Processes and Pipes

COS 217
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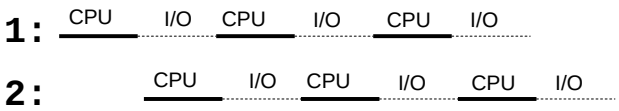
When to Change Which Process is Running?

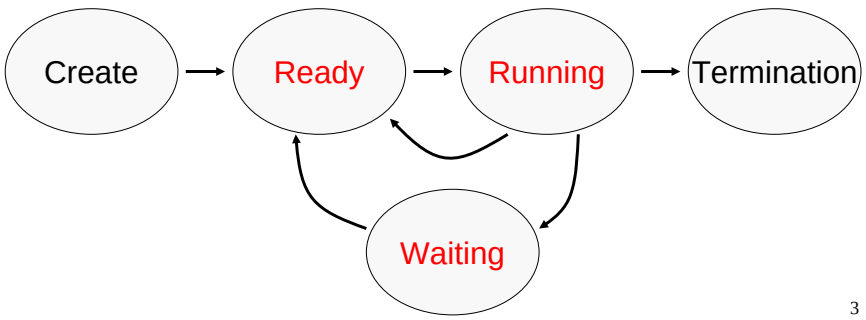
- When a process is stalled waiting for I/O
  - Better utilize the CPU, e.g., while waiting for disk access



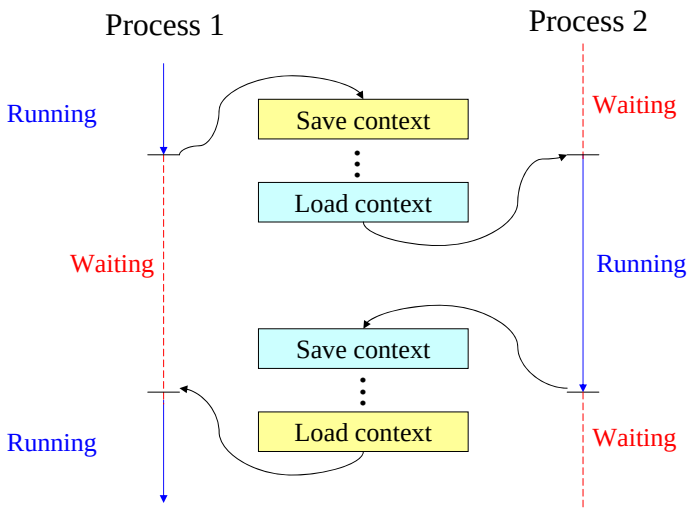
- When a process has been running for a while
  - Sharing on a fine time scale to give each process the illusion of running on its own machine
  - Trade-off efficiency for a finer granularity of fairness

Life Cycle of a Process

- Running: instructions are being executed
- Waiting: waiting for some event (e.g., I/O finish)
- Ready: ready to be assigned to a processor



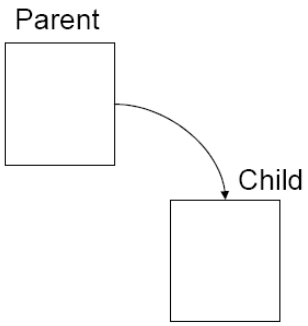
Switching Between Processes



Fork

- Create a new process (system call)
  - child process inherits state from parent process
  - parent and child have separate copies of that state
  - parent and child share access to any open files

```
pid = fork();
if (pid != 0) {
    /* in parent */
    ...
} else {
    /* in child */
    ...
}
```



Fork

- Inherited:
  - user and group IDs
  - signal handling settings
  - stdio
  - file pointers
  - current working directory
  - root directory
  - file mode creation mask
  - resource limits
  - controlling terminal
  - all machine register states
  - control register(s)
  - . . .
- Separate in child
  - process ID
  - address space (memory)
  - file descriptors
  - parent process ID
  - pending signals
  - timer signal reset times
  - . . .

Wait

- Parent waits for a child (system call)
  - blocks until a child terminates
  - returns pid of the child process
  - returns –1 if no children exists (already exited)
  - status

```
#include <sys/types.h>
#include <sys/wait.h>

pid_t wait(int *status);
```

- Parent waits for a specific child to terminate

```
#include <sys/types.h>
#include <sys/wait.h>

pid_t waitpid(pid_t pid, int *status, int options);
```


Exec

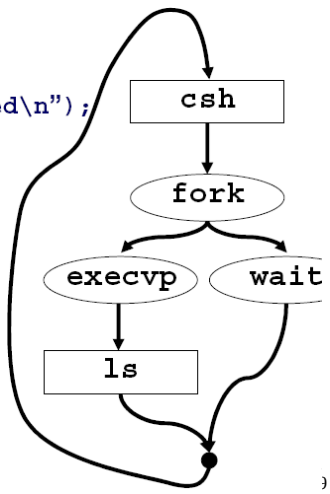
- Overlay current process image with a specified image file (system call)
  - affects process memory and registers
  - has no affect on file table
- Example:

```
execlp("ls", "ls", "-l", NULL);
fprintf(stderr, "exec failed\n");
exit(1);
```


Fork/Exec

- Commonly used together by the shell

```
... parse command line ...
pid = fork()
if (pid == -1)
   fprintf(stderr, "fork failed\n");
else if (pid == 0) {
   /* in child */
   execvp(file, argv);
   fprintf(stderr,
           "exec failed\n");
} else {
   /* in parent */
   pid = wait(&status);
}
... return to top of loop ...
```



System

- Convenient way to invoke fork/exec/wait
  - Forks new process
  - Execs command
  - Waits until it is complete

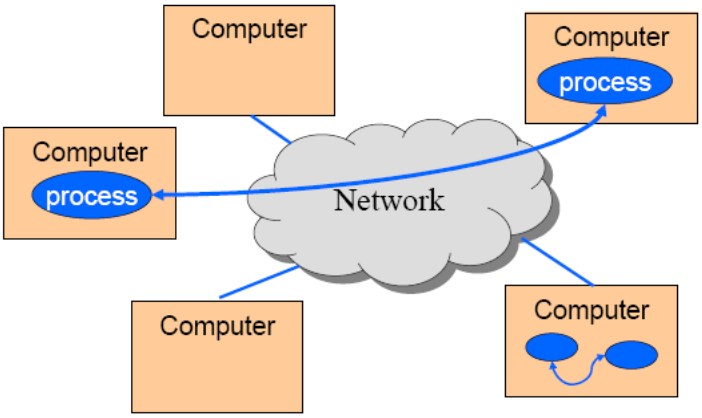
```
int system(const char *cmd);
```

- Example:

```
int main()
{
     system("echo Hello world");
}
```


Networks

- Mechanism by which two processes exchange information and coordinate activities

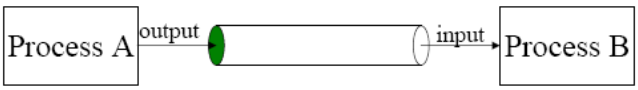


Interprocess Communication

- Pipes
  - Processes must be on same machine
  - One process spawns the other
  - Used mostly for filters
- Sockets
  - Processes can be on any machine
  - Processes can be created independently
  - Used for clients/servers, distributed systems, etc.

Pipes

- Provides an interprocess communication channel



- A filter is a process that reads from `stdin` and writes to `stdout`

Creating a Pipe

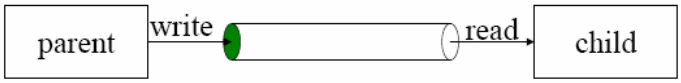
- Pipe is a communication channel abstraction
  - Process A can write to one end using "write" system call
  - Process B can read from the other end using "read" system call
- System call

```
int pipe( int fd[2] );
return 0 upon success –1 upon failure
fd[0] is open for reading
fd[1] is open for writing
```

- Two coordinated processes created by **`fork`** can pass data to each other using a pipe.

Pipe Example

```
int pid, p[2];
...
if (pipe(p) == -1)
   exit(1);
pid = fork();
if (pid == 0) {
   close(p[1]);
   ... read using p[0] as fd until EOF ...
}
else {
    close(p[0]);
    ... write using p[1] as fd ...
    close(p[1]); /* sends EOF to reader */
    wait(&status);
}
```



Dup

- Duplicate a file descriptor (system call)

```
int dup( int fd );
```

duplicates `fd` as the lowest unallocated descriptor

- Commonly used to implement redirection of stdin/stdout
- Example: redirect stdin to "foo"

```
int fd;
fd = open("foo", O_RDONLY, 0);
close(0);
dup(fd);
close(fd);
```


Dup2

- For convenience…

```
dup2( int fd1, int fd2 );
```

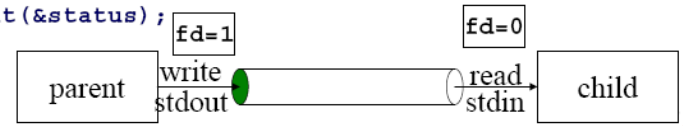
use `fd2` (`new`) to duplicate `fd1` (`old`)
closes `fd2` if it was in use

- Example: redirect stdin to "foo"

```
fd = open("foo", O_RDONLY, 0);
dup2(fd,0);
close(fd);
```

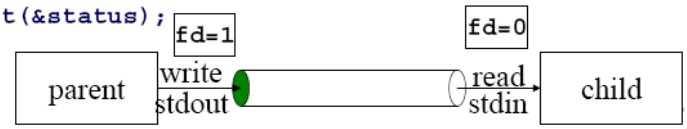

Pipes and Stdio

```
int pid, p[2];
if (pipe(p) == -1)
   exit(1);
pid = fork();
if (pid == 0) {
   close(p[1]);
   dup2(p[0],0);
   close(p[0]);
   ... read from stdin ...
}
else {
   close(p[0]);
   dup2(p[1],1);
   close(p[1]);
   ... write to stdout ...
   wait(&status);
}
```



Pipes and Exec


```
int pid, p[2];
if (pipe(p) == -1)
   exit(1);
pid = fork();
if (pid == 0) {
   close(p[1]);
   dup2(p[0],0);
   close(p[0]);
   execl(...);
}
else {
   close(p[0]);
   dup2(p[1],1);
   close(p[1]);
   ... write to stdout ...
   wait(&status);
}
```



A Unix Shell!

- Loop
  - Read command line from stdin
  - Expand wildcards
  - Interpret redirections < > |
  - pipe (as necessary), fork, dup, exec, wait
- Start from code on previous slides, edit it until it's a Unix shell!