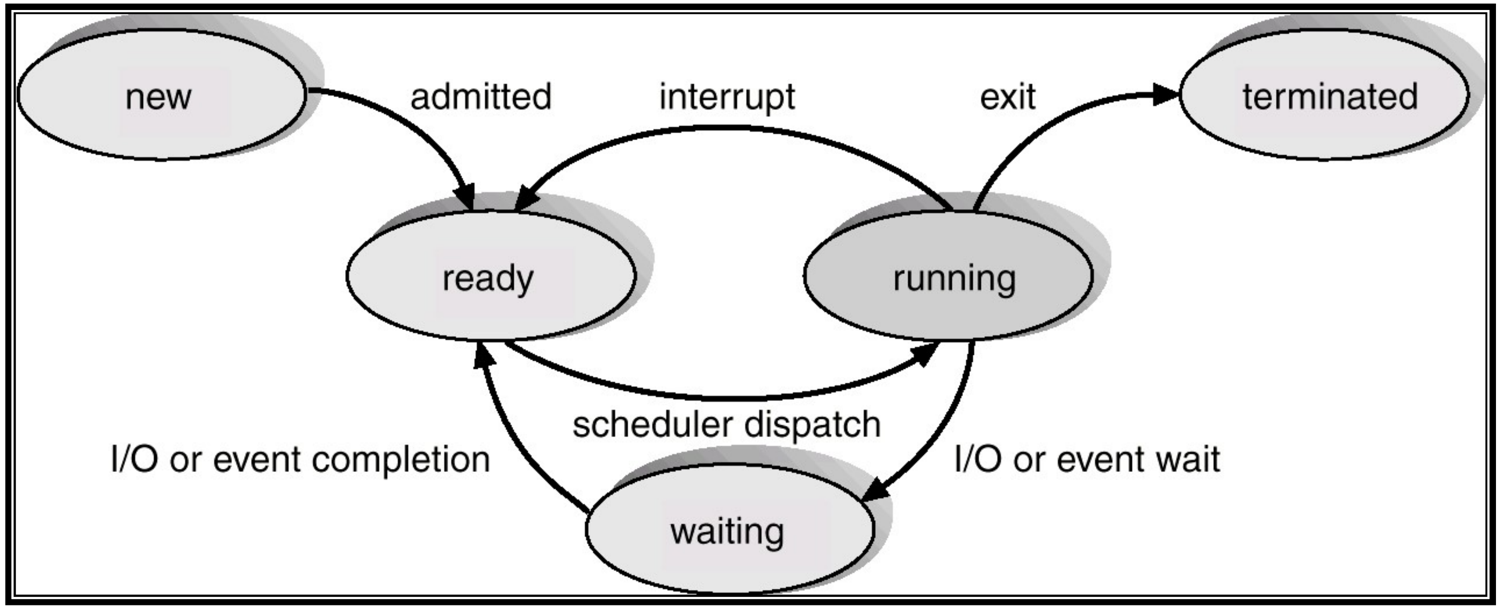
Process in a System

Program vs. Process

- Program
  - ✓ Executable file on a disk
  - ✓ Loaded into memory and executed by the kernel

- Process
  - ✓ Executing instance of a program
  - ✓ The basic unit of execution and scheduling
  - ✓ A process is named using its process ID (PID)
  - ✓ Other IDs associated with a process
    - ➢ Real User ID
    - ➢ Real Group ID
    - ➢ Effective User ID
    - ➢ Effective Group ID
    - ➢ etc.

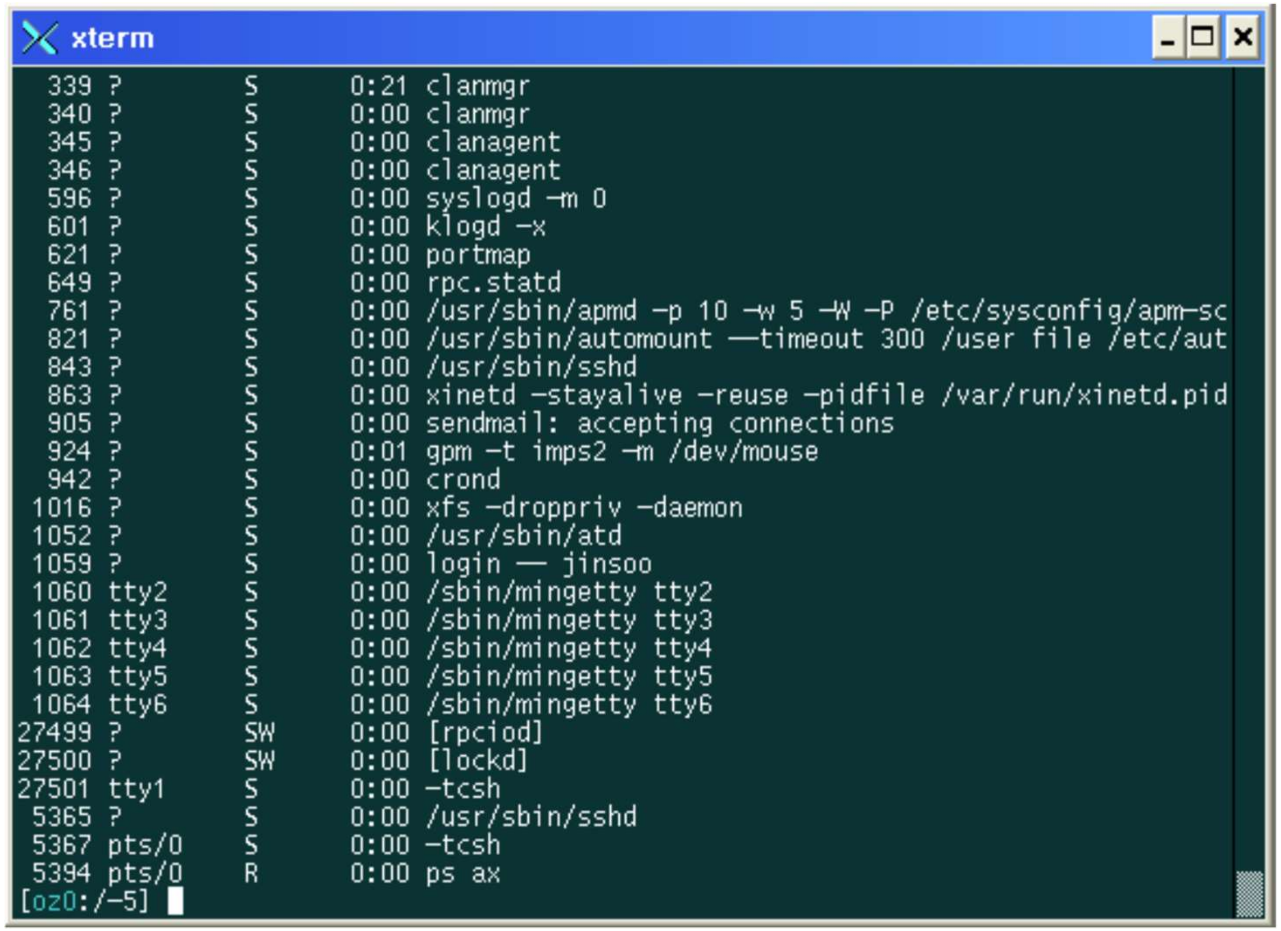
Process State



- new: The process is being created
- running: Instructions are being executed
- waiting: The process is waiting for some event to occur
- ready: The process is waiting to be assigned
- terminated: the process has finished execution

Process State (cont'd)

- <ps> command



```
  339 ?        S      0:21 clanmgr
  340 ?        S      0:00 clanmgr
  345 ?        S      0:00 clanagent
  346 ?        S      0:00 clanagent
  596 ?        S      0:00 syslogd -m 0
  601 ?        S      0:00 klogd -x
  621 ?        S      0:00 portmap
  649 ?        S      0:00 rpc.statd
  761 ?        S      0:00 /usr/sbin/apmd -p 10 -w 5 -W -P /etc/sysconfig/apm-sc
  821 ?        S      0:00 /usr/sbin/automount --timeout 300 /user file /etc/aut
  843 ?        S      0:00 /usr/sbin/sshd
  863 ?        S      0:00 xinetd -stayalive -reuse -pidfile /var/run/xinetd.pid
  905 ?        S      0:00 sendmail: accepting connections
  924 ?        S      0:01 gpm -t imps2 -m /dev/mouse
  942 ?        S      0:00 crond
 1016 ?        S      0:00 xfs -droppriv -daemon
 1052 ?        S      0:00 /usr/sbin/atd
 1059 ?        S      0:00 login -- jinsoo
 1060 tty2     S      0:00 /sbin/mingetty tty2
 1061 tty3     S      0:00 /sbin/mingetty tty3
 1062 tty4     S      0:00 /sbin/mingetty tty4
 1063 tty5     S      0:00 /sbin/mingetty tty5
 1064 tty6     S      0:00 /sbin/mingetty tty6
27499 ?        SW     0:00 [rpciod]
27500 ?        SW     0:00 [lockd]
27501 tty1     S      0:00 -tcsh
 5365 ?        S      0:00 /usr/sbin/sshd
 5367 pts/0    S      0:00 -tcsh
 5394 pts/0    R      0:00 ps ax
[oz0:/-5]
```

R: Runnable
S: Sleeping
T: Traced or Stopped
D: Uninterruptible Sleep
Z: Zombie

IDs associated with a process

- Get various IDs

  #include <sys/types.h>
  #include <unistd.h>

  - ✓ pid_t getpid(void);
    - ➢ return: process ID of calling process
  - ✓ pid_t getppid(void);
    - ➢ return: parent process ID of calling process
  - ✓ uid_t getuid(void);
    - ➢ return: real user ID of calling process
  - ✓ uid_t geteuid(void);
    - ➢ return: effective user ID of calling process
  - ✓ gid_t getgid(void);
    - ➢ return: group ID of calling process
  - ✓ gid_t getegid(void);
    - ➢ reutrnL effective group ID of calling process

Create a new process

- fork: the only way a new process is created

  #include <sys/types.h>

  #include <unistd.h>

  ✓ pid_t fork(void);

  ✓ return: 0 in child, process ID of child in parent, -1 on error

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
main() {
    int pid;
    if ((pid = fork()) == 0)
        /* child */
        printf("I am %d. My parent is %d\n", getpid(), getppid());
    else
        /* parent */
        printf("I am %d. My child is %d\n", getpid(), pid);
}
```

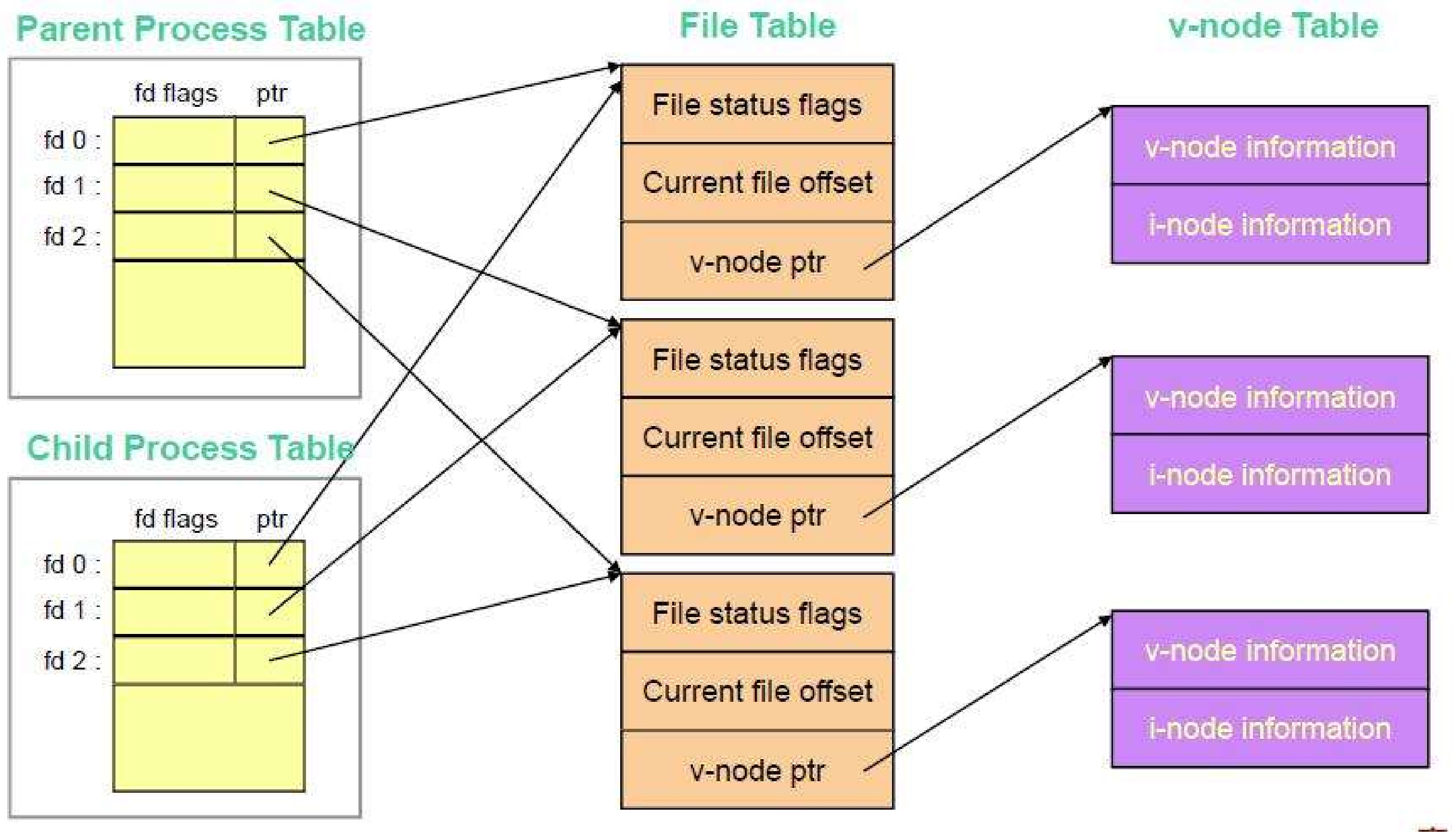
Create a new process (cont'd)

- Why fork() ? ➔ Very useful when the child..
  - ✓ is cooperating with the parent
  - ✓ relies upon the parent's data to accomplish its task
  - ✓ example: Web server

```
while (1) {
    int sock = accept();
    if ((pid = fork()) == 0) {
        /* Handle client request */

    } else {
        /* Close socket */

    }
}
```

Create a new process (cont'd)

- Sharing of open files between parent and child after fork



Exercise

- fork example

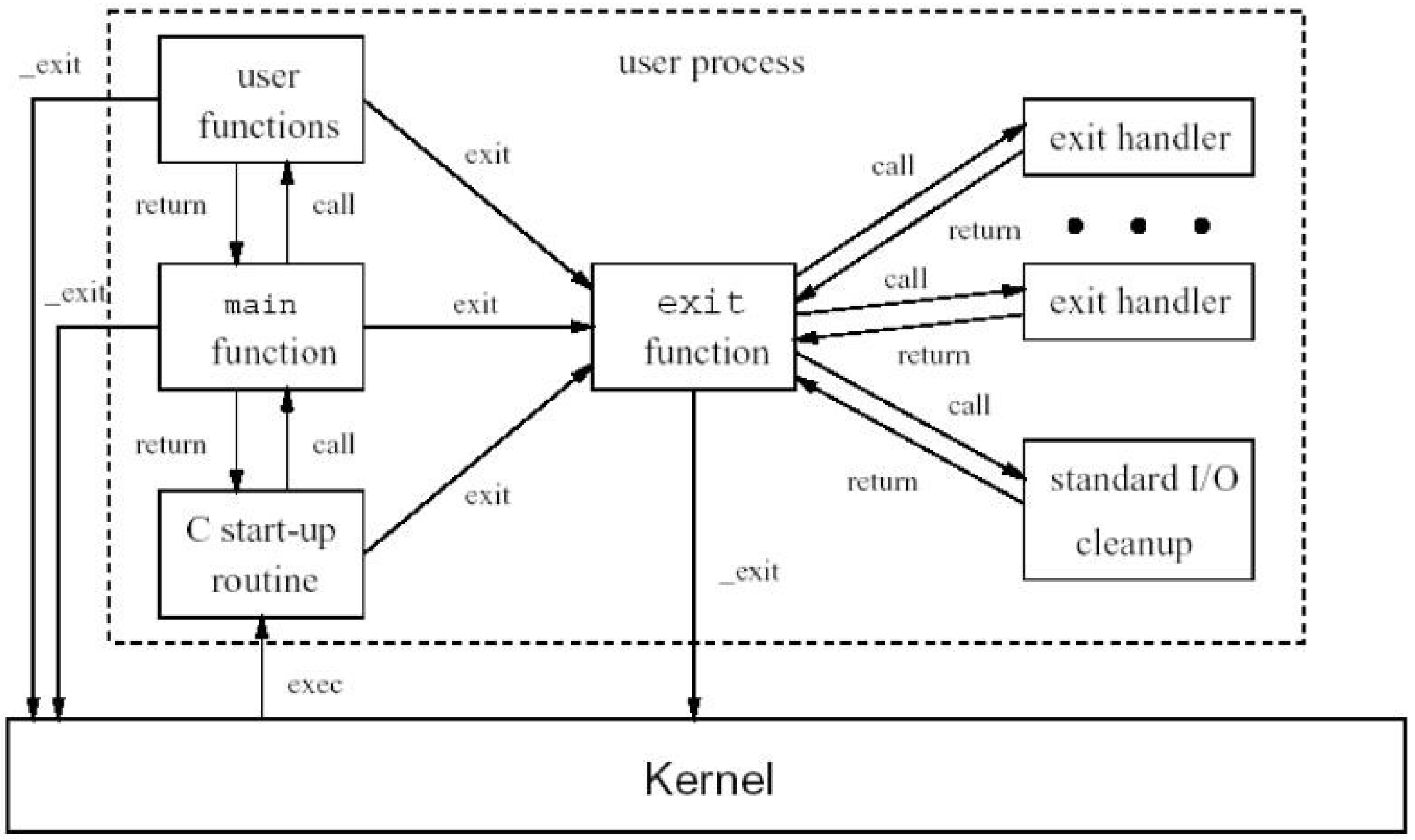
```
$ arm-linux-gnueabihf-gcc –o fork fork.c (or make fork)

move “fork” to the target board
$./fork
```

Terminate a process

- Normal termination
  - ✓ return from main()
  - ✓ calling exit()
  - ✓ calling _exit()

- Abnormal termination
  - ✓ calling abort()
  - ✓ terminated by a signal

Start and Termination of a C program



Terminate a process

- exit

  #include <stdlib.h>
  - ✓ void exit(int status);
  - ✓ return: 0 if OK, nonzero on error

  #include <unistd.h>
  - ✓ void _exit(int status);
  - ✓ return: 0 if OK, nonzero on error

- Register an exit handler

  #include <stdlib.h>
  - ✓ int atexit(void (*func)(void));
  - ✓ return: 0 if OK, nonzero on error

Exercise

- atexit example

```
$ arm-linux-gnueabihf-gcc –o exit exit.c (or make exit)

move "exit" to the target board
$./exit
```

Wait for process termination

- wait

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

  - ✓ pid_t wait(int *statloc);
  - ✓ pid_t waitpid(pid_t pid, int *statloc, int options);
  - ✓ return: process ID if OK, 0 or -1 on error
    - ➢ With **WNOHANG** option, waitpid will not block if a child specified by pid is not immediately available. In this case, the return is 0

  - ✓ The calling process will
    - ➢ block (if all of its children are still running)
    - ➢ return immediately with the termination status of a child (if a child has terminated and is waiting for its termination status to be fetched)
    - ➢ return immediately with an error (if it doesn't have any child processes)

Exercise

- wait example

```
$ arm-linux-gnueabihf-gcc -o wait wait.c (or make wait)
$ ./wait     (in the target board)
```

- a program with race condition

```
$ arm-linux-gnueabihf-gcc –o race race.c (or make race)
$ ./race     (in the target board)
```

- modification to avoid race condition using wait system call

```
$ arm-linux-gnueabihf-gcc –o worace worace.c (or make worace)
$./worace     (in the target board)
```

Execute another program in a program

- exec

```
#include <unistd.h>

✓ int execl(char *pathname, char *arg0, … /* (char *) 0 */ );
✓ int execv(char *pathname, char *argv[]);
✓ int execle(char *pathname, char *arg0, … /* (char *) 0,
                              char *envp[] */ );
✓ int execve(char *pathname, char *argv[], char *envp[]);
✓ int execlp(char *filename, char *arg0, … /* (char *) 0 */ );
✓ int execvp(char *filename, char *argv[]);
```

✓ return: -1 on error, no return on success

Execute a command string in a program

- system

  #include <stdlib.h>

  - ✓ int system(char *cmdstring);
  - ✓ return: termination status of the shell if OK, -1 on error
  - ✓ system is implemented by calling fork, exec, and waitpid

```
#include <stdio.h>
#include <stdlib.h>
main()
{
   system("ls -al“);
   system(“date”);
   system(“who”);
}
```

Exercise

- Access environment variables

```
$ arm-linux-gnueabihf-gcc –o env env.c (or make env)
$ ./env
```

- exec example

```
$ arm-linux-gnueabihf-gcc –o exec exec.c (or make exec)
$ ./exec
```

- system example

```
$ arm-linux-gnueabihf-gcc –o system system.c (or make system)
$ ./system
```

Thread

- Why thread?
  - ✓ Web server example using thread
    - ➢ We can create a new thread for each request

```
webserver()
{
    while(1) {
        int sock = accept();
        thread_fork(handle_request, sock);
    }
}

Handle_request(int sock)
{
    /* process request */
    close(sock);
}
```

Thread (cont'd)

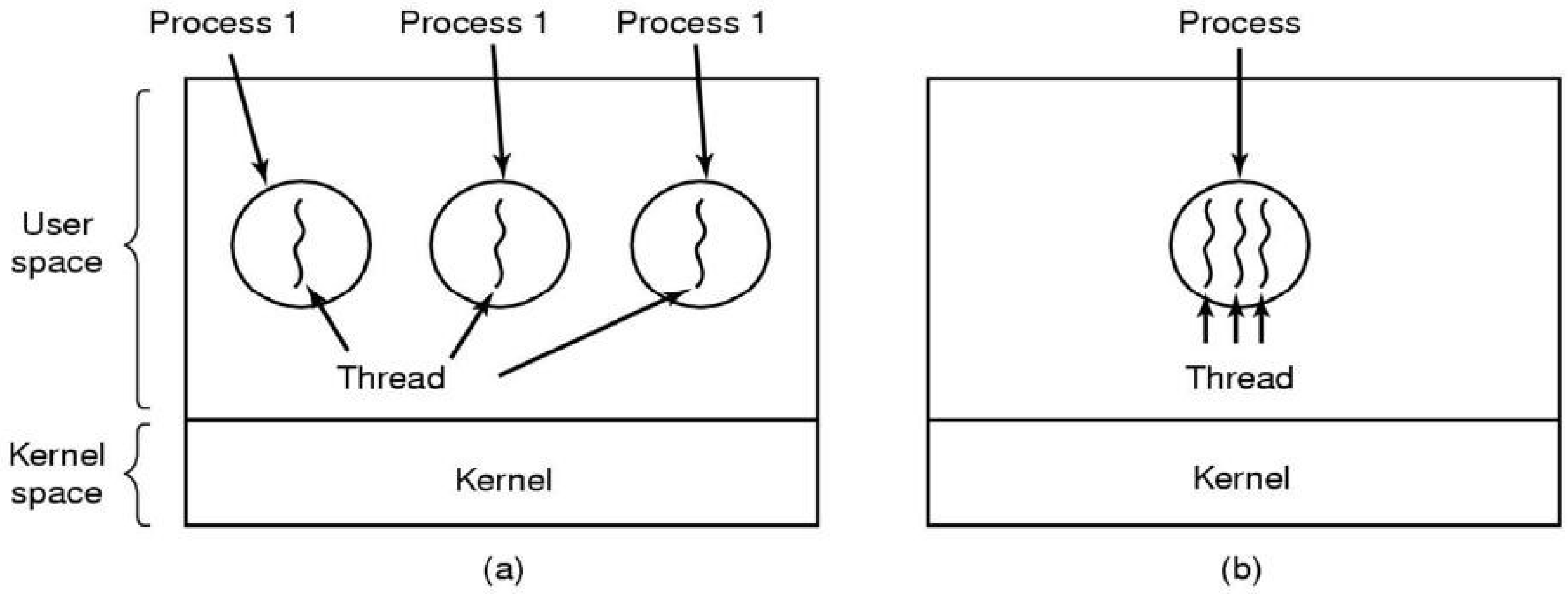
- Why thread? (cont'd)
  - ✓ Responsiveness
  - ✓ Resource sharing
  - ✓ Economy
  - ✓ Utilization of MP architectures

Thread concept

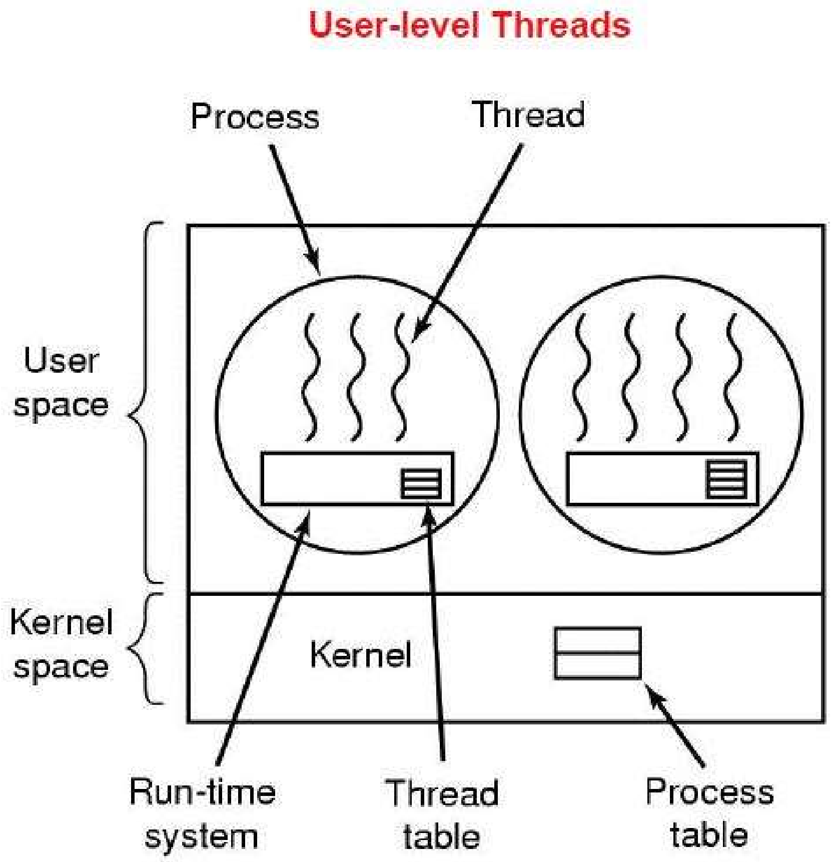
- Separate the concept of a process from its execution state
  - ✓ Process: address space, resources, other general process attributes
  - ✓ Execution state: PC, SP, registers, etc.

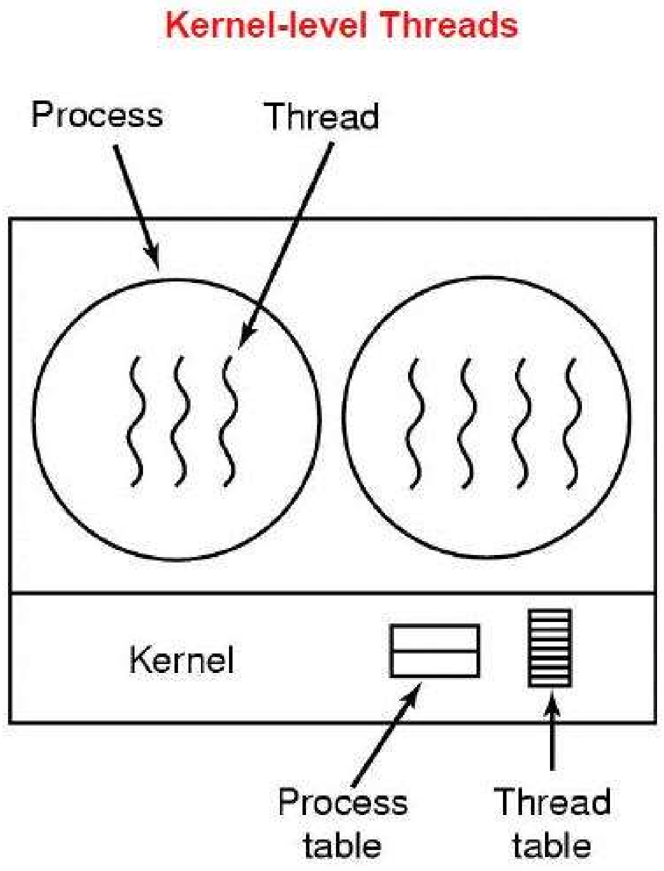
  - ✓ This execution state is usually called
    - ➢ A thread of control
    - ➢ A thread, or
    - ➢ A lightweight process (LWP)

Thread concept (cont'd)



Thread implementation





Thread implementation (cont'd)

- User-level threads
  - ✓ The user-level threads library implements thread operations
  - ✓ They are small and fast
  - ✓ User-level threads are invisible to the OS
  - ✓ OS may make poor decisions
    - ➢ E.g. blocking I/O

- Kernel-level threads
  - ✓ All thread operations are implemented in the kernel
  - ✓ The OS schedules all of the threads in a system
  - ✓ Kernel threads are cheaper than processes
  - ✓ They can still be too expensive

Thread implementation (cont’d)

- Pthreads
  - ✓ A POSIX standard (IEEE 1003.1c) API for thread creation and synchronization
  - ✓ API specifies behavior of the thread library, implementation is up to development of the library
  - ✓ Common in UNIX operating systems
  - ✓ Link with *–lpthread* option

- Linux implementation
  - ✓ Kernel-level implementation, but..
    - ➢ a modified process(or task) per thread
  - ✓ System call clone() for thread creation
  - ✓ NGPT (Next Generation POSIX Threading) by IBM

Pthread libraries for thread control

- Create a thread

  #include <pthread.h>
  - ✓ int pthread_create(pthread_t *tid, pthread_attr_t *attr,
    void *(start_routine)(void *), void *arg);
  - ✓ return: 0 if OK, nonzero on error

- Terminate a thread

  #include <pthread.h>
  - ✓ void pthread_exit(void *retval);

- Wait for termination of another thread

  #include <pthread.h>
  - ✓ int pthread_join(pthread_t tid, void **tread_return);
  - ✓ return:0 if OK, nonzero on error

Exercise

- Pthread example

```
$ arm-linux-gnueabihf-gcc –o thread thread.c –lpthread (or make thread)
$ ./thread
```

- Command-line process: iteration version using one process

```
$ arm-linux-gnueabihf-gcc –o cmd_i cmd_i.c (or make cmd_i)
$ ./cmd_i
CMD> doit
Doing doit
Done
CMD> quit
```

- Command-line processor: a process per command

```
$ arm-linux-gnueabihf-gcc –o cmd_p cmd_p.c (or make cmd_p)
$ ./ cmd_p
```

- Command-line processor: a thread per command

```
$ arm-linux-gnueabihf-gcc –o cmd_t cmd_t.c (or make cmd_t)
$ ./ cmd_t
```

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