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Scheduling

COMP3231 Operating Systems

2004 S2

- Uniprocessor Scheduling
- Realtime Systems
- Multiprocessor Scheduling

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SCHEDULING

➜ Determination of which process is allowed to run

➜ What are the objectives?

- Maximise:
  - CPU utilisation
  - throughput (number of tasks completed per time unit)
- Minimise:
  - Turnaround time (submission to completion)
  - Waiting time (sum of time spent in Ready-queue)
  - Response time (time from start of request to production of first response)
- Fairness:
  - every task should be handled eventually (no starvation)
  - tasks with similar characteristics should be treated equally

different type of systems have different priorities!

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TYPES OF SCHEDULING

➜ Long-term scheduling (admission scheduler):

The decision to admit a process, i.e., add its threads(s) to the pool of threads that can execute (batch systems)

➜ Medium-term scheduling (memory scheduler):

The decision to suspend/resume processes, i.e., to control the pool of threads whose process images are fully or partially resident (mainly in the absence of VM)

➜ Short-term scheduling (CPU scheduler) :

The decision which ready thread will be dispatched next

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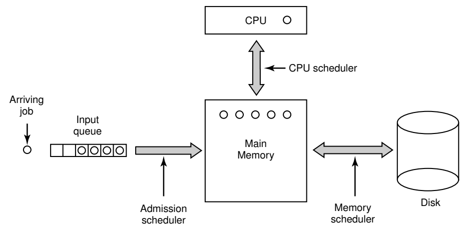

➜ Admission Scheduler:

- Controls the degree of multiprogramming: More threads ⇒ less CPU time

➜ Memory Scheduler

- Part of the swapping function, based on the need to manage the degree of multiprogramming

➜ CPU scheduler

- Executes most frequently, invoked when an event occurs

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CPU Scheduler

Scheduling decisions are necessary when a thread

① switches from running to waiting state
  - e.g., wait for I/O, other thread to terminate,...

② switches from running to ready
  - e.g., interrupt

③ switches from waiting to ready
  - e.g., completion of I/O request

④ terminates

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Preemptive vs Nonpreemptive Scheduling

Non-preemptive:

- ➜ Once a thread is in the running state, it will continue
- ➜ thread can monopolise the CPU
- ➜ co-operative multitasking: thread may yield CPU

Preemptive:

- ➜ Currently running thread may be interrupted and moved to the ready state by the operating system
- ➜ requires hardware support (timer)
- ➜ incurs costs (additional context switches, data consistency)
- ➜ what about kernel routines?

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Scheduling Criteria

➜ User-oriented

- Response Time
  - Elapsed time between the submission of a request until there is output.
- Waiting time
  - Total time thread has been waiting in ready queue
- Turnaround time
  - Amount of time to execute a particular thread (from creation to exit)

➜ System-oriented

- Effective and efficient utilization of the processor
- Throughput
  - number of completed threads per second

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Scheduling criteria

➜ Performance-related

- Quantitative
- Measurable such as response time and throughput

➜ Not performance related

- Qualitative
- Predictability

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Scheduling Criteria

Different priorities for different types of systems:

- ➜ Batch
  - non-preemptive policies, or preemptive with long quantums are acceptable
  - Throughput, turnaround time, CPU utilisation
- ➜ Interactive
  - preemption essential
  - response time, proportionality
- ➜ Realtime (hard & soft)
  - preemption often not necessary for hard realtime systems
  - meeting deadlines, predictability

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CPU-I/O Burst Cycle

Processes typically consist of alternating

- ➜ CPU bursts and
- ➜ I/O bursts

Duration and frequency of bursts vary greatly from process to process

- ➜ CPU bound: few very long CPU bursts
- ➜ I/O bound: many, short CPU bursts

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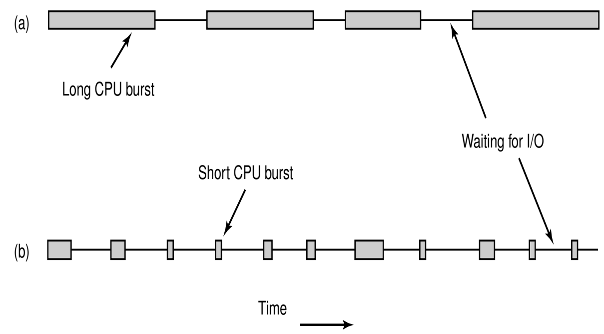

(a) CPU bound
(b) I/O bound

Burst length information can be used to optimise scheduling

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Prediction of CPU Burst Length

- ➜ We don't know length of next CPU burst, can we predict it?

Assumption: Next CPU burst will be similar length to previous one.

T_i: actual length of ith burst
S_i: estimated length of ith burst

—

- ➜ Simple averaging: Length of next burst is equal to average of previous bursts:

$$S_{n+1} = \frac{1}{n} * \sum_{i=1}^{n} T_i$$

- ➜ or, to avoid recomputing the sum in every step

$$S_{n+1} = \frac{1}{n} * T_n + \frac{n-1}{n} S_n$$

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- Exponential averaging: Recent observations are more important than old ones, we want to give them more weight:

$$S_{n+1} = \alpha * T_n + (1 - \alpha) S_n$$

for $0 < \alpha < 1$

- The larger α, the less weight is given to older observations

$$S_{n+1} = \alpha T_n + (1 - \alpha)\alpha T_{n-1} + (1 - \alpha)^2 \alpha T_{n-2} + \ldots$$

Fast to compute for $\alpha = 0.5$

$$S_{n+1} = 0.5 * T_n + 0.5^2 * T_{n-1} + 0.5^3 T_{n-2} + \ldots = 0.5 * (T_n + S_n)$$

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Metrics

- Execution time: T_s
- Waiting time: time a thread waits for execution:

$$T_w$$

- Turnaround time: time a thread spends in the system (waiting plus execution time):

$$T_w + T_s = T_r$$

- Normalised turnaround time:

$$T_r / T_s$$

(long waiting times can be tolerated for long run times)

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Scheduling example

Thread	Arrival Time	CPU Burst Length
A	0	3
B	2	6
C	4	4
D	6	5
E	8	2

What is the optimal order (preemptive and non-preemptive) with respect to waiting time, turnaround time, normalised turnaround time?

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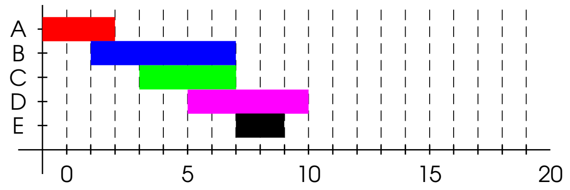

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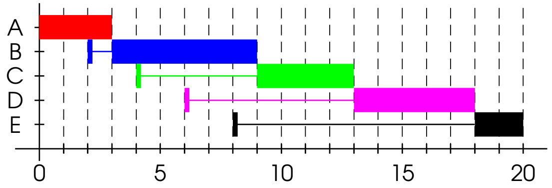
First-come-first-served (FCFS) scheduling:



- ➜ Nonpreemptive: each thread, once scheduled, runs to completion
- ➜ Scheduler selects the oldest thread in the *ready* queue

Performance:

- ➜ Average waiting time: not optimal, since even short threads may have to wait a very long time
- ➜ I/O threads have to wait until CPU-bound thread completes, favors CPU-bound threads (convoy effect)
- ➜ Not suitable for time sharing systems

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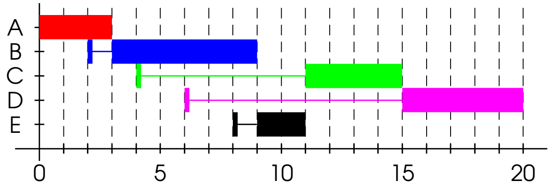
Shortest-thread-next scheduling:



- ➜ Non-preemptive policy
- ➜ Select thread with shortest expected burst length
  - Short thread jumps ahead of longer running threads
- ➜ May need to abort thread exceeding its estimate
- ➜ Possibility of starvation of longer running threads

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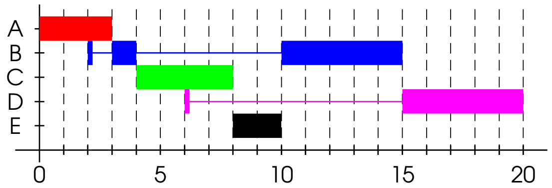
Shortest-remaining-time scheduling:



- ➜ Preemptive version of shortest-thread-next policy
- ➜ Must estimate processing time

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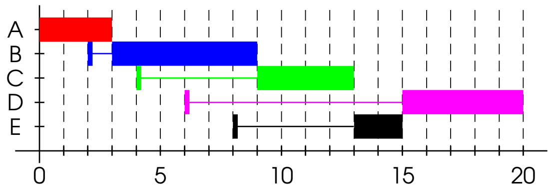
Highest-response-ratio-next (HRRN) scheduling:



- ➜ Attempt to minimise average normalised turnaround time
- ➜ Choose next thread with the highest ratio

$$\frac{w+s}{s}$$

w: waiting time

s: (expected/past) service time

- use past behaviour as a predictor for the future

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Performance of HRRN:

- ➜ Shorted threads are favoured
- ➜ Aging without service increases ratio, longer threads can get past shorter jobs