Lecture 5

Threads & CPU scheduling I

Lecture Information

Ceng328 *Operating Systems* at March 16, 2010

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Contents

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- A thread (also referred to as a *light-weight process LWP*) is a basic unit of CPU utilization.
- All threads in a process have exactly the same address space, which means that they also share the same global variables.
- It shares with other threads belonging to the same process its code section, data section, and other OS resources, such as open files and signals (see Fig. 1).

Per process items	**Per thread items**
Address space	Program counter
Global variables	Registers
Open files	Stack
Child processes	State
Pending alarms	
Signals and signal handlers	
Accounting information	

Figure: The first column lists some items shared by all threads in a process (process properties). The second one lists some items private to each thread.

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- If a process has multiple threads of control in the same address space running in quasi-parallel, as though they were separate processes (except for the shared address space).

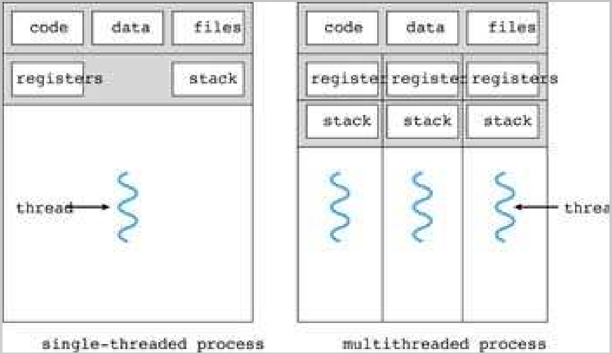

Figure: Single-threaded and multithreaded processes.

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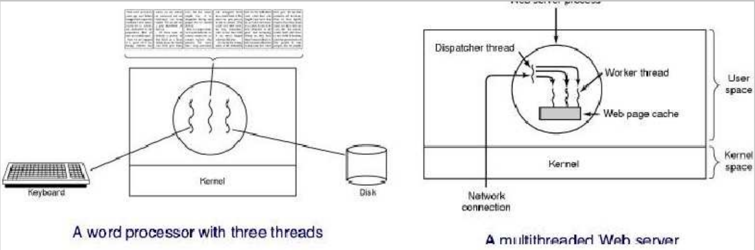
- Like a traditional process (i.e., a process with only one thread), a thread can be in any one of several states.
- The transitions between thread states are the same as the transitions between process states.

Motivation

- An application typically is implemented as a separate process with several threads of control.



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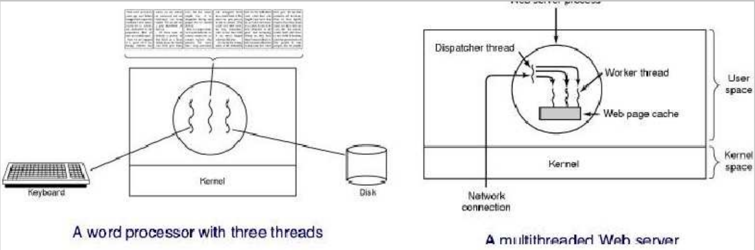

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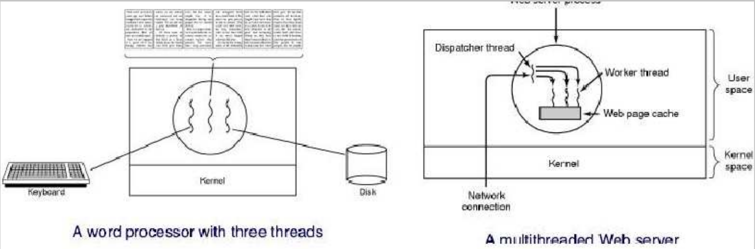
  - A word processor may have a thread for displaying graphics, another thread for responding to keystrokes from the user, and a third thread for performing spelling and grammar checking in the background.
  - A web browser might have one thread display images or text while another thread retrieves data from the network.



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The benefits of multithreaded programming can be broken down into four major categories:

1. **Responsiveness.** Multithreading an interactive application may allow a program to continue running even if part of it is blocked or is performing a lengthy operation, thereby increasing responsiveness to the user.

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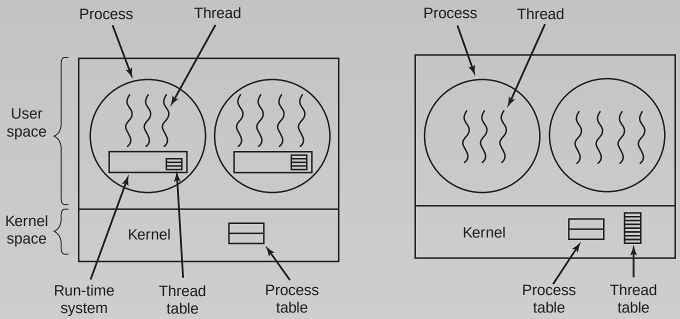
3. **Economy of Overheads.** Allocating memory and resources for process creation is costly. Because threads share resources of the process to which they belong, it is more economical to create and context-switch threads.
4. **Utilization of multiprocessor architectures.** The benefits of multithreading can be greatly increased in a multiprocessor architecture, where threads may be running in parallel on different processors (real parallelism).

Multithreading Models I

- Support for threads may be provided either at the user level, for user threads, or by the kernel, for kernel threads.



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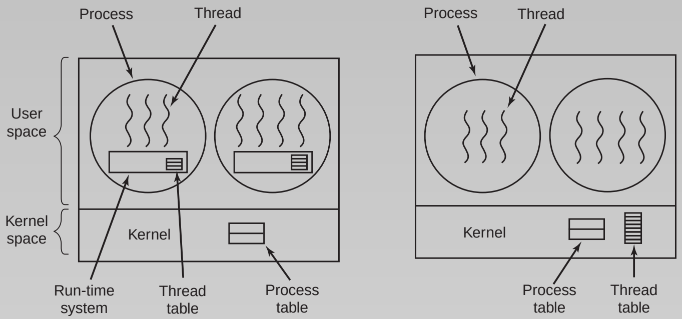

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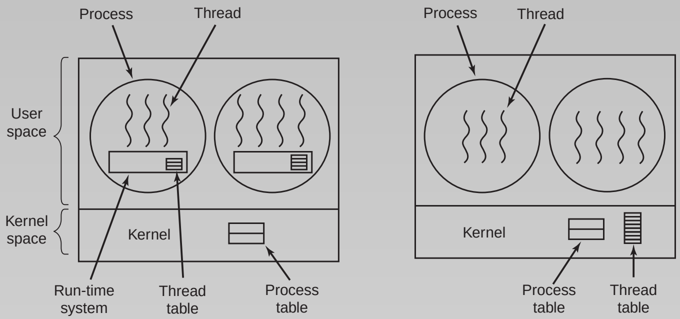

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- Despite their better performance, user-level threads packages have a major problem as if a thread starts running, no other thread in that process will ever run unless the first thread voluntarily gives up the CPU.
- While user threads usually have lower management load compared to kernel threads, one must consider this in relation to their lower functionality.

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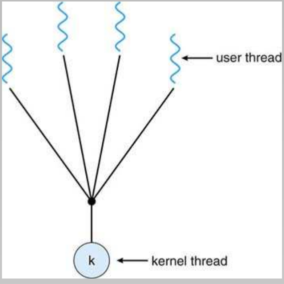
- if one thread blocks, another may be run. In addition, if one thread in a process causes a page fault, the kernel can easily check to see if the process has any other runnable threads.
- Ultimately, there must exist a relationship between user threads and kernel threads.

Many-to-One Model

- The many-to-one model (see Fig. 5) maps many user-level threads to one kernel thread.



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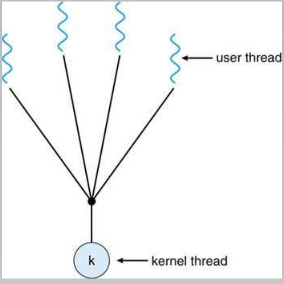

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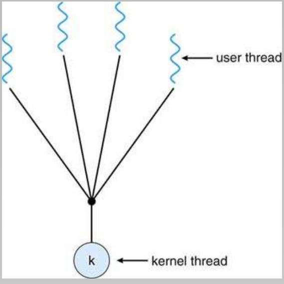

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- Thread management is done by the thread library in user space, so it is efficient; but the entire process will block if a thread makes a blocking system call.
- Also, because only one thread can access the kernel at a time, multiple threads are unable to run in parallel on multiprocessors.

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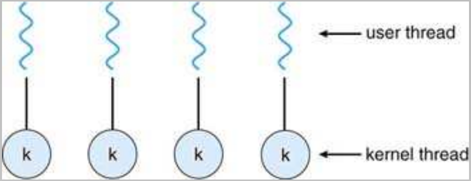

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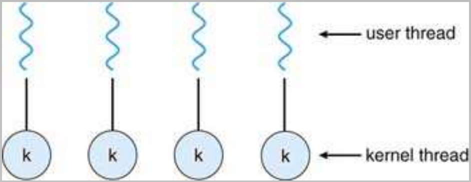

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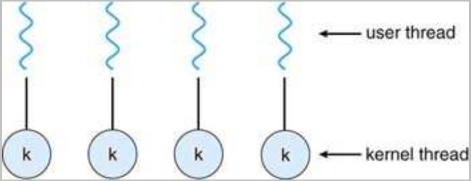

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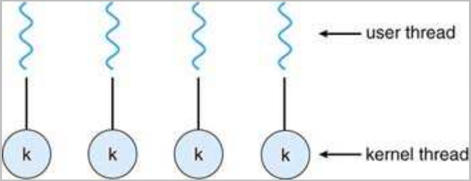

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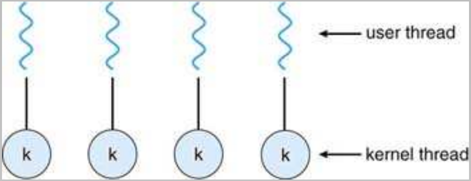

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- Linux, along with the family of Windows OSs implement the one-to-one model.

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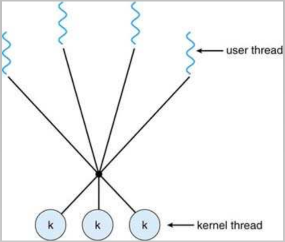

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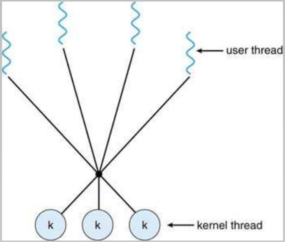

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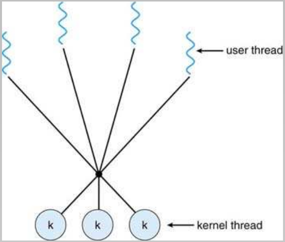

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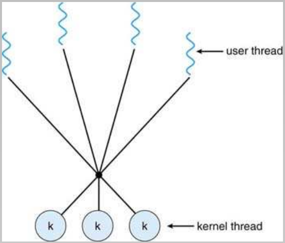

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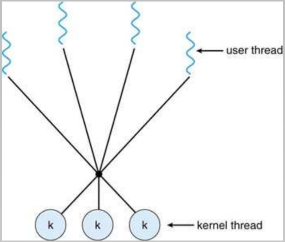

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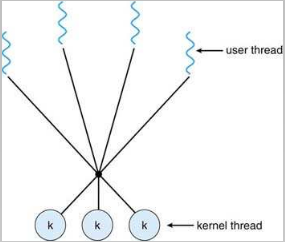

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  - Developers can create as many user threads as necessary, and the corresponding kernel threads can run in parallel on a multiprocessor.
  - Also, when a thread performs a blocking system call, the kernel can schedule another thread for execution.
- Whereas the many-to-one model allows the developer to create as many user threads as she wishes, true concurrency is not gained because the kernel can schedule only one thread at a time.

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  3. **Java**. The Java thread API allows thread creation and management directly in Java programs.
     - However, because in most instances the JVM is running on top of a host OS, the Java thread API is typically implemented using a thread library available on the host system.

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    - Such a call is important because there is *no clock interrupt to actually enforce time-sharing as there is with processes*.
    - Thus it is important for threads to be polite and voluntarily surrender the CPU from time to time to give other threads a chance to run.

Pthreads II

```
#include <pthread.h>
#include <stdio.h>
int sum; /* this data is shared by the thread(s) */
void *runner(void *param); /* the thread */
int main(int argc, char *argv[])
{
  pthread_t tid; /* the thread identifier */
  pthread_attr_t attr; /* set of thread attributes */
  if (argc != 2) {
    fprintf(stderr, "usage: a.out <integer value>\n");
    return -1;
  }
  if (atoi(argv [1]) < 0) {
    fprintf(stderr,"%d must be >= 0\n",atoi(argv[1]));
    return -1;
  }
  /* get the default attributes */
  pthread_attr_init (&attr);
  /* create the thread */
  pthread_create(&tid,&attr,runner,argv[1]) ;
  /* wait for the thread to exit */
  pthread_join(tid,NULL) ;
  printf (" sum = %d\n", sum) ;
}
```

Pthreads III

- The C program shown above and below demonstrates the basic Pthreads API for constructing a multithreaded program that calculates the summation of a nonnegative integer in a separate thread (do not forget to compile with *-lpthread* flag.).

```
/* The thread will begin control in this function */
void *runner(void *param)
{
  int i, upper = atoi(param);
  sum = 0;
  for (i = 1; i <= upper; i++)
    sum += i;
  pthread_exit(0) ;
}
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  - If *exec*() is called immediately after forking, then duplicating all threads is unnecessary, as the program specified in the parameters to *exec*() will replace the process. In this instance, duplicating only the calling thread is appropriate.
  - If, however, the separate process does not call *exec*() after forking, the separate process should duplicate all threads.

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   - Pthreads refers to such points as cancellation points.

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- Synchronous signals are delivered to the same process that performed the operation that caused the signal (that is the reason they are considered synchronous).

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- Every signal has a **default signal handler** that is run by the kernel when handling that signal.
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- Linux provides the ability to create threads using the *clone*() system call (*fork*() system call for duplicating a process) .
- In fact, Linux generally uses the term **task** -rather than process or thread - when referring to a flow of control within a program.
- When *clone*() is invoked, it is passed a set of flag. Some of these flags are listed in Fig. 9 below:

flag	meaning
CLONE_FS	File-system information is shared.
CLONE_VM	The same memory space is shared.
CLONE_SIGHAND	Signal handlers are shared.
CLONE_FILES	The set of open files is shared.

Figure: Some flags for *clone*() system call.

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- However, if none of these flags are set when *clone*() is invoked, no sharing takes place, resulting in functionality similar to that provided by the *fork*() system call.

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- Thus, its scheduling is central to OS design.
- Many of the same issues that apply to process scheduling also apply to thread scheduling, although some are different.

CPU-I/O Burst Cycle I

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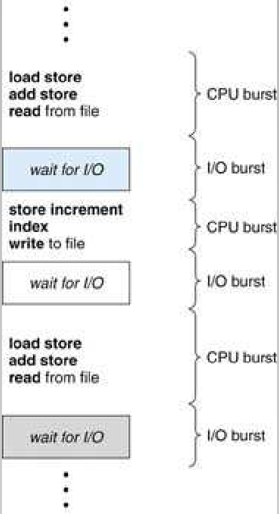

Figure: Alternating sequence of CPU and I/O bursts.

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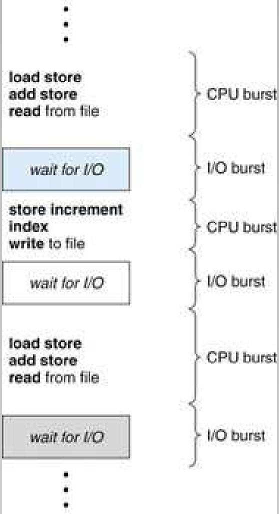

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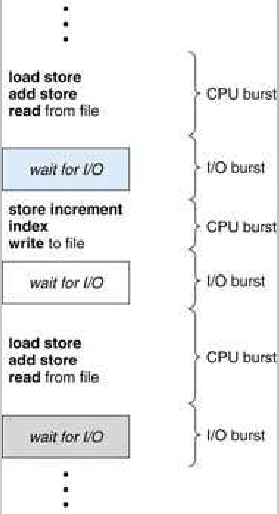

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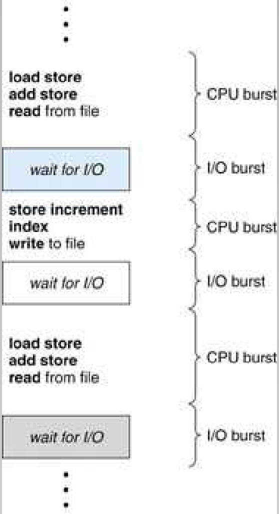

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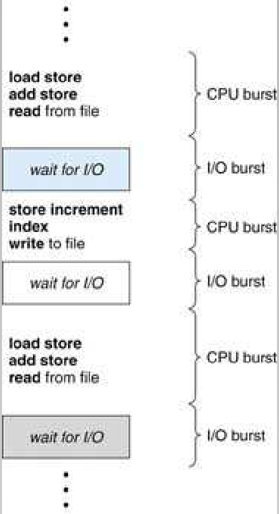

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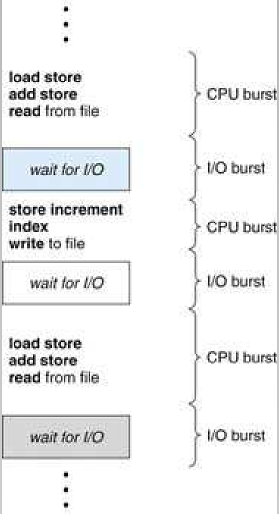

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- Eventually, the final CPU burst ends with a system request to terminate execution (see Fig. 10).

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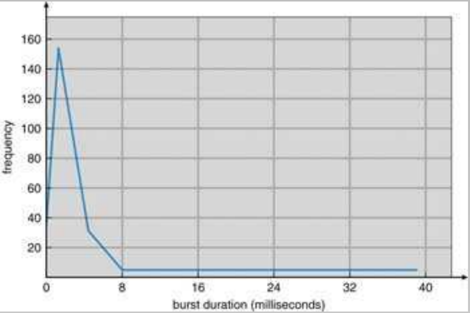

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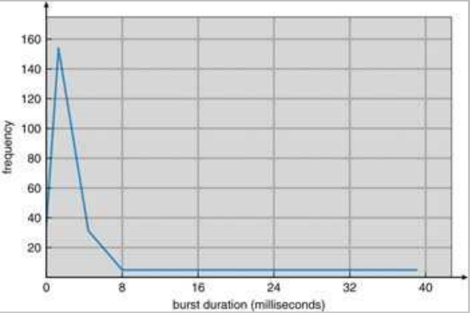

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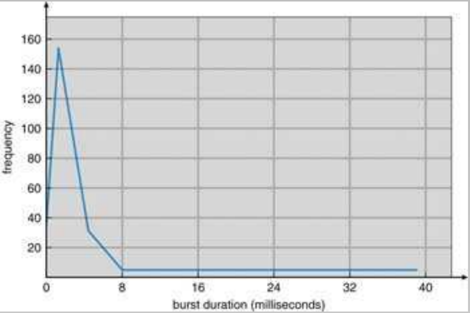

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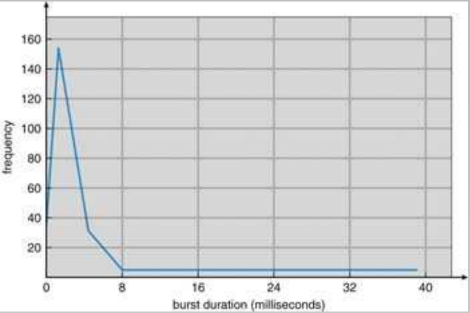

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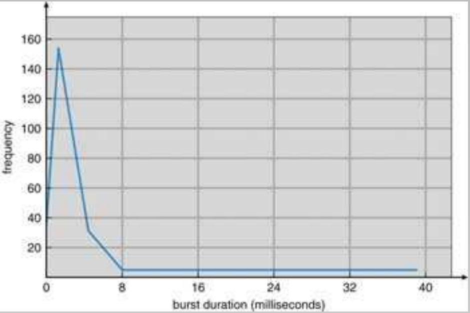

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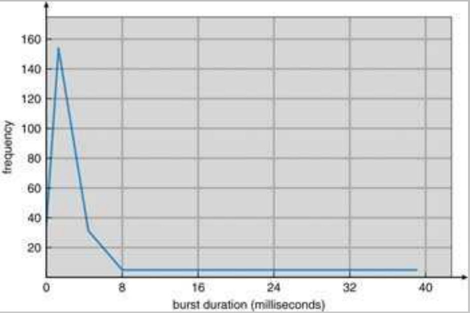

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- This distribution can be important in the selection of an appropriate CPU-scheduling algorithm.

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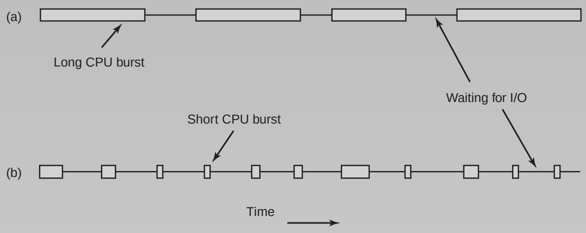

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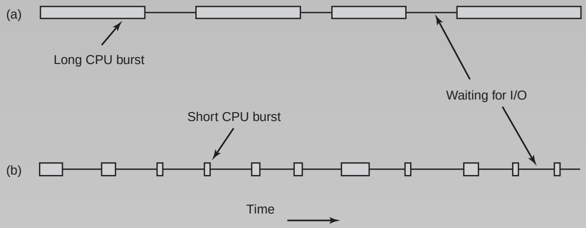

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- Having some CPU-bound processes and some I/O-bound processes in memory together is a better idea than first loading and running all the CPU-bound jobs and then when they are finished loading and running all the I/O-bound jobs (**a careful mix of processes**).

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- The records in the queues are generally process control blocks (PCBs) of the processes.

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  1. When a process switches from the running state to the waiting state (for example, as the result of an I/O request or an invocation of wait for the termination of one of the child processes).
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- For situations 1 and 4, there is no choice in terms of scheduling. A new process (if one exists in the ready queue) must be selected for execution.
- There is a choice, however, for situations 2 and 3.

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  - While one is updating the data, it is preempted so that the second process can run.
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  - In such situations, we need new mechanisms to coordinate access to shared data.

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- In contrast, a **pre-emptive scheduling algorithm** picks a process and lets it run for a maximum of some fixed time. If it is still running at the end of the time interval, it is suspended and the scheduler picks another process to run. Round-Robin (RR), Priority Scheduling.

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- The time it takes for the dispatcher to stop one process and start another running is known as the **dispatch latency**.

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  - **Waiting time**. The CPU scheduling algorithm does not affect the amount of time during which a process executes or does I/O; it affects only the amount of time that a process spends waiting in the ready queue.
  - **Response time**. In an interactive system, turnaround time may not be the best criterion. Thus, another measure is the time from the submission of a request until the first response is produced.

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  - Given a mix of short jobs and long jobs, a scheduler that always ran short jobs and never ran long jobs might achieve an excellent throughput (many short jobs per hour) but at the expense of a terrible turnaround time for the long jobs.

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  - If short jobs kept arriving at a steady rate, the long jobs might never run, making the mean turnaround time infinite while achieving a high throughput.
- It is desirable to maximize **CPU utilization** and **throughput** and to minimize **turnaround time**, **waiting time**, and **response time**.

Scheduling Criteria III

- Some goals of the scheduling algorithm under different circumstances, see Fig. 13.

All systems
Fairness - giving each process a fair share of the CPU
Policy enforcement - seeing that stated policy is carried out
Balance - keeping all parts of the system busy

Batch systems
Throughput - maximize jobs per hour
Turnaround time - minimize time between submission and termination
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Interactive systems
Response time - respond to requests quickly
Proportionality - meet users' expectations

Real-time systems
Meeting deadlines - avoid losing data
Predictability - avoid quality degradation in multimedia systems

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- Under all circumstances, fairness is important.
- Another general goal is keeping all parts of the system busy when possible.