Scheduling Bits & Pieces

Windows Scheduling

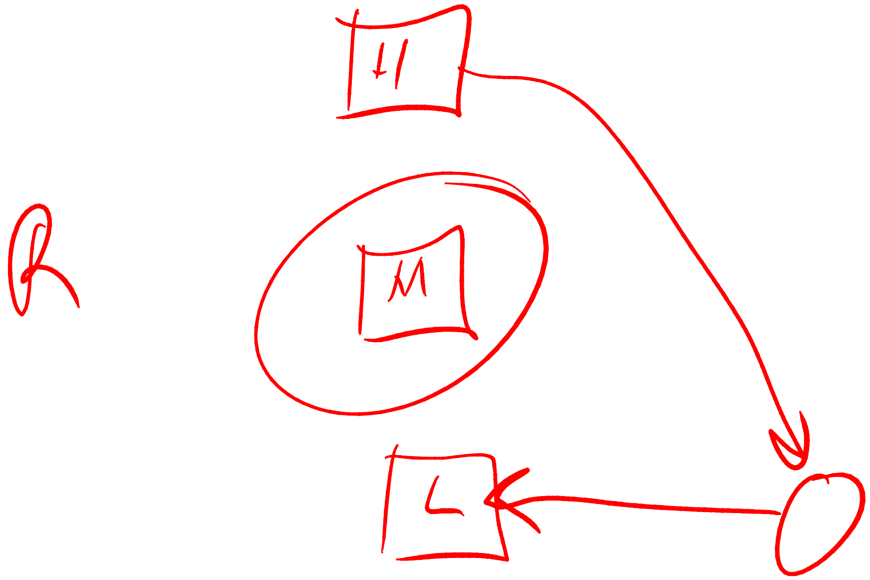
		Win32 process class priorities					
		Real-time	High	Above Normal	Normal	Below Normal	Idle
Win32 thread priorities	Time critical	31	15	15	15	15	15
	Highest	26	15	12	10	8	6
	Above normal	25	14	11	9	7	5
	Normal	24	13	10	8	6	4
	Below normal	23	12	9	7	5	3
	Lowest	22	11	8	6	4	2
	Idle	16	1	1	1	1	1

Figure 11-27. Mapping of Win32 priorities to Windows priorities.

Windows Scheduling

- Priority Boost when unblocking
  - Actual boost dependent on resource
    - Disk (1), serial (2), keyboard (6), soundcard (8)…..
    - Interactive, window event, semaphore (1 or 2)
  - Boost decrements if quantum expires
- Anti-starvation hack
  - If a ready process does not run for long time, it gets 2 quanta at priority 15

Priority Inheritance



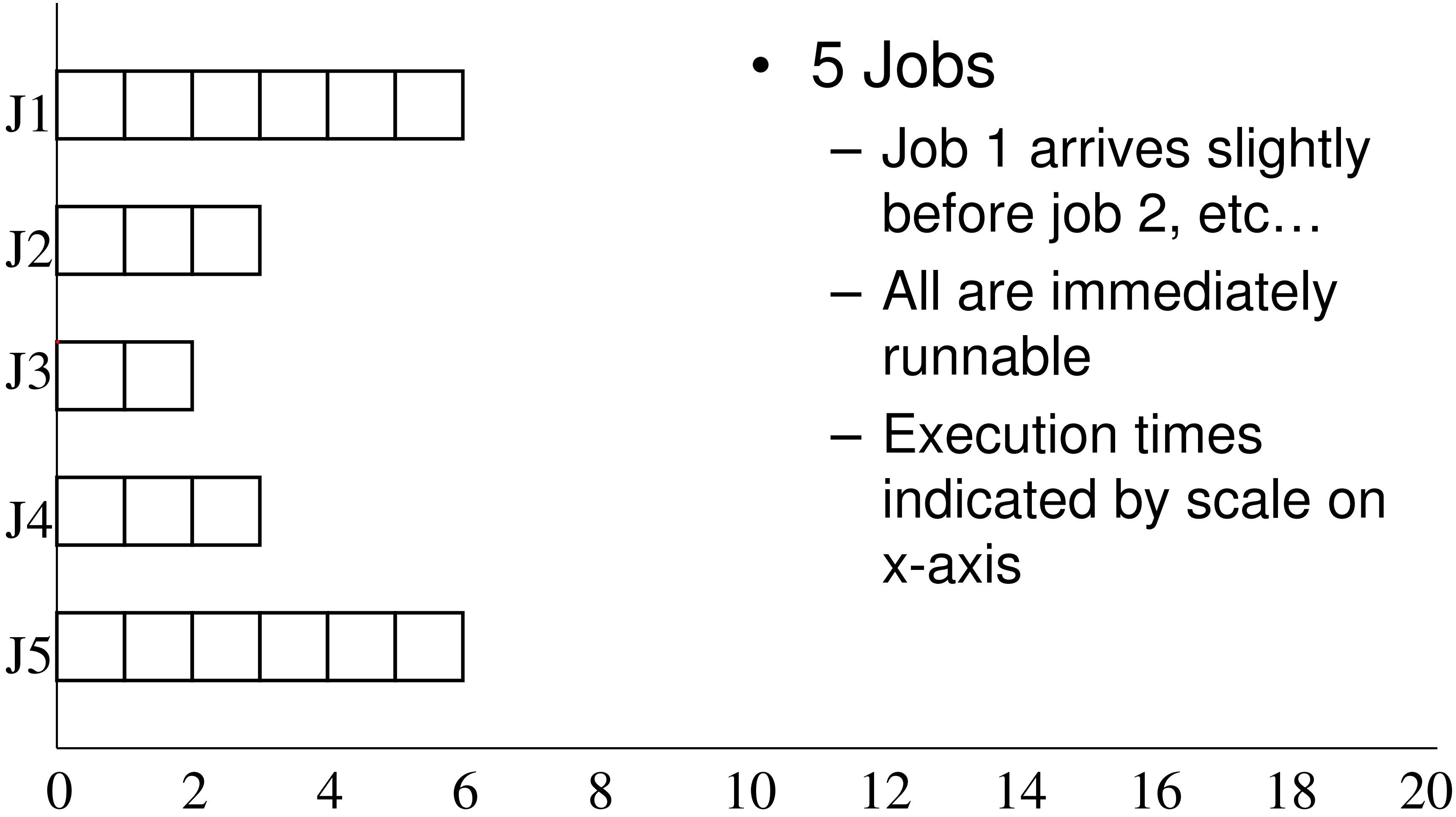
Batch Algorithms

- Maximise *throughput*
  - Throughput is measured in jobs per hour (or similar)
- Minimise *turn-around time*
  - Turn-around time (T_r)
    - difference between time of completion and time of submission
    - Or waiting time (T_w) + execution time (T_e)
- Maximise *CPU utilisation*
  - Keep the CPU busy
  - Not as good a metric as overall throughput

First-Come First-Served (FCFS)

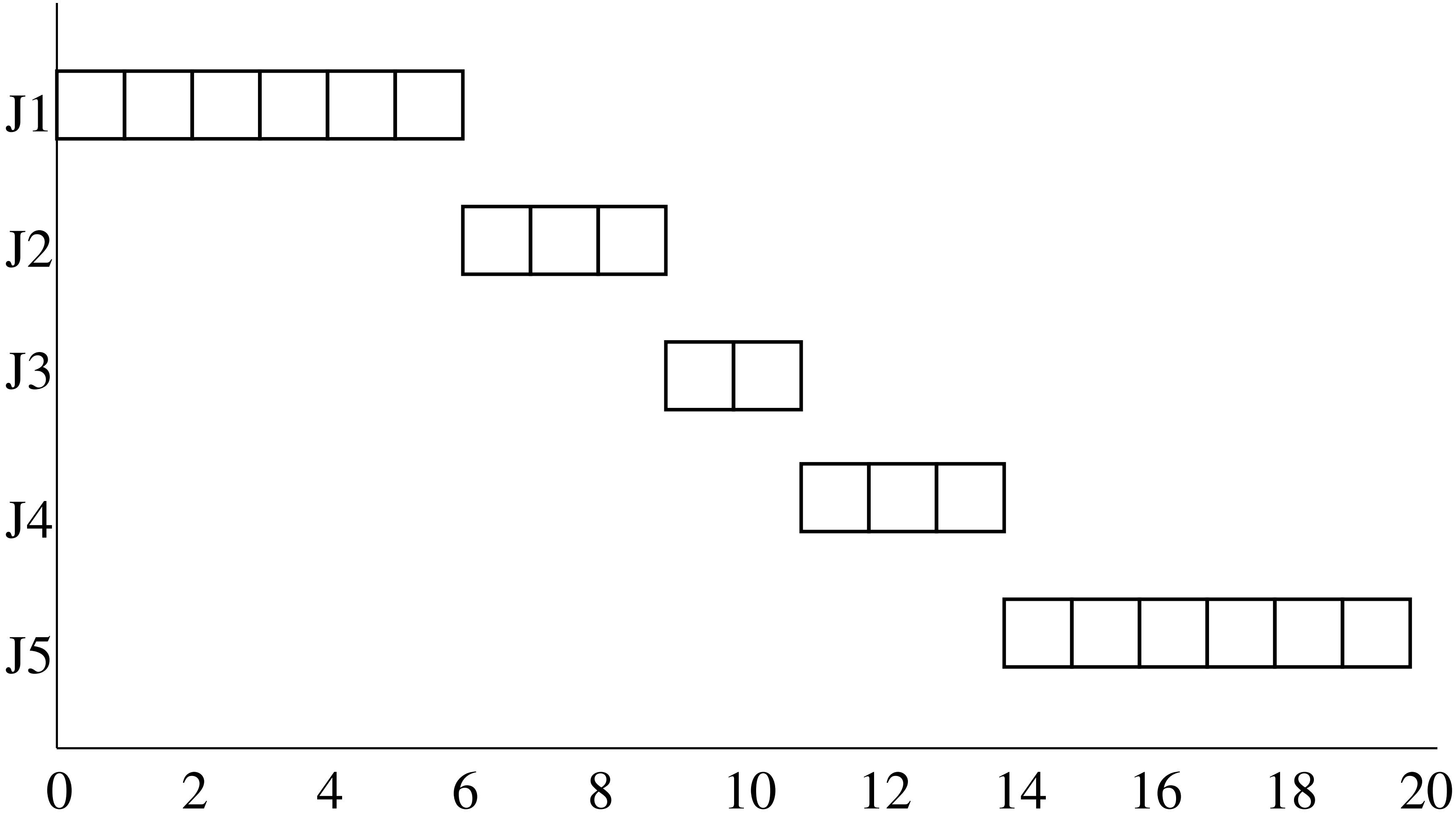
- Algorithm
  - Each job is placed in single queue, the first job in the queue is selected, and allowed to run as long as it wants.
  - If the job blocks, the next job in the queue is selected to run
  - When a blocked jobs becomes ready, it is placed at the end of the queue

Example



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

FCFS Schedule



FCFS

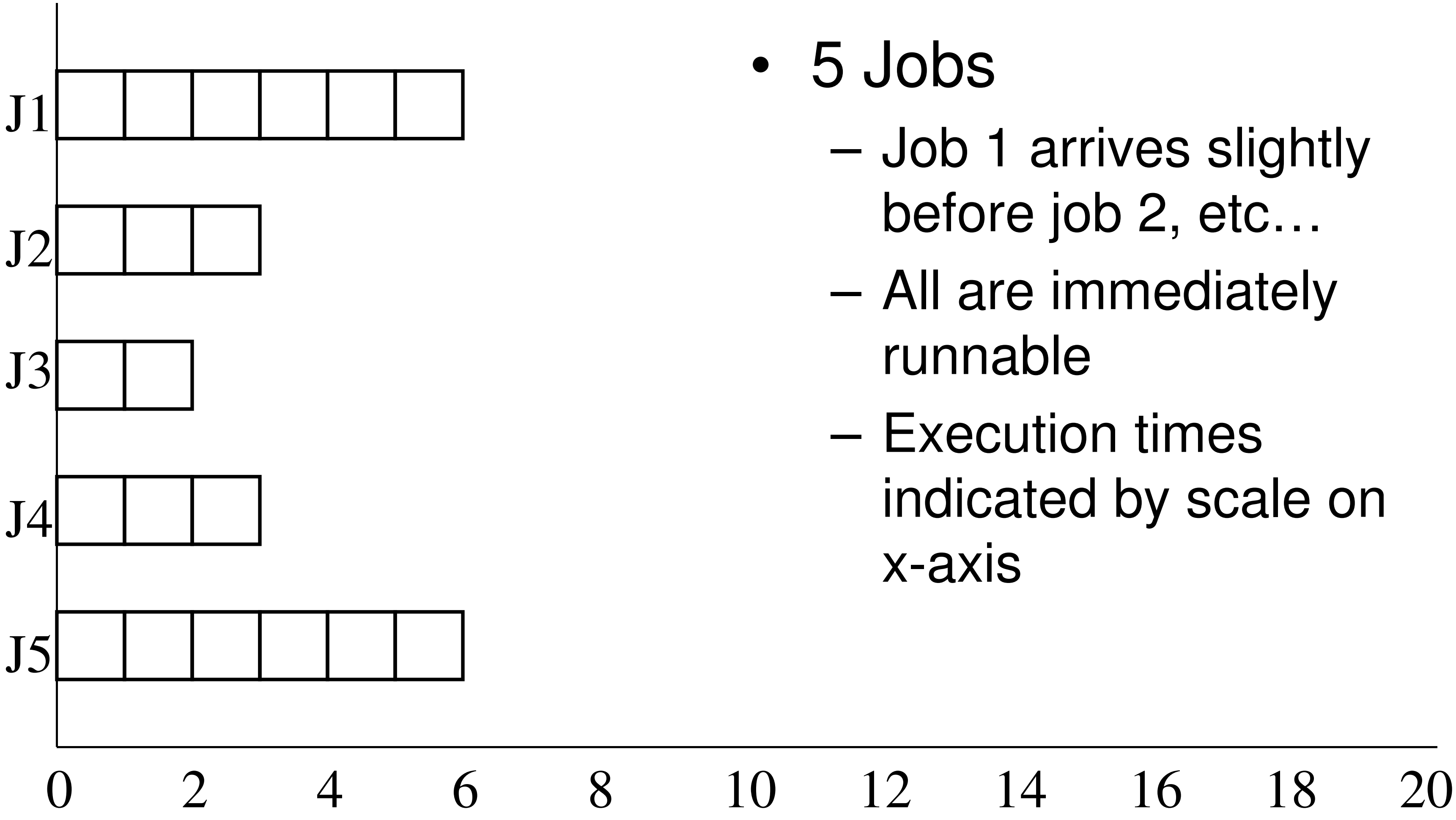
- Pros
  - Simple and easy to implement
- Cons
  - I/O-bound jobs wait for CPU-bound jobs

  ⇒Favours CPU-bound processes
    - Example:
      - Assume 1 CPU-bound process that computes for 1 second and blocks on a disk request. It arrives first.
      - Assume an I/O bound process that simply issues a 1000 blocking disk requests (very little CPU time)
      - FCFS, the I/O bound process can only issue a disk request per second
        - » the I/O bound process take 1000 seconds to finish
      - Another scheme, that preempts the CPU-bound process when I/O-bound process are ready, could allow I/O-bound process to finish in 1000* average disk access time.

Shortest Job First

- If we know (or can estimate) the execution time *a priori*, we choose the shortest job first.
- Another non-preemptive policy

Our Previous Example



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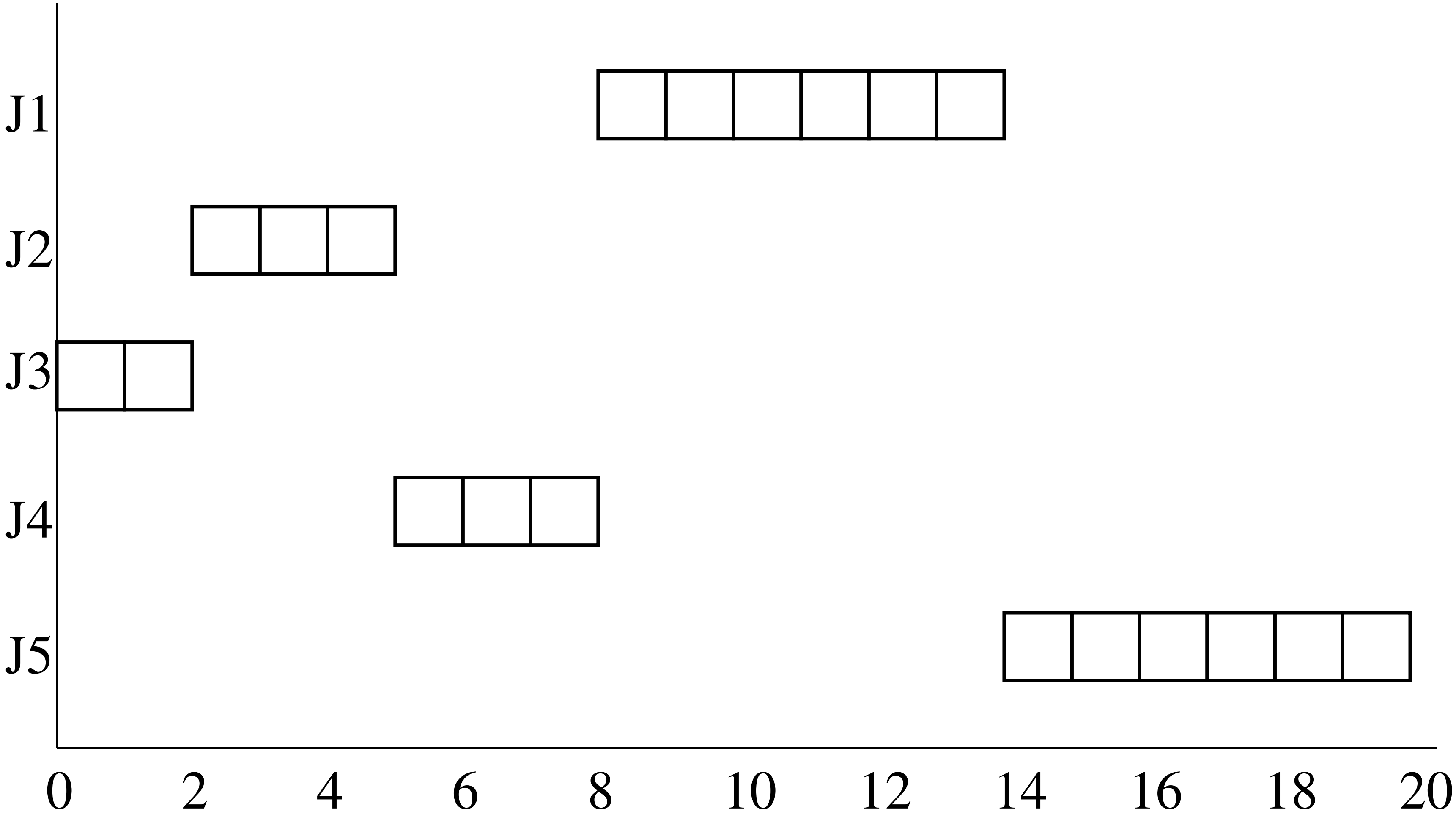
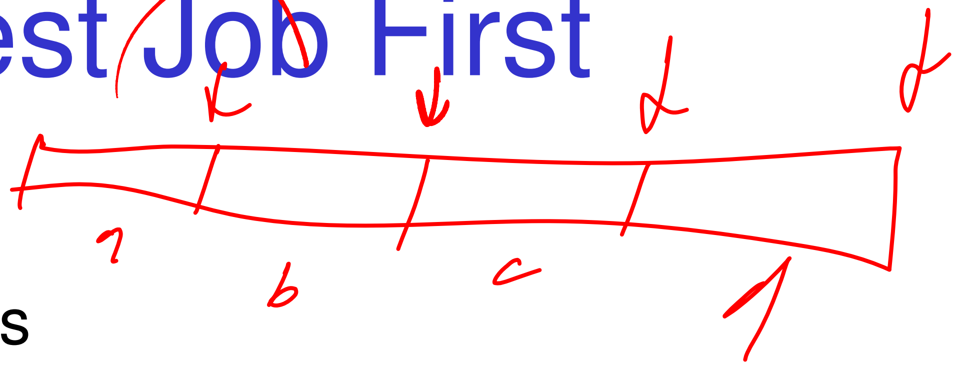
Shortest Job First



Shortest Job First

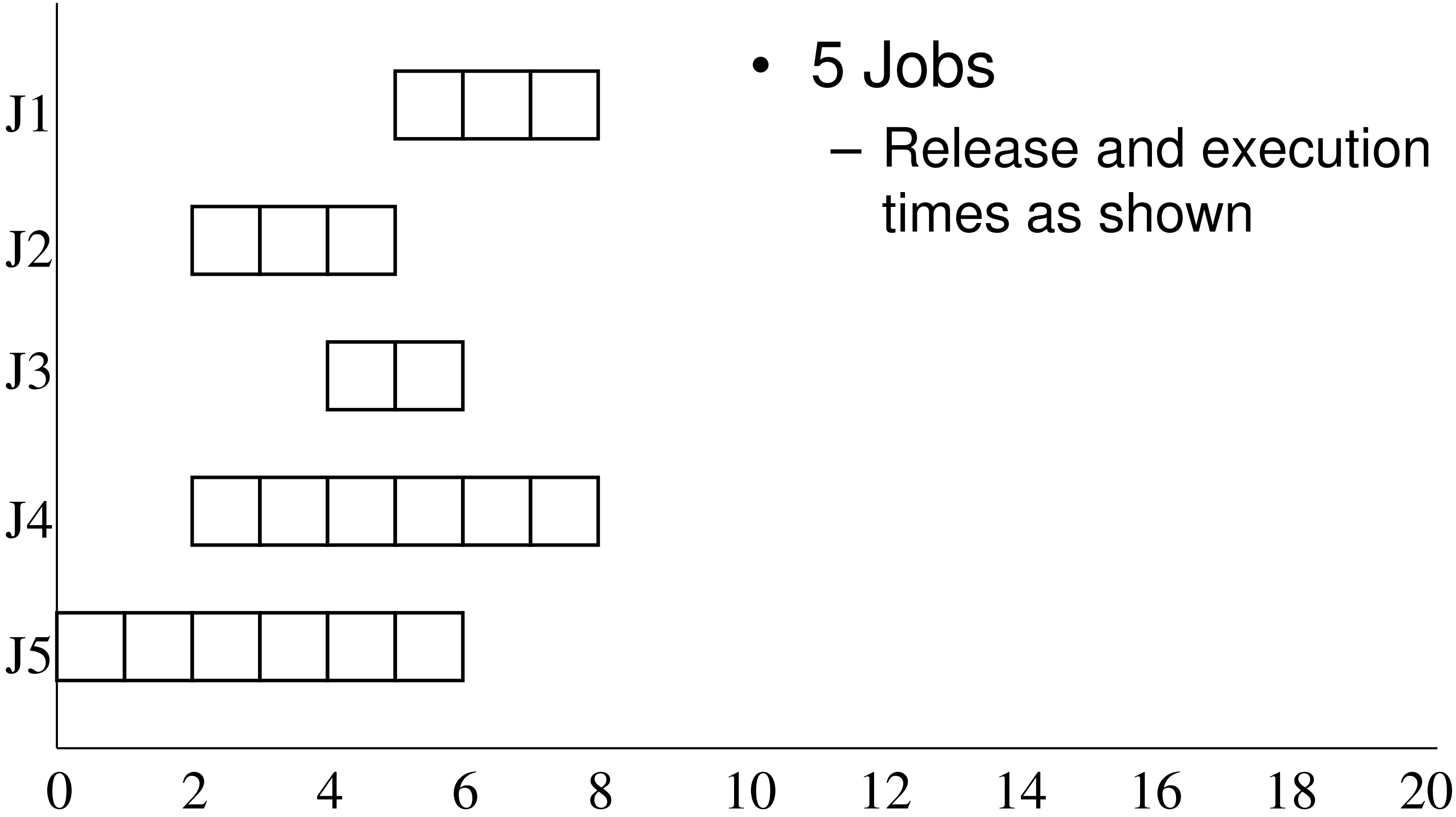


- Con
  - May starve long jobs
  - Needs to predict job length
- Pro
  - Minimises average turnaround time (if, and only if, all jobs are available at the beginning)
  - Example: Assume for processes with execution times of *a, b, c, d.*
    - *a* finishes at time *a*, *b* finishes at *a + b*, *c* at *a + b + c*, and so on
    - Average turn-around time is $(4a + 3b + 2c + d)/4$
    - Since *a* contributes most to average turn-around time, it should be the shortest job.

Shortest Remaining Time First

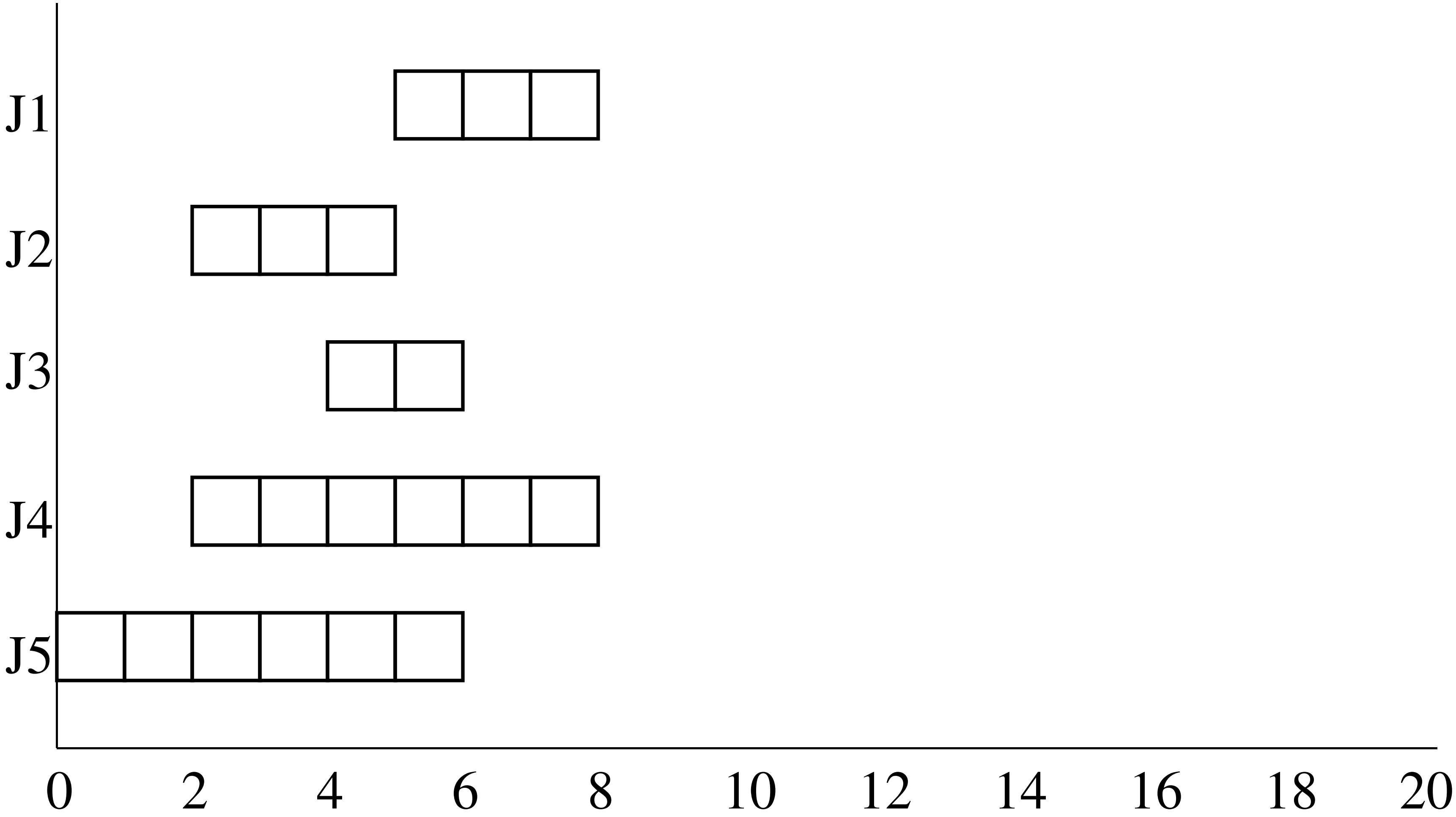
- A preemptive version of shortest job first
- When ever a new jobs arrive, choose the one with the shortest remaining time first
  - New short jobs get good service

Example



- 5 Jobs
  - Release and execution times as shown

Shortest Remaining Time First



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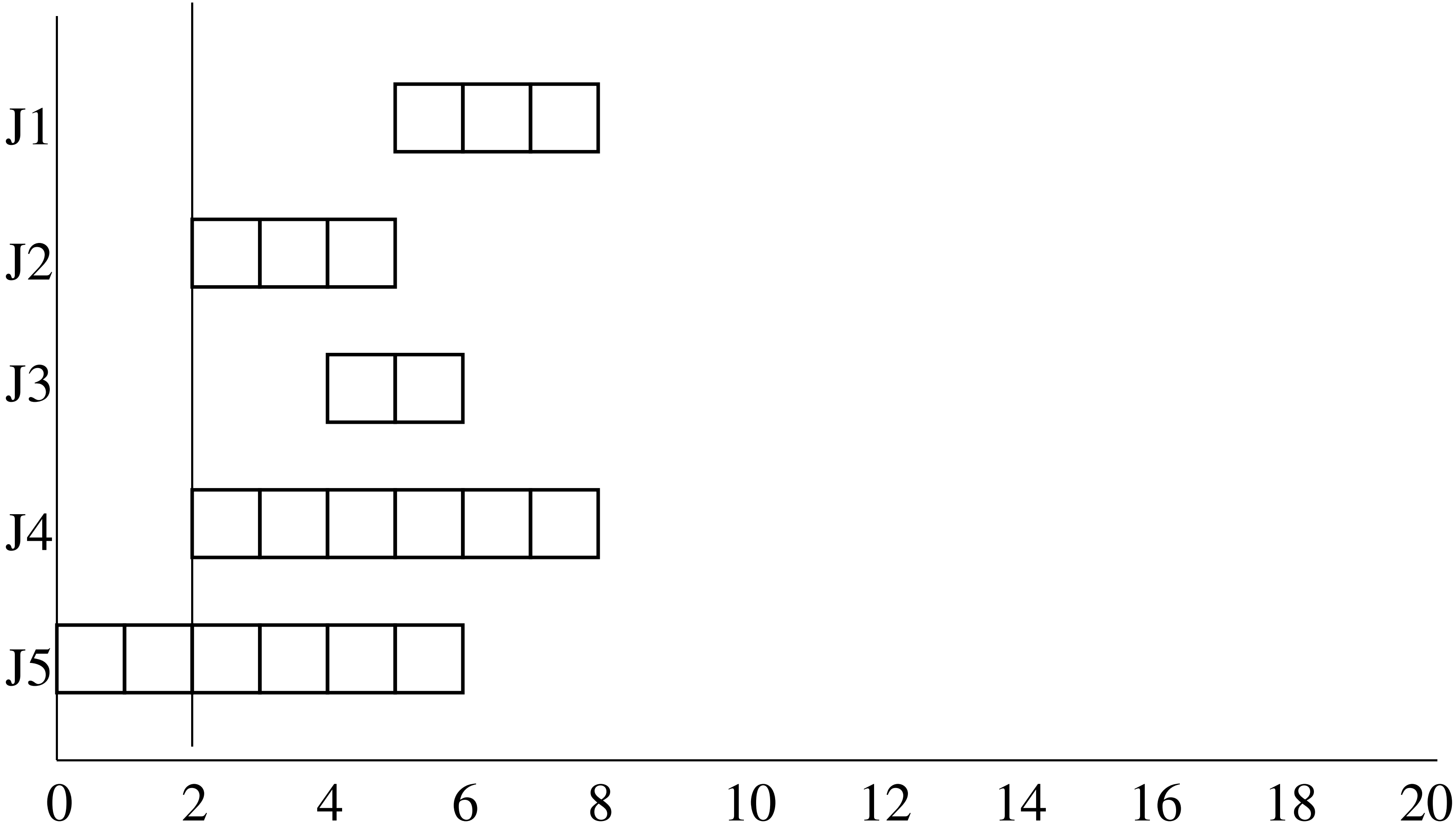

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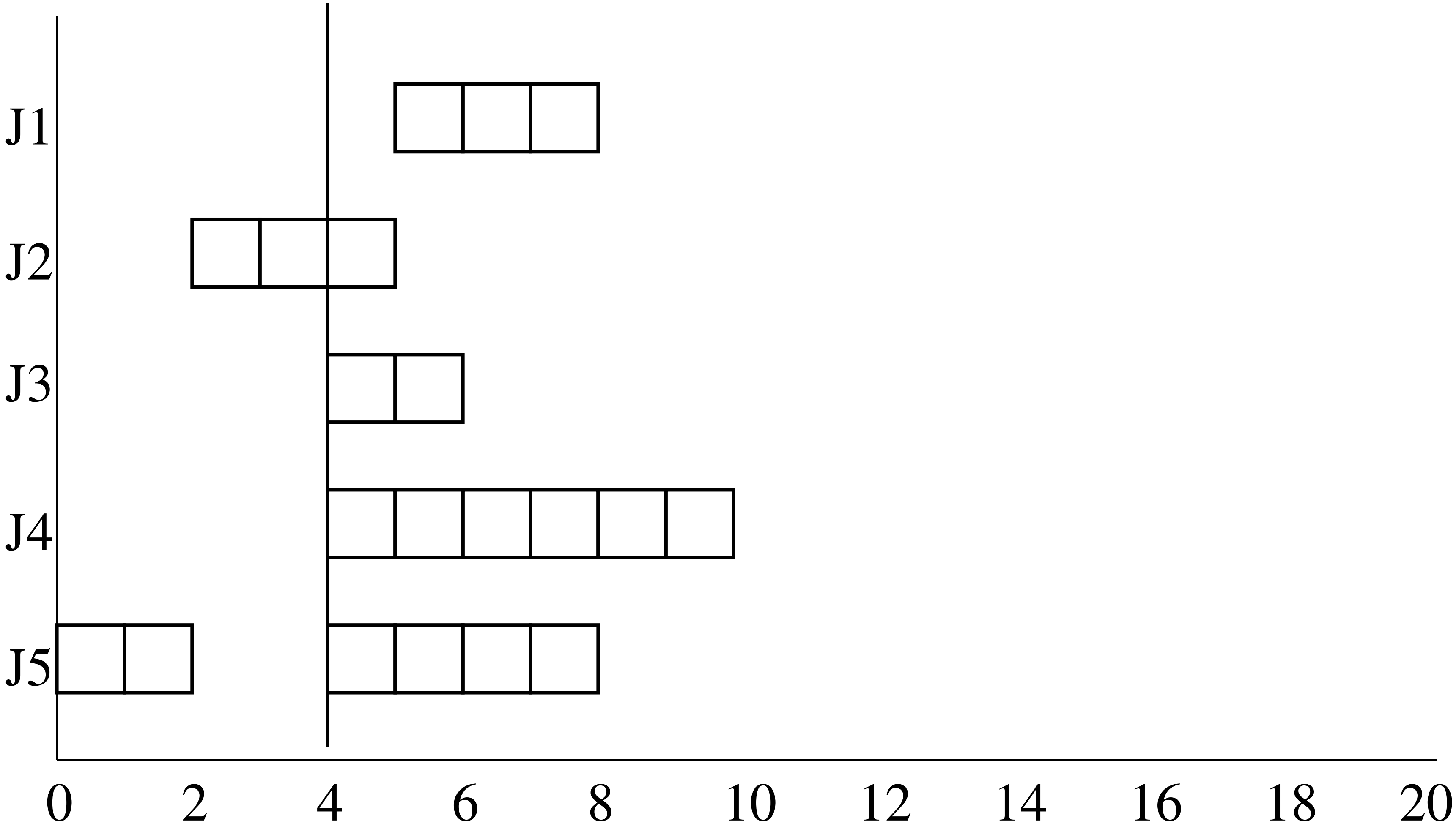

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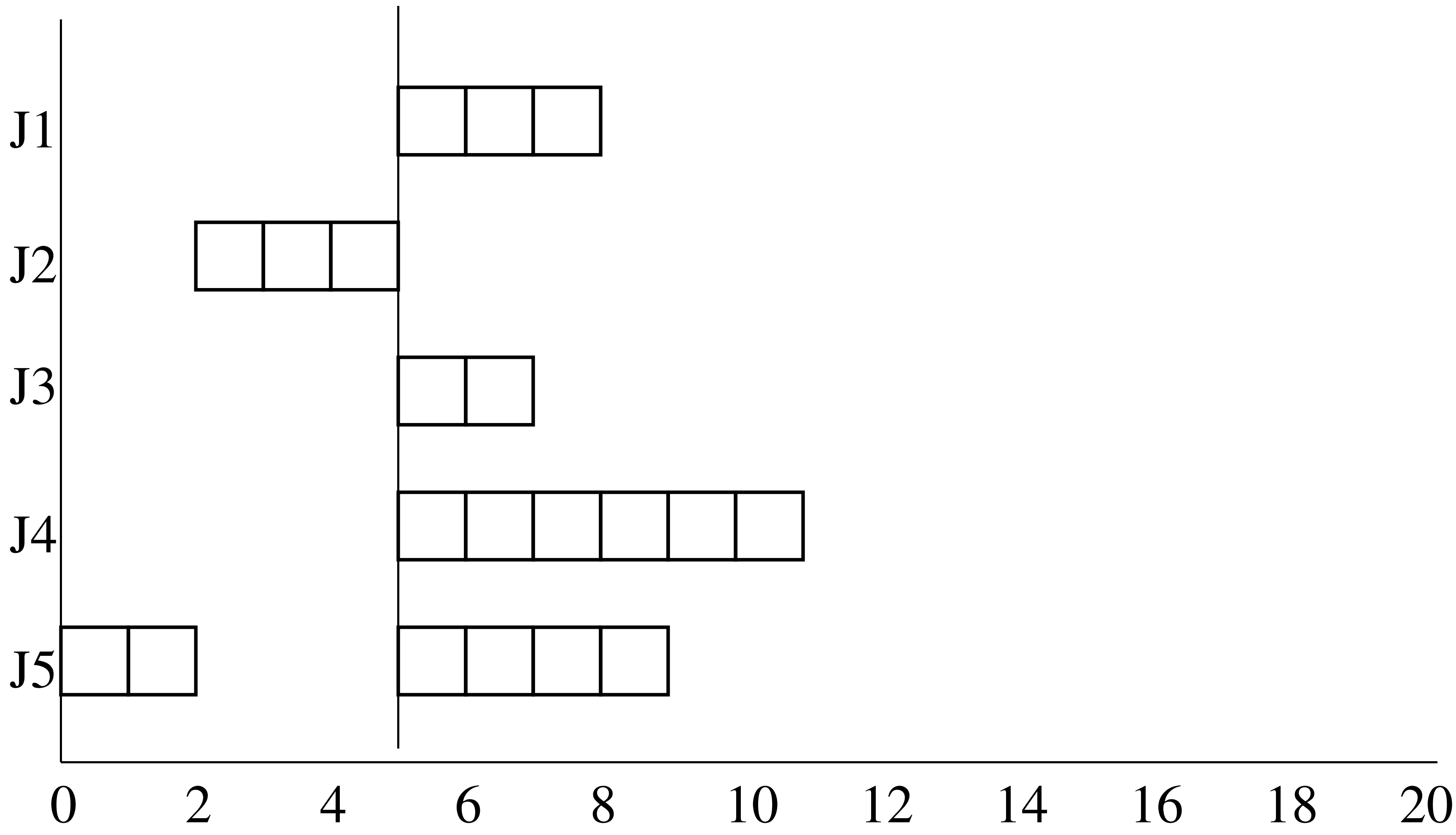

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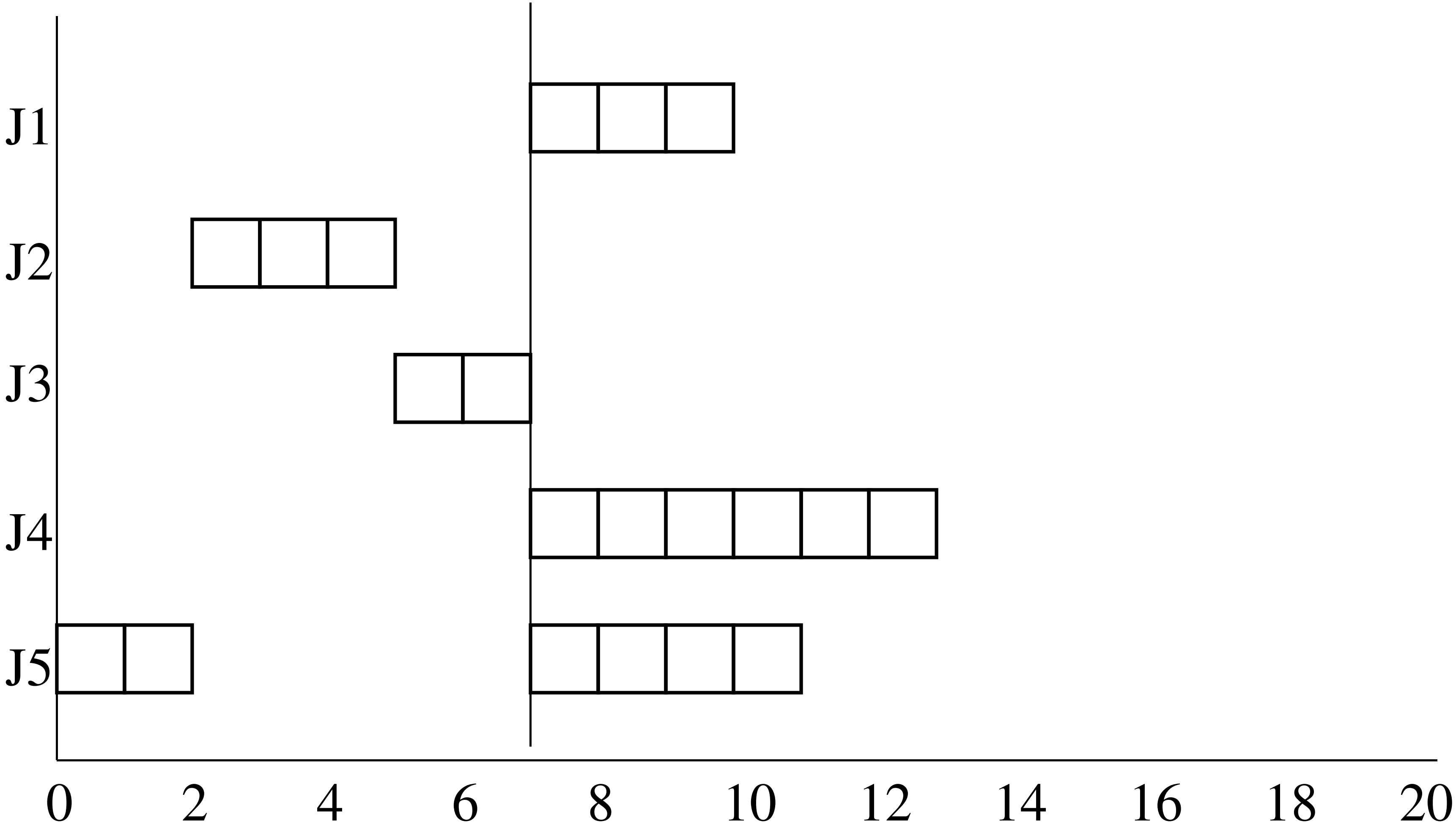

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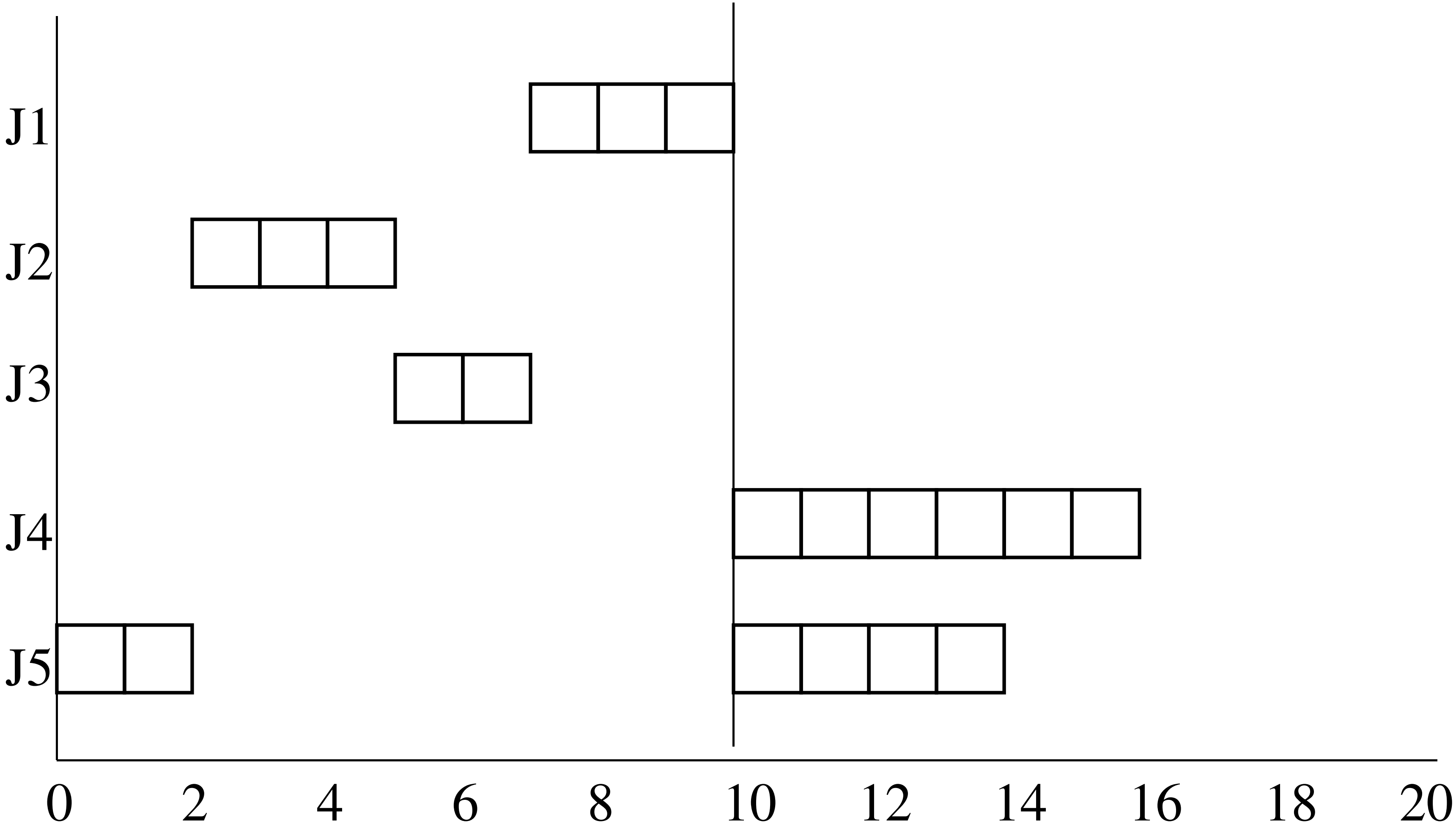

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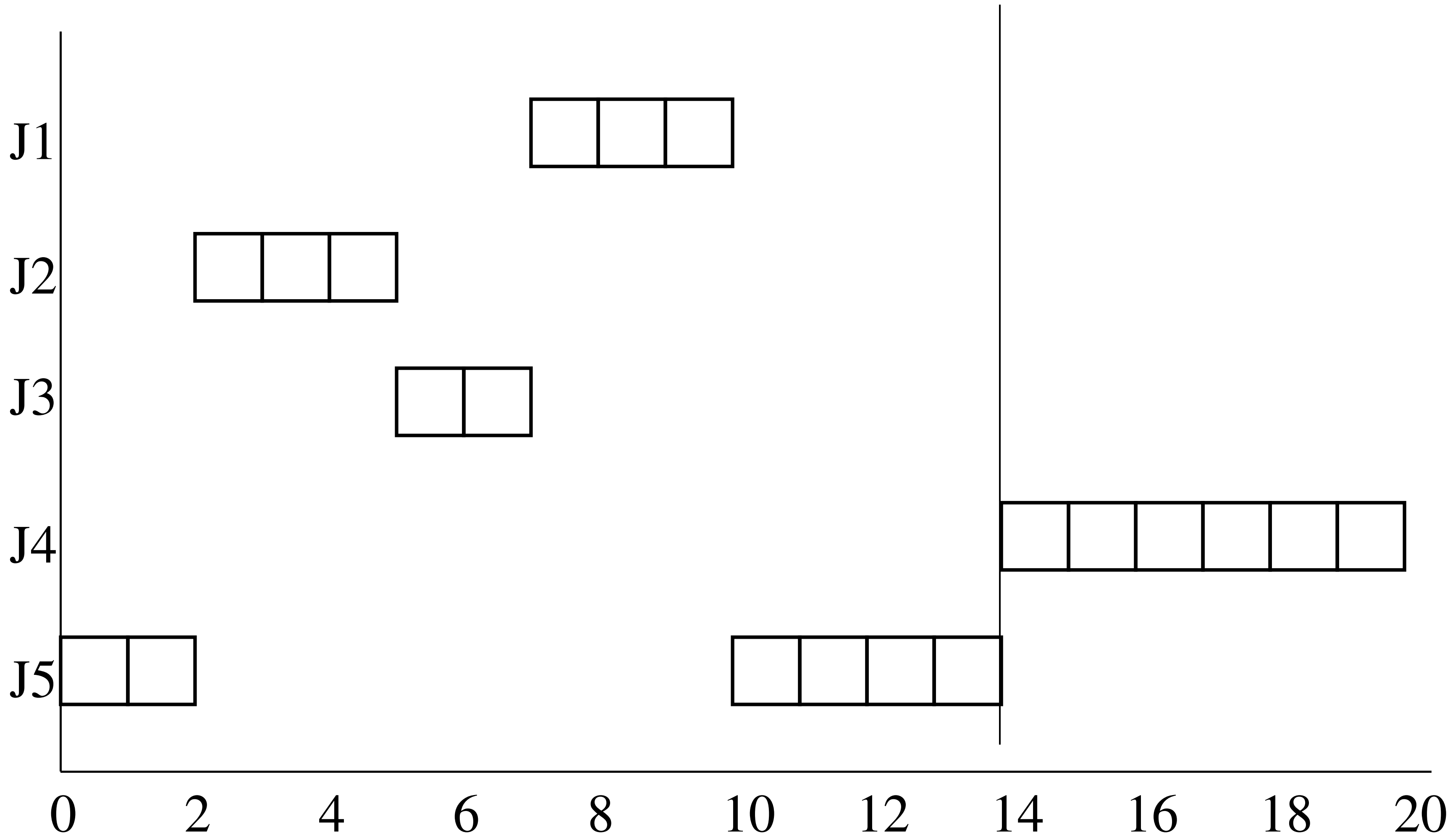
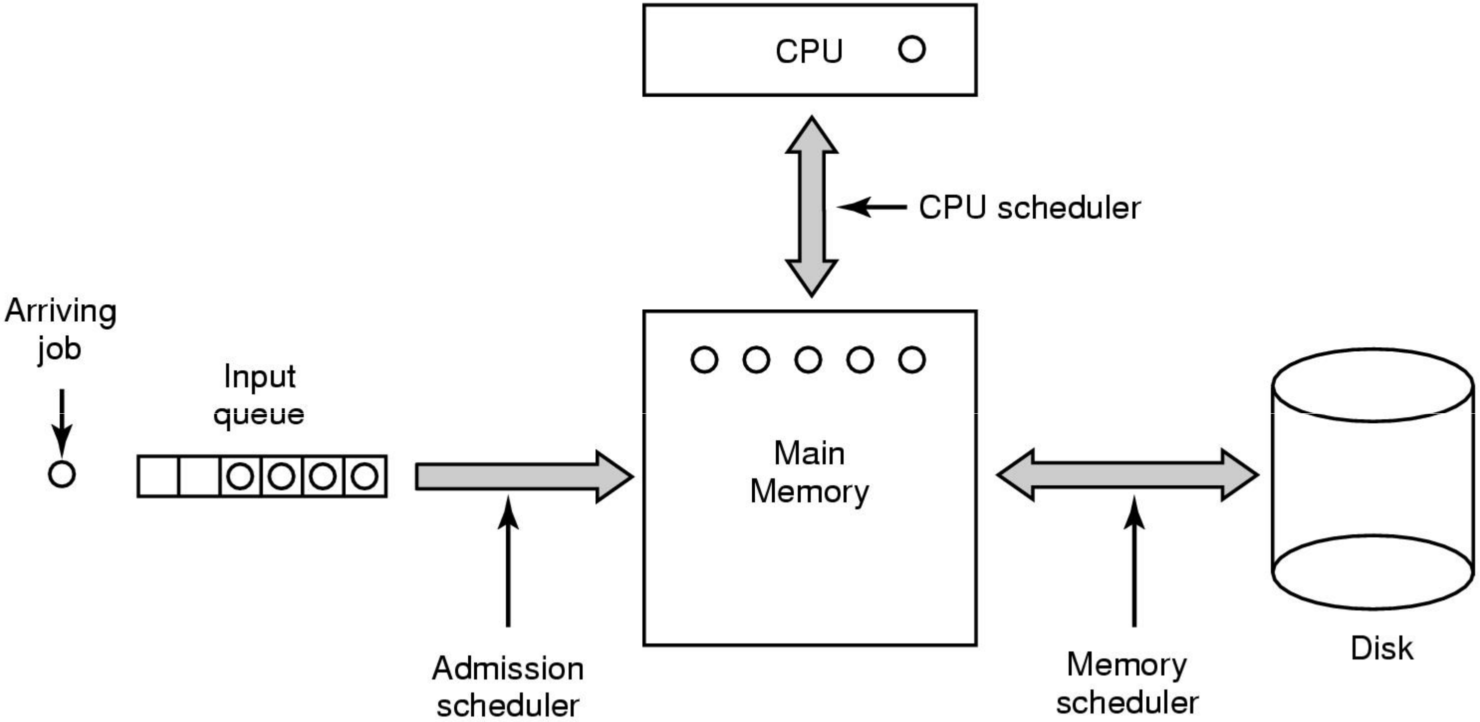


Scheduling in Batch Systems



Three level scheduling

Three Level Scheduling

- Admission Scheduler
  - Also called *long-term* scheduler
  - Determines when jobs are *admitted* into the system for processing
  - Controls degree of multiprogramming
  - More processes $\Rightarrow$ less CPU available per process

Three Level Scheduling

- CPU scheduler
  - Also called *short-term* scheduler
  - Invoked when ever a process blocks or is released, clock interrupts (if preemptive scheduling), I/O interrupts.
  - Usually, this scheduler is what we are referring to if we talk about a *scheduler*.

Three Level Scheduling

- Memory Scheduler
  - Also called *medium-term* scheduler
  - Adjusts the degree of multiprogramming via suspending processes and swapping them out

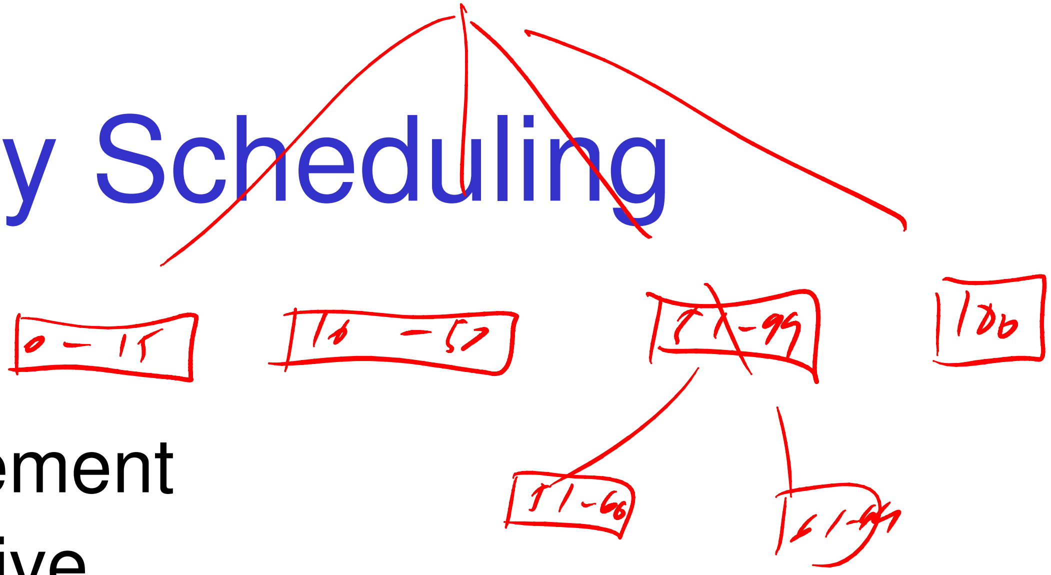
Some Issues with Priorities

- Require adaption over time to avoid starvation (not considering hard real-time which relies on strict priorities).
- Adaption is:
  - usually ad-hoc,
    - hence behaviour not thoroughly 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 for immediate effect
  - Tickets can be traded to implement individual scheduling policy between co-operating threads
  - Starvation free
    - A process holding a ticket will eventually be scheduled.

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

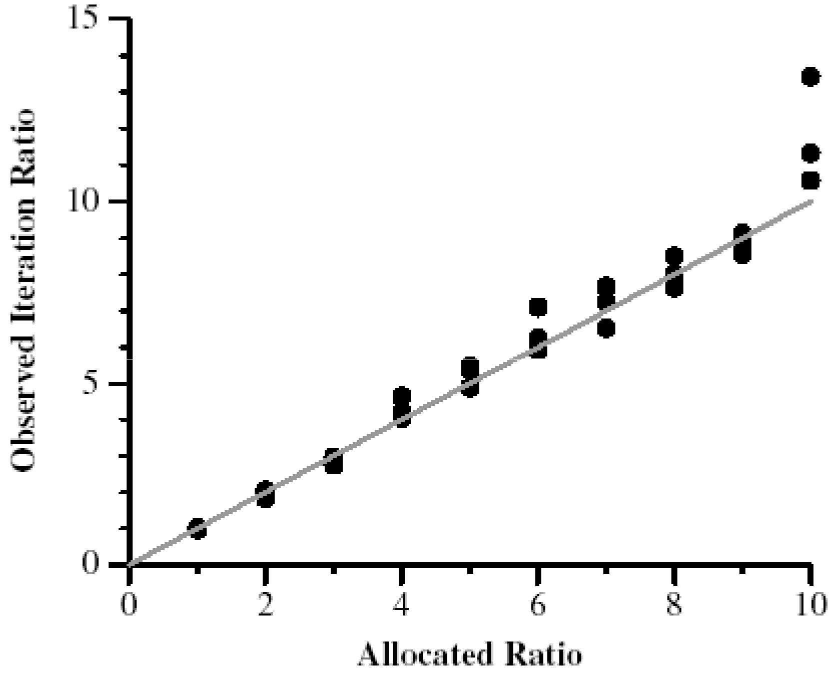


Figure 4: **Relative Rate Accuracy.** For each allocated ratio, the observed ratio is plotted for each of three 60 second runs. The gray line indicates the ideal where the two ratios are identical.

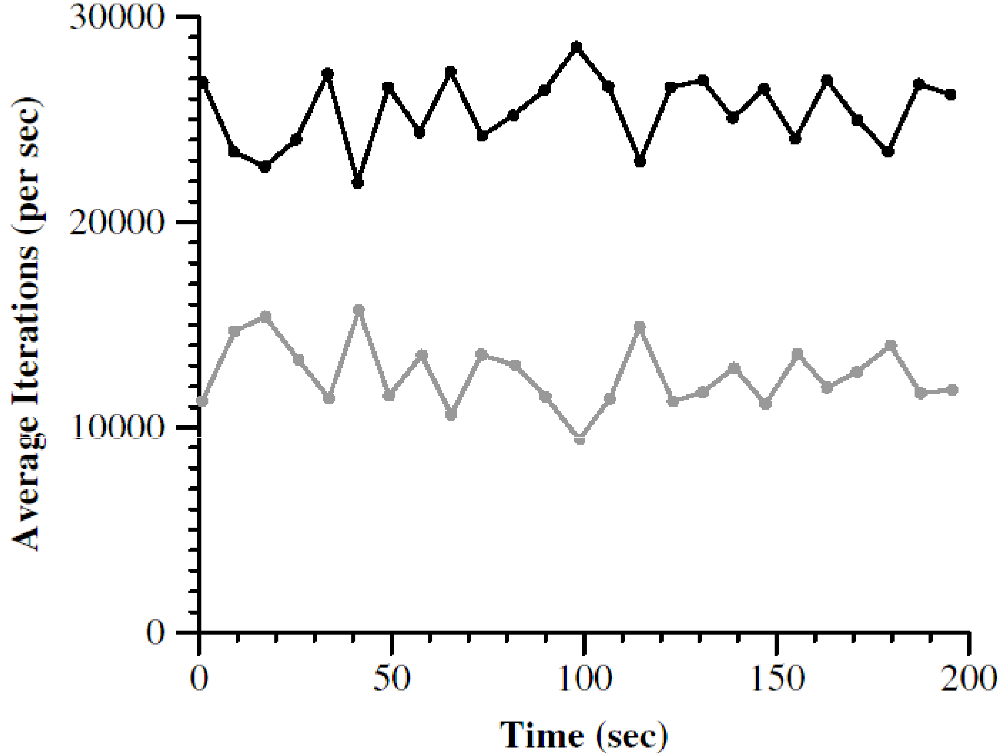


Figure 5: **Fairness Over Time.** Two tasks executing the Dhrystone benchmark with a 2 : 1 ticket allocation. Averaged over the entire run, the two tasks executed 25378 and 12619 iterations/sec., for an actual ratio of 2.01 : 1.

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