Systems and Networking I

Applied Computer Science and Artificial Intelligence

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Recap from Last Lecture

- Process is the **unit of execution** (running on a single CPU)
- OS keeps track of process-related information using an ad hoc data structure called Process Control Block (PCB)
- Process can be in one of **5 possible states**: **new**, **ready**, **waiting**, **running**, or **terminated**
- Context **switch** to intertwine the execution of multiple processes
- Process communication either via **message passing** or **shared memory**

Today: CPU Scheduling

$\boxed{\text{Policy to establish which process to execute on the CPU}}$

- Basic scheduling concepts
- Scheduling **criteria/metrics**
- Scheduling **algorithms**
- Advanced scheduling concepts

Basic Concepts

- Almost every program has some alternating cycles of CPU computations and I/O waiting
- Even a simple fetch from main memory takes a long time relatively to CPU speed
- <u>**Our assumptions:**</u> Multi-programmed, uni-processor system

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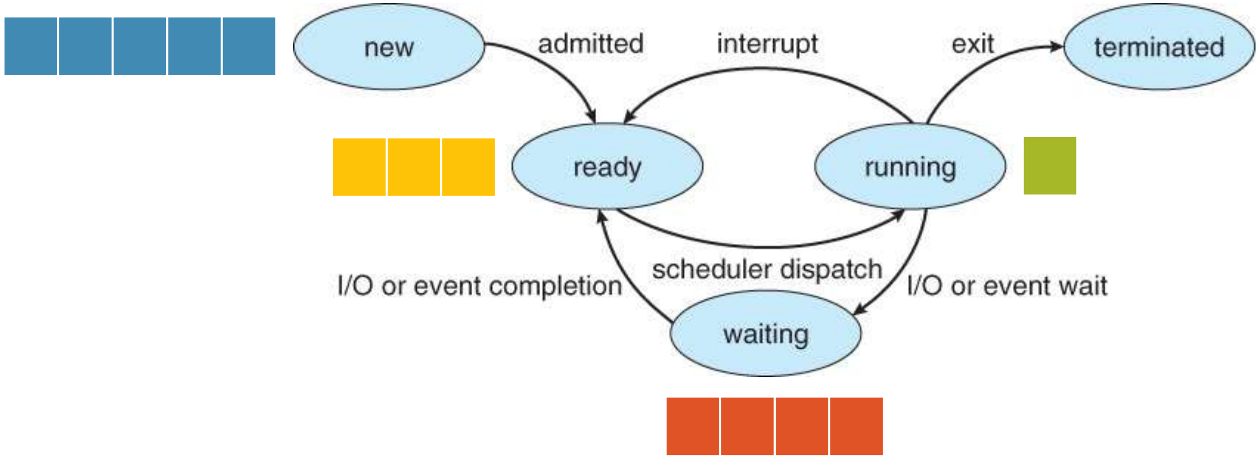
- A scheduling system allows one process to use the CPU while another is waiting for I/O, thereby maximizing system utilization
- **Challenge:** Make the system as "efficient" and "fair" as possible, subject to varying and often dynamic conditions

Process Execution State Diagram



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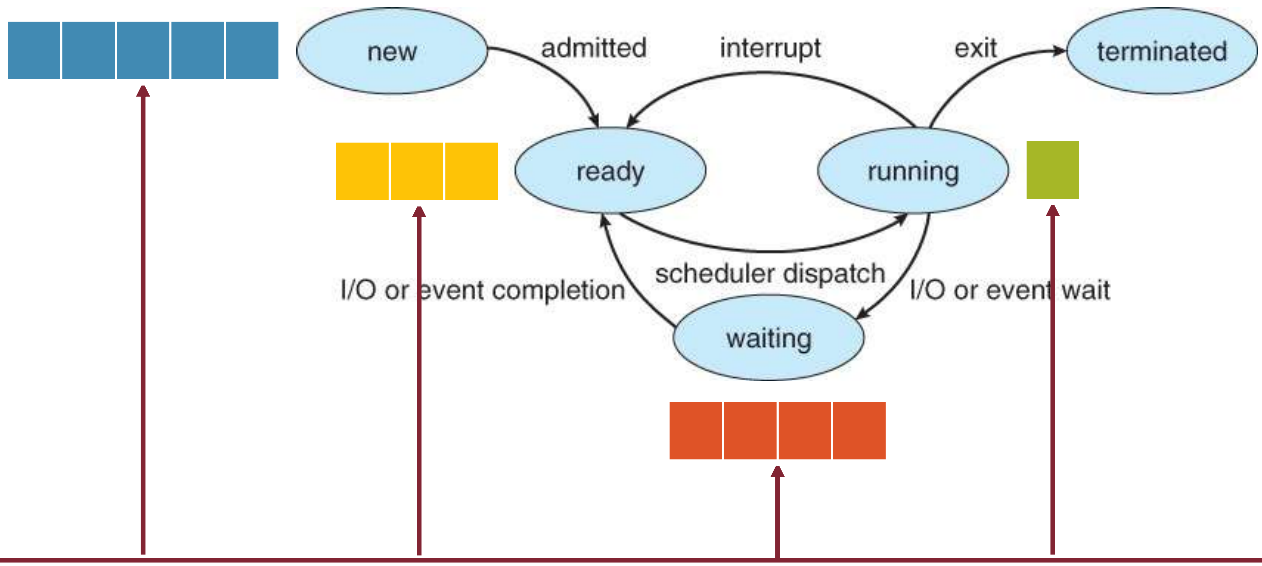
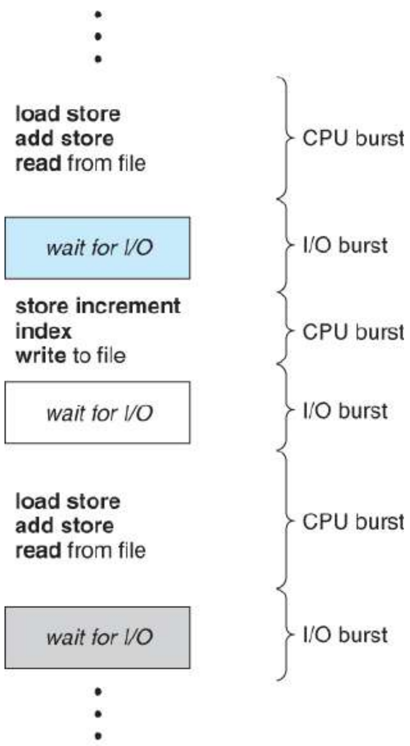


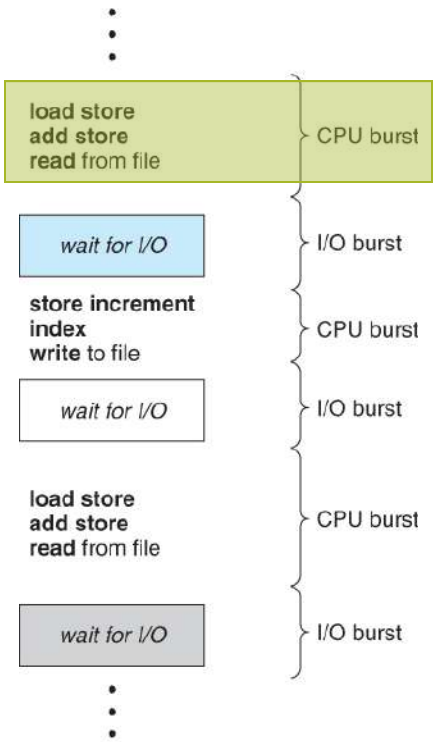
Processes managed by the OS reside in exactly one of the state queues

CPU vs. I/O Burst Cycle



All processes alternate between two states in a continuing cycle: CPU burst and I/O burst

CPU vs. I/O Burst Cycle



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CPU burst → performing calculations

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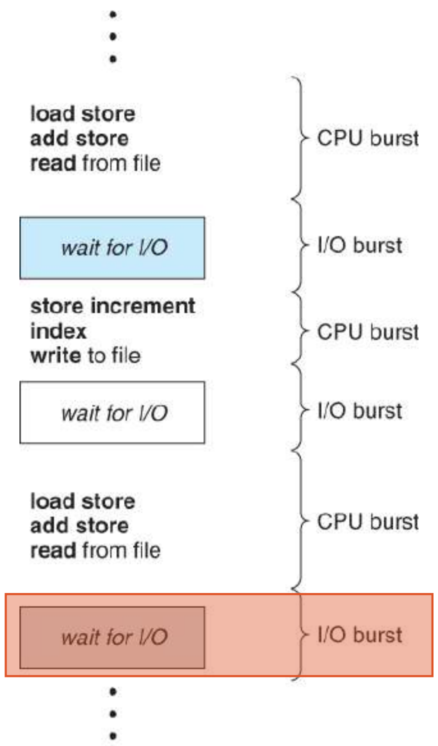

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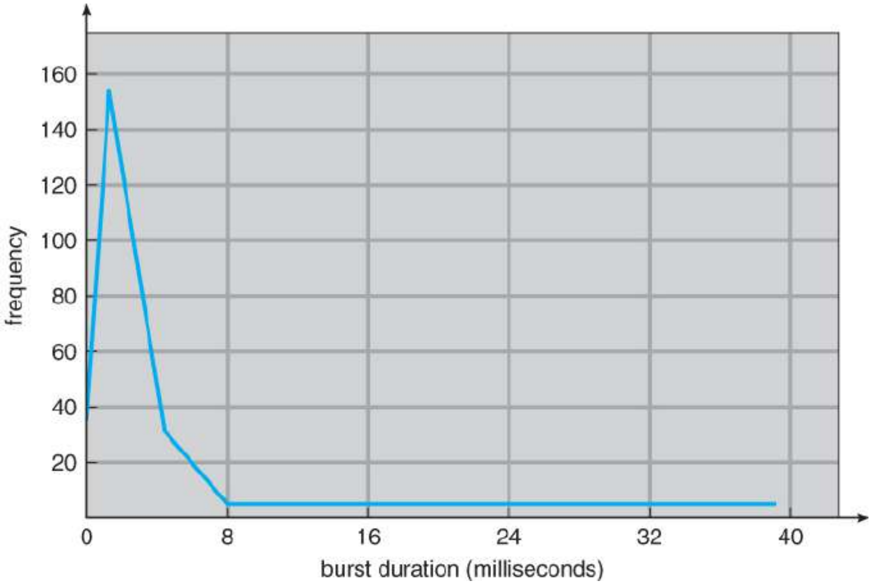
I/O burst → waiting for data transfer in or out of the system

CPU Burst Cycle: Frequency Pattern



Highly skewed distribution

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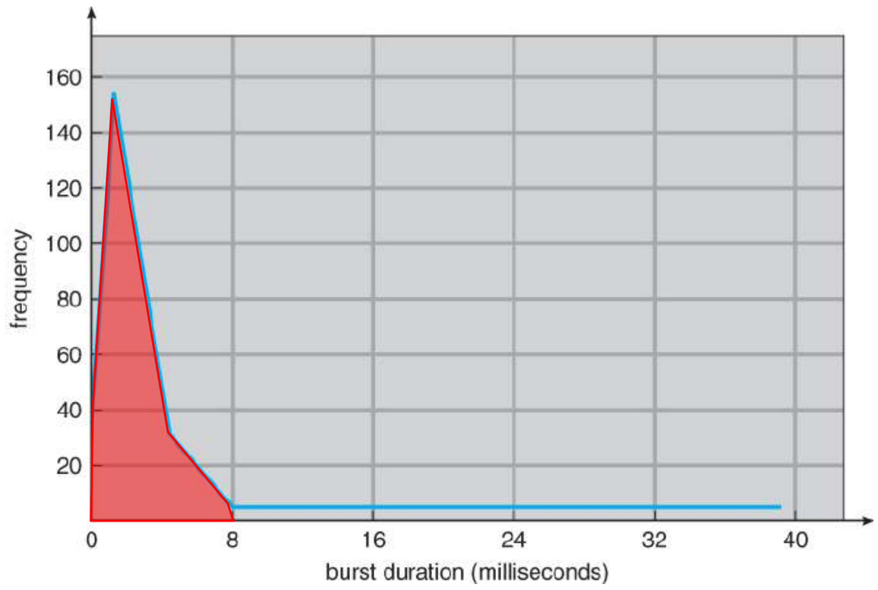

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The vast majority of processes have short CPU bursts

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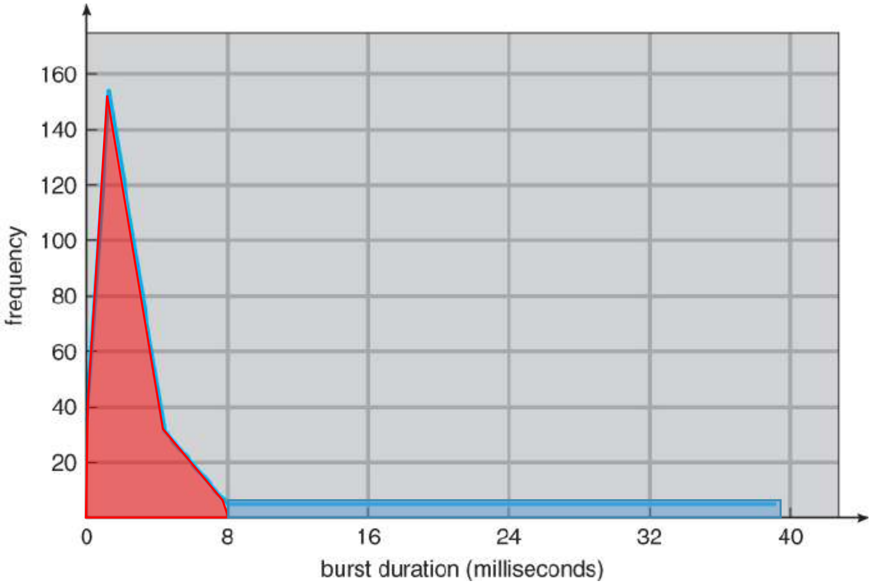

Highly skewed distribution

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Few processes exhibit very long CPU bursts

Long- vs. Short-term Scheduling

Long-term scheduling

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Policy goals vs. Mechanism implementations

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for an I/O request or invocation of the wait system call

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in response to an interrupt

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after I/O completion or a return from wait

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4. When a process is created or terminates

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No choice!
A new process must be selected

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Either continue with the current process or select a new one

Non-preemptive vs. Preemptive

Non-preemptive scheduling

If it takes place only when there is no choice (i.e., conditions 1 and 4)

Once a process starts it keeps running until it either voluntarily blocks or it finishes

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Preemptive scheduling

Whenever scheduling takes also place under conditions 2 and 3

Non-preemptive vs. Preemptive: Examples

	Windows	Mac	UNIX-like
Non-preemptive	up to Win 3.x	up to Mac OS 9.x	–
Preemptive	since Win 95	since Mac OS X	since forever

Preemption: Issues

- Preemption might cause troubles if it occurs while:
  - the kernel is busy implementing a system call (e.g., updating critical kernel data structures)
  - two processes share data, one may get interrupted in the middle of updating shared data structures

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    should only be done in rare situations, and only on very short pieces of code that will finish quickly

The Dispatcher

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- Its functions include:
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  - Jumping to the proper location in the newly loaded program
- The dispatcher is run on every context switch therefore the time it consumes (**dispatch latency**) must be as shortest as possible

Useful Definitions

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NOTE

I/O waiting time is not considered here!

Useful Definitions

$$T^{arrival} = \text{arrival time}$$

$$T^{completion} = \text{completion time}$$

$$T^{burst} = \text{burst time}$$

$$T^{turnaround} = \text{tournaround time} = T^{completion} - T^{arrival}$$

$$T^{waiting} = \text{waiting time} = T^{turnaround} - T^{burst}$$

Scheduling Criteria/Metrics

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  - CPU utilization
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Scheduling: Trade-off

- Ideally, choose a CPU scheduler that optimizes all metrics simultaneously
- Generally, the above is impossible and a trade-off is needed!
- **Idea:** Choose a scheduling algorithm based on its ability to satisfy a given policy

Scheduling Policies

- Minimize **average** response time
  - Provide output to the user as quickly as possible

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Typical of batch systems

A Quick Note on Terminology

JOB/TASK

General unit of CPU execution

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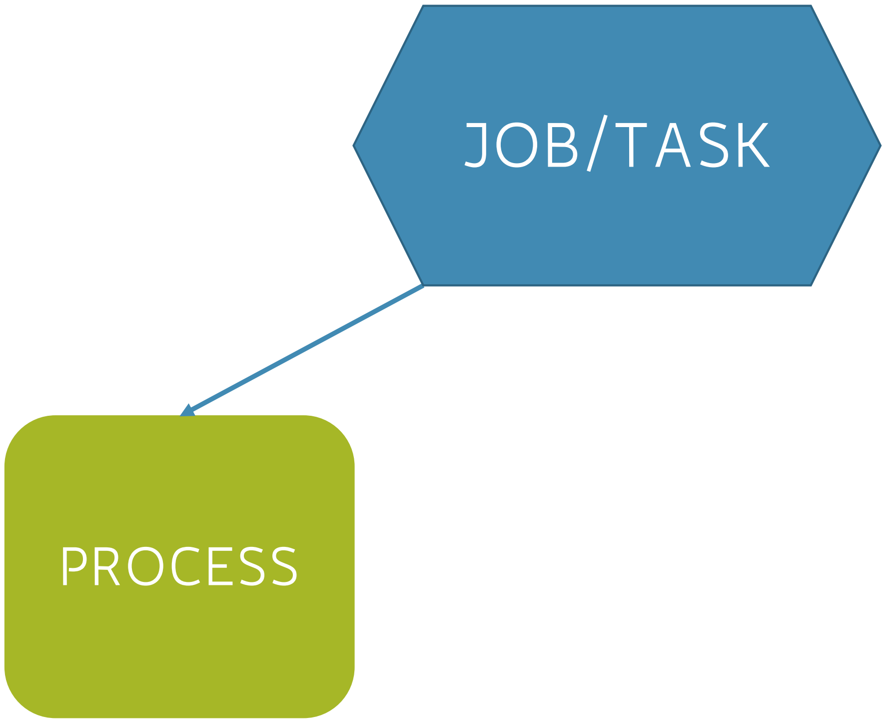

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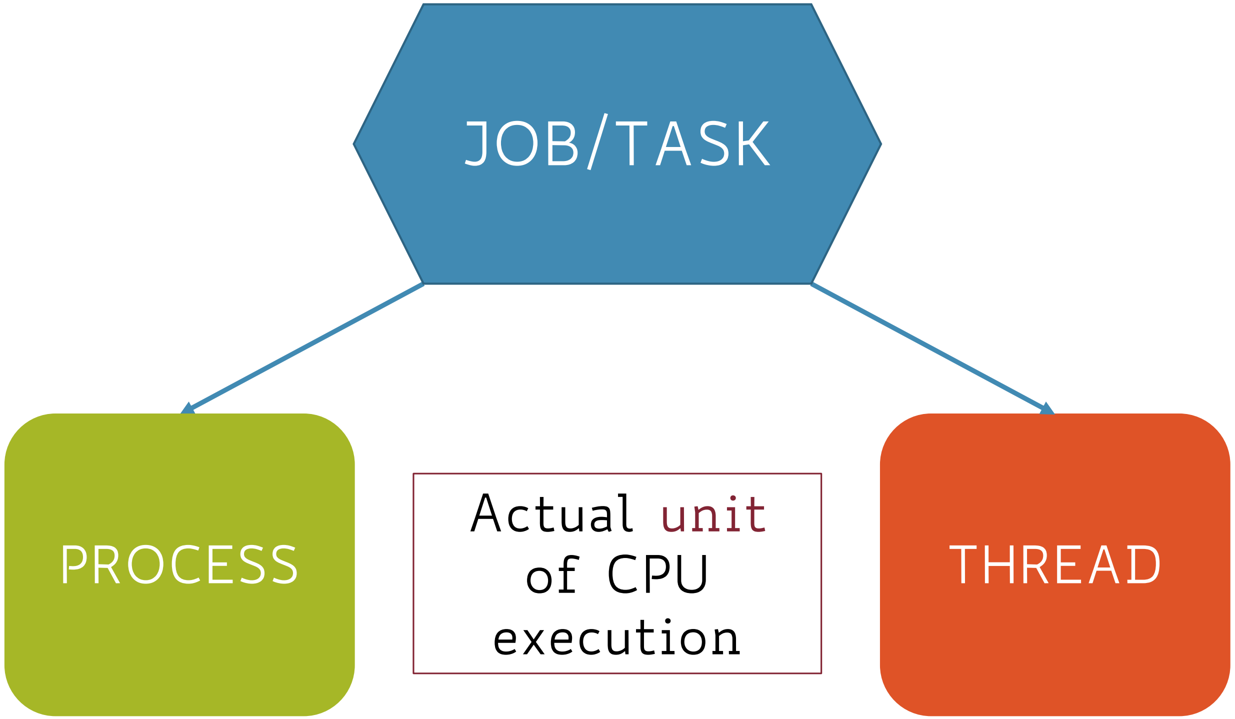

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We will talk about threads very soon but for now most of the things we will be discussing remain valid even on a multi-threaded system

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- Scheduling allows one process to use the CPU while another is waiting for I/O
- The goal of scheduling is to maximize system utilization
- **non-preemptive** vs. **preemptive** scheduler
- Different scheduling policies optimize different metrics