Operating Systems and Concurrency

Lecture 4: Processes Scheduling

G52OSC/COMP2007

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- Processes have **"control structures"** associated with them (process control blocks and process tables)
- Processes can have different **states** and **transition** between them (e.g. new, ready, running, blocked, terminated)

- The operating system maintains multiple **process queues** (e.g. **ready queue**, event queues, etc.)
- The operating system **manages processes** on the user's behalf (e.g. `fork()`, `exit()`, ...)

- Introduction to **process scheduling**
- Types of **process schedulers**
- **Evaluation criteria** for scheduling algorithms
- Typical **process scheduling algorithms**

- The OS is responsible for **managing** and **scheduling processes**
  - Decide when to **admit** processes to the system (new $\rightarrow$ ready)
  - Decide which process to **run** next (ready $\rightarrow$ run)
  - Decide when and which processes to **interrupt** (running $\rightarrow$ ready)

- It relies on the **scheduler** (dispatcher) to decide which process to run next, which uses a **scheduling algorithm** to do so
- The type of algorithm used by the scheduler is influenced by the **type of operating system** (e.g., real time vs. batch)

Process Schedulers

Classification by Time Horizon

- **Long term**: applies to **new processes** and controls the degree of multiprogramming by deciding which processes to admit to the system when
  - A good **mix** of **CPU** and **I/O bound processes** is favourable to keep all resources as busy as possible
  - **Usually absent** in popular modern OS

- **Medium term**: controls swapping and the degree of multi-programming
- **Short term**: decide which process to run next
  - Manages the **ready queue**
  - Invoked very **frequently**, hence must be **fast**
  - Usually called in response to **clock interrupts**, **I/O interrupts**, or **blocking system calls**

Process Schedulers
Classification by Time Horizon

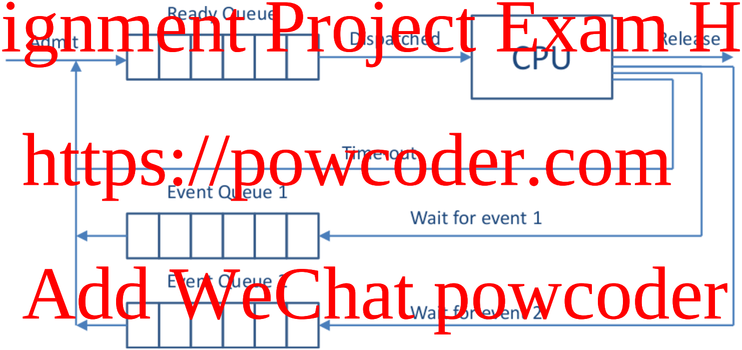


Figure: Queues in OS

Exam 2013-2014: Where do the process schedulers fit in with the state transitions?

- **Non-preemptive**: processes are only interrupted voluntarily (e.g., I/O operation or “nice” system call – `yield()`)
  - Windows 3.1 and DOS were non-preemptive

- **Preemptive**: processes can be **interrupted forcefully** or **voluntarily**
  - This requires context switches which generate **overhead**, too many of them should be avoided (recall last lecture)
  - Prevents processes from **monopolising the CPU**
  - **Most popular** modern operating systems are preemptive

Performance Assessment
Criteria

- **User oriented criteria**:
  - **Response time**: minimise the time between creating the job and its first execution
  - **Turnaround time**: minimise the time between creating the job and finishing it
  - **Predictability**: minimise the variance in processing times
- **System oriented criteria**:
  - **Throughput**: maximise the number of jobs processed per hour
  - **Fairness**:
    - Are processing power/waiting time equally distributed?
    - Are some processes kept waiting excessively long (**starvation**)
- Evaluation criteria can be **conflicting**, i.e., **improving the response time** may require **more context switches**, and hence **worsen the throughput** and **increase the turn around time**

- Algorithms considered:
  1. First Come First Served (**FCFS**)/ First In First Out (**FIFO**)
  2. **Shortest job first**
  3. **Round Robin**
  4. **Priority queues**

- Performance measures used:
  - **Average response time**: the average of the time taken for all the processes to start
  - **Average turnaround time**: the average time taken for all the processes to finish

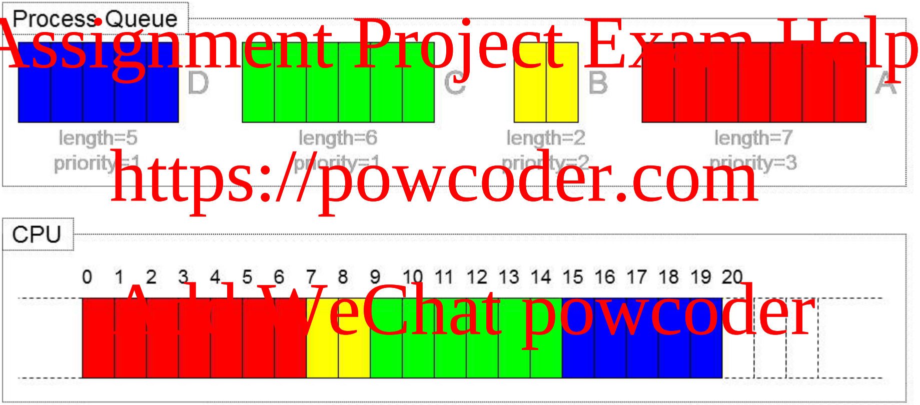
- Images/animations by Jon Garibaldi!

- Concept: a **non-preemtive algorithm** that operates as a **strict queueing mechanism** and schedules the processes in the same order that they were added to the queue

- Advantages: **positional fairness** and easy to implement
- Disadvantages:
  - **Favours long processes** over short ones (think of the supermarket checkout!)
  - Could **compromise resource utilisation**, i.e., CPU vs. I/O devices

Scheduling Algorithms

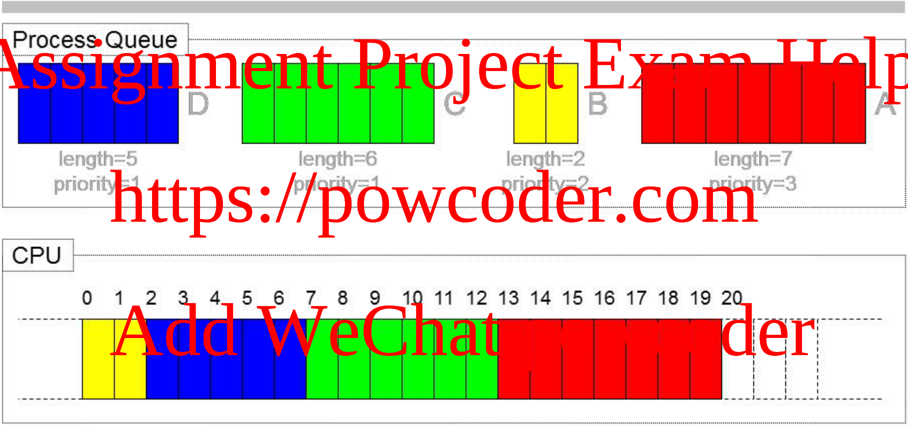
First Come First Served



- Average response time = $0 + 7 + 9 + 15 = \frac{31}{4} = 7.75$
- Average turn around time = $7 + 9 + 15 + 20 = \frac{51}{4} = 12.75$

- Concept: A **non-preemtive algorithm** that starts processes in order of **ascending processing time** using a provided/known estimate of the processing

- Advantages: always result in the **optimal turn around time**
- Disadvantages:
  - **Starvation** might occur
  - **Fairness** and **predictability** are compromised
  - **Processing times have to be known** beforehand



- Average response time = $0 + 2 + 7 + 13 = \frac{22}{4} = 5.5$
- Average turn around time = $2 + 7 + 13 + 20 = \frac{42}{4} = 10.5$

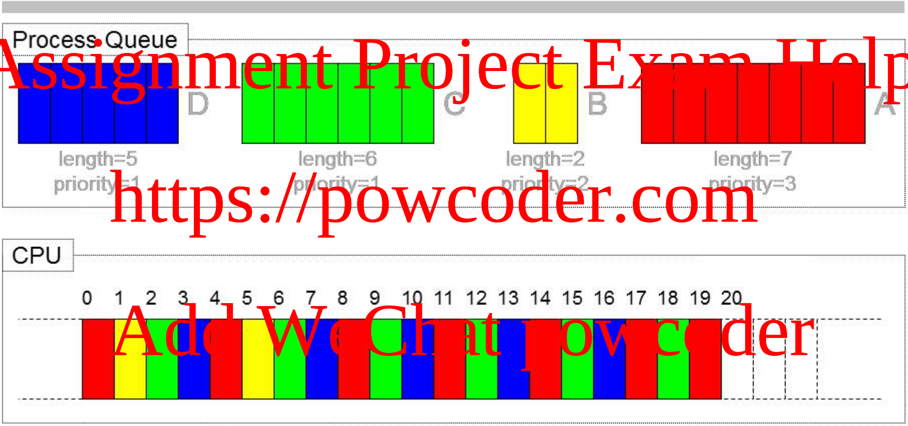
- Concept: a **preemptive version of FCFS** that forces **context switches at periodic intervals** or **time slices**
  - Processes **run in the order that they were added** to the queue
  - Processes are forcefully **interrupted by the timer**
- Advantages:
  - Improved **response time**
  - Effective for general purpose **interactive/time sharing systems**
- Disadvantages:
  - Increased **context switching** and thus overhead
  - **Favours CPU bound processes** (which usually run long) over I/O processes (which do not run long)
    - Can be prevented by working with multiple queues?
  - Can **reduce to FCFS**

Exam 2013-2014: Round Robin is said to favour CPU bound processes over I/O bound processes. Explain why may this be the case (if this is the case at all)?

- The **length** of the **time slice** must be carefully considered!
- For instance, assuming a **multi-programming system** with **preemptive scheduling** and a **context switch time** of 1ms:
  - E.g., a **good (low) response time** is achieved with a **small time slice** (e.g. 1ms) $\Rightarrow$ low throughput
  - E.g., a **high throughput** is achieved with a **large time slice** (e.g. 1000ms) $\Rightarrow$ high response time
- If a time slice is only **used partially**, the next process **starts immediately**

Scheduling Algorithms

Round Robin

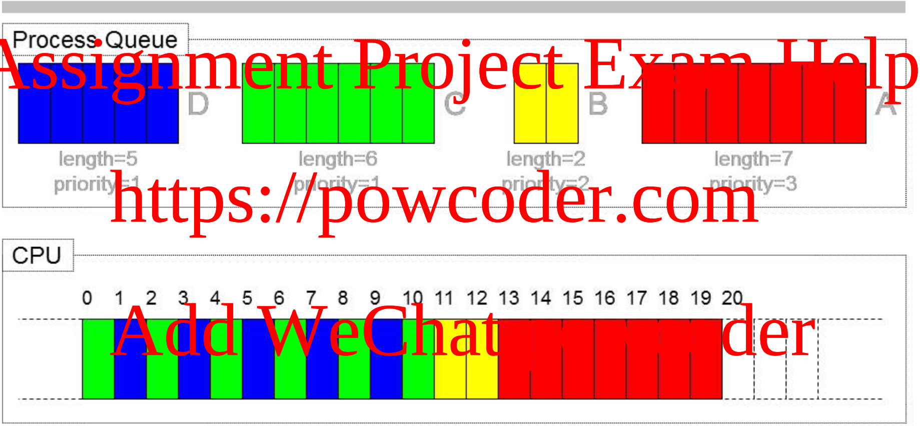


- Average response time = $0 + 1 + 2 + 3 = \frac{6}{4} = 1.5$
- Average turn around time = $6 + 17 + 19 + 20 = \frac{62}{4} = 15.5$

- Concept: A **preemptive algorithm** that schedules processes by priority (high $\rightarrow$ low)
  - A **round robin** is used **within the same priority levels**
  - The process priority is saved in the **process control block**
- Advantages: can **prioritise I/O bound jobs**
- Disadvantages: low priority processes may suffer from **starvation** (when priorities are static)

Exam 2013-2014: Out of the following four scheduling algorithms, which one can lead to starvation: FCFS, shortest job first, round robin, highest priority first? Explain your answer.

Scheduling Algorithms
Priority Queues



- Average response time = $0 + 1 + 11 + 13 = \frac{25}{4} = 6.25$
- Average turn around time = $10 + 11 + 13 + 20 = \frac{54}{4} = 13.5$

- Give the **order in which the processes are scheduled** when using **priority queues**, together with the **times at which they will start, end, and are interrupted** (all processes are available at the time of scheduling)
- You can assume a time slice of 15 milliseconds
- Calculate the **average response and turn around time**

	FCFS Position	**CPU burst time**	**Priority**
Process A	1	67	1 (high)
Process B	2	37	1 (high)
Process C	3	14	2 (low)
Process D	4	16	2 (low)

- The OS is responsible for **process scheduling**

- Different types of schedulers exist (e.g. pre-emptive, short term, etc.)
- Different **evaluation criteria** exist for process scheduling
- Different **algorithms** should be considered