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Systems, Networks & Concurrency 2020

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Scheduling

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Scheduling

References for this chapter

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Ada Reference Manual - Language and Standard Libraries;
ISO/IEC 8652:201x (E)

[Stallings2001]
Stallings, William
Operating Systems
Prentice Hall, 2001

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Scheduling

Motivation and definition of terms

Purpose of scheduling

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Scheduling

Motivation and definition of terms

Purpose of scheduling

Two scenarios for scheduling algorithms:

1. Ordering resource assignments (CPU time, network access, …).
   ☞ live, on-line application of scheduling algorithms.
2. Predicting system behaviours under anticipated loads.
   ☞ simulated, off-line application of scheduling algorithms.

Predictions are used:

- *at compile time*: to confirm the feasibility of the system, or to predict resource needs, …
- *at run time*: to permit admittance of new requests or for load-balancing, …

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Scheduling

Motivation and definition of terms

Criteria

	Performance criteria:	**Predictability** criteria:
Process / user perspective:		
	minimize the …	minimize *deviation* from given …
Waiting time	minima / maxima / average / variance	value / minima / maxima
Response time	minima / maxima / average / variance	value / minima / maxima / deadlines
Turnaround time	minima / maxima / average / variance	value / minima / maxima / deadlines
System perspective:		
	maximize the …	
Throughput	minima / maxima / average	
Utilization	CPU busy time	

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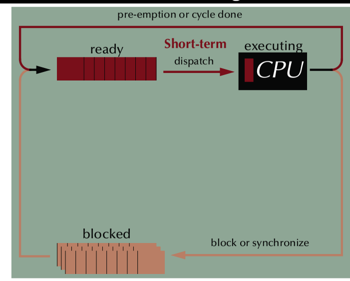
Scheduling

Definition of terms

Time scales of scheduling



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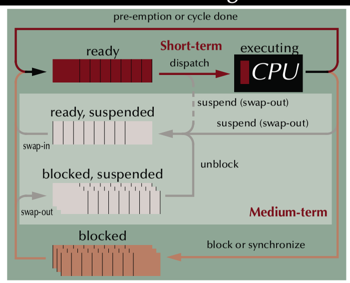
Scheduling

Definition of terms

Time scales of scheduling



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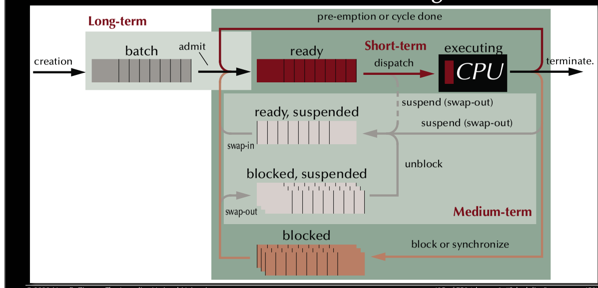
Scheduling

Definition of terms

Time scales of scheduling



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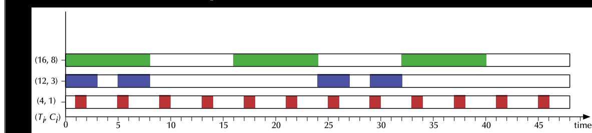
Scheduling

Performance scheduling

Requested resource times



Tasks have an **average time between instantiations** of
and a constant **computation time** of

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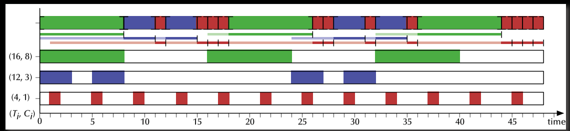
Scheduling

Performance scheduling

First come, first served (FCFS)



Waiting time: 0..11, average: 5.9 – **Turnaround time**: 3..12, average: 8.4

As tasks apply *concurrently* for resources, the actual sequence of arrival is non-deterministic.
☞ hence even a deterministic scheduling schema like FCFS can lead to different outcomes.

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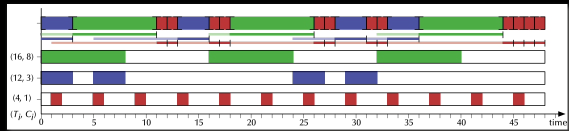
Scheduling

Performance scheduling

First come, first served (FCFS)



Waiting time: 0..11, average: 5.4 – **Turnaround time**: 3..12, average: 8.0

☞ In this example:
the average waiting times vary between 5.4 and 5.9
the average turnaround times vary between 8.0 and 8.4

☞ **Shortest possible maximal turnaround time!**

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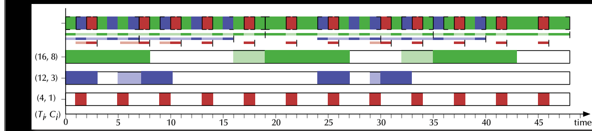
Scheduling

Performance scheduling

Round Robin (RR)



Waiting time: 0..5, average: 1.2 – **Turnaround time**: 1..20, average: 5.8

☞ Optimized for swift initial responses.
☞ "Stretches out" long tasks.

☞ **Bound maximal waiting time!** (depended only on the number of tasks)

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Scheduling

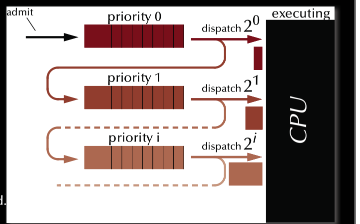
Performance scheduling

Feedback with 2^i pre-emption intervals

- Implement multiple hierarchical ready-queues.
- Fetch processes from the highest filled ready queue.
- Dispatch more CPU time for lower priorities (2^i units).

☞ Processes on lower ranks may suffer **starvation**.

☞ New and short tasks will be preferred.



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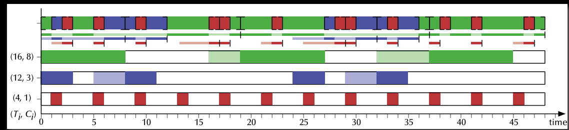
Performance scheduling

Feedback with 2^i pre-emption intervals - sequential



Waiting time: 0..5, average: 1.5 – **Turnaround time**: 1..21, average: 5.7

☞ Optimized for swift initial responses.
☞ Prefers short tasks and long tasks can suffer starvation.

☞ **Very short initial response times!** and good average turnaround times.

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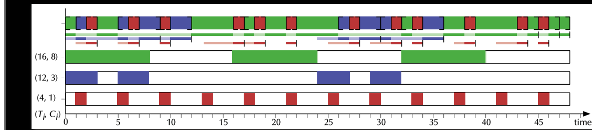
Scheduling

Performance scheduling

Feedback with 2^i pre-emption intervals - overlapping



Waiting time: 0..3, average: 0.9 – **Turnaround time**: 1..45, average: 7.7

☞ Optimized for swift initial responses.
☞ Prefers short tasks and long tasks can suffer starvation.

☞ **Long tasks are delayed until all queues run empty!**

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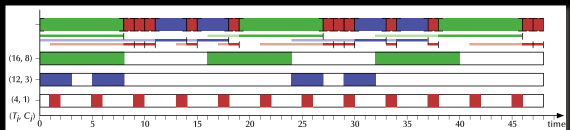
Scheduling

Performance scheduling

Shortest job first



Waiting time: 0..11, average: 3.7 – **Turnaround time**: 1..14, average: 6.3

☞ Optimized for good average performance with minimal task-switches.
☞ Prefers short tasks but all tasks will be handled.

☞ **Good choice if computation times are known and task switches are expensive!**

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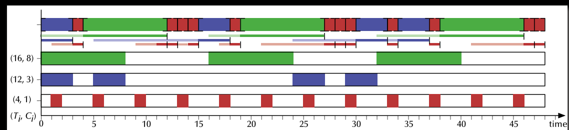
Scheduling

Performance scheduling

Shortest job first



Waiting time: 0..10, average: 3.4 – **Turnaround time**: 1..14, average: 6.0

☞ Can be sensitive to non-deterministic arrival sequences.

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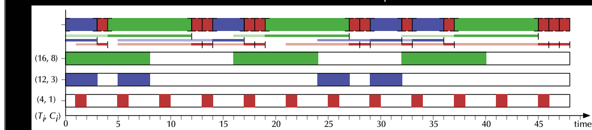
Performance scheduling

Highest Response Ration $\frac{W_i + C_i}{C_i}$ First (HRRF)



Waiting time: 0..9, average: 4.1 – **Turnaround time**: 2..13, average: 6.6

☞ Blend between Shortest-Job-First and First-Come-First-Served.
☞ Prefers short tasks but long tasks gain preference over time.

☞ **More task switches and worse averages than SJF but better upper bounds!**

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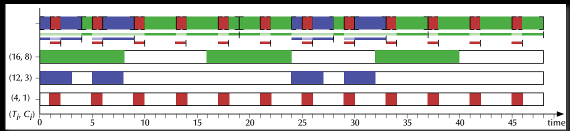
Scheduling

Performance scheduling

Shortest Remaining Time First (SRTF)



Waiting time: 0..6, average: 0.7 – **Turnaround time:** 1..21, average: 4.4

- ☞ Optimized for good averages.
- ☞ Prefers short tasks and long tasks can suffer starvation..

☞ **Better averages than Feedback scheduling but with longer absolute waiting times!**

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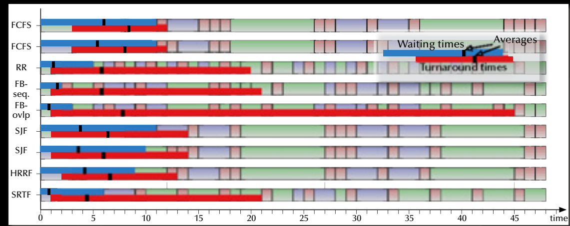
Scheduling

Performance scheduling

Comparison (in order of appearance)



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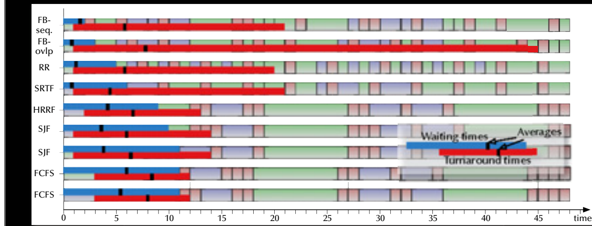
Scheduling

Performance scheduling

Comparison by shortest maximal waiting



☞ Providing upper bounds to waiting times ☞ Swift response systems

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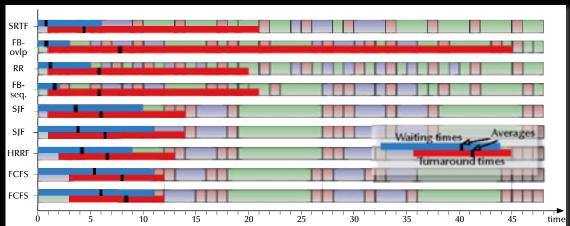
Scheduling

Performance scheduling

Comparison by shortest average waiting



☞ Providing short average waiting times ☞ Very swift response in most cases

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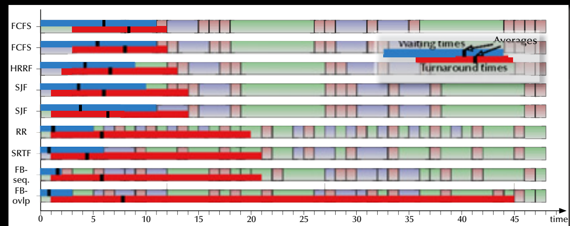
Scheduling

Performance scheduling

Comparison by shortest maximal turnaround



☞ Providing upper bounds to turnaround times ☞ No tasks are left behind

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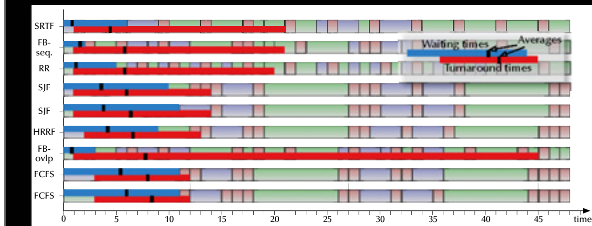
Scheduling

Performance scheduling

Comparison by shortest average turnaround



☞ Providing good average performance ☞ High throughput systems

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Scheduling

Performance scheduling

Comparison overview

	Selection	Pre-emption	Waiting	Turnaround	Preferred jobs	Starvation possible?
Methods without any knowledge about the processes						
FCFS	$\max(W_i)$	no	long	long average & short maximum	equal	no
RR	equal share	yes	bound	good average & large maximum	short	no
FB	priority queues	yes	very short	short average & long maximum	short	no
Methods employing computation time C_i and elapsed time E_i						
SJF	$\min(C_i)$	no	medium	medium	short	yes
HRRF	$\max\left(\frac{W_i + C_i}{C_i}\right)$	no	controllable compromise	controllable compromise	controllable	no
SRTF	$\min(C_i - E_i)$	yes	very short	wide variance	short	yes

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Scheduling

Predictable scheduling

Towards predictable scheduling …

Task requirements (Quality of service):

- ☞ Guarantee **data flow** levels
- ☞ Guarantee **reaction** times
- ☞ Guarantee **deadlines**
- ☞ Guarantee **delivery** times
- ☞ Provide **bounds** for the variations in results

Examples:

- Streaming media broadcasts, playing HD videos, live mixing audio/video, …
- Reacting to users, Reacting to alarm situations, …
- Delivering a signal to the physical world at the required time, …

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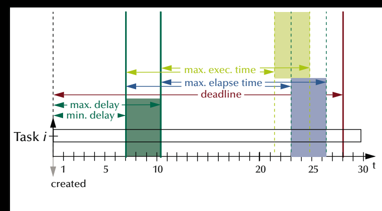
Scheduling

Predictable scheduling

Temporal scopes

Common attributes:

- Minimal & maximal **delay** after creation
- Maximal **elapsed time**
- Maximal **execution time**
- Absolute **deadline**



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Scheduling

Predictable scheduling

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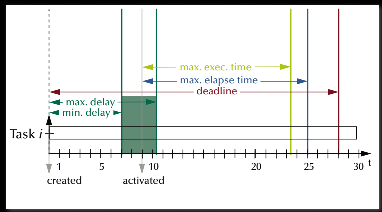

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Scheduling

Predictable scheduling

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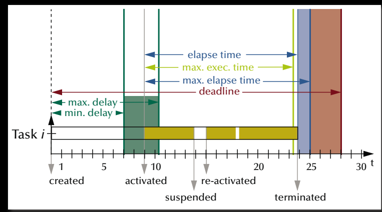

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Scheduling

Predictable scheduling

Temporal scopes

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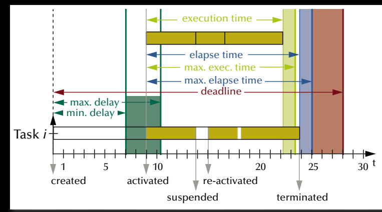

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Scheduling

Predictable scheduling

Common temporal scope attributes

Temporal scopes can be:

Periodic	☞ controllers, routers, schedulers, streaming processes, …
Aperiodic	☞ periodic 'on average' tasks, i.e. regular but not rigidly timed, …
Sporadic / Transient	☞ user requests, alarms, I/O interaction, …

Deadlines can be:

Semantics defined by application

"Hard"	☞ single failure leads to severe malfunction and/or disaster
"Firm"	☞ results are meaningless after the deadline
	☞ only multiple or permanent failures lead to malfunction
"Soft"	☞ results are still useful after the deadline

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Scheduling

Summary

Scheduling

- **Basic performance scheduling**
  - Motivation & Terms
  - Levels of knowledge / assumptions about the task set
  - Evaluation of performance and selection of appropriate methods
- **Towards predictable scheduling**
  - Motivation & Terms
  - Categories & Examples