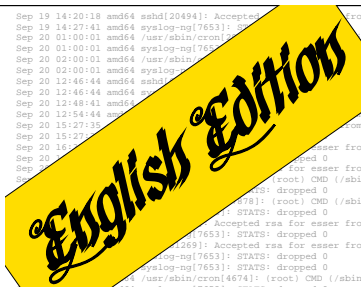


```

Sep 19 14:20:18 amd64 sshd[20494]: Accepted rsa for esser from ::ffff:87.234.201.207 port 61557
Sep 19 14:27:41 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 01:00:01 amd64 /usr/sbin/cron[17878]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 20 01:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 02:00:01 amd64 /usr/sbin/cron[17878]: (root) CMD (/sbin/evlogmgr -c "age > *30d")
Sep 20 02:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 12:46:44 amd64 sshd[6516]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62004
Sep 20 12:46:44 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 12:48:41 amd64 sshd[6509]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62105
Sep 20 12:54:44 amd64 sshd[6694]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62514
Sep 20 15:27:35 amd64 sshd[9077]: Accepted rsa for esser from ::ffff:87.234.201.207 port 64242
Sep 20 15:27:35 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 16:37:11 amd64 sshd[10102]: Accepted rsa for esser from ::ffff:87.234.201.207 port 63375
Sep 20 16:37:11 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 16:38:10 amd64 /usr/sbin/cron[17878]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 21 01:00:01 amd64 /usr/sbin/cron[17055]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 21 01:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 21 02:00:01 amd64 /usr/sbin/cron[17878]: (root) CMD (/sbin/evlogmgr -c "age > *30d")
Sep 21 02:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 21 17:43:26 amd64 sshd[31088]: Accepted rsa for esser from ::ffff:87.234.201.207 port 63397
Sep 21 17:43:26 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 21 17:53:19 amd64 sshd[32491]: Accepted rsa for esser from ::ffff:87.234.201.207 port 64391
Sep 21 18:43:26 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 21 19:43:26 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 22 01:00:01 amd64 /usr/sbin/cron[4674]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 22 01:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 22 02:00:01 amd64 /usr/sbin/cron[5499]: (root) CMD (/sbin/evlogmgr -c "age > *30d")
Sep 22 02:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 22 20:23:21 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 23 01:00:01 amd64 /usr/sbin/cron[2479]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 23 01:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 23 02:00:01 amd64 /usr/sbin/cron[25555]: (root) CMD (/sbin/evlogmgr -c "age > *30d")
Sep 23 02:00:01 amd64 syslog-ng[7653]: STA dropped 0
Sep 23 18:04:05 amd64 sshd[6554]: Accepted rsa for esser from ::ffff:192.168.1.5 port 59771 ssh2
Sep 23 18:04:05 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 23 18:04:34 amd64 sshd[6606]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62093
Sep 24 01:00:01 amd64 /usr/sbin/cron[12436]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 24 01:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 24 02:00:01 amd64 /usr/sbin/cron[13253]: (root) CMD (/sbin/evlogmgr -c "age > *30d")
Sep 24 02:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 24 11:15:48 amd64 sshd[20998]: Accepted rsa for esser from ::ffff:87.234.201.207 port 64456
Sep 24 11:15:48 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 24 13:49:08 amd64 sshd[23197]: Accepted rsa for esser from ::ffff:87.234.201.207 port 61330
Sep 24 13:49:08 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 24 15:42:07 amd64 kernel: snd_seq_midi_event: unsupported module, tainting kernel.
Sep 24 15:42:07 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 24 15:42:07 amd64 kernel: snd_seq_oss: unsupported module, tainting kernel.
Sep 24 20:25:31 amd64 sshd[29399]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62566
Sep 24 20:25:31 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 25 01:00:02 amd64 /usr/sbin/cron[6621]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 25 01:00:02 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 25 02:00:01 amd64 /usr/sbin/cron[1484]: (root) CMD (/sbin/evlogmgr -c "age > *30d")
Sep 25 02:00:02 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 25 10:59:25 amd64 sshd[8888]: Accepted rsa for esser from ::ffff:87.234.201.207 port 64183
Sep 25 10:59:25 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 25 10:59:47 amd64 sshd[8921]: Accepted rsa for esser from ::ffff:87.234.201.207 port 64253
Sep 25 11:30:02 amd64 sshd[9372]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62029
Sep 25 11:59:25 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 25 14:05:37 amd64 sshd[11554]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62822
Sep 25 14:05:37 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 25 14:06:10 amd64 sshd[11586]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62951
Sep 25 14:07:17 amd64 sshd[11608]: Accepted rsa for esser from ::ffff:87.234.201.207 port 63392
Sep 25 14:08:13 amd64 sshd[11630]: Accepted rsa for esser from ::ffff:87.234.201.207 port 63709
Sep 25 15:25:33 amd64 sshd[12930]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62778

```



Scheduling (2)

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Sep 19 14:20:18 amd64 sshd[20494]: Accepted rsa for esser from ::ffff:87.234.201.207 port 61557
Sep 19 14:27:41 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 01:00:01 amd64 /usr/sbin/cron[29278]: (root) CMD (/sbin/evlogmgr -c "severity=DEBUG")
Sep 20 01:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 02:00:01 amd64 /usr/sbin/cron[30103]: (root) CMD (/sbin/evlogmgr -c "age > *30d")
Sep 20 02:00:01 amd64 syslog-ng[7653]: STATS: dropped 0
Sep 20 12:46:44 amd64 sshd[6516]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62004
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Sep 25 15:25:33 amd64 sshd[12930]: Accepted rsa for esser from ::ffff:87.234.201.207 port 62778

```

Schedulers for batch systems

Examples of schedulers

Concrete scheduling methods

1. for batch systems
2. for interactive systems
3. for real time systems

Batch Processing

Features of Batch Processing

- Non-interactive systems (no regular user processes)
- Job Management System accepts Jobs; system informs about completion
- Typical tasks: long computations, software compilation

Batch Processing

Historically:

- Batch operation with punch cards
- Program code and data on punch cards
- No I/O (no devices except card reader, printer)
- Card stack (batch) determines order of execution
- read program code from cards ...
- and data from more cards
- run computation
- punch results on cards or print them
- next job

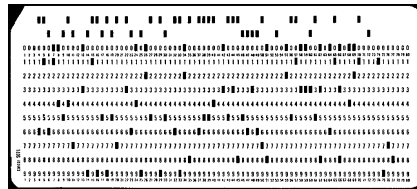


Bild: <http://www.fao.org/docrep/X5738E/x5738e0h.htm>

Batch Processing

Schedulers for batch processing

- First Come, First Served (FCFS)
- Shortest Job First (SJF)
- Shortest Remaining Time (SRT)
- Three Level Scheduling

Batch Processing

Modern batch systems

- standard machines (with disks, network, etc.)
- no interactive operation (no login etc.)
- Job management tool accepts jobs
- Long term scheduler decides when to start a job – possibly based on information about resource usage and expected runtime of the program

First Come, First Served (FCFS)

Simple queue

- Append new processes to the end of the queue
- Scheduler picks next process in the queue
- Process runs until finished or until it blocks (cooperative scheduler, no preemption)
- Blocked processes move to end of queue when they become ready again

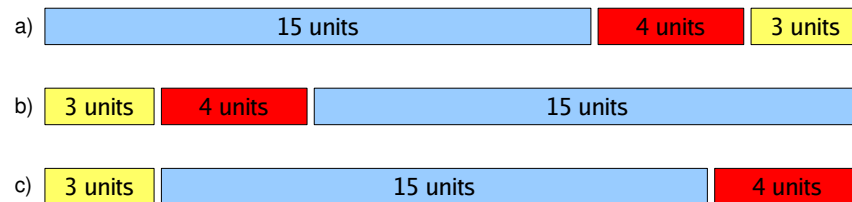
FCFS Example

Three processes
with compute times

T1: 15 units
T2: 4 units
T3: 3 units

Average time from
process creation to end:

a) $(15+19+22) / 3 = 18,67$
b) $(3+7+22) / 3 = 10,67$
c) $(3+18+22) / 3 = 14,33$



FCFS: CPU vs. I/O bound processes

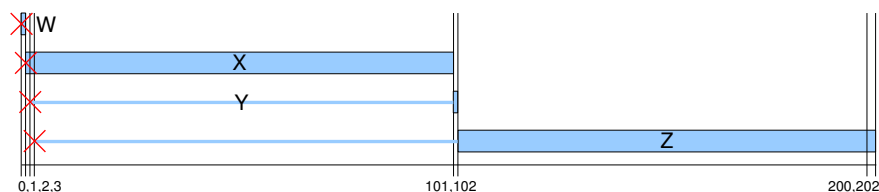
FCFS prefers CPU bound processes

- While a CPU bound process runs, all the others have to wait
- An I/O bound process will eventually execute, but runs only shortly (until next I/O) and then has to rejoin the queue at the end
- Inefficient utilization of both CPU and I/O devices

FCFS: Good for long processes

- FCFS prefers processes with long runtimes
- Example: 4 processes W, X, Y, Z

| process | arrival time | Service Time T_s | start time | end time | Turnaround T_r | T_r/T_s |
|---------|--------------|-----------------------|------------|----------|---------------------|---------------|
| W | 0 | 1 | 0 | 1 | 1 | 1,00 |
| X | 1 | 100 | 1 | 101 | 100 | 1,00 |
| Y | 2 | 1 | 101 | 102 | 100 | 100,00 |
| Z | 3 | 100 | 102 | 202 | 199 | 1,99 |



Shortest Job First (SJF)

- No preemption (as in FCFS)
- Next CPU burst time of all processes is known or must be estimated
- Strategy: Execute the process that will have the shortest CPU burst
- minimizes average turnaround time of all processes
- Principle was visible in the FCFS example

SJF Example

in the FCFS example slide:
order of execution b) is SJF



SJF Properties

General problem:

How can we know how long a process will run?

- Batch system; programmer must estimate runtime
-> in case of huge underestimation: cancel job
- system with a limited set of programs (always the same load) -> acquire statistics about program execution times
- interactive processes: calculate averages of burst times seen so far

Without runtime information this scheduling method is only a theoretical option

SJF Properties

[A2] Response time: overall much better,
but larger variance (some processes have a
worse turnaround or response time),
therefore:

[A4] bad predictability

Burst Length Estimation (1)

Simple version: Mean Value

$$S_{n+1} = \frac{1}{n} \sum_{i=1}^n T_i = \frac{1}{n} T_n + \frac{n-1}{n} S_n$$

mit:

T_i : Length of the i^{th} CPU burst of the process

S_i : Predicted length of the i^{th} CPU burst

S_1 : Predicted length of the 1st CPU burst
(not calculated)

Burst Length Estimation (2)

Exponential Average

$$S_{n+1} = \alpha T_n + (1 - \alpha) S_n \quad \text{with } \alpha: \text{ weighing factor between 0 and 1}$$

Example: $\alpha = 0,8$:

$$S_2 = 0,8 T_1 + 0,2 S_1$$

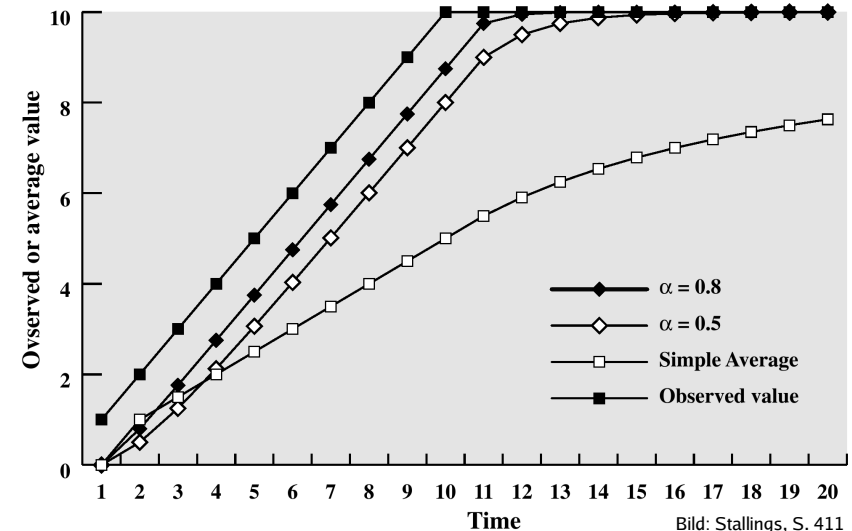
$$S_3 = 0,8 T_2 + 0,2 S_2 = 0,8 T_2 + 0,2(0,8 T_1 + 0,2 S_1)$$

$$\dots = 0,8 T_2 + 0,16 T_1 + 0,04 S_1$$

$$S_4 = 0,8 T_3 + 0,2 S_3 = 0,8 T_3 + 0,2(0,8 T_2 + 0,16 T_1 + 0,04 S_1)$$

$$\dots = 0,8 T_3 + 0,16 T_2 + 0,032 T_1 + 0,008 S_1$$

Burst Length Estimation (4)

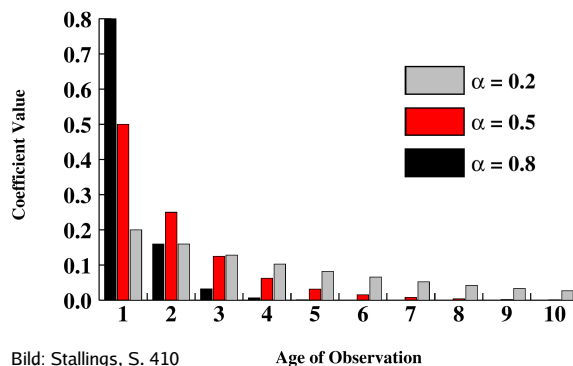


Burst Length Estimation (3)

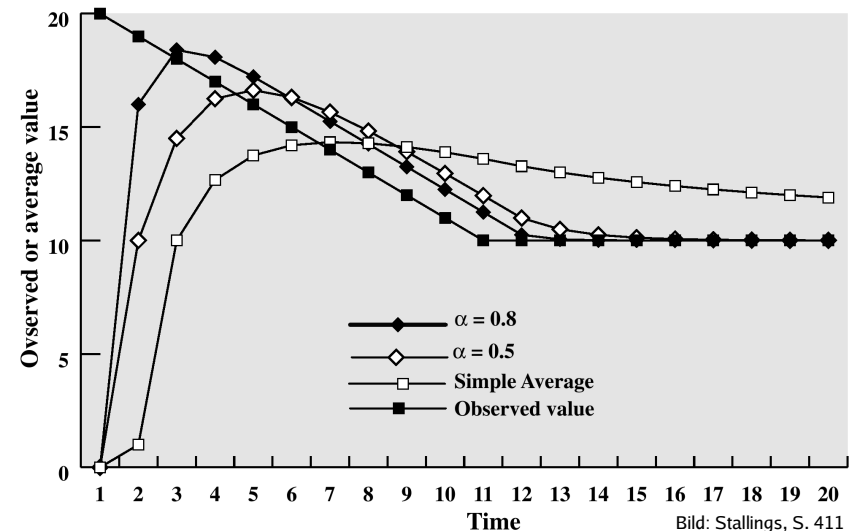
Exponential average, general formula:

$$S_{n+1} = \sum_{i=0}^n (1 - \alpha)^{n-i} \alpha T_i \quad \text{with } T_0 := S_1$$

Weight of an old measured value constantly reduced – data „age“



Burst Length Estimation (5)



SJF & Priority Schedulers

SJF is a special case of Priority Scheduling
(-> Schedulers for interactive systems)

$$\text{Priority}(P) = 1 / L(P)$$

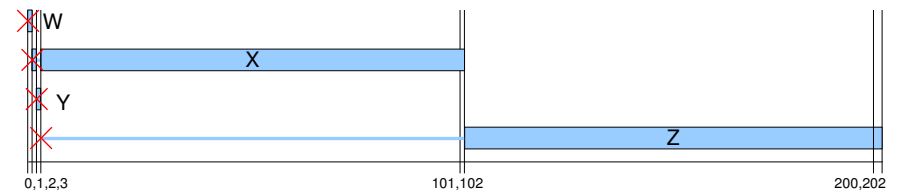
with $L(P)$ = expected length of P's next CPU burst

short burst time -> high priority

SRT-Beispiel

Old FCFS example: SRT preempts X:
Y appears later but is shorter

| process | arrival time | Service Time T_s | start time | end time | Turnaround T_r | T_r/T_s |
|---------|--------------|--------------------|------------|----------|------------------|-----------|
| W | 0 | 1 | 0 | 1 | 1 | 1,00 |
| X (1) | 1 | 100 | 1 | 2 (*) | | |
| Y | 2 | 1 | 2 | 3 | 1 | 1,00 |
| X (2) | | | 3 | 102 | 102-1=101 | 1,01 |
| Z | 3 | 100 | 102 | 202 | 199 | 1,99 |



Shortest Remaining Time (SRT)

- Similar to SJF, but:
- preemptive
- Regular recalculation, how much execution time remains
- Scheduler checks execution order every time a new process is created
- For a shorter job (including new ones) system will preempt the active job
- Needs a good runtime estimation (as with SJF)

Three Level Scheduling

With batch systems scheduling can be split into three components:

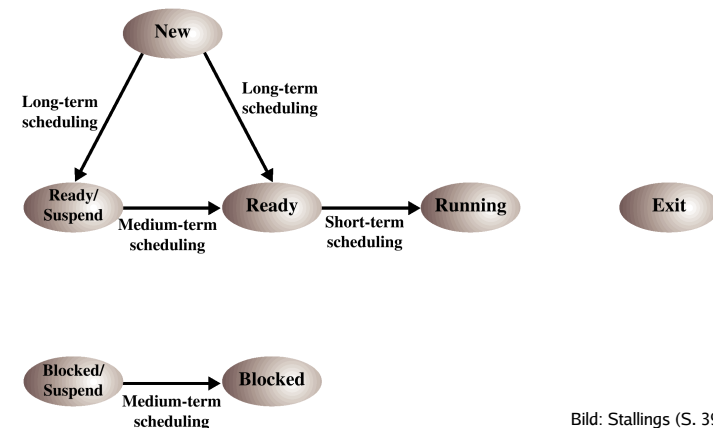


Bild: Stallings (S. 395)