Technische Hochschule Rosenheim
Technical University of Applied Sciences

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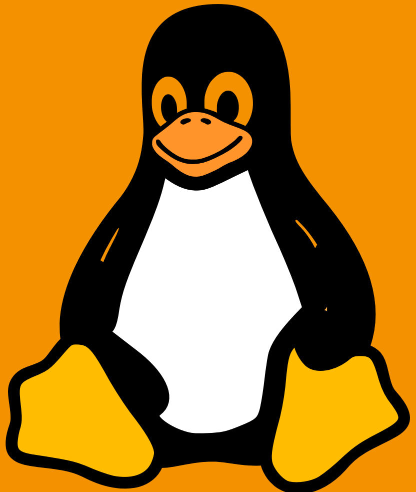
OS 11 – Scheduling



source: iconspng.com

The lecture is based on the work and the documents of Prof. Dr. Ludwig Frank

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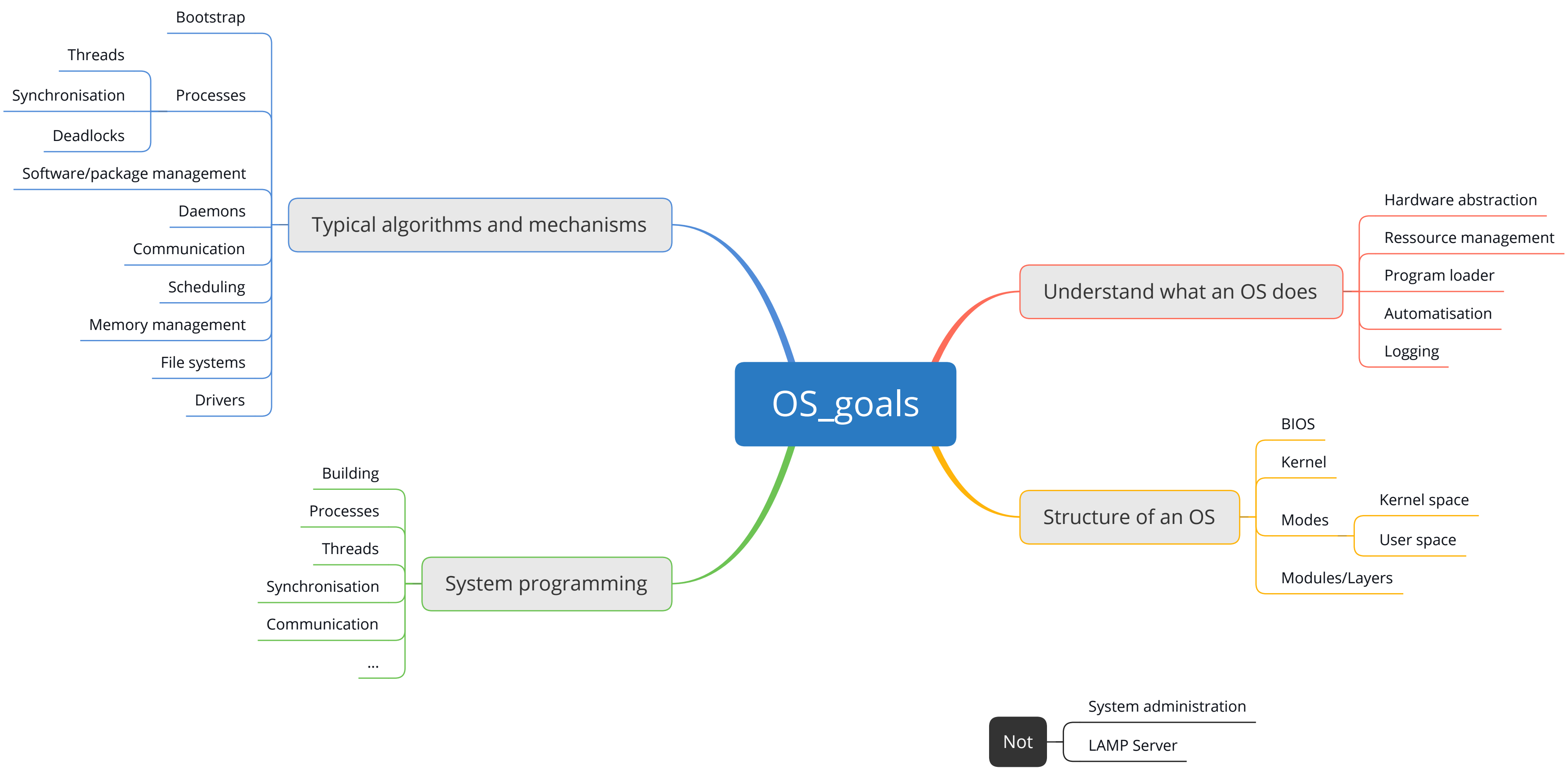
Goal



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Goal

OS::Scheduling

- Scheduling theory and terms
- Scheduling strategies
- Scheduling on Linux

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Scheduling

Scheduling is a technique to **distribute computing resources** like processor time, bandwidth, memory, or device I/O **to the processes** on a computer system.

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Scheduler

The **scheduler** is such a **program** that **distributes** the **resources** to the processes.

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Scheduling time frame

Long term scheduling

Determines which processes (jobs) are admitted to the system for processing.

Mid term scheduling

Allocation of bandwidth, memory, or device I/O to a process/thread.

Short term scheduling

Allocation of a process/thread to a CPU core.

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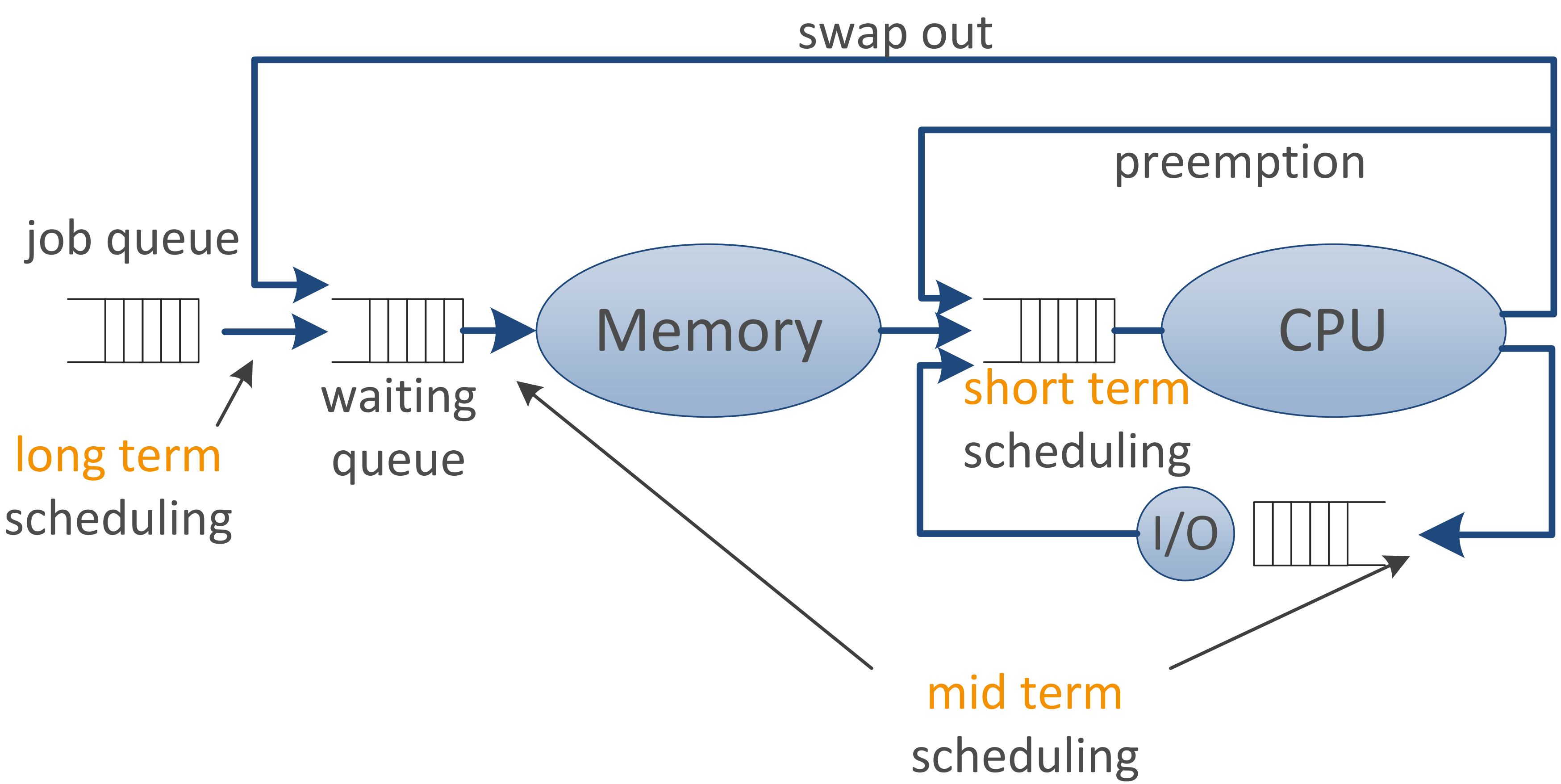
Scheduling time frame overview



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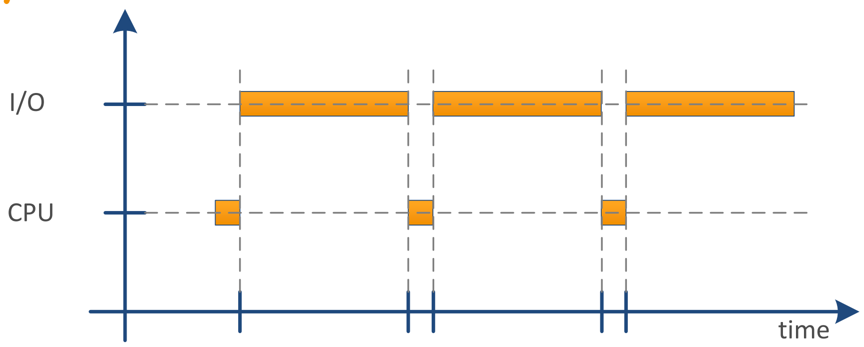
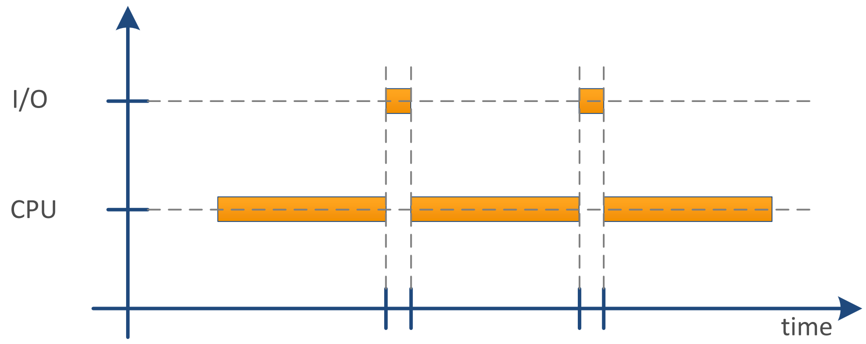
I/O-bound vs CPU-bound

I/O-bound



CPU-bound



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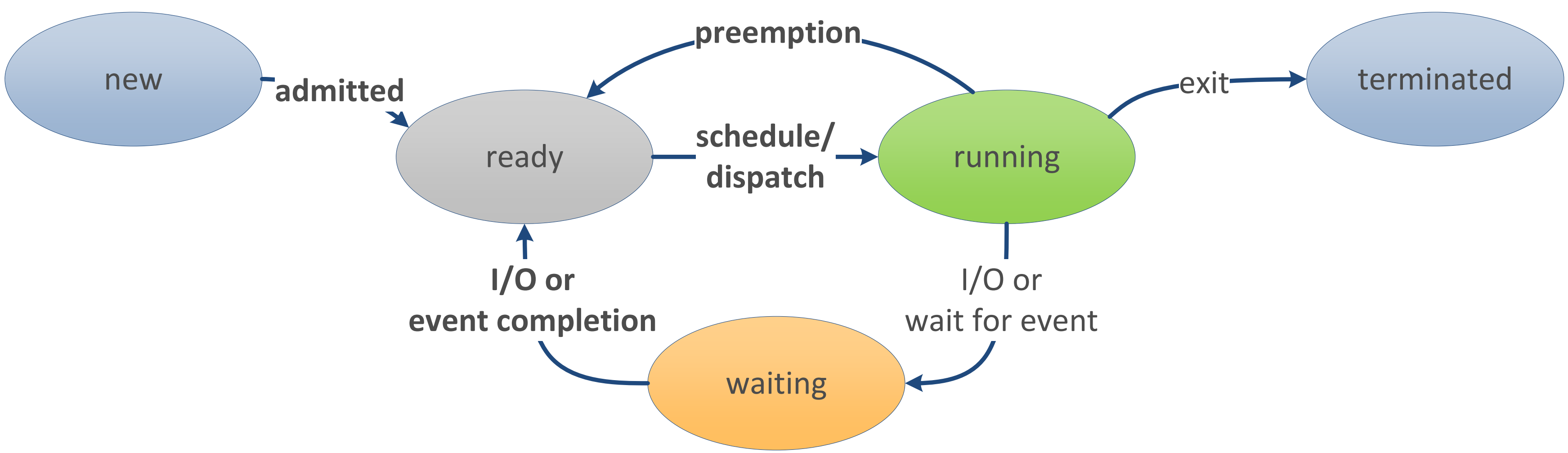
Process states



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Scheduling terms

Term	Description
CPU usage	CPU usage up to 100% if possible.
throughput	The number of completed processes in a time frame. Should be as high as possible.
arrival time	The point in time at which a process arrives for execution in the system.
processing time	The time a process takes to run on the CPU.
waiting time	The time a process has to wait until it can run.
residence time	The total time a process takes to finish (= processing time + waiting time).

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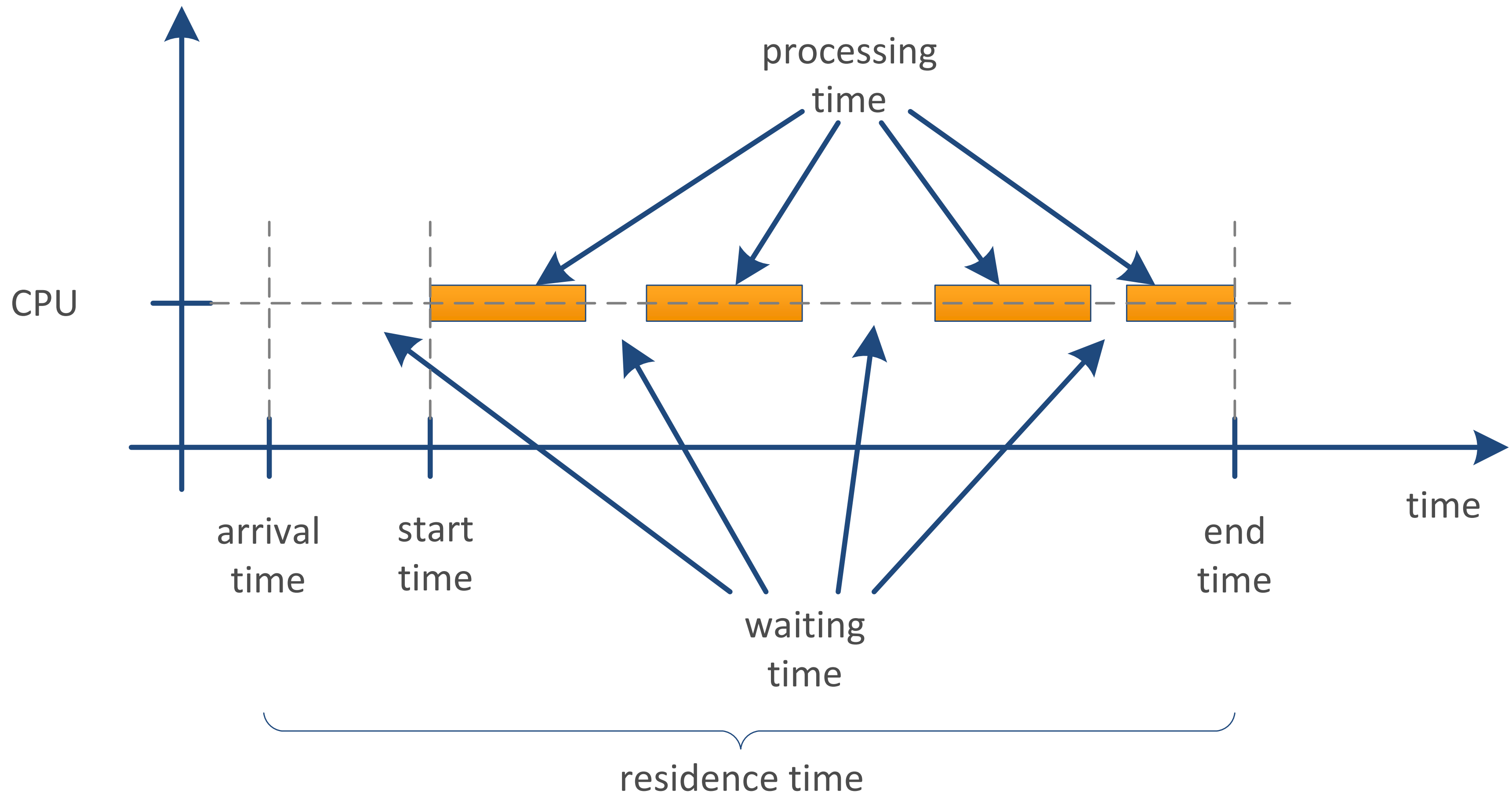
Time aspects



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System categories

System type	Description
Job processing system	Typically users submit jobs (programs with its parameters) to a system. The job scheduler decides when the job starts.
Interactive system	With an interactive system, the users work directly: a PC (terminal, desktop), smartphone, ...
Real-time system	A real-time system usually observes and controls a physical process in the real world. It must guarantee that it reacts fast enough.

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Scheduling Goals

All systems

fairness	-	Every process can run on the CPU.
policy enforcement	-	The system's policy is enforced.
balance	-	All parts of the system are busy.

Job processing system

throughput	-	Maximize the number of jobs in a time frame.
residence time	-	Minimize the residence time for each job.
CPU usage	-	The CPU is constantly used as long as there are jobs in the queue.

Interactive system

response time	-	Respond quickly to requests.
proportionality	-	Consider the requirements for all users.

Real-time system

meet deadline	-	Meet always the deadline of all processes.
predictability	-	Always guarantee the same periodic execution (small jitter).

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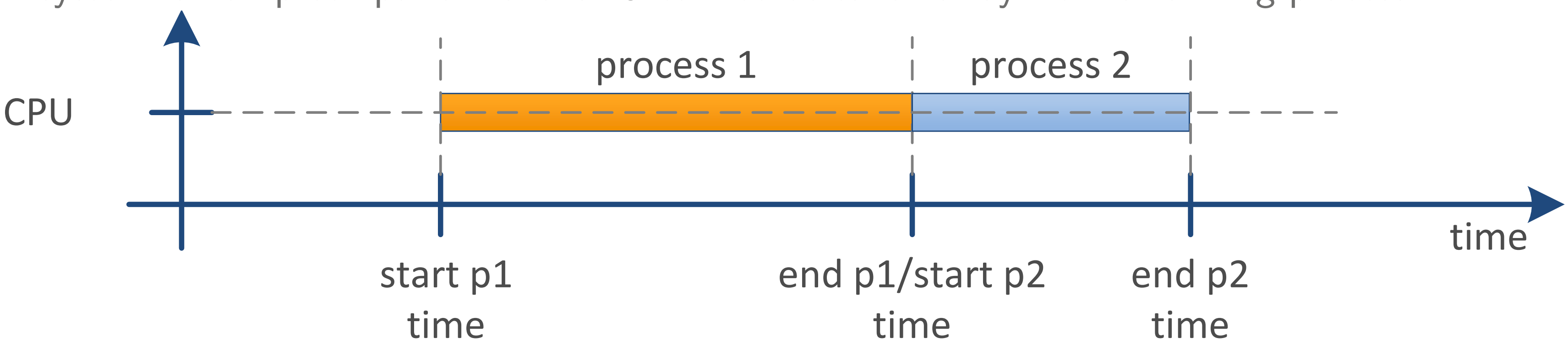
Preemption

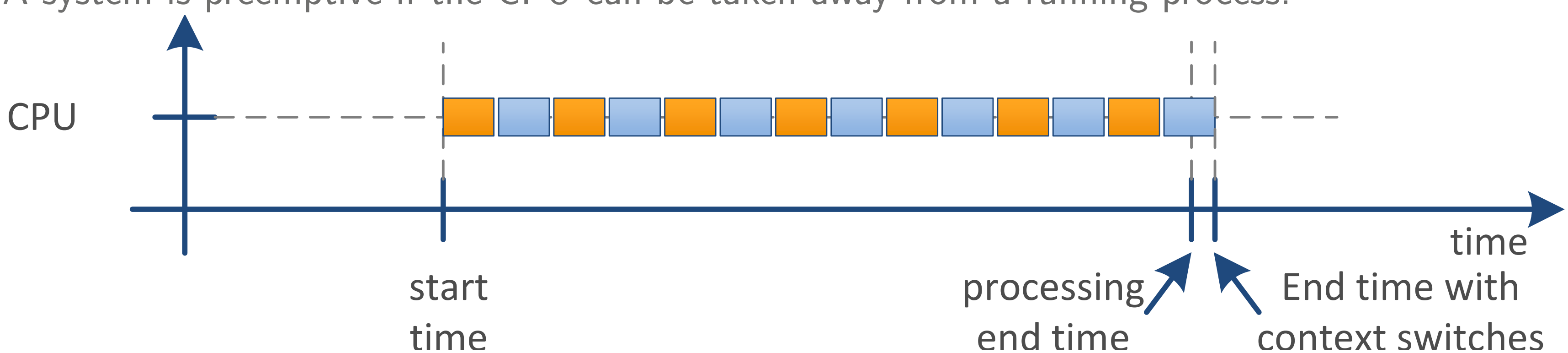
Non-preemptive system

A system is non-preemptive if the CPU cannot be taken away from a running process.



Preemptive system

A system is preemptive if the CPU can be taken away from a running process.



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Context switch

A context switch **changes the active process or thread** on the CPU. This may be expensive (takes some time).

Procedure:

- Save the register content of the currently running process into its PCB.
- Select a new process to run.
- Load/restore memory information into the CPU (MMU) from its PCB.
- Load/restore the register content of the new process from its PCB.

Time for context switches:

- Time to switch processes: $\approx 3600ns$ per context switch (Intel E5440 CPU)
- Time to switch threads: $\approx 1300ns$ per context switch (Intel E5440 CPU)

Source for measured times: `https://blog.tsunanet.net/2010/11/how-long-does-it-take-to-make-context.html`

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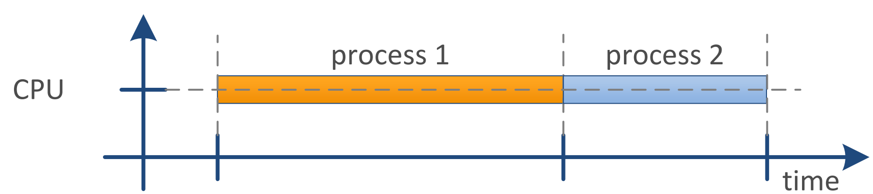
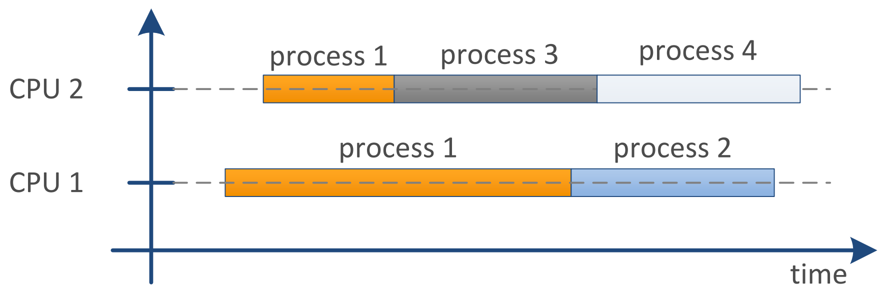
Scheduling: single vs multi core CPU

Single core CPU



Multi core CPU



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Questions?

All right? $\Rightarrow$

Question? $\Rightarrow$ and use **chat**

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Scheduling strategies

How would you schedule processes on your computer?

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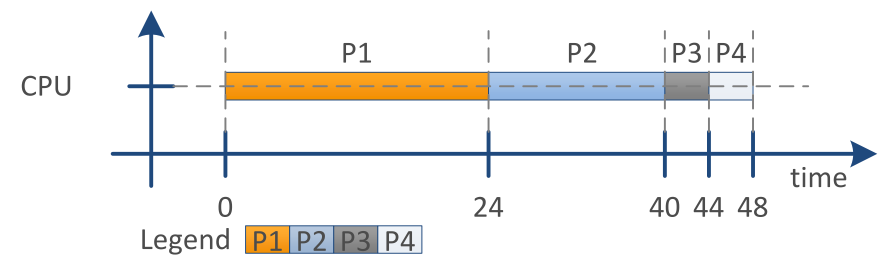
FCFS - first come first served

The arrival order (time) in the waiting queue is the scheduling order.

Or.	ar. time	Process	proc. time	res. time
1	0	P1	24	24
2	0	P2	16	40
3	0	P3	4	44
4	0	P4	4	48

Mean res. time $= (24 + 40 + 44 + 48)/4 = 39$



Properties

- A faire order (arrival time).
- Small jobs may wait long.
- Not good for interactive system: does not guarantee a good response time.

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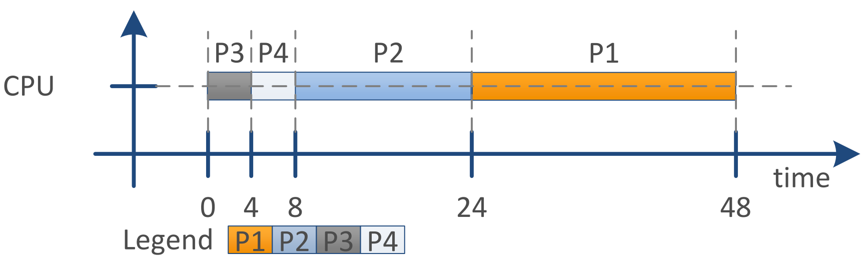
SJF - shortest jobs first

The job with the smallest processing time is scheduled first.

Or.	ar. time	Process	proc. time	res. time
1	0	P1	24	48
2	0	P2	16	24
3	0	P3	4	4
4	0	P4	4	8

Mean res. time $= (48 + 24 + 4 + 8)/4 = 21$



Properties

- SJF optimises the throughput.
- The processing time is often not available (prediction also hard).
- Processing time is predicted: by user, automatically?
- Jobs with a long processing time may not get scheduled (starvation).

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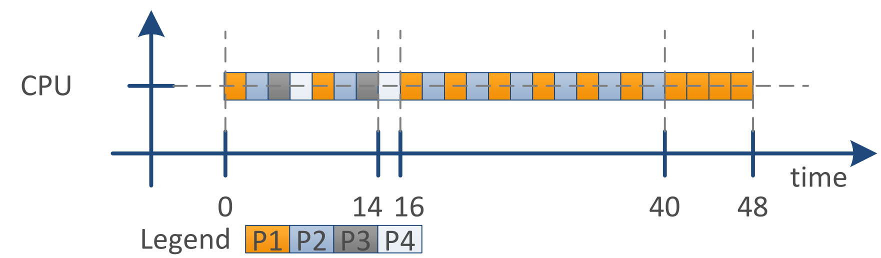
RR - round robin

Every process in the queue get the required resource for a limited amount of time (time slice). Then the preempted process is placed to the last position in the waiting queue.

Here: time slice = 2

Or.	ar. time	Process	proc. time	res. time
1	0	P1	24	48
2	0	P2	16	40
3	0	P3	4	14
4	0	P4	4	16

Mean res. time $= (48 + 40 + 14 + 16)/4 = 29.5$



Properties

- Good for interactive systems.
- Too many process switches causes context switches–and that are expensive.
- The average waiting time is often longer than with other scheduling strategies.

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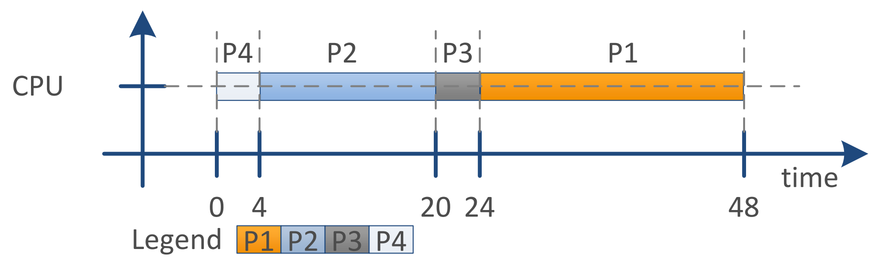
EDF - earliest deadline first

The process whose deadline ends first is processed first.

Or.	ar. time	Process	proc. time	deadl.	res. time
1	0	P1	24	60	48
2	0	P2	16	20	20
3	0	P3	4	28	24
4	0	P4	4	4	4

Mean res. time $= (48 + 20 + 24 + 4)/4 = 24$



Properties

- Used in real-time systems.
- Is not always optimal on multi-core CPUs.

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Priority based

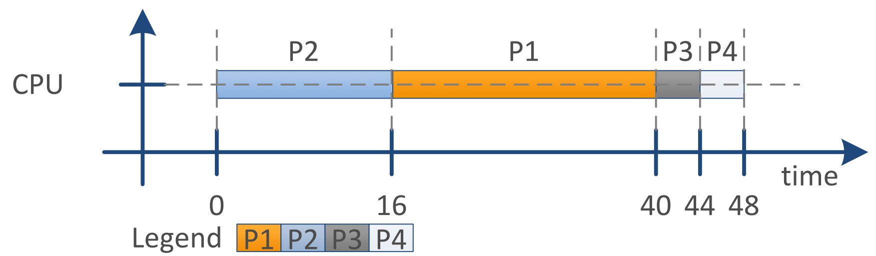
External priority

The process with the highest priority is scheduled first. The user can define the priority on startup or change it during execution.

Here: 1 = highest priority, 4 = lowest priority (depends on OS definition)

Or.	ar. time	Process	proc. time	prio	res. time
1	0	P1	24	2	40
2	0	P2	16	1	16
3	0	P3	4	3	44
4	0	P4	4	4	48

Mean res. time $= (40 + 16 + 44 + 48)/4 = 37$



Properties

- The important processes are scheduled first.
- Long-running processes with a high priority can cause low priority processes to be kept away from the CPU for a long time.

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Priority based

Internal priority

After a process runs for a while, its priority is automatically lowered. After some long waiting time, the priority can automatically be increased again.

Properties

- Solves the issue of the external priority.
- Improves the response time.

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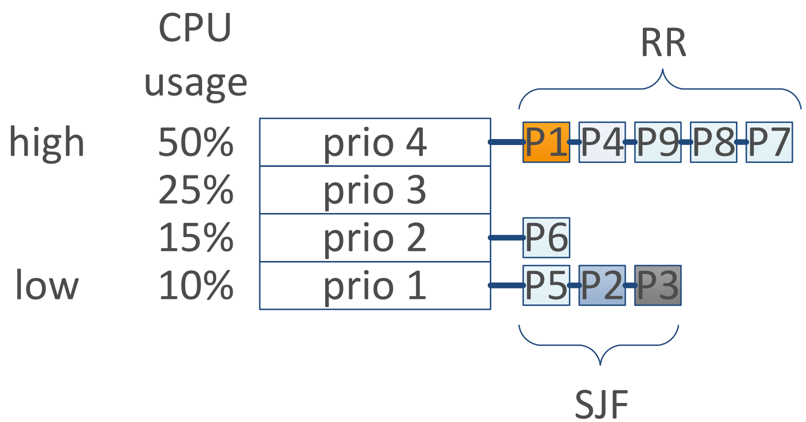
Multilevel queue scheduling

There exist multiple queues, whereas each can have its own scheduling strategy.



Properties

- Combination of different strategies.
- Each queue can have its own CPU usage.
- Improves response time while taking priorities into account.

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Linux priorities

Supports 140 different priority classes (0...139)
The lower the value, the higher the priority.

Normal processes: 100...139 $[0 \ldots 39]$

Parameter	Definition	Description
NI	$NI = -20 \ldots +19$	Nice value ranges from $-20 \ldots +19$. Users can only increase the nice value, but not lower it.
PR	$PR = 20 + NI$	The priority PR ranges from 0...39. Default user processes usually submitted with $NI = 0 => PR = 20$.

Real-time processes: 0...99 $[-100 \ldots -1]$

Parameter	Definition	Description
RT	$RT = 1 \ldots 99$	The real-time priority RT ranges from 1...99
PR	$PR = -1 - RT$	The priority PR ranges from $-100 \ldots -1$.

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Linux commands

Command	Description
`top`	Shows processes in live view.
`htop`	Shows processes in live view.
`ps ax -o pid,rtprio,pri,ni,cmd`	Shows processes with pid, rtprio, pri, ni, and its cmd.
`nice -n 15 make -j`	Starts a parallel build with $NI = 15$
`nice -n -5 make -j`	Starts a parallel build with $NI = -5$
`renice -n 15 -p 1000`	Change $NI = 15$ of process with PID 1000.
`renice -n -5 -p 1000`	Change $NI = -5$ of process with PID 1000.

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Summary and outlook

Summary

- Scheduling theory and terms
- Scheduling strategies
- Scheduling on Linux

Outlook

- Memory management