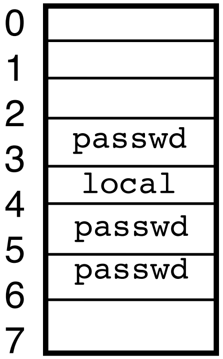
stdout is still entry 1 in file descriptor table

```
int f_des_[2];

pipe(f_des);

close(fileno(stdout) );  // close standard output

dup(f_des[1]);           // duplicate 1st free descriptor
             // as write end of pipe
```

pipes

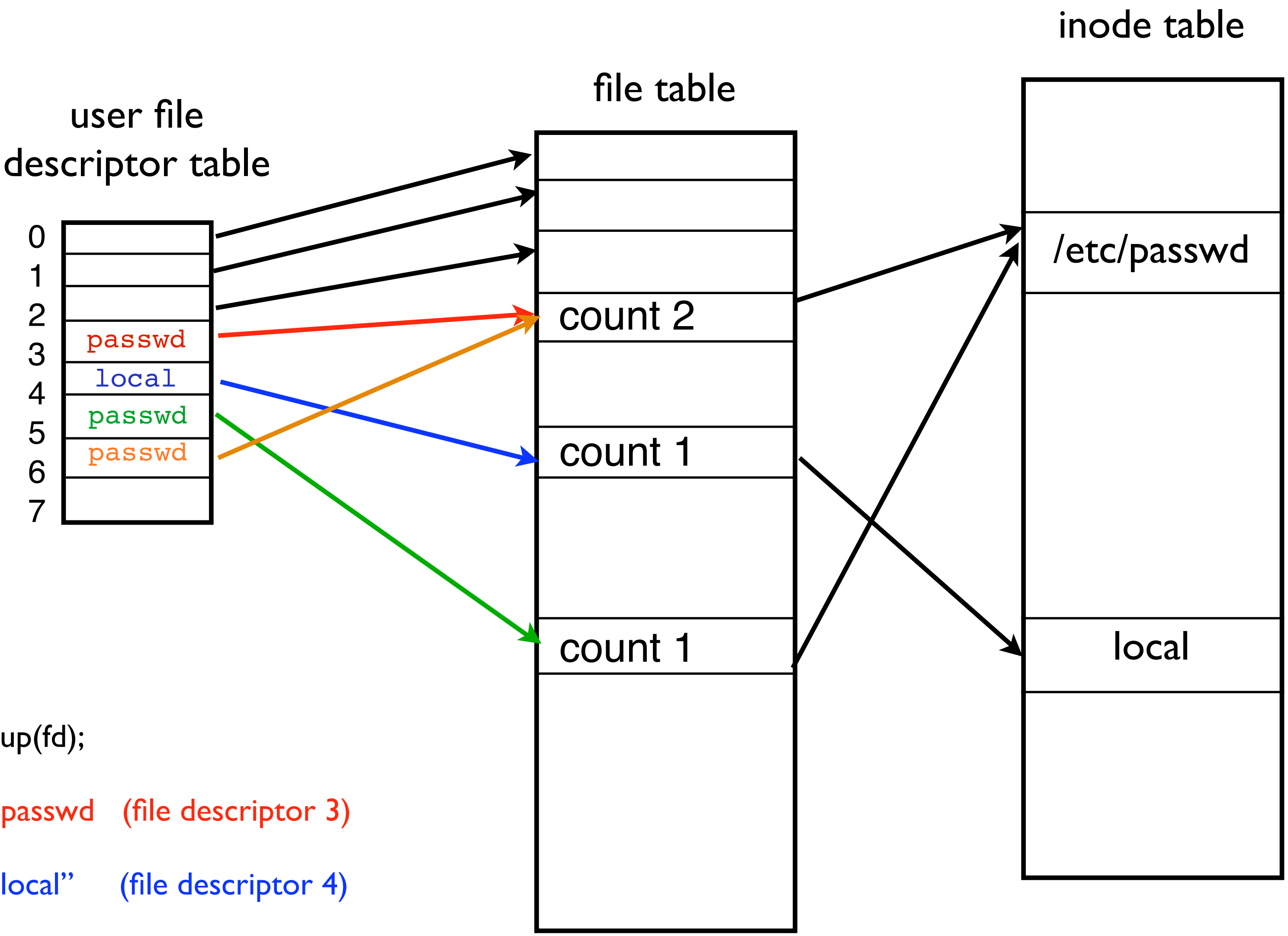
- newfd = dup(fd)
  - open /etc/passwd (file descriptor 3)
  - open file “local” (file descriptor 4)
  - open /etc/passwd (file descriptor 5)
  - dup fd 3 (file descriptor 6)

user file
descriptor table



0	
1	
2	
3	passwd
4	local
5	passwd
6	passwd
7	

pipes



newfd = dup(fd);

open /etc/passwd (file descriptor 3)

open file “local” (file descriptor 4)

open /etc/passwd (file descriptor 5)

dup fd 3 (file descriptor 6)

pipes

- dup2

```
int dup2 ( int oldfd, int newfd );
```

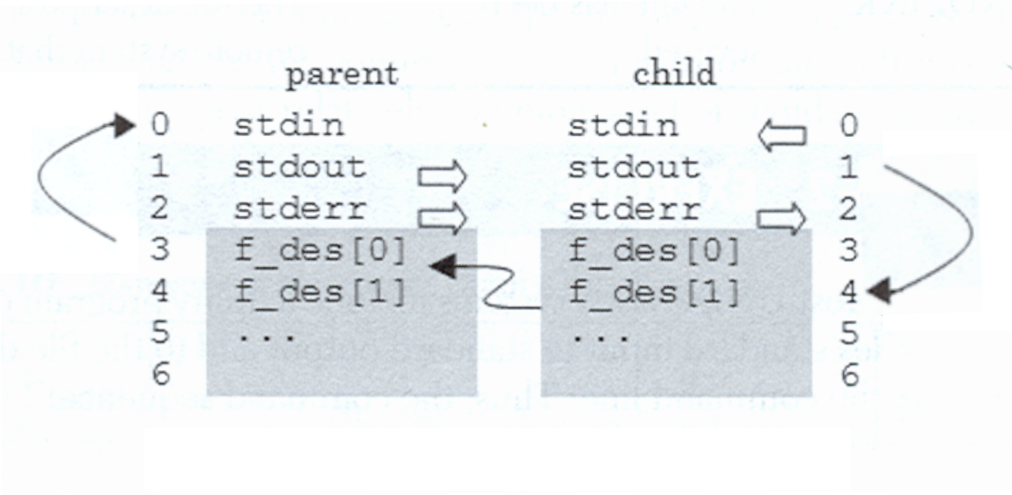
Closes and duplicates file descriptor

atomic operation

if **`newfd`** is already open

closed before duplicating

pipes



```
/* A home grown last | sort cmd pipeline. */
enum { READ, WRITE };

int
main( ) {
  int       f_des[2];
  if (pipe(f_des) == -1) {
    perror("Pipe");
    return 1;
  }
  switch (fork( )) {
  case -1:
    perror("Fork");
    return 2;
  case 0:                                       // In the child
    dup2( f_des[WRITE], fileno(stdout));
    close(f_des[READ] );
    close(f_des[WRITE]);
    execl("/usr/bin/last", "last", (char *) 0);
    return 3;
  default:                                      // In the parent
    dup2( f_des[READ], fileno(stdin));
    close(f_des[READ] );
    close(f_des[WRITE]);
    execl("/bin/sort", "sort", (char *) 0);
    return 4;
  }
  return 0;
}
```

pipes

- Summary - unnamed pipes
- Create pipes
- Generate child process
- Close/duplicate file descriptors
- Close unneeded ends of pipe
- Communicate

pipes

- popen pclose system calls

```
FILE *popen ( const char *command, const char *type);

int pclose ( FILE *stream);
```

fork child process
duplicate file descriptors
pass command

pipes

`popen`

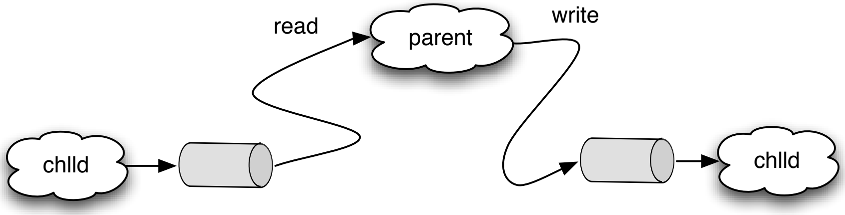
- duplicate file descriptors
- fork child process which will exec /bin/sh
- /bin/sh executes passed shell command
- duplicate file descriptors
  - W: parent process can write to standard input of new shell
    - file pointer referenced by popen
  - R: parent process can read from standard output of new shell
- fully buffered
- pass command argument

`poclose`

- close data stream penned by `popen`
- returns exit status of shell command

pipes

```
/* Using the popen and pclose I/O commands*/
......
;
int
main(int argc, char *argv[ ]) {
  FILE    *fin, *fout;
  char    buffer[PIPE_BUF];
  int     n;
  if (argc < 3) {
    cerr << "Usage " << argv << "cmd1 cmd2" << endl;
    return 1;
  }

  fin  = popen(argv[1], "r");


  fout = popen(argv[2], "w");
  fflush(fout);
  while ((n = read(fileno(fin), buffer, PIPE_BUF)) > 0)
    write(fileno(fout), buffer, n);
  pclose(fin);
  pclose(fout);
  return 0;
}
```



```
#a.out last more
```

forks child that executes command argv[1] output read by parent with file pointer fin

forks child that executes command argv[2] input read from parent’s output

pipes

- named pipes (FIFO)
  - directory entry
  - permissions
  - can be used by unrelated processes
  - data stored in kernel not in file system
  - creation
    - **`mknod   name p`**
    - **`mkfifo  name p`**

`mknod`: generate special files (block character device files in /dev)
nonpriviledged users can only generate named pipes

```
%mkfifo APIPE p
```

```
prw-r--r--     1 dcanas  dcanas    0 Sep 16 11:21 APIPE
```

pipes

```
%mkfifo APIPE p

 prw-r--r--     1 dcanas   dcanas    0 Sep 16 11:21 APIPE


% cat copy.c > APIPE &
[1] 287

% cat < APIPE

this is the contents of copy.c
a test file for pipes
last line

[1]+  Done
```

pipes

- System call

```
int mknod(const char *pathmane, mode_t mode, dev_t dev);
```

- creates a file descriptor by pathname
- file types and permissions are ORed
- dev argument only for character, block devices
  - use 0 for FIFO
- File types;

S_FIFO	FIFO special (non privileged users)
S_IFCHR	character special
S_IFDIR	directory
S_IFBLK	block special
S_IFREG	ordinary file

pipes

- System call

```
int mkfifo(const char *pathmane, mode_t mode );
```

uses `mknod` to create a `FIFO`