Multi Processes and Scheduling

ECE 469, Feb 15

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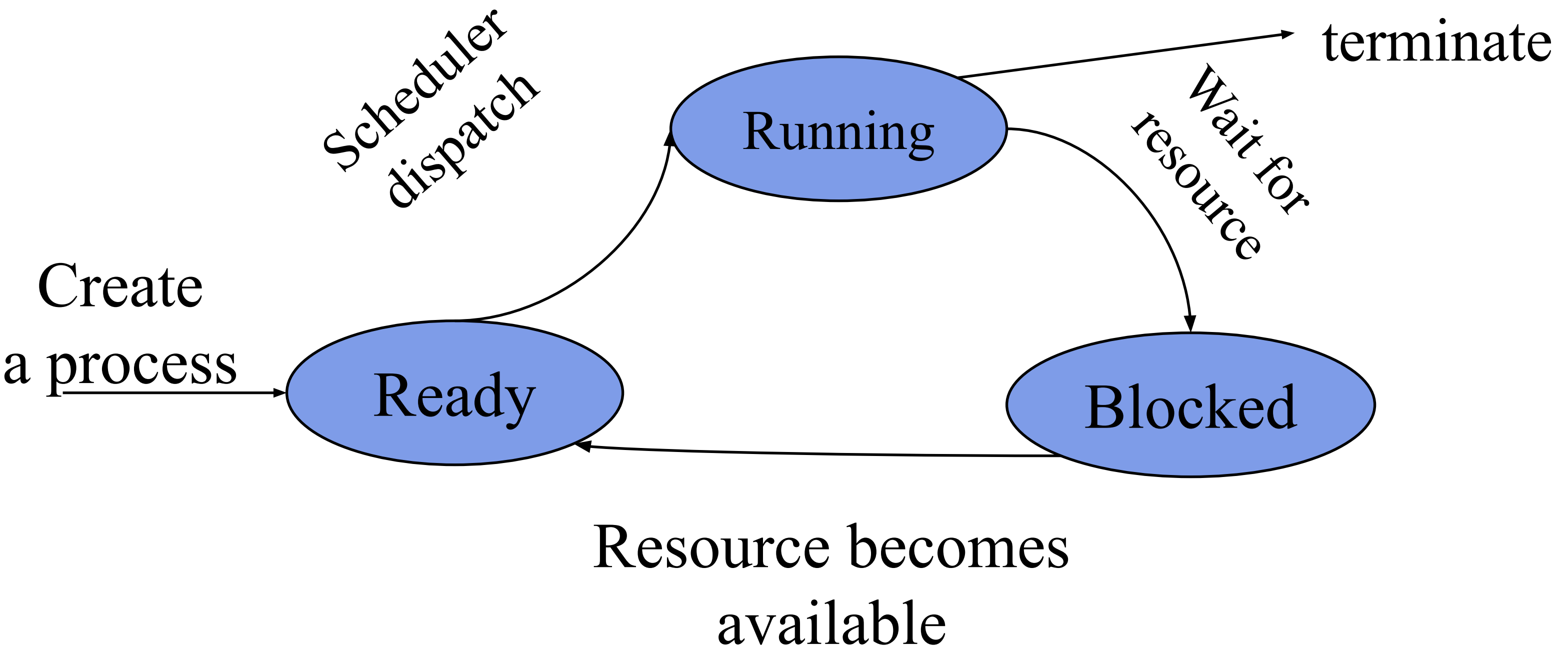
Recap: Users, Programs, Processes

- Users have accounts on the system
- Users launch programs
- There can be multiple programs (i.e., processes), which want to run at the same time

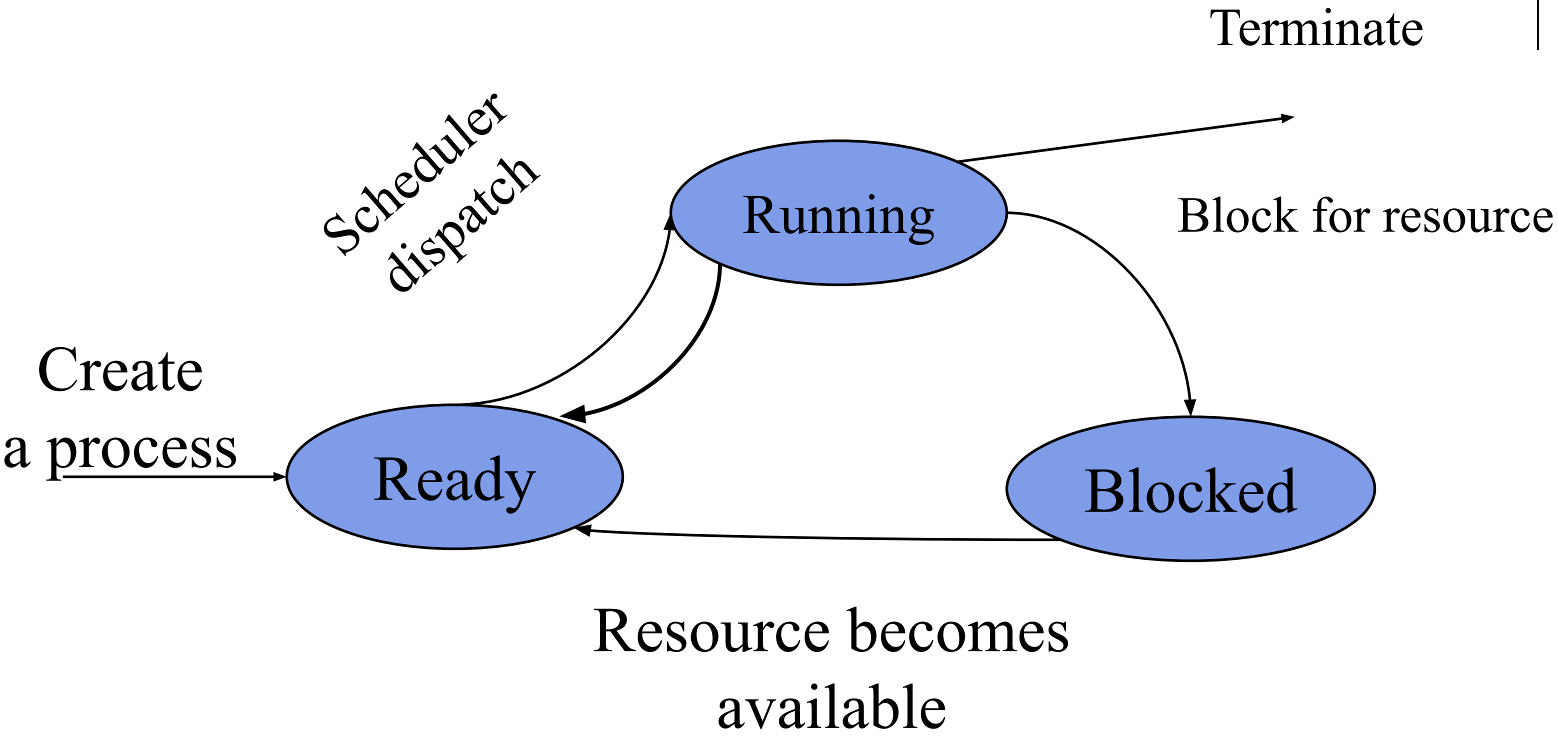
Sequential execution of each process

- Assuming single-threaded program
- No concurrency inside a process
- Everything happens sequentially
- Often with interleaved CPU/IO operations

Process Life Cycle



Non-Preemptive Scheduling



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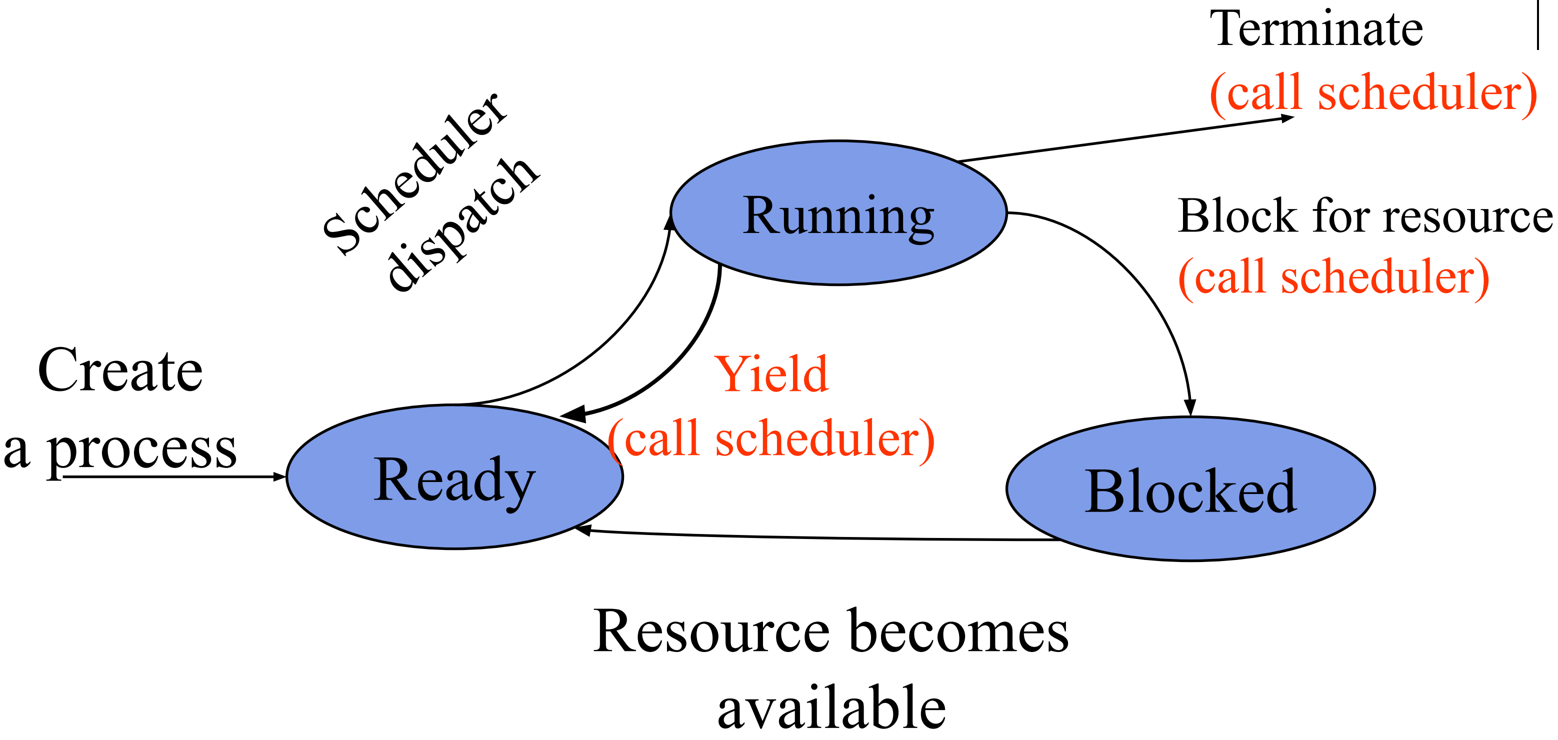


Non-Preemptive Scheduling

- Any issues?
- What if a process runs:

```
int main() {
    while(1);
}
```

Concurrent Processes

- Processes in a system can execute concurrently (multitasking)

- Motivations for allowing concurrent execution
  - Physical resource sharing (system utilization)
  - Computational speedup – with several CPUs
  - Modularity (chrome)
  - Convenience (desktop: chrome, google drive, clock, weather)

- Logical resource sharing (eg password files)

Time Sharing Systems

- Timesharing systems support interactive use:
  - each user feels he/she has the entire machine
- How?
  - optimize response time
  - based on time-slicing

Preemptive Scheduling

- Basic idea
  - before moving process to running, OS sets timer
  - if process yields/blocks, clear timer, go to scheduler
  - If timer expires, go to scheduler

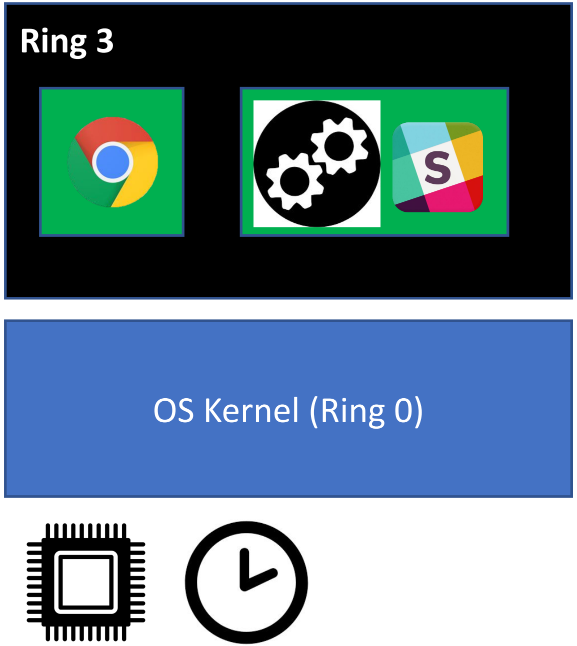
Preemptive Scheduling

- How does the OS know that the timer expired?

```c
int main() {
    while(1);
}
```

Preemptive Scheduling

- Preemptive Multitasking (Lab 4)
- CPU generates an interrupt to force execution at kernel after some time quantum
  - E.g., 1000Hz, on each 1ms..



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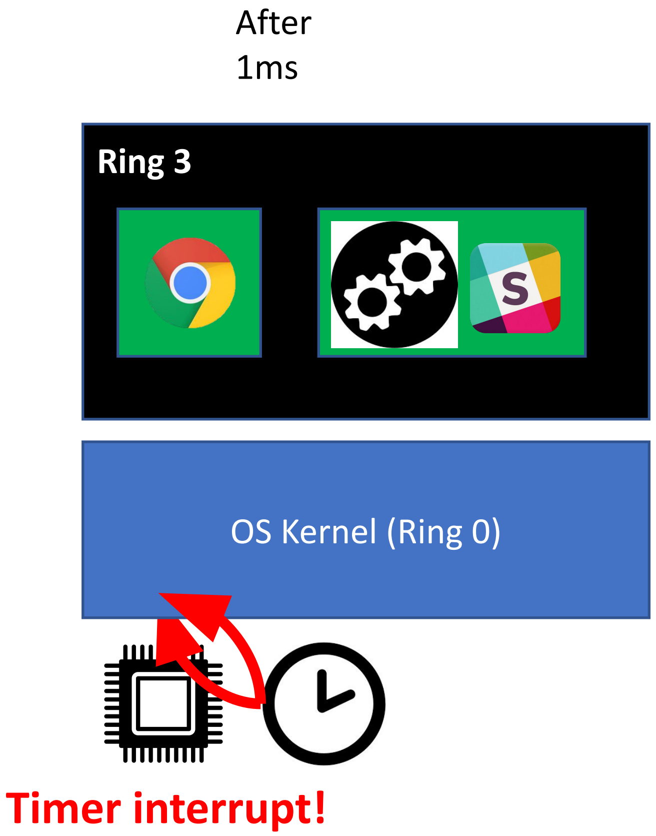

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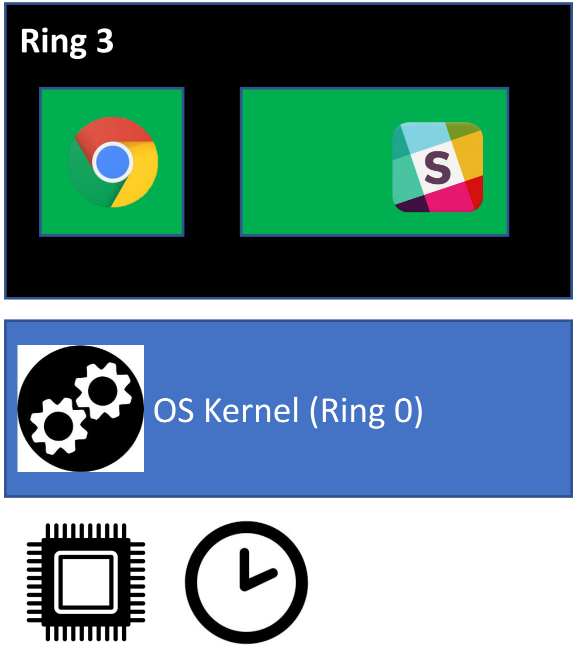
- Guaranteed execution in kernel
  - Let kernel mediate resource contention



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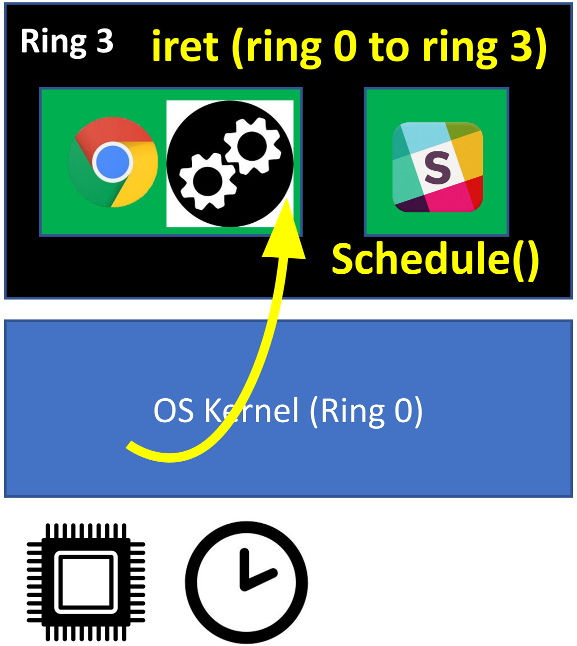


Context Switch

- Definition: Switching the CPU to another process, which involves saving the state of the old process and loading the state of the new process

- **What state**?

- Where to store them?

Process State: Process Control Block (PCB)

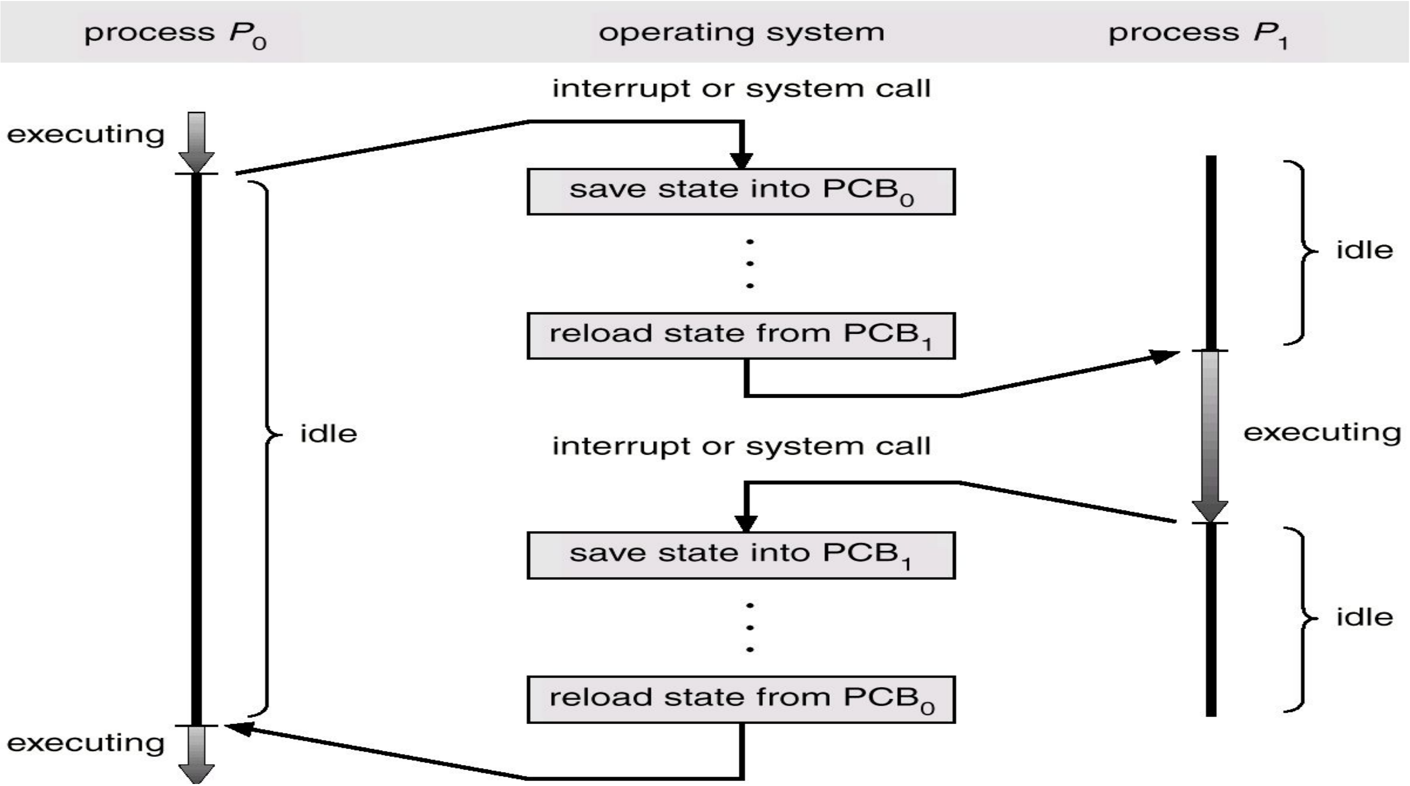
- A.K.A User Environment (JOS)

- Process management info
  - State (ready, running, blocked)
  - PC & Registers, parents, etc
  - CPU scheduling info (priorities, etc.)

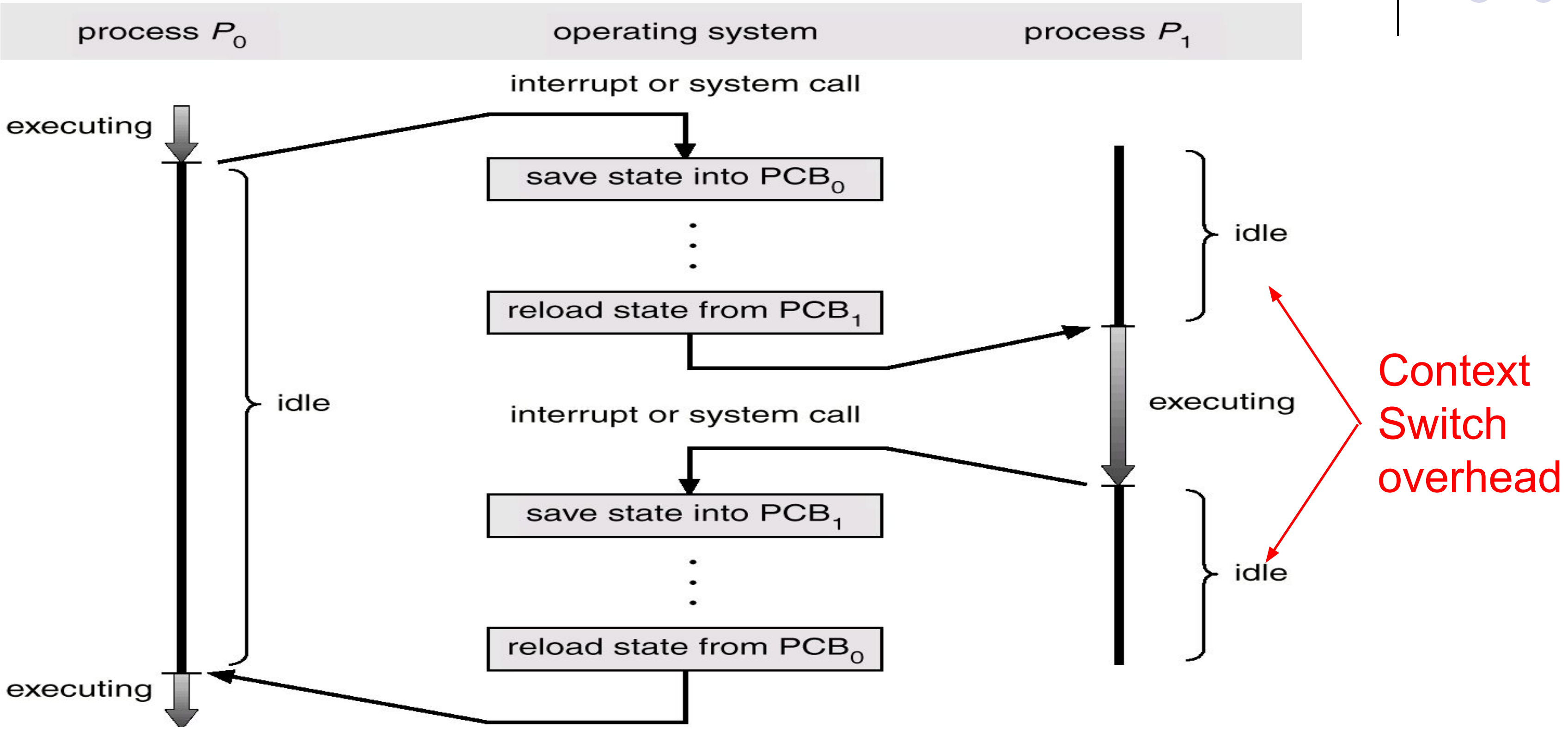
- Memory management info
  - Segments, page table, stats, etc

- I/O and file management
  - Communication ports, directories, file descriptors, etc

Context Switch



Context Switch



Preemptive Scheduling Considerations

- Timer granularity
  - **Finer timers = more responsive, high overhead**
  - **Coarser timers = less responsive, more efficient**

- CPU Accounting (CPU running stats)
  - Used by the scheduler
  - Useful for the programmer

Preemptive Scheduling Considerations

- Mechanism + policy
- Mechanisms fairly simple:
  - Save state into a PCB and Restore state from another PCB

Preemptive Scheduling Considerations

- Mechanism + policy
- Mechanisms fairly simple:
    - Save state into a PCB and Restore state from another PCB
- Policy choices harder:
    - When should we switch?

Challenges in Policy

- Flexibility - variability in job types
  - Long vs. short
  - Interactive vs. non-interactive
  - I/O-bound vs. compute-bound
- Issues
  - Short jobs shouldn't suffer
  - (Interactive) Users shouldn't be annoyed

Challenges in Policy (2)

- Fairness
  - All users should get access to CPU
  - Amount of CPU should be roughly even?

- Issue
  - Short-term vs. long-term fairness

Goals

- Goals (Performance metrics)
  - Minimize turnaround time
    - avg time to complete a job
    - $T_{turnaround} = T_{completion} - T_{arrival}$
  - Maximize throughput
    - operations (jobs) per second
    - Minimize overhead of context switches: large quanta
    - Efficient utilization (CPU, memory, disk etc)
  - Short response time
    - $T_{response} = T_{firstrun} - T_{arrival}$
    - type on a keyboard
    - Small quanta
  - Fairness
    - fair, no stavaton, no deadlock

Goals

- Goals often conflict
  - Response time vs. throughput
  - fairness vs. avg turnaround time?

Goals and Assumptions

- Goals (Performance metrics)
  - Minimize turnaround time
    - avg time to complete a job
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Scheduling Policies

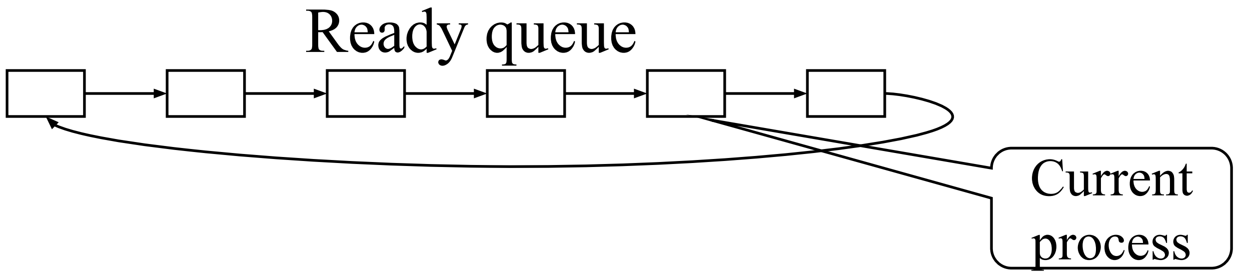
- Is there an optimal scheduling policy?
  - Even if we narrow down to one goal?

- But we don't know about future
  - Offline vs. online

Scheduling Policies

- Round Robin
- SJCF
- SRTCF

Round Robin



- Each runs a time slice or quantum: Fair
- How do you choose time slice?
  - Overhead vs. response time
  - Overhead is typically about 1% or less
  - Quantum typically between 10 ~ 100 millisec

Is Fairness always good?

- Assume 10 jobs waiting to be scheduled, each takes 100 seconds
  - Assume no other overhead
  - Total CPU time? 1000 seconds, always

- Implications?
  - Last job always finishes at 1000 seconds
  - So what's the point of scheduling?

Non-Preemptive Scheduling

- Job 1 – start 0, end 100
- Job 2 – start 100, end 200
- …
- Job 10 – start 900, end 1000

- Average turnaround time =100 + 200 +… /10 = 550 sec

Round Robin

- Assume each quantum is 1 second

- Job 0 – 0, 10, 20, 30, 40,…, 990
- Job 1 – 1, 11, 21, 31,…, 991
- Job 2 – 2, 12, 22, 32,…, 992
- …

- Avg turnaround time = 990+991+…/10 = 995 sec

Is Fairness always good?

- Unfair policy was faster!
- Job 10 always ended at the same time
- Round-Robin just hurt jobs 1-9 with no gain

Why use Round Robin?

- Imagine 10 jobs
  - Jobs 1-9 are 100 seconds
  - Job 10 is 10 seconds

- Which policy is better now?

Non-preemptive scheduling

- Jobs 1-9 are 100 seconds
- Job 10 is 10 seconds

Non-preemptive scheduling

- Jobs 1-9 are 100 seconds
- Job 10 is 10 seconds

- Job 0 – start 0, end 100
- Job 1 – start 100, end 200
- Job 10 – start 900, end 910

- Avg turnaround time = 100+200+…910/N = 541

Round Robin scheduling

- Jobs 1-9 are 100 seconds
- Job 10 is 10 seconds

- Job 0 – 0, 10, 20, …, 900
- Job 1 – 1, 11, 21, …, 901
- Job 10 – 9, 19, 29, …, 99

- Avg turnaround time = 900 + 901 + 908 + 99 / 10 = 824

Round Robin scheduling

- Jobs 1-9 are 100 seconds
- Job 10 is 10 seconds

- Job 0 – 0, 10, 20, …, 900
- Job 1 – 1, 11, 21, …, 901
- Job 10 – 9, 19, 29, …, 99

9% work drop

2% avg turnaround drop for FIFO

17% avg turnaround drop for RR

- Avg turnaround time = 900 + 901 + 908 + 99 / 10 = 824

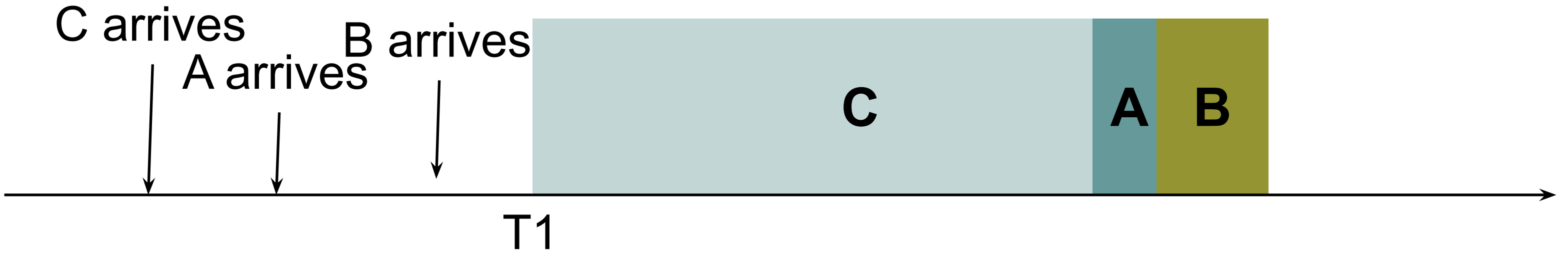
Why use Round Robin?

- Imagine 10 jobs
  - Jobs 1 is 100 seconds
  - Job 2-10 is 10 seconds

- Which policy is better now?
  - FIFO: average turnaround 145
  - RR: average turnaround 105

STCF (SJF) – Shortest Job First

- What shall we do if we care about turn-around time?
  - FIFO can be bad



- STCF/SJF
  - schedule shortest (total completion time) job first

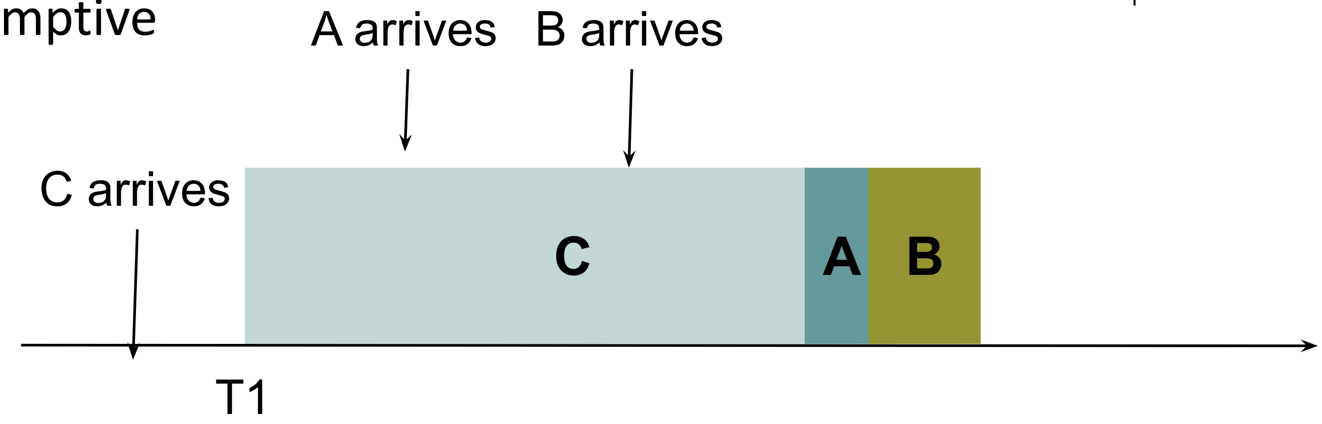
SJF: Pros and Cons

- Can we do better than Shortest Job First in terms of average turnaround time?
    - Assume all jobs arrive at the beginning
- In fact, SJF can be proved to be the optimal scheduling algorithm with the above assumption
    - But we are not going to prove it, since this is not a theory class 😊

- SJF Advantage
    - Minimal average turnaround time
- Disadvantage
    - Difficult to know the future, has to run until finish

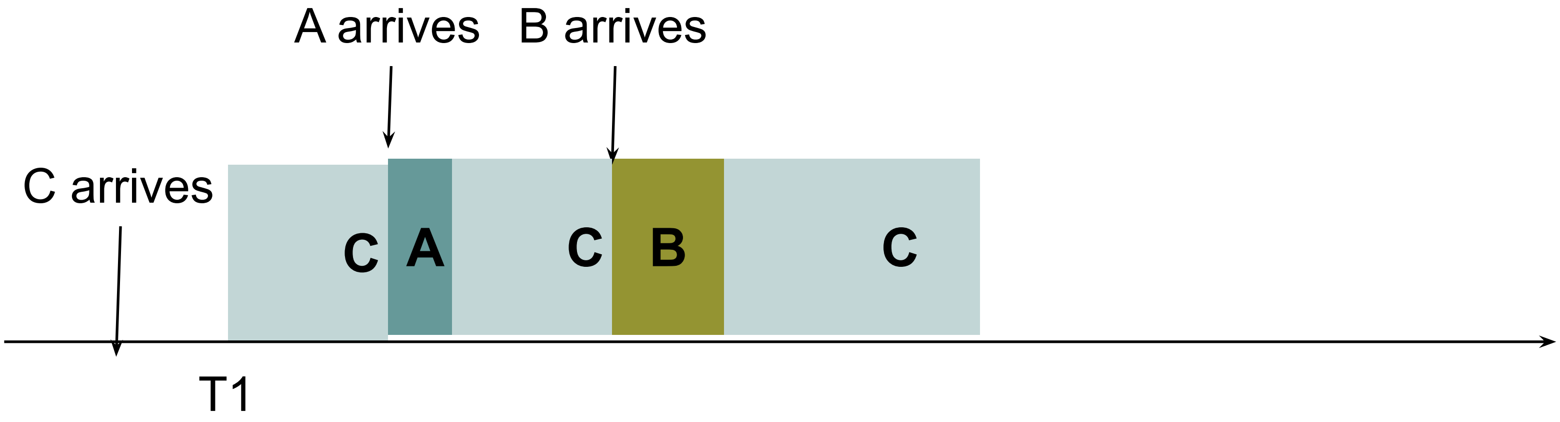
STCF

- Shortest time to completion first (shortest job first)
  - Non-preemptive



SRTCF

- Shortest remaining time to completion first
  - Preemptive



Any potential problems?
- Can cause starvation!

Policy Decisions

- Need to accommodate interactive jobs
  - Need some kind of RR
- Diversity in jobs – job length, I/O mix
  - RR also appears to help
- SJF also has virtue
  - Reduce avg. turnaround time
- Can we accommodate all?

Scheduling Policies Advantages

FIFO	Response time
RR	Throughput
SJF	Avg. turnaround time
	Fairness

Scheduling Policies Advantages

FIFO	Response time
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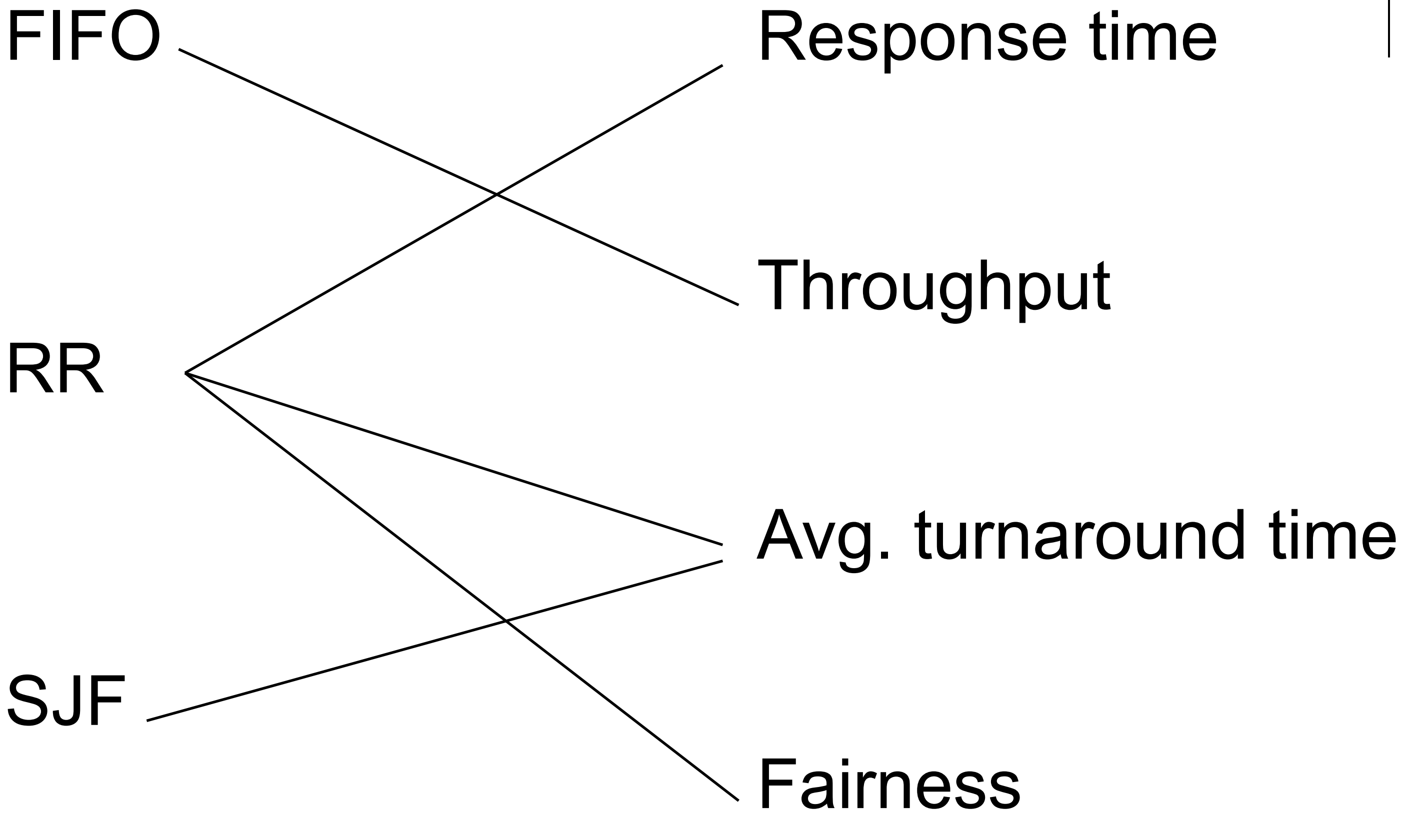
Scheduling Policies Advantages



Scheduling Policy Issues

- Fairness
- Flexibility
- **High utilization (efficiency)**
- Good response time
- Good turnaround time

Scheduling Policy Issues

- High utilization (efficiency)
  - Lots of processes (want diff resources)
  - Lots of resources (want full parallelism)

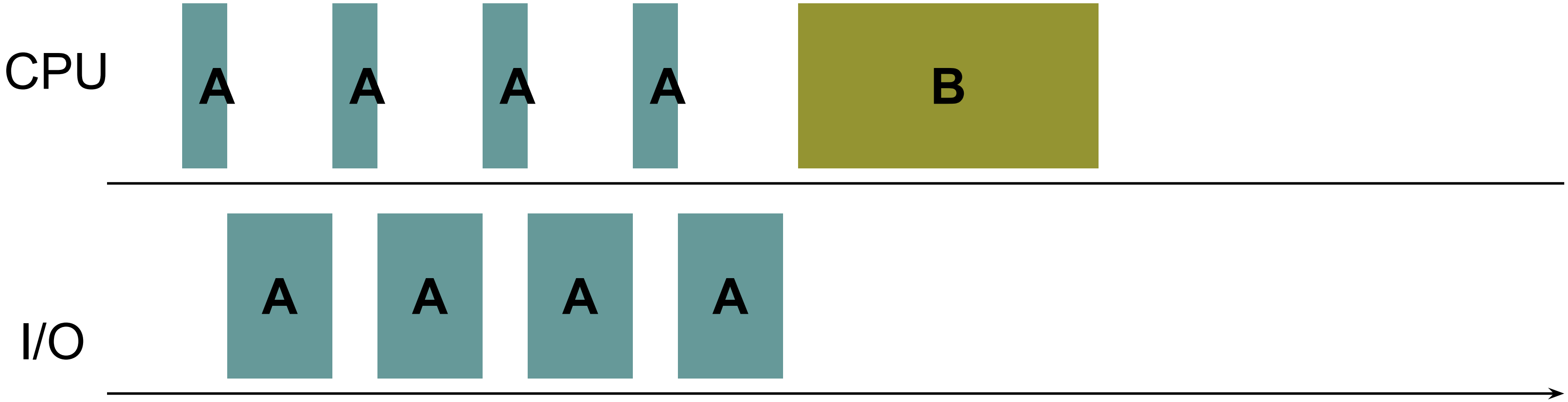
- Issue?
  - How do you get the most useful work out of the system? (job throughput)

Adding I/O into mix

- Resource utilization example
  - A and B each uses 100% CPU
  - C loops forever (1ms CPU and 10ms disk)
  - Time slice 99ms: roughly 30% of disk utilization with Round Robin and roughly 70% of CPU utilization
  - Time slice 1ms: roughly 90% of disk utilization with Round Robin and nearly 100% of CPU utilization

- What do we learn from this example?
  - Small time slice can improve utilization / fairness to I/O jobs

Handling I/Os



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