# Interactive Scheduling



# Two Level Scheduling

- Interactive systems commonly employ two-level scheduling
  - CPU scheduler and Memory Scheduler
    - Memory scheduler was covered in VM
  - We will focus on CPU scheduling

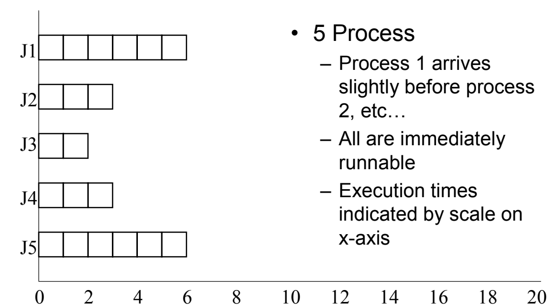


# Round Robin Scheduling

- Each process is given a *timeslice* to run in
- When the timeslice expires, the next process preempts the current process, and runs for its timeslice, and so on
- Implemented
  - A ready queue
  - A regular timer interrupt



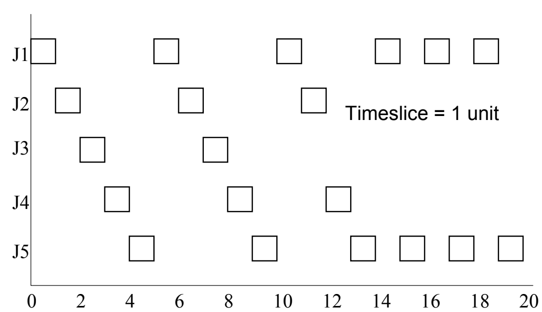
# Our Earlier Example




- 5 Process
  - Process 1 arrives slightly before process 2, etc…
  - All are immediately runnable
  - Execution times indicated by scale on x-axis

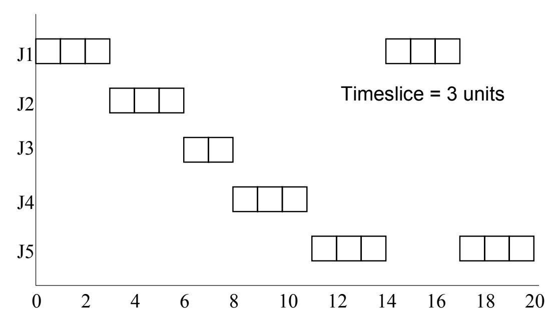


# Round Robin Schedule






# Round Robin Schedule



## Round Robin

- Pros
  - Fair, easy to implement
- Con
  - Assumes everybody is equal
- Issue: What should the timeslice be?
  - Too short
    - Waste a lot of time switching between processes
    - Example: timeslice of 4ms with 1 ms context switch = 20% round robin overhead
  - Too long
    - System is not responsive
    - Example: timeslice of 100ms
      - If 10 people hit "enter" key simultaneously, the last guy to run will only see progress after 1 second.
    - Degenerates into FCFS if timeslice longer than burst length

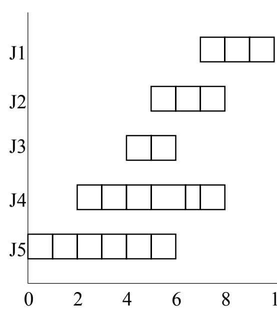


## Priorities

- Each Process (or thread) is associated with a priority
- Provides basic mechanism to influence a scheduler decision:
  - Scheduler will always chooses a thread of higher priority over lower priority
- Priorities can be defined internally or externally
  - Internal: e.g. I/O bound or CPU bound
  - External: e.g. based on importance to the user



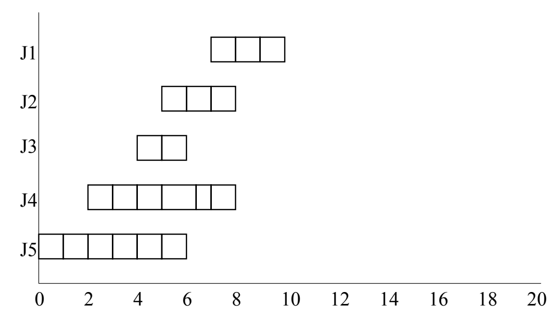
## Example




- 5 Jobs
  - Job number equals priority
  - Priority 1 > priority 5
  - Release and execution times as shown
- Priority-driven preemptively scheduled



## Example



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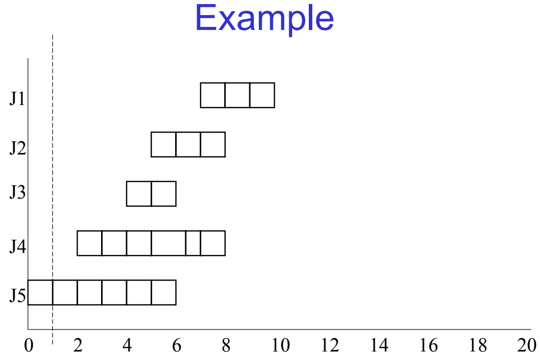




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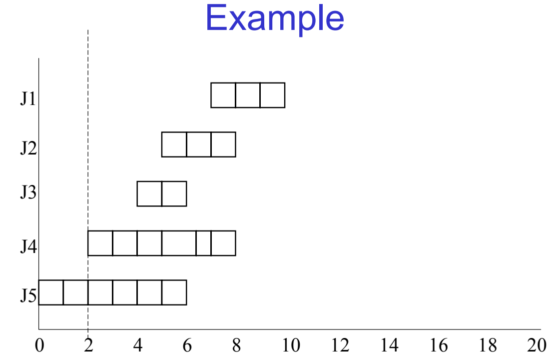

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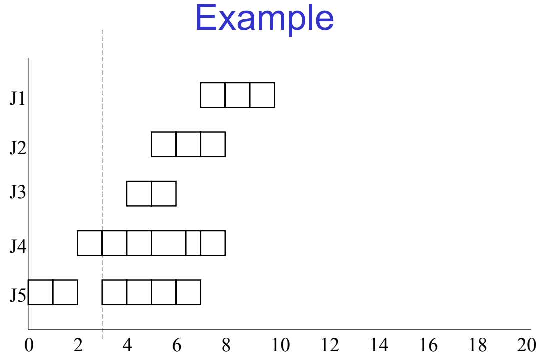


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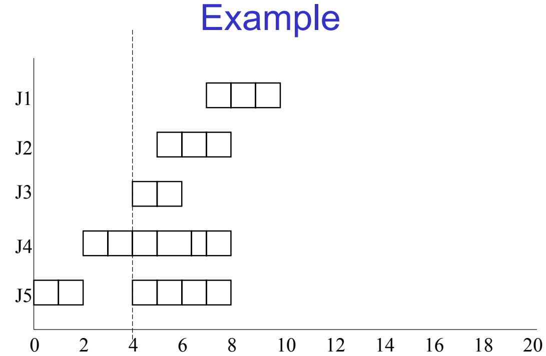


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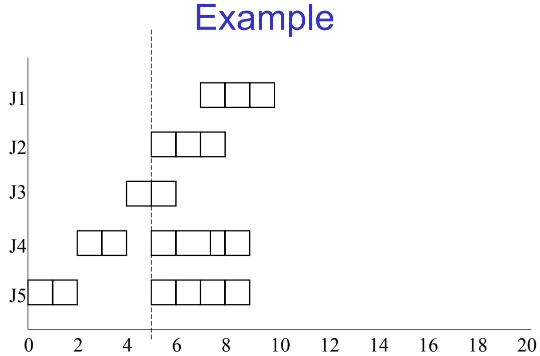


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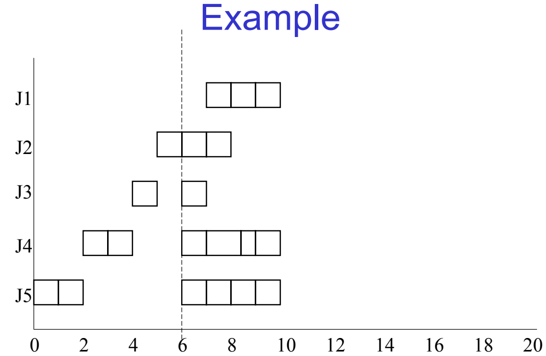


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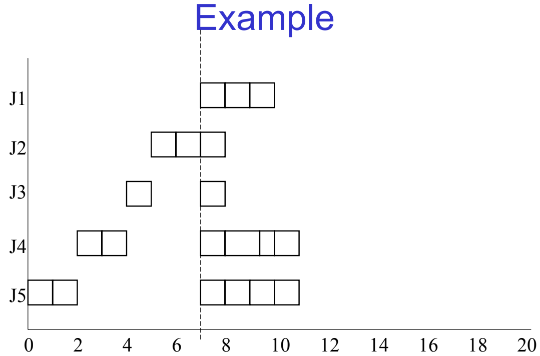


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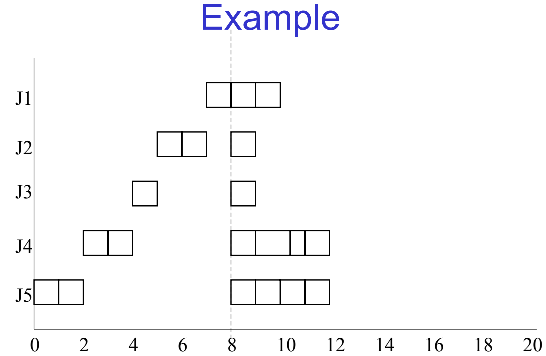


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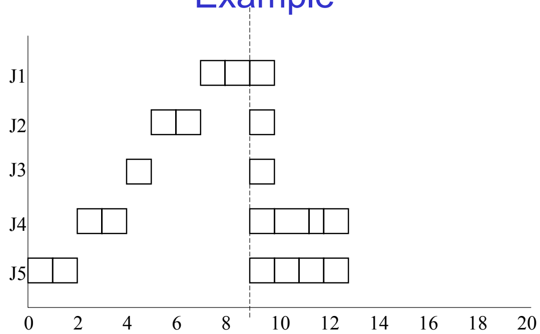




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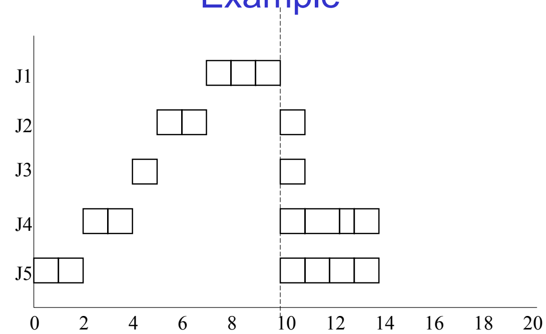




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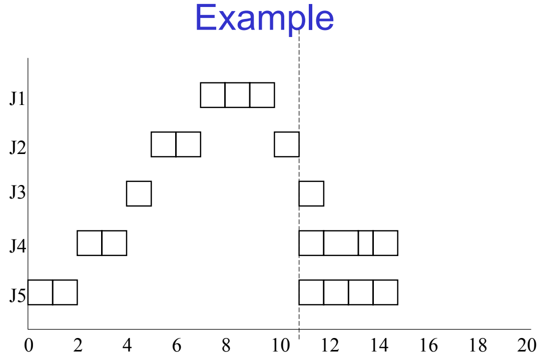




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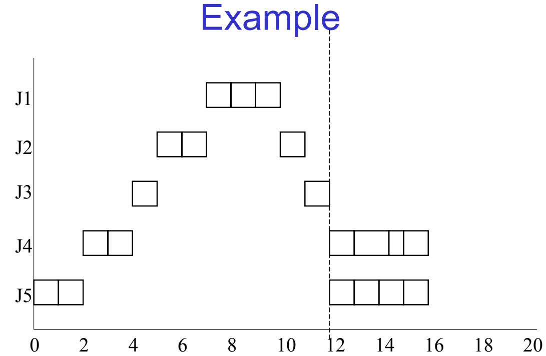




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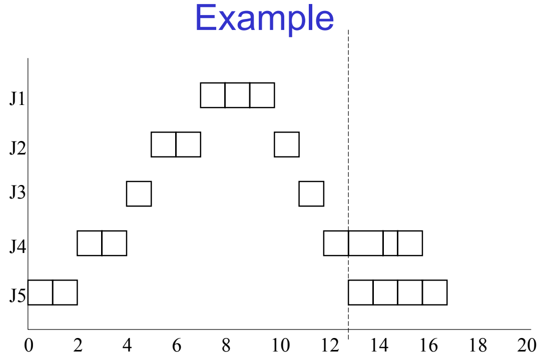




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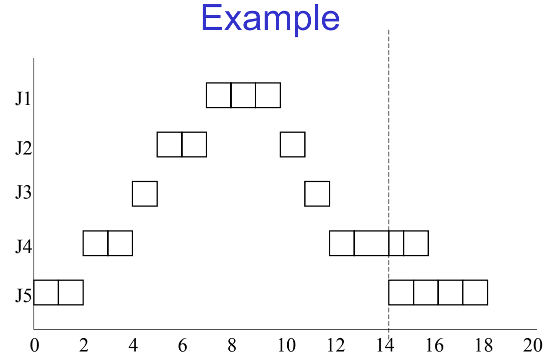

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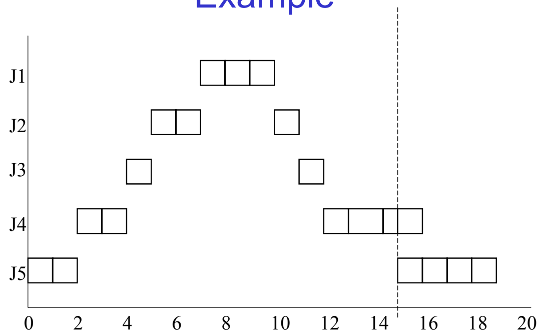




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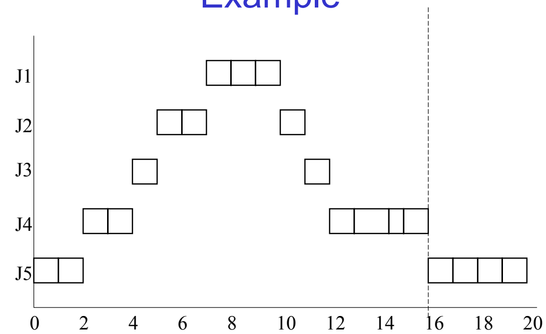




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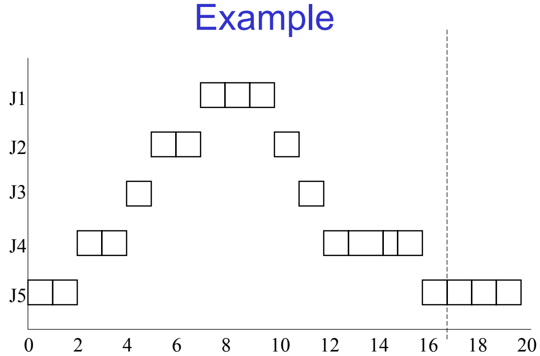




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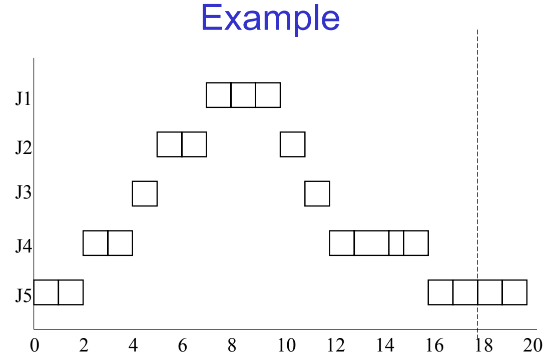




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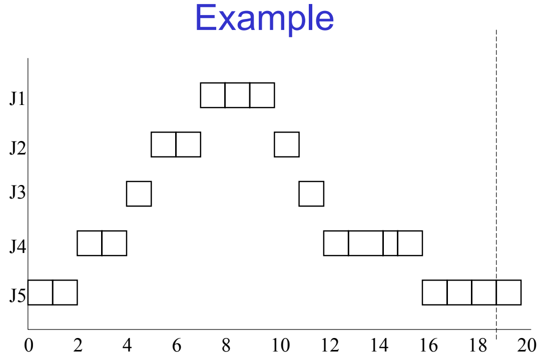




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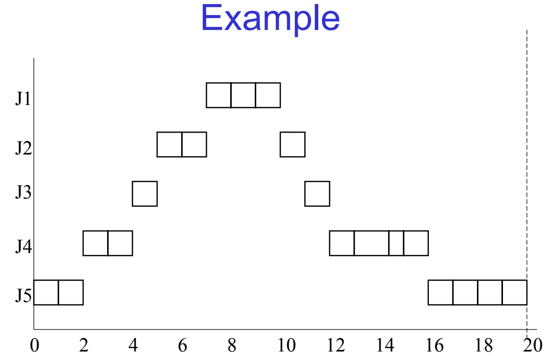
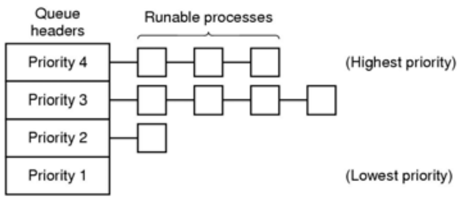


## Priorities

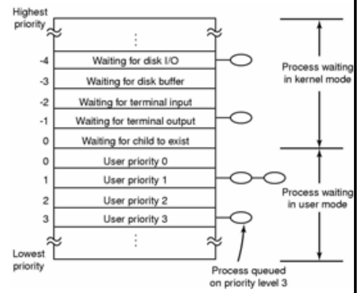



- Usually implemented by multiple priority queues, with round robin on each queue
- Con
  - Low priorities can starve
    - Need to adapt priorities periodically
      - Based on ageing or execution history



## Traditional UNIX Scheduler

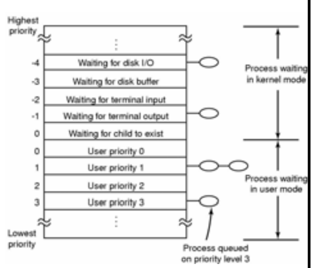
- Two-level scheduler
  - High-level scheduler schedules processes between memory and disk
  - Low-level scheduler is CPU scheduler
    - Based on a multi-level queue structure with round robin at each level






## Traditional UNIX Scheduler

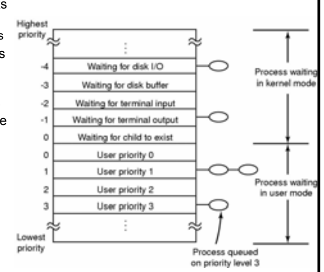
- The highest priority (lower number) is scheduled
- Priorities are re-calculated once per second, and re-inserted in appropriate queue
  - Avoid starvation of low priority threads
  - Penalise CPU-bound threads






## Traditional UNIX Scheduler

- *Priority = CPU_usage +nice +base*
  - *CPU_usage* = number of clock ticks
    - Decays over time to avoid permanently penalising the process
  - *Nice* is a value given to the process by a user to permanently boost or reduce its priority
    - Reduce priority of background jobs
  - *Base* is a set of hardwired, negative values used to boost priority of I/O bound system activities
    - Swapper, disk I/O, Character I/O






## Some Issues with Priorities

- Require adaption over time to avoid starvation (not considering hard real-time which relies on strict priorities).
- Adaption is:
  - usually ad-hoc,
    - hence poorly understood, and unpredictable
  - Gradual, hence unresponsive
- Difficult to guarantee a desired share of the CPU
- No way for applications to trade CPU time



## Lottery Scheduling

- Each process is issued with “lottery tickets” which represent the right to use/consume a resource
  - Example: CPU time
- Access to a resource is via “drawing” a lottery winner.
  - The more tickets a process possesses, the higher chance the process has of winning.

## Lottery Scheduling

- Advantages
  - Simple to implement
  - Highly responsive (can reallocate tickets held)
  - Tickets can be traded to implement individual scheduling policy between co-operating threads



## Example Lottery Scheduling

- Four process running concurrently
  - Process A: 15% CPU
  - Process B: 25% CPU
  - Process C: 5% CPU
  - Process D: 55% CPU
- How many tickets should be issued to each?



## Lottery Scheduling Performance

Observed performance of two processes with varying ratios of tickets

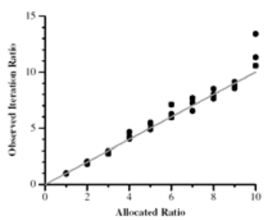



Figure 4: **Relative Rate Accuracy.** For each allocated ratio, the observed ratio is plotted for each of three 60 second runs. The gray line indicates the ideal where the two ratios are identical.



## Fair-Share Scheduling

- So far we have treated processes as individuals
- Assume two users
  - One user has 1 process
  - Second user has 9 processes
- The second user gets 90% of the CPU
- Some schedulers consider the owner of the process in determining which process to schedule
  - E.g., for the above example we could schedule the first user's process 9 times more often than the second user's processes
- Many possibilities exist to determine a *fair* schedule
  - E.g. Appropriate allocation of tickets in lottery scheduler