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```

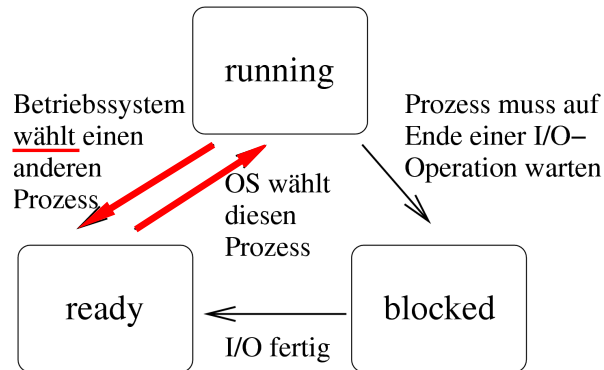
Sep 19 14:20:41 amd64 sshd[2097]: Accepted rsa for esser from ::ffff:87.234.201.207 port 63597
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Sep 20 01:00:01 amd64 /usr/sbin/cron[29278]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
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```



Scheduling (1)

Pick a process to run

State transitions



```

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```

Introduction

Scheduling – what is it about?

- Multitasking: Several processes compete for resources
- OS manages resources
- Computing time (using the processor)
- Scheduler decides:
Execute which process when?
- Order of execution relevant for overall performance of operating system

Preemptive Scheduling

process preemption possible?

- **cooperative scheduling:**
 - process computes as long as it wants to; until the next I/O operation or `exit()`
 - Scheduler only active when process blocks or gives up CPU on its own: `schedule()`
- **preemptive scheduling:**
 - Timer regularly activates scheduler which decides what process can continue

Scheduling – what is it about?

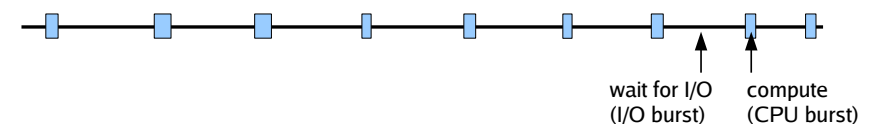
When does the scheduler run?

- new process creation (fork)
- active process blocks (I/O operation)
- blocked process becomes ready
- active process terminates (exit)
- process has computed for too long
- interrupt occurs

Processes: I/O or CPU bound

I/O bound:

- process has only short compute bursts (CPU) between I/O bursts



CPU bound:

- process has long CPU bursts between I/O bursts



Frequent context switches?

Factors

- **Time needed for context switch:** scheduler needs time to save process state
→ lost compute time
- **processes' waiting time:** frequent switches create stronger impression of parallelism

Goals of Scheduling (2)

From system (administrator)'s perspective

- **[S1] Throughput:** number of processes completing (per unit of time)
- **[S2] Processor utilization:** time (in %) in which the processor was busy
- **[S3] Fairness:** Treat processes as equals, no "process starvation"
- **[S4] Priorities** should be enforced
- **[S5] Resources** should be balanced

Goals of Scheduling (1)

From users' perspective

- **[A1] Turnaround time:** How long from start to end of process?
- **[A2] Response time:** How quickly does the process respond to interaction?
- **[A3] Deadlines** must be met
- **[A4] Predictability:** similar jobs should behave similarly. No variation in response / turnaround time
- **[A5] Proportionality:** „simple things“ are quick

[A1] Turnaround time

How much time passed between starting and completion of a process?

- n processes p_1 bis p_n start at time t_0 and complete at times t_1 bis t_n
- average execution time:
 $1/n * \sum_i (t_i - t_0)$
- depends on specific set of processes; calculation only makes sense in order to compare scheduling algorithms

[A2] Response time

How quickly does the system react to user interactions?

- user presses key, clicks mouse etc. and waits for a reaction
- How much time passed between causing the interrupt and activating the process which will handle the input?
- low tolerance towards long waiting times; 2-4 seconds critical, more is unacceptable

[A4] Predictability

Similar processes show similar behavior?

- intuitively: similar process should behave similarly, i. e.
- turnaround and response time always similar
- independent from the system's state
- difficult if system allows arbitrarily many processes → limitations?

[A3] Deadlines

Does the system meet deadlines?

- realtime systems: special needs
- processes must finish tasks in given times, so they need sufficient compute time and they need it in time
- How often are deadlines missed?
- maximize percentage of deadlines met

[A5] Proportionality

Things that seem „simple“ are handled quickly

- Users have a (possibly false) picture of how some technical things work
- Users are more likely to accept waiting time, when he believes that the process is complex

[S1] Throughput

Terminating processes

- # of processes that finish per unit of time (e. g. per hour) should be high
- measures how much work is getting done
- depends on specific set of processes; calculation only make sense in order to compare several scheduling algorithms

[S3] Fairness

All processes have equal chances (to run)

- Each process should eventually become active (no process starvation)
- No big variance in waiting times and turnaround times
- If we have process priorities:
→ „some are more equal“

[S2] Processor Utilization

Always keep the CPU busy

- percentage of CPU cycles in which the CPU was not idle (but busy)
- Interesting factor when compute time is very expensive (commercial data center)

[S4] Priorities

Treat more or less important processes accordingly

- priority classes: processes with high priority are favored by scheduler
- avoid situation in which low priority processes never run (because there is always a high priority process)

[S5] Balance Resources

„OS manages the resources“

- basic concept of OS: give uniform access to all resources and keep them busy
- CPU scheduler influences (non-) uniform utilization of I/O devices
- prefer processes that want to use resources which are currently idle

Requirements on the Operating System (2)

Batch processing

- S3 Fairness
- S4 Priorities
- S5 Balance resources
- S1 Throughput
- A1 Turnaround time
- S2 Processor utilization

Requirements on the Operating System (1)

Drei Kategorien

- Batch processing
- Interactive system
- Real time system

Immer wichtig:

- S3 Fairness
- S4 Priorities
- S5 Balance resources

Requirements on the Operating System (3)

Interaktives System

- S3 Fairness
- S4 Priorities
- S5 Balance resources
- A2 Response time
- A5 Proportionality

Requirements on the Operating System (4)

Echtzeitsystem

- S3 Fairness
- S4 Priorities
- S5 Balance resources
- A3 Deadlines
- A4 Predictability

```

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Sep 23 18:04:05 amd64 sshd[6554]: Accepted rsa for esser from ::ffff:87.234.201.207 port 61507
Sep 23 18:04:05 amd64 syslog-ng[7653]: STATS: dropped 0
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```

Practice I: Linux

Types of Scheduling

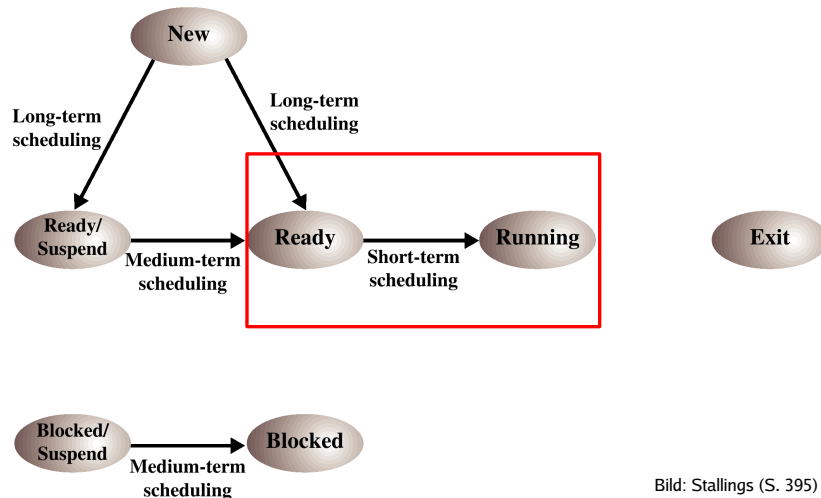


Bild: Stallings (S. 395)

Linux: nice & renice (1)

Influence Linux scheduler:

- nice, increase nice value, or decrease it as system administrator (when starting a program)
- ranges from +19 (very nice) to -20, default: 0
- renice, change nice value of active program
- Nice value is (just) one component of priority, that the scheduler considers
- only root can decrease a nice value

Linux: nice & renice (2)

```
$ nice -10 ./calculate      $ nice -n 10 ...
# nice --10 ./important    # nice -n -10 ...

$ pidof nedit
26980
$ renice 19 26980
26980: Old priority 0, new priority 19
$ renice 0 26980
renice: 26980: setpriority: Permission denied
# renice -20 26980
26980: Old priority 19, new priority -20
```

Linux: nice values in process list

Name	PID	GID	Status	Nutzer %	System %	Priorität	Vm-Größ	VmRss	Benutzer	Befehl
aio/0	128	0	Ruht	0,00	0,00	-5	0	12	root	
oqueue/0	334	0	Ruht	0,00	0,00	-5	0	12	root	
events/0	3	0	Ruht	0,00	0,00	-5	0	12	root	
kacpid	8	0	Ruht	0,00	0,00	-5	0	12	root	
kauditd	2988	0	Ruht	0,00	0,00	-5	0	12	root	
kblockd/0	7	0	Ruht	0,00	0,00	-5	0	12	root	
khelper	4	0	Ruht	0,00	0,00	-5	0	12	root	
khubd	1365	0	Ruht	0,00	0,00	-5	0	12	root	
kpsmoused	371	0	Ruht	0,00	0,00	-5	0	12	root	
ksériod	335	0	Ruht	0,00	0,00	-5	0	12	root	
kthread	5	0	Ruht	0,00	0,00	-5	0	12	root	
reiserfs/0	1924	0	Ruht	0,00	0,00	-5	0	12	root	
rpciod/0	17370	0	Ruht	0,00	0,00	-5	0	12	root	
sosi_éh_0	1796	0	Ruht	0,00	0,00	-5	0	12	root	
usb-storage	1797	0	Ruht	0,00	0,00	-5	0	12	root	
udevd	873	873	Ruht	0,00	0,00	-4	1 860	352	root	/sbin/udevd
auditd	2986	2986	Ruht	0,00	0,00	-3	9 860	368	root	/sbin/auditd
acpid	2254	2254	Ruht	0,00	0,00	0	1 516	360	root	/sbin/acpid
bash	3910	3910	Ruht	0,00	0,00	0	4 420	588	esser	/bin/bash
bash	3912	3912	Ruht	0,00	0,00	0	4 424	584	esser	/bin/bash