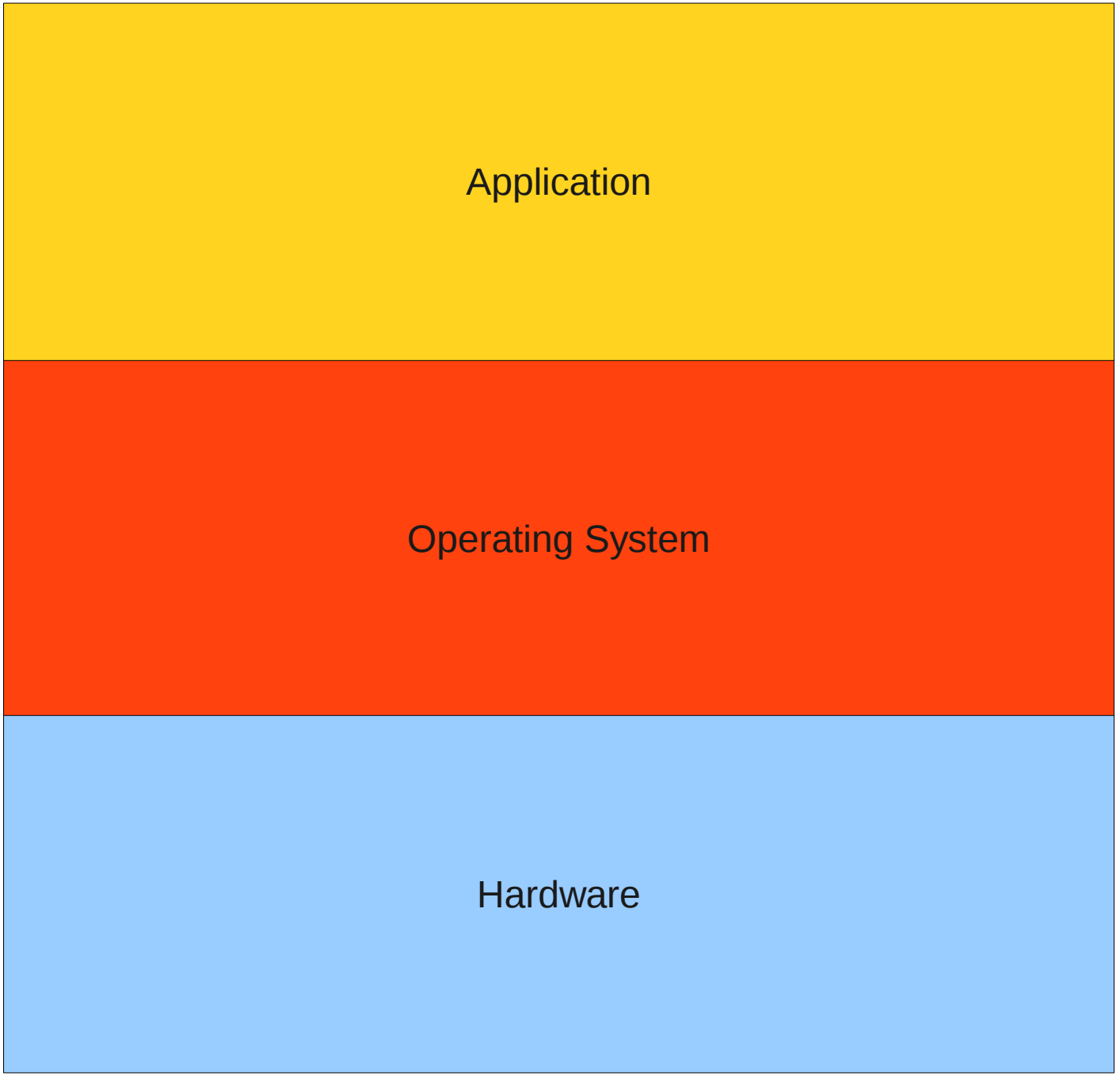
RT OS
and
RT Linux

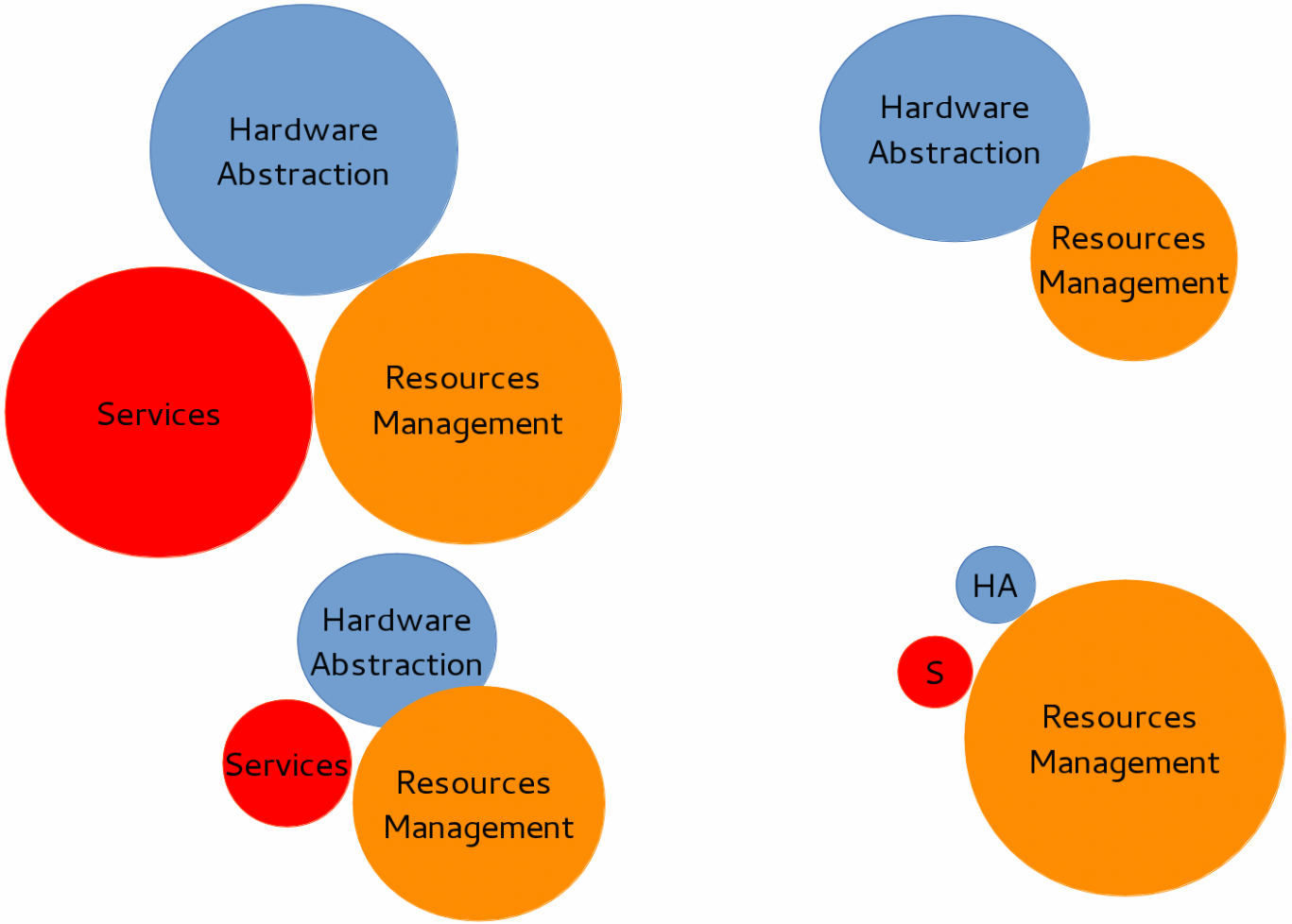
Daniel Bristot de Oliveira

Who I'm and what we will talk about?

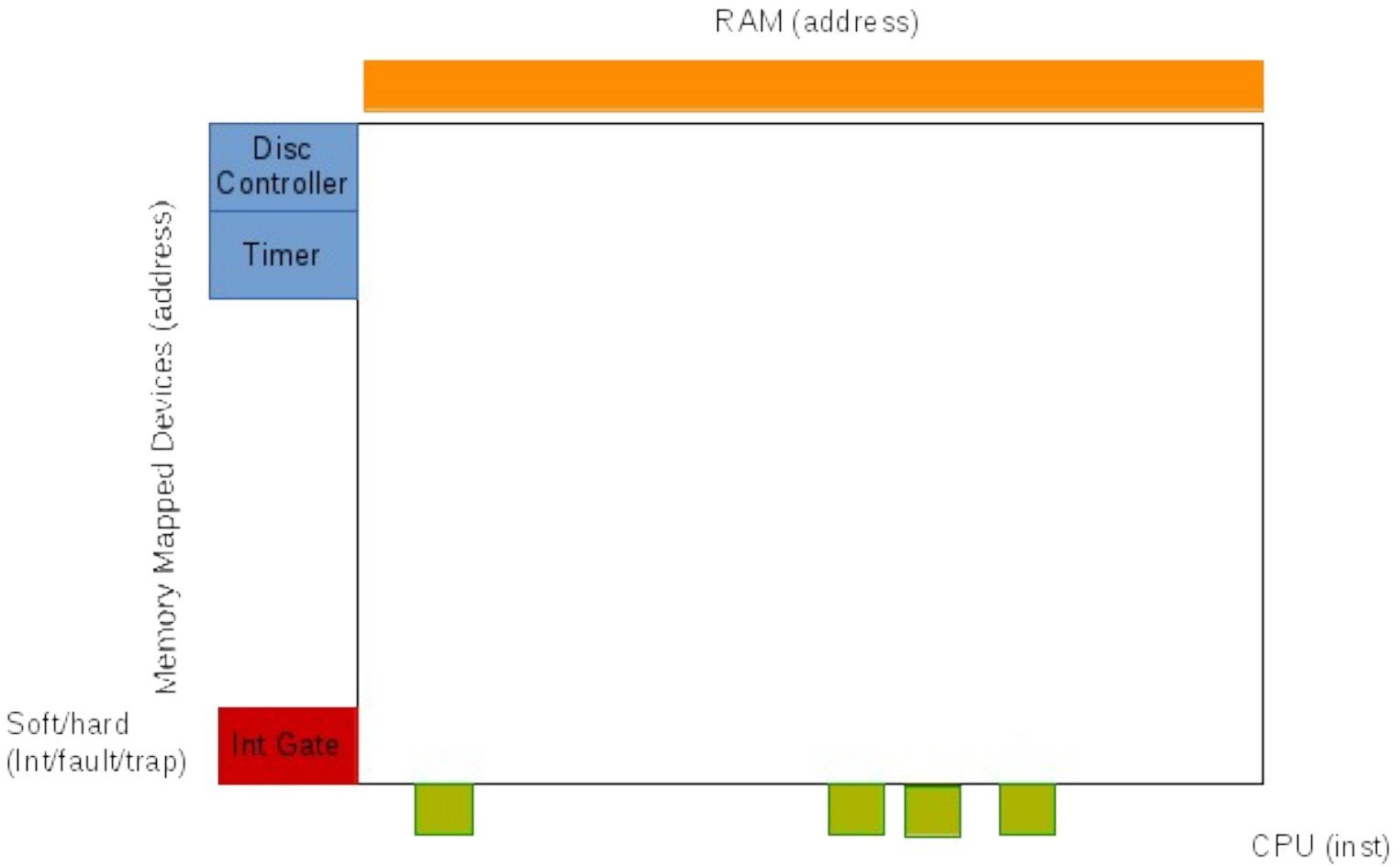
an Operating System overview


Application
Operating System
Hardware

Tasks of an OS

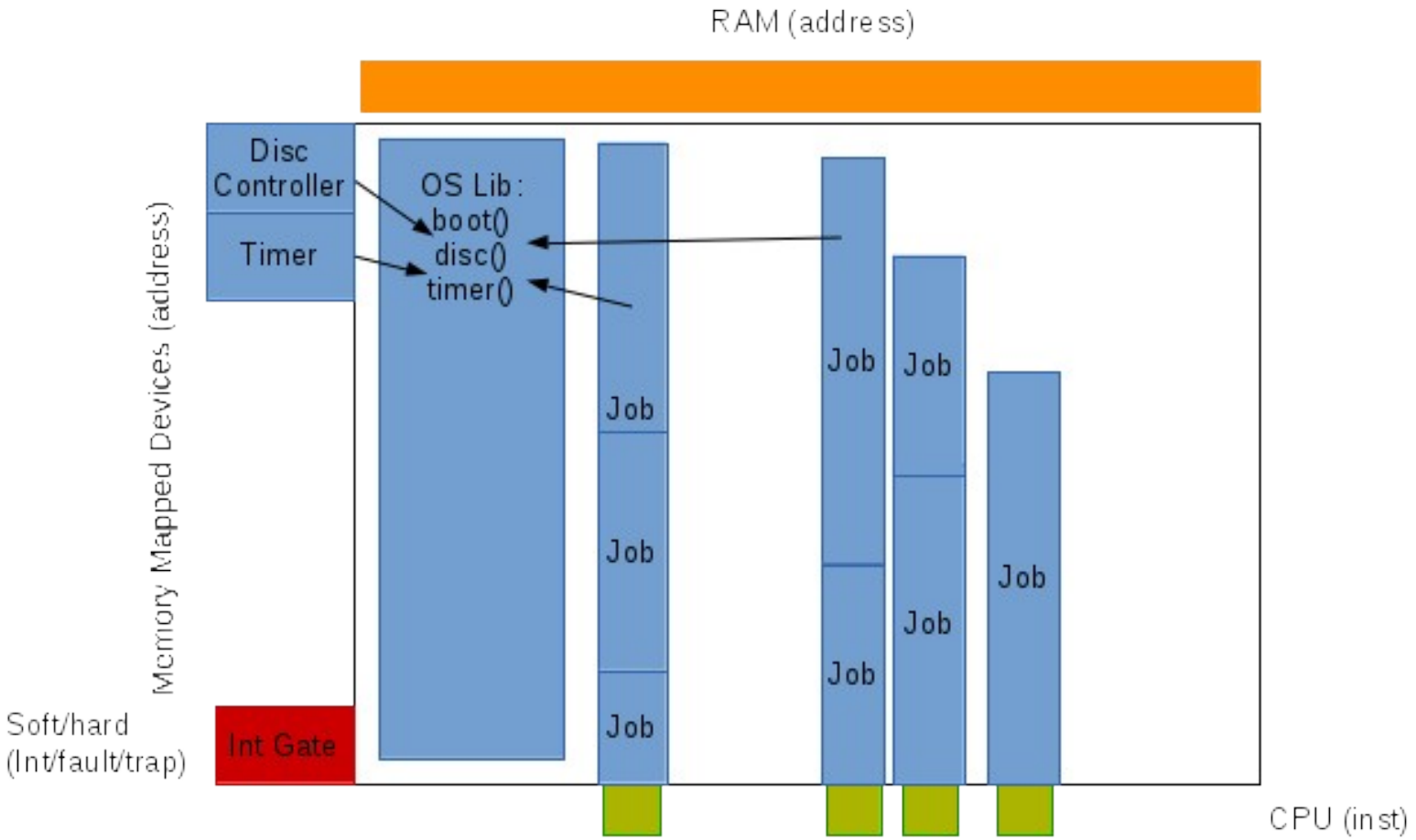


Hardware...

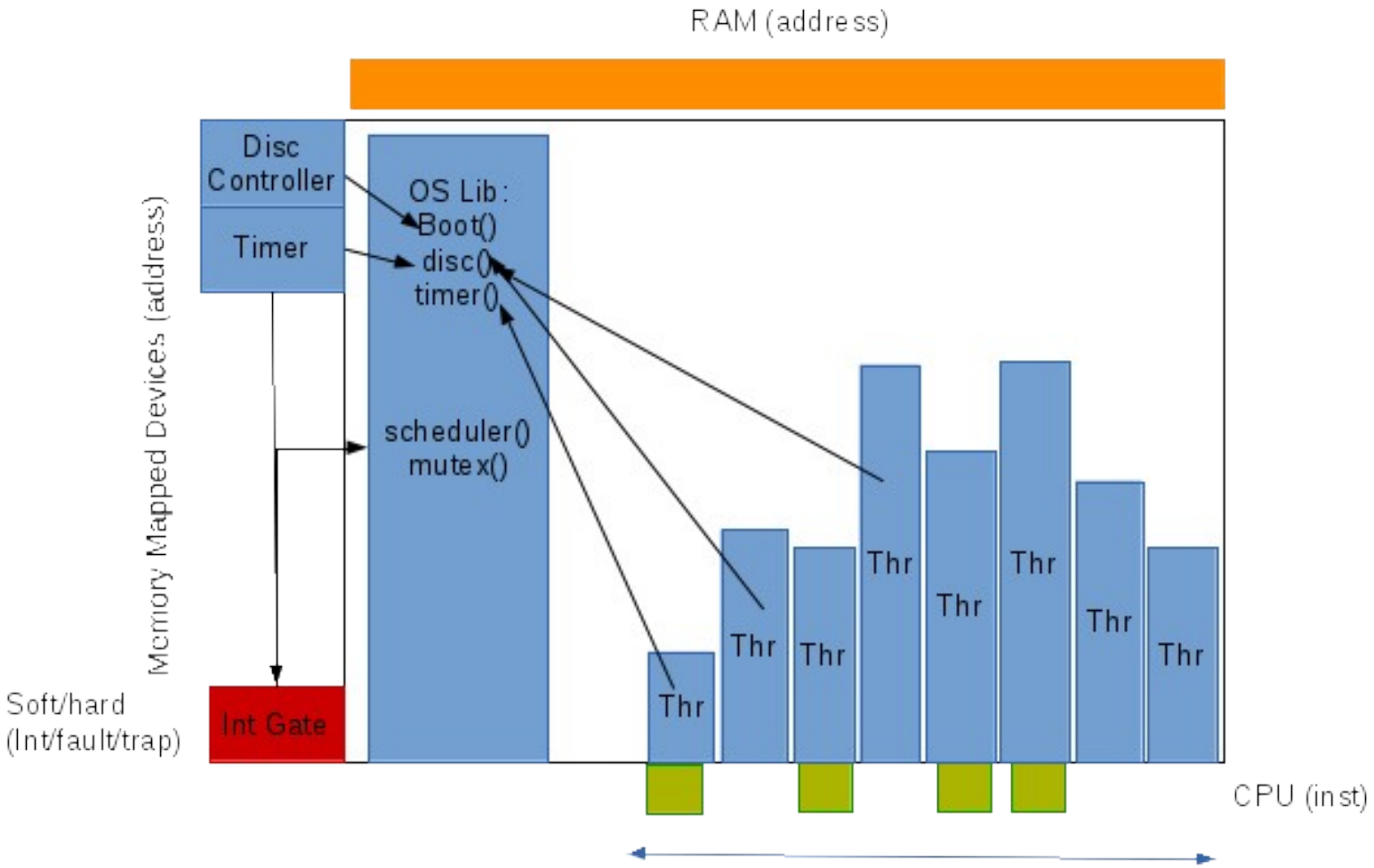

RAM (address)
Disc Controller
Timer
Memory Mapped Devices (address)
Soft/hard (Int/fault/trap)
Int Gate
CPU (inst)

Embedded system without OS

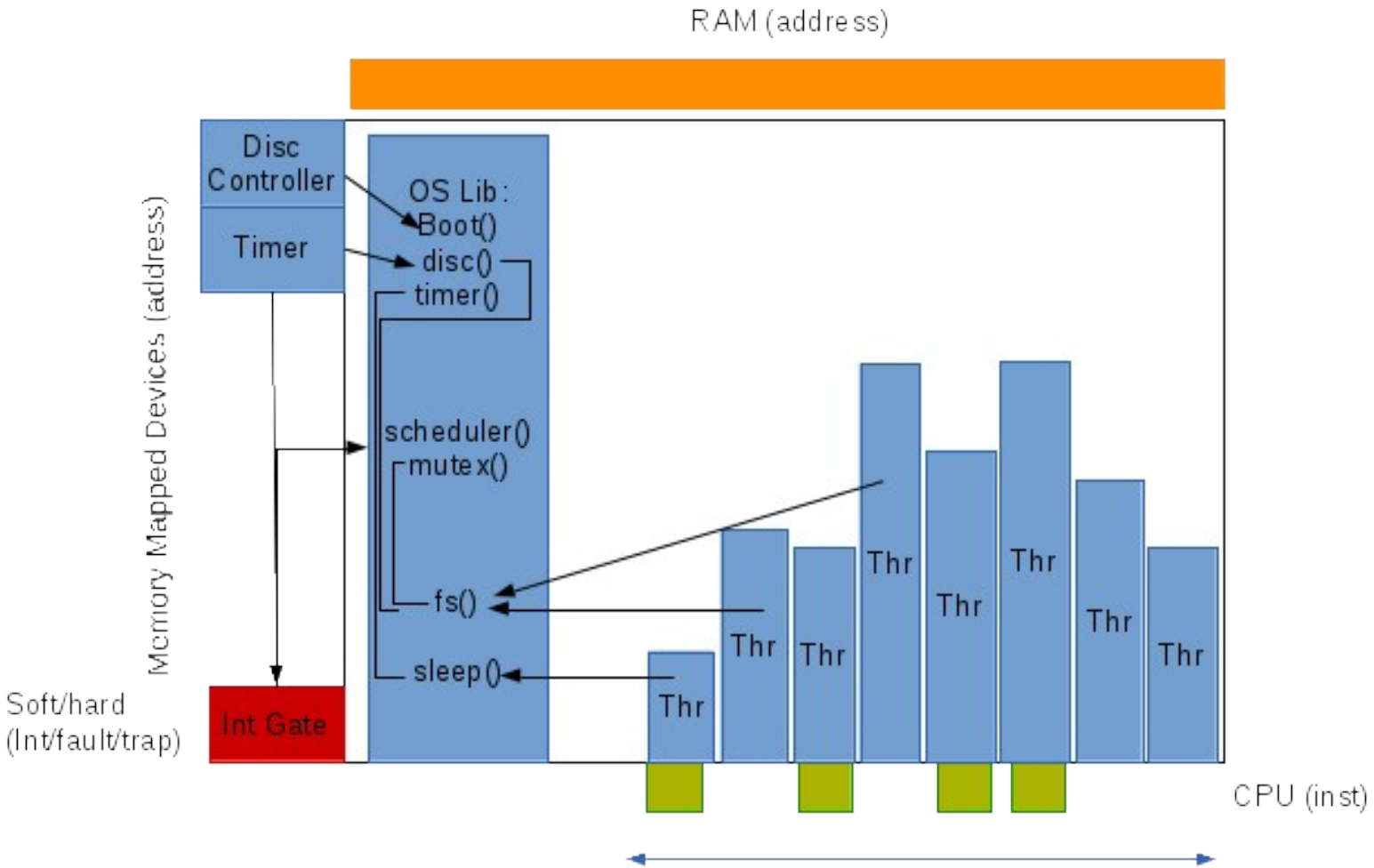
OS as a library



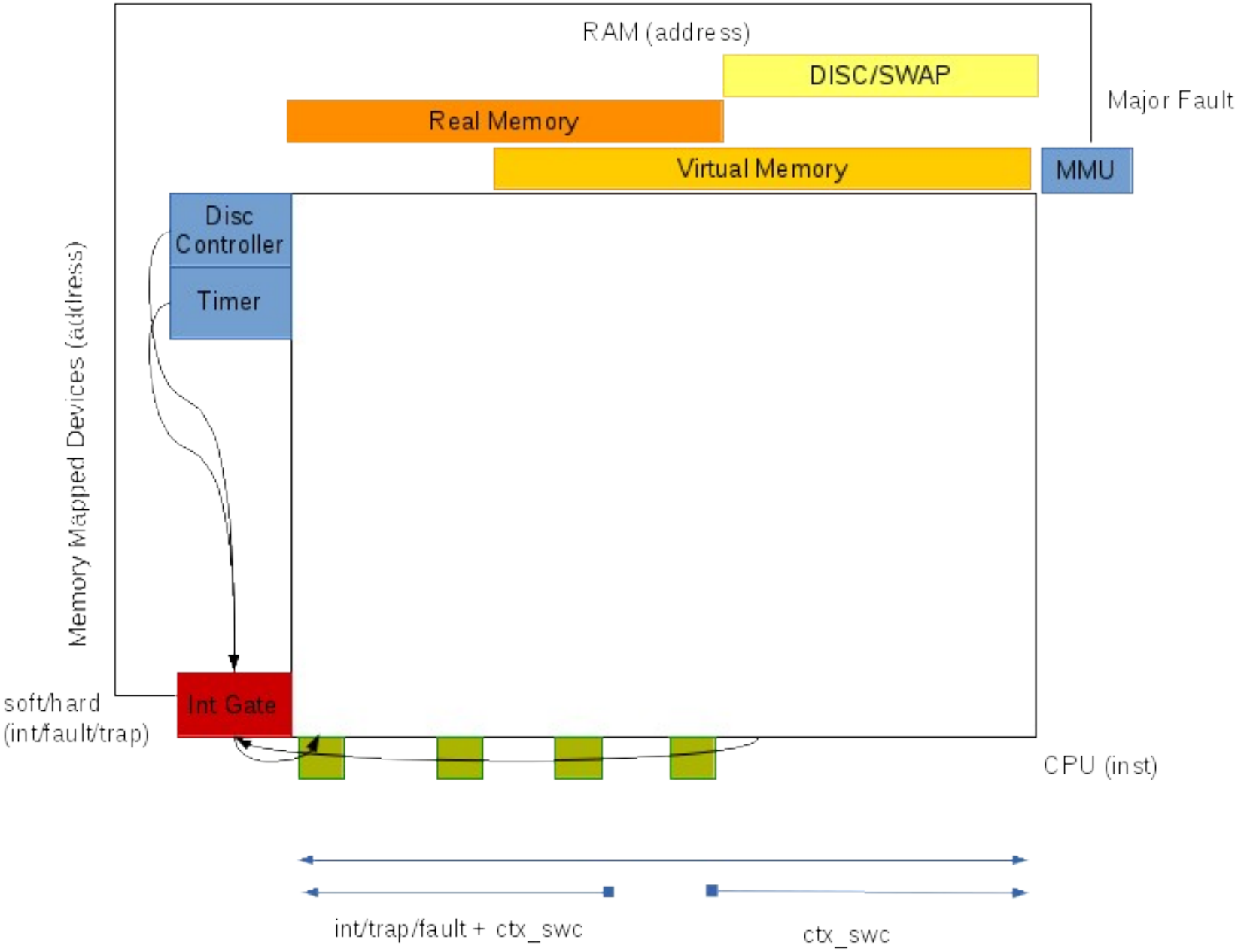
OS as a library



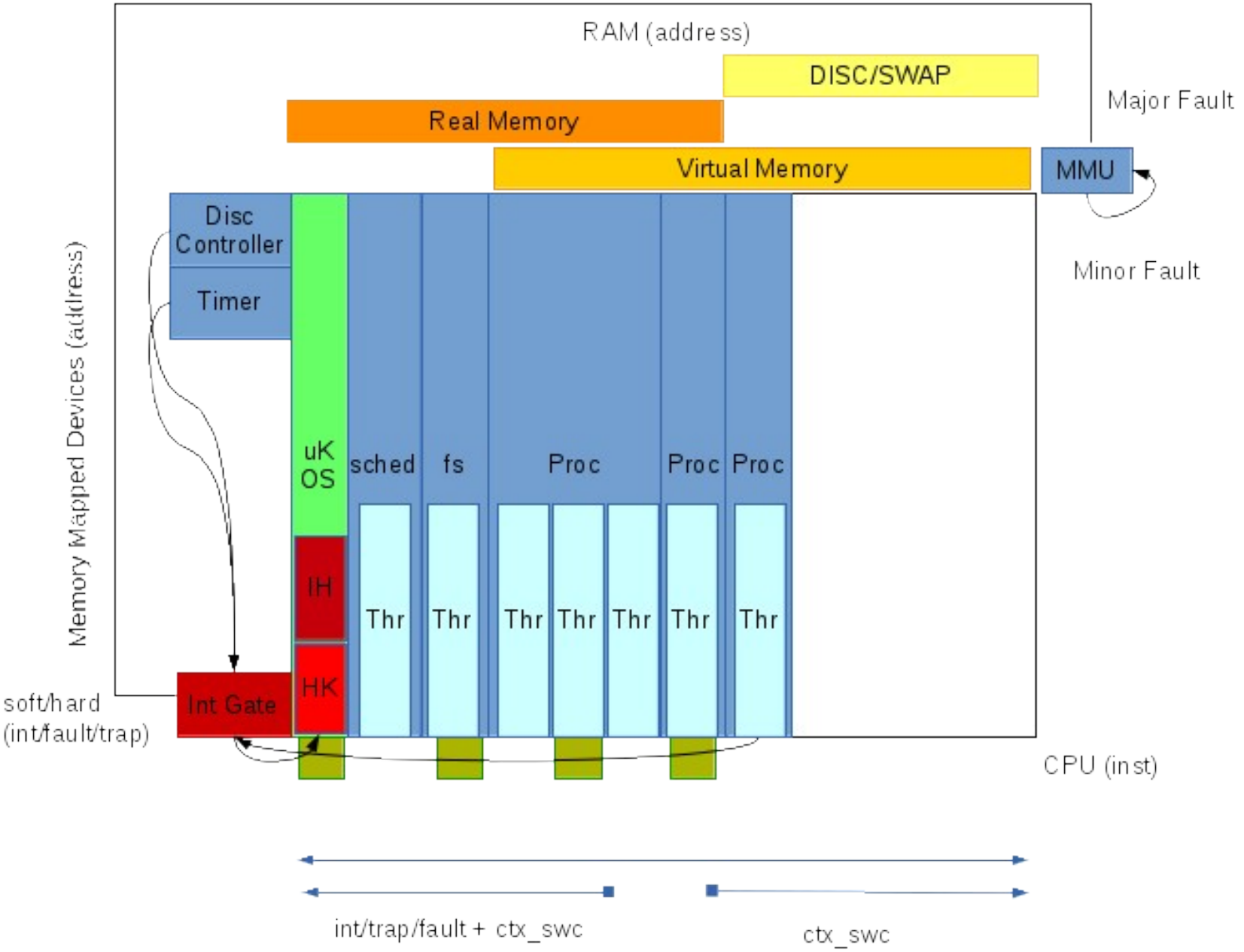
OS as a library



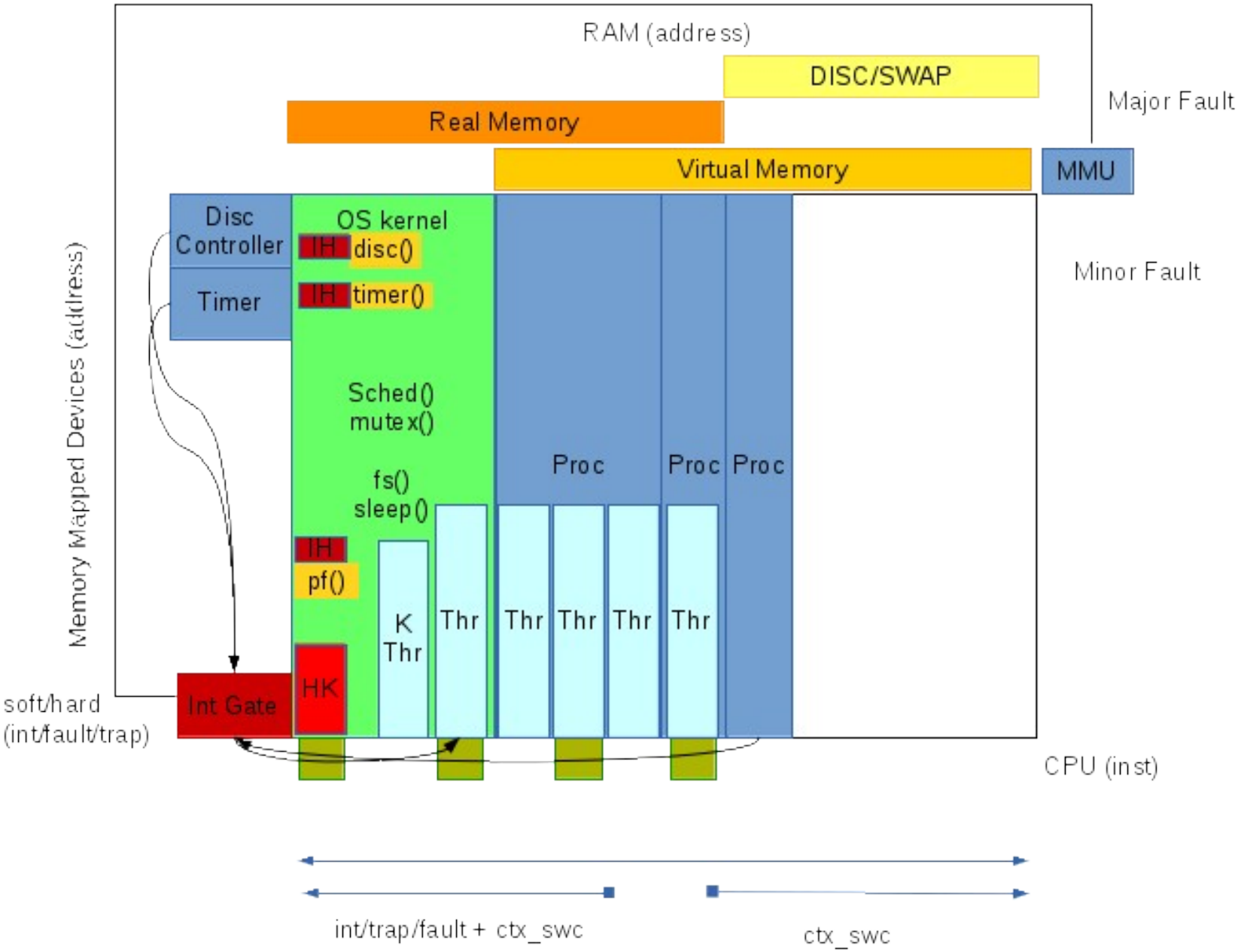
Memory Protection - MMU



OS with a Micro-Kernel



OS as we know


RAM (address)
DISC/SWAP
Major Fault
Real Memory
Virtual Memory
MMU
Disc Controller
Timer
OS kernel
IH disc()
IH timer()
Minor Fault
Memory Mapped Devices (address)
Sched()
mutex()
fs()
sleep()
Proc
Proc
Proc
IH
pf()
K Thr
Thr
Thr
Thr
Thr
Thr
HK
Int Gate
soft/hard
(int/fault/trap)
CPU (inst)
int/trap/fault + ctx_swc
ctx_swc

What does Real-Time means?

Event -> Response,

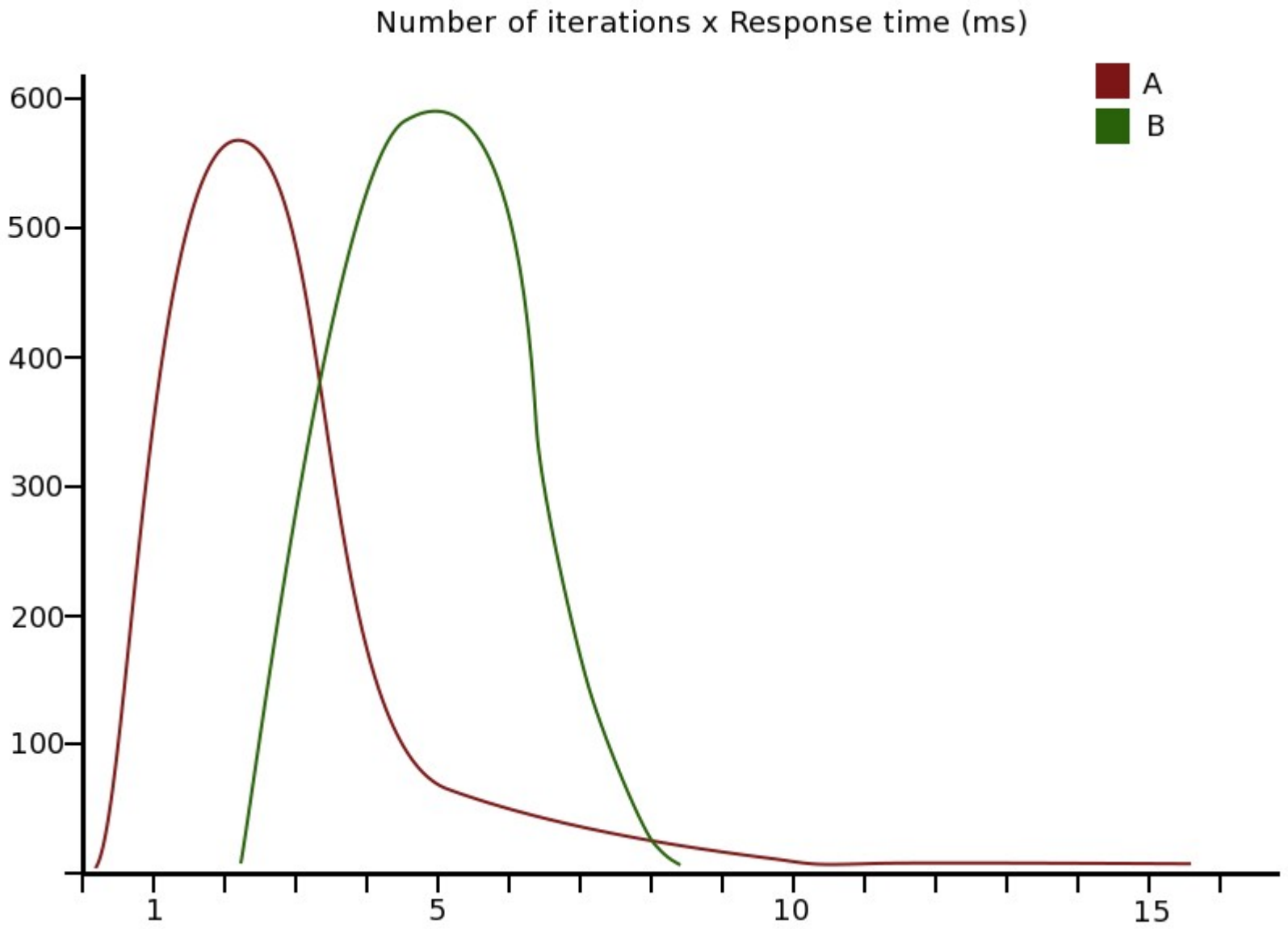
latency,

response time,

deadline...

Real-Time means fast?

Real Time != FAST!



RT means

Determinism,

WCET,

Response Time.

What is a Real-Time Operating System?

Deterministic hardware

+

Deterministic hardware abstraction

+

Services with WCET

+

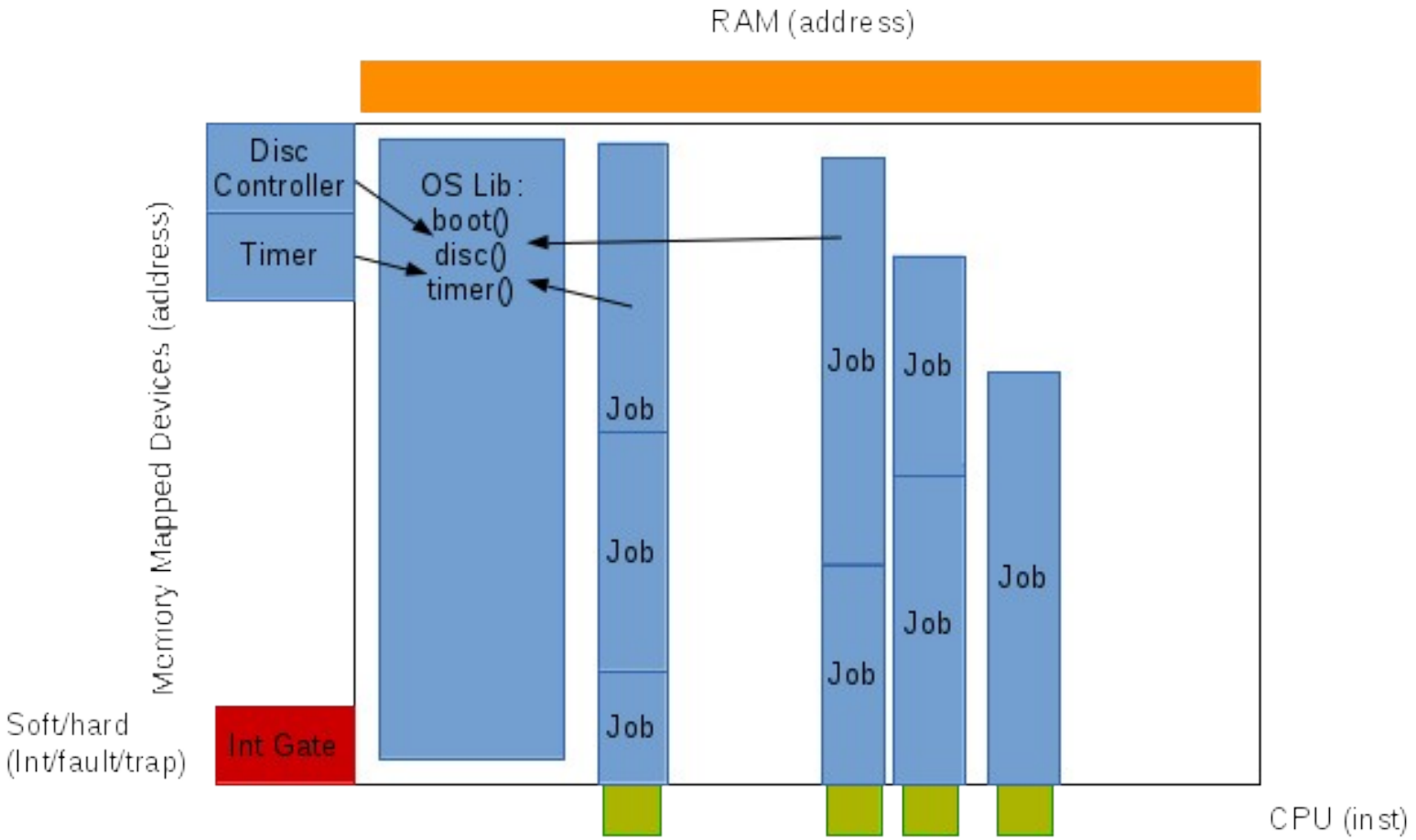
Deterministic Resource Management

=

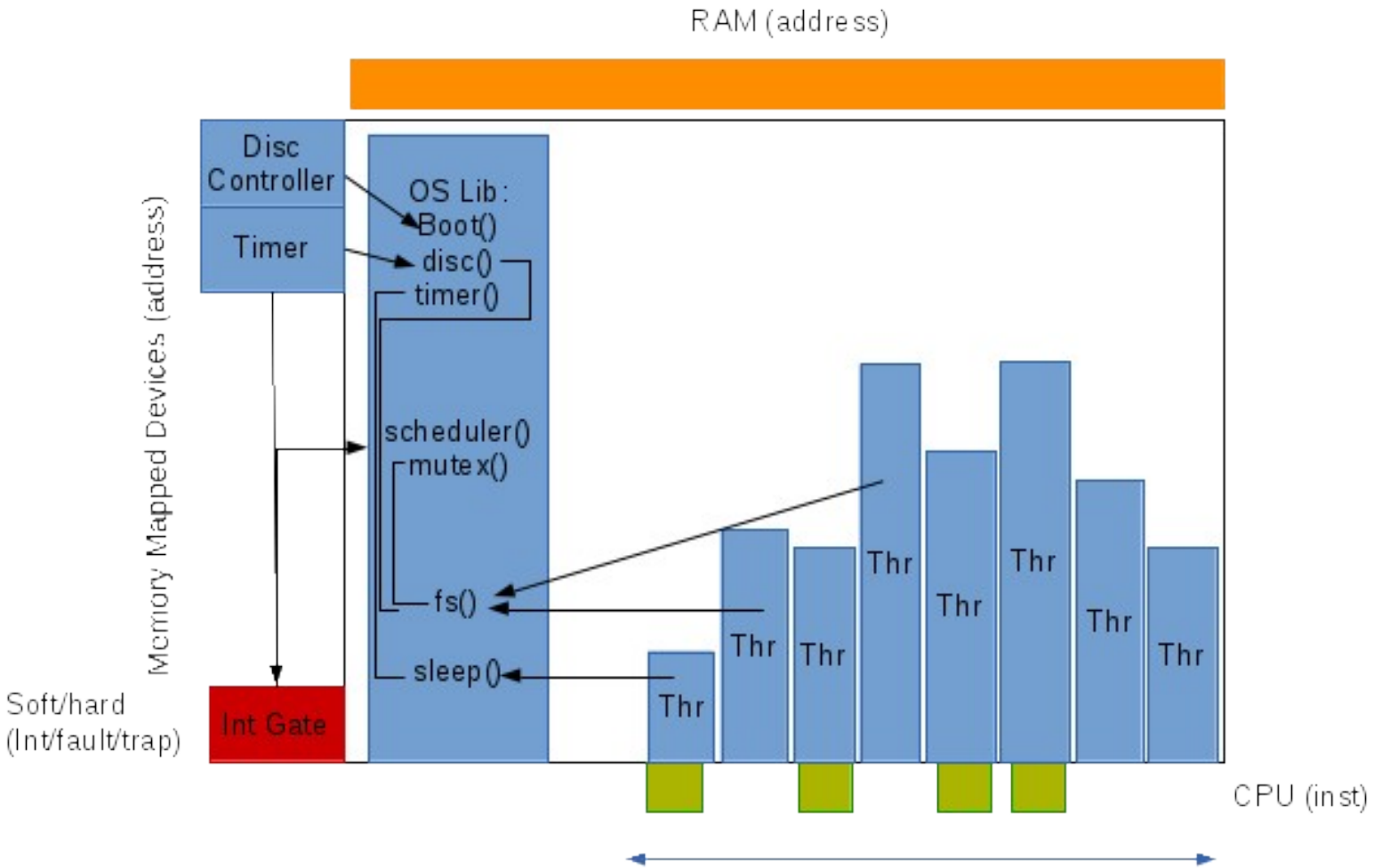
?

Real-Time Operating System Examples

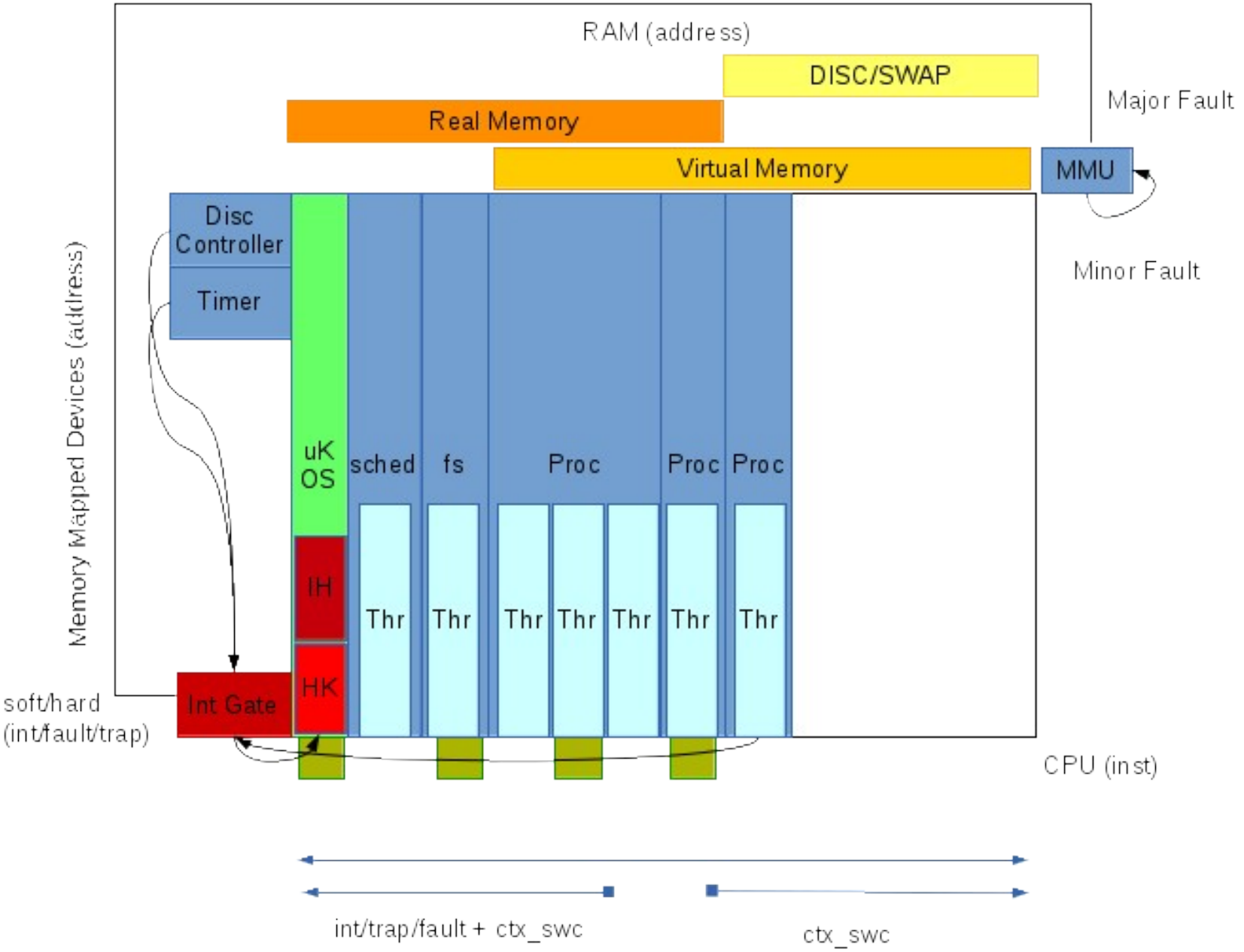
?


RAM (address)
Disc Controller
Timer
OS Lib:
boot()
disc()
timer()
Job
Job
Job
Job
Job
Job
Job
Job
Memory Mapped Devices (address)
Soft/hard
(Int/fault/trap)
Int Gate
CPU (inst)

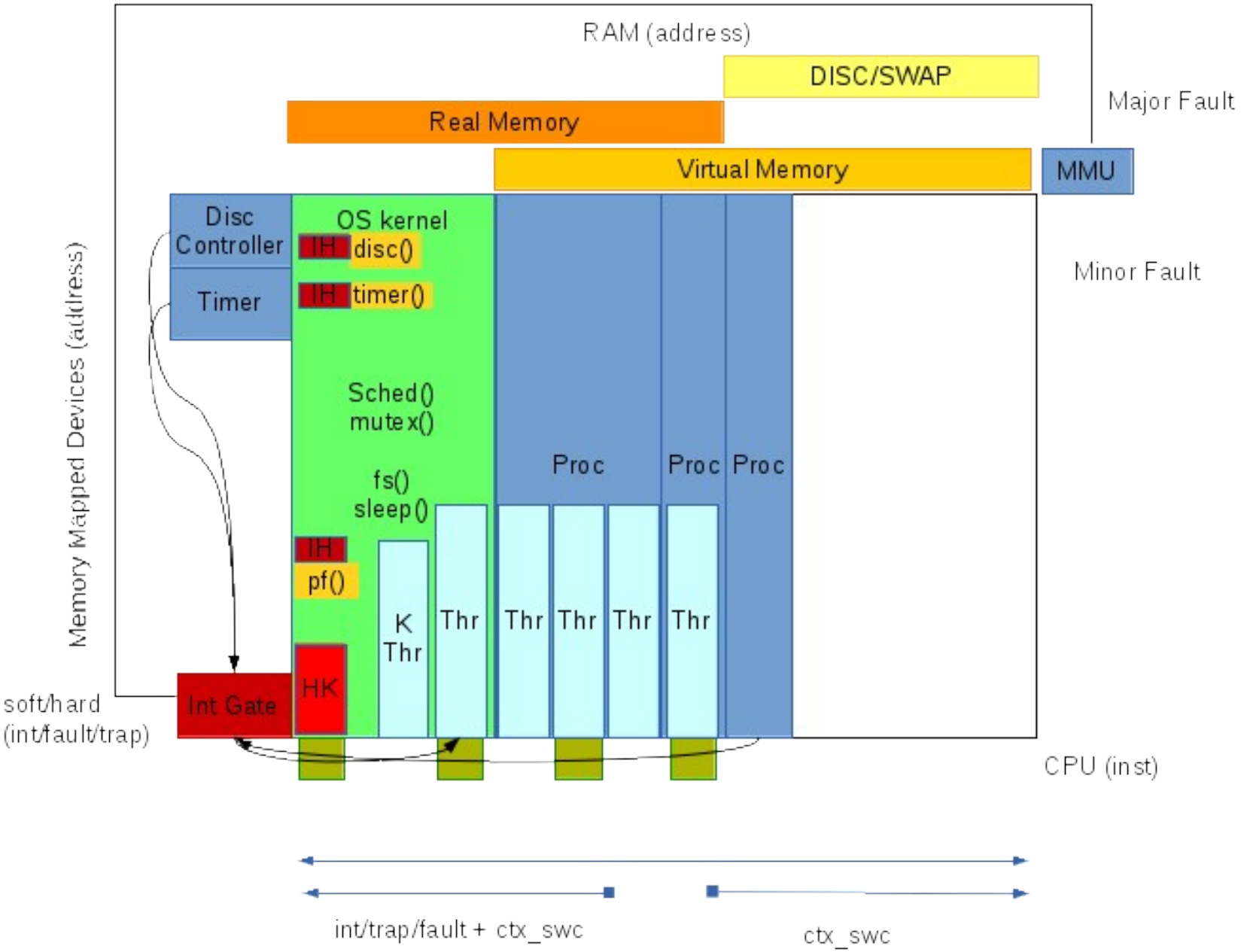
FreeRTOS


RAM (address)
Disc Controller
Timer
OS Lib:
Boot()
disc()
timer()
scheduler()
mutex()
fs()
sleep()
Memory Mapped Devices (address)
Soft/hard
(Int/fault/trap)
Int Gate
Thr
CPU (inst)

Neutrino (QNX)



Linux ?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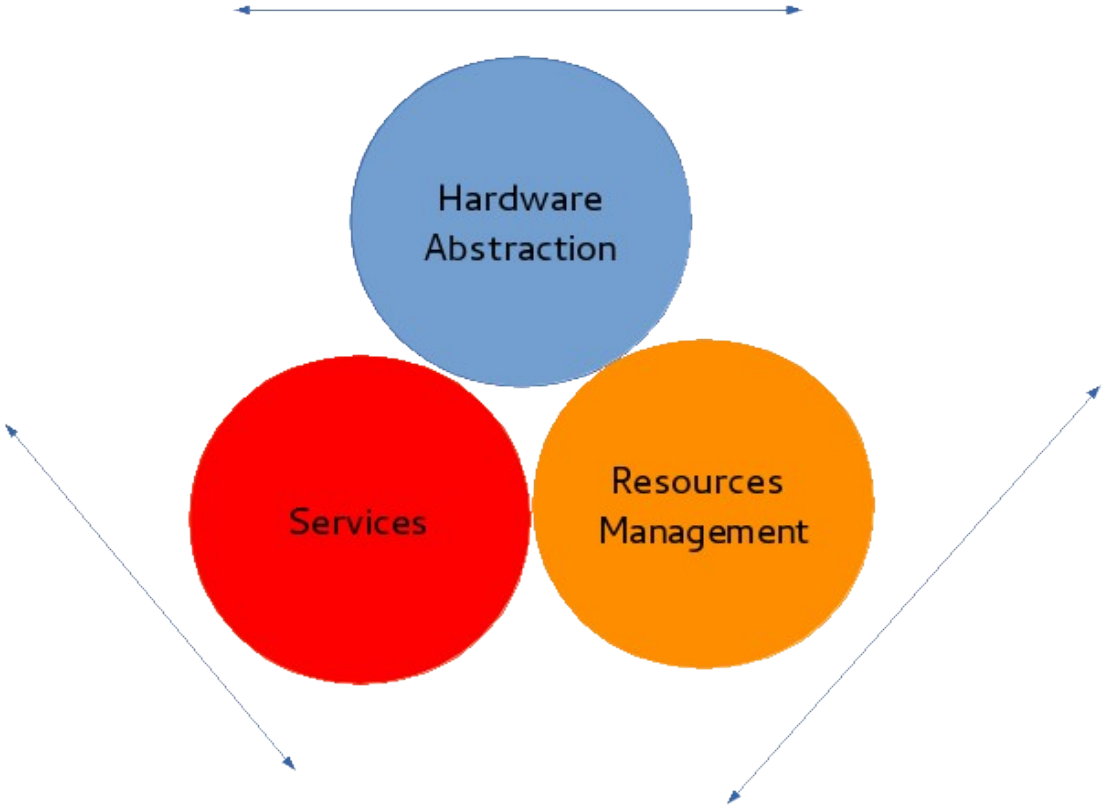
Thr
Thr
Thr
Thr
Thr
Thr
HK
Int Gate
soft/hard
(int/fault/trap)
CPU (inst)
int/trap/fault + ctx_swc
ctx_swc

Why is Linux not a RTOS?

Linux is too much flexible



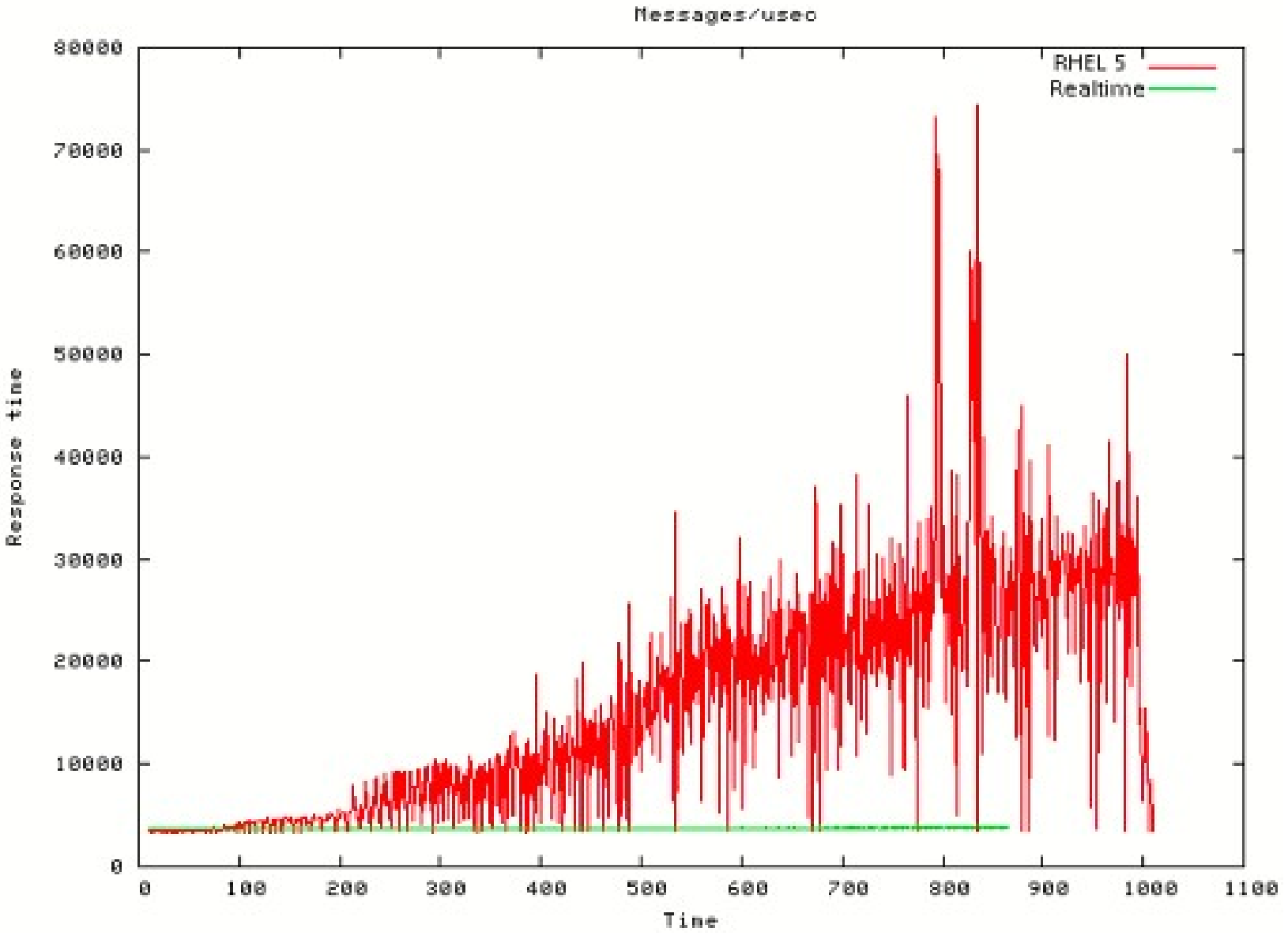
General Purpose OS

- Linux not is a RTOS by conception
- Higher throughput rather than higher determinism.
  - High latency.
- But has:
  - Static priority sched: FIFO and RR

Linux as a RTOS?

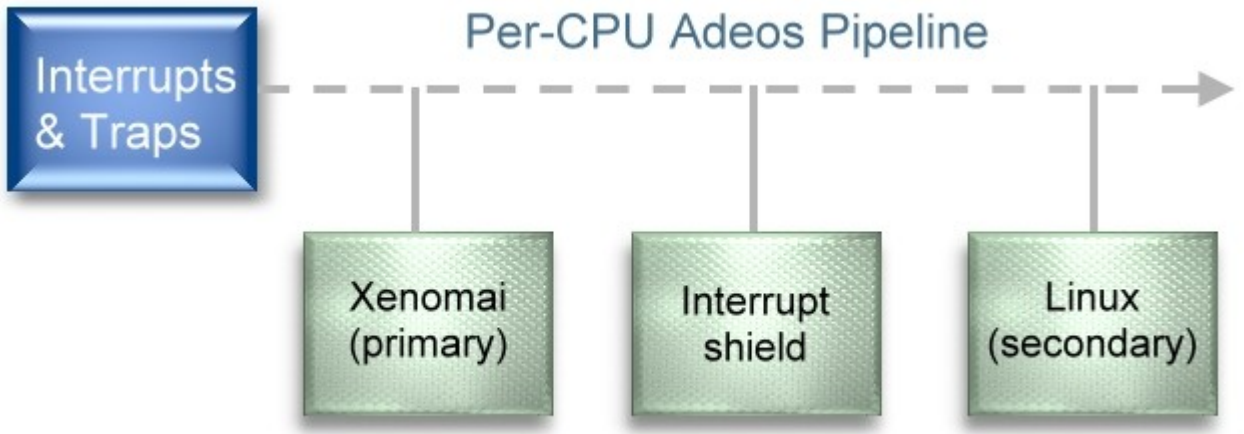
- Why?
- Hardware support
  - ARM, MIPS, POWERPC, intel, TILE 64, ADBF...
- Services
  - FS, Network Stack...
- Money
  - Rich company X needs a low latency Oracle database.

How Red Hat shows your Real-Time Linux



Real-Time Linux: Past, Present, Possible Futures...

RTAI and Xenomai


Per-CPU Adeos Pipeline
Interrupts & Traps
Xenomai (primary)
Interrupt shield
Linux (secondary)

RT Task on Xenomai

+

Non-RT on Linux...

=

):) <- this is a bipolar emoticon

PREEMPT-RT

- latency
+ control over OS tasks

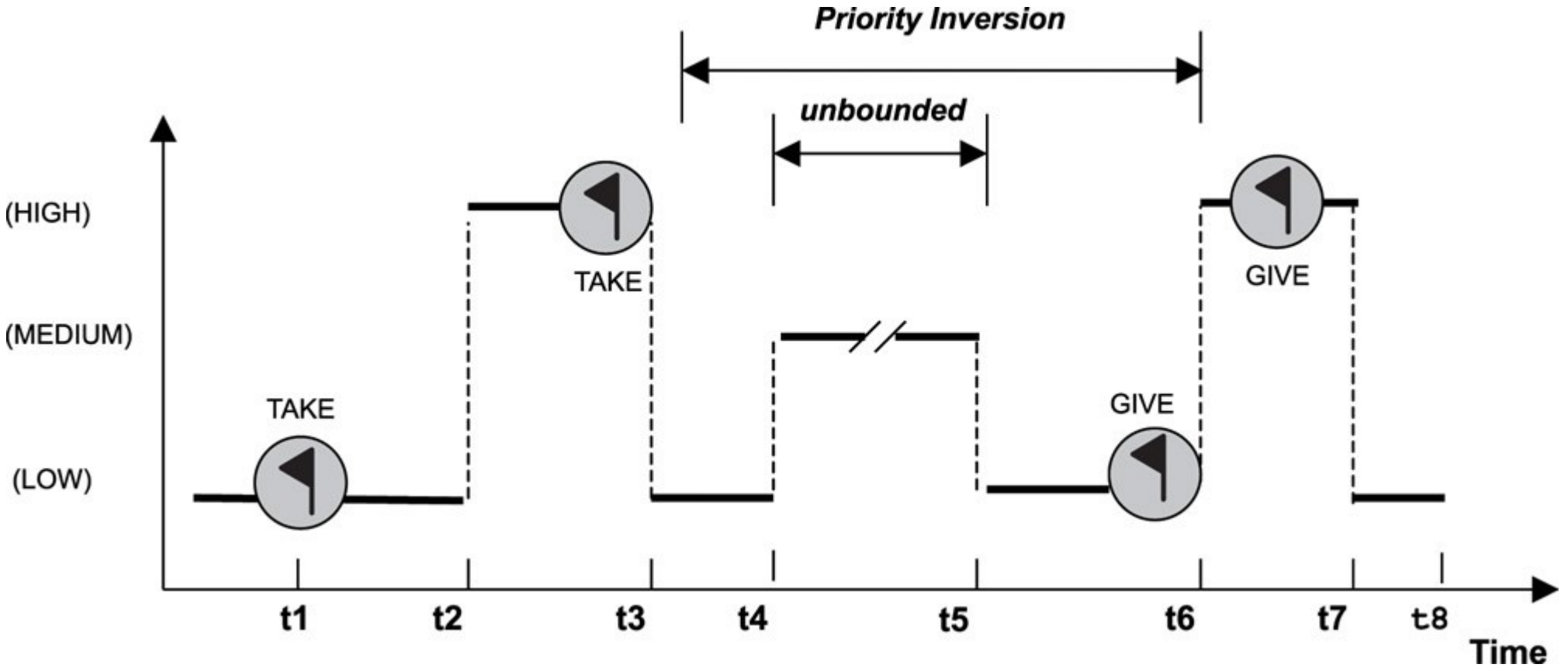
Sources of latency

- IRQ Handling
  - Softirq
- Preempt off
  - spinlocks
- IRQ off

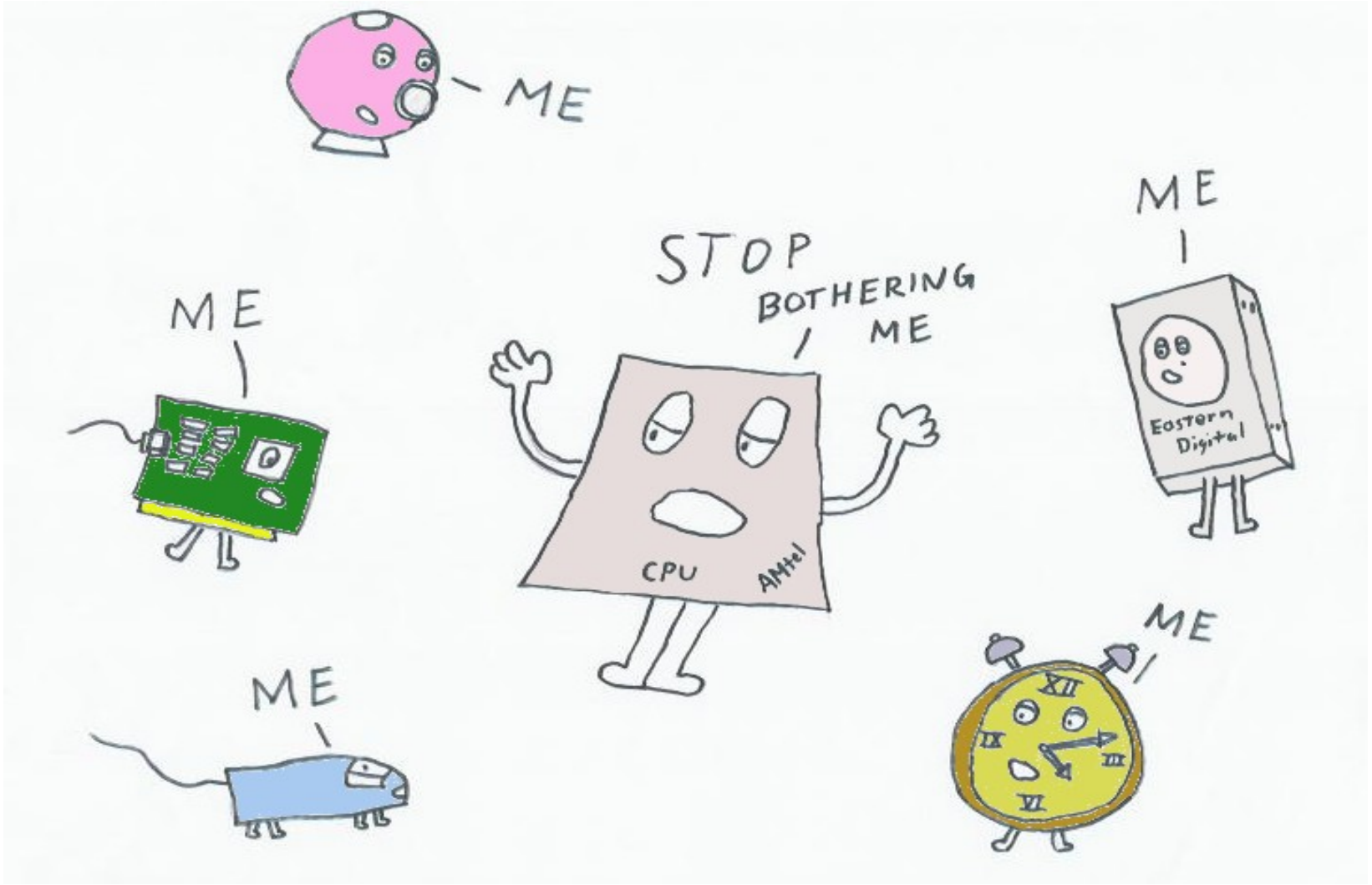
Preemptive lock

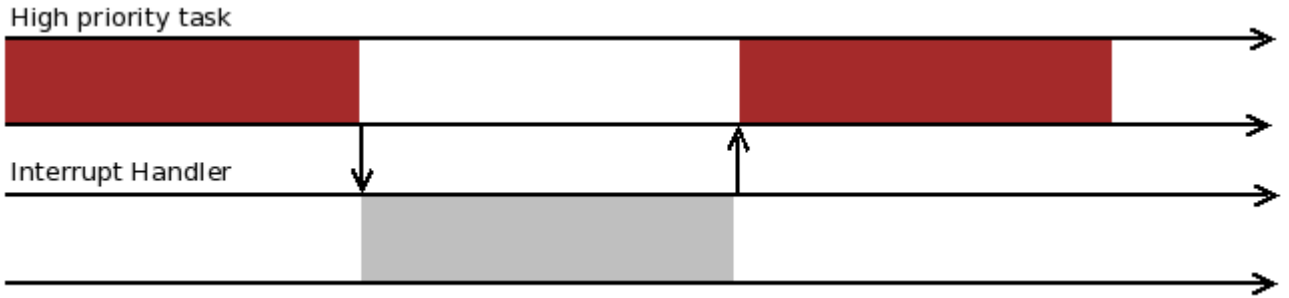
Priority inversion

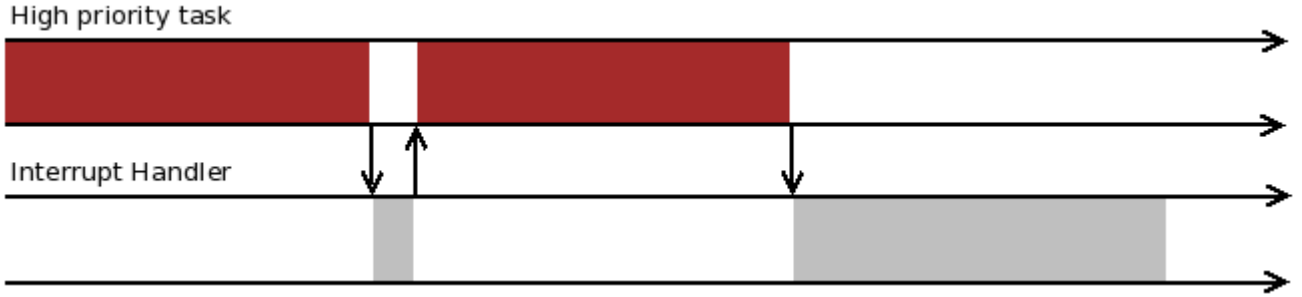
problems...

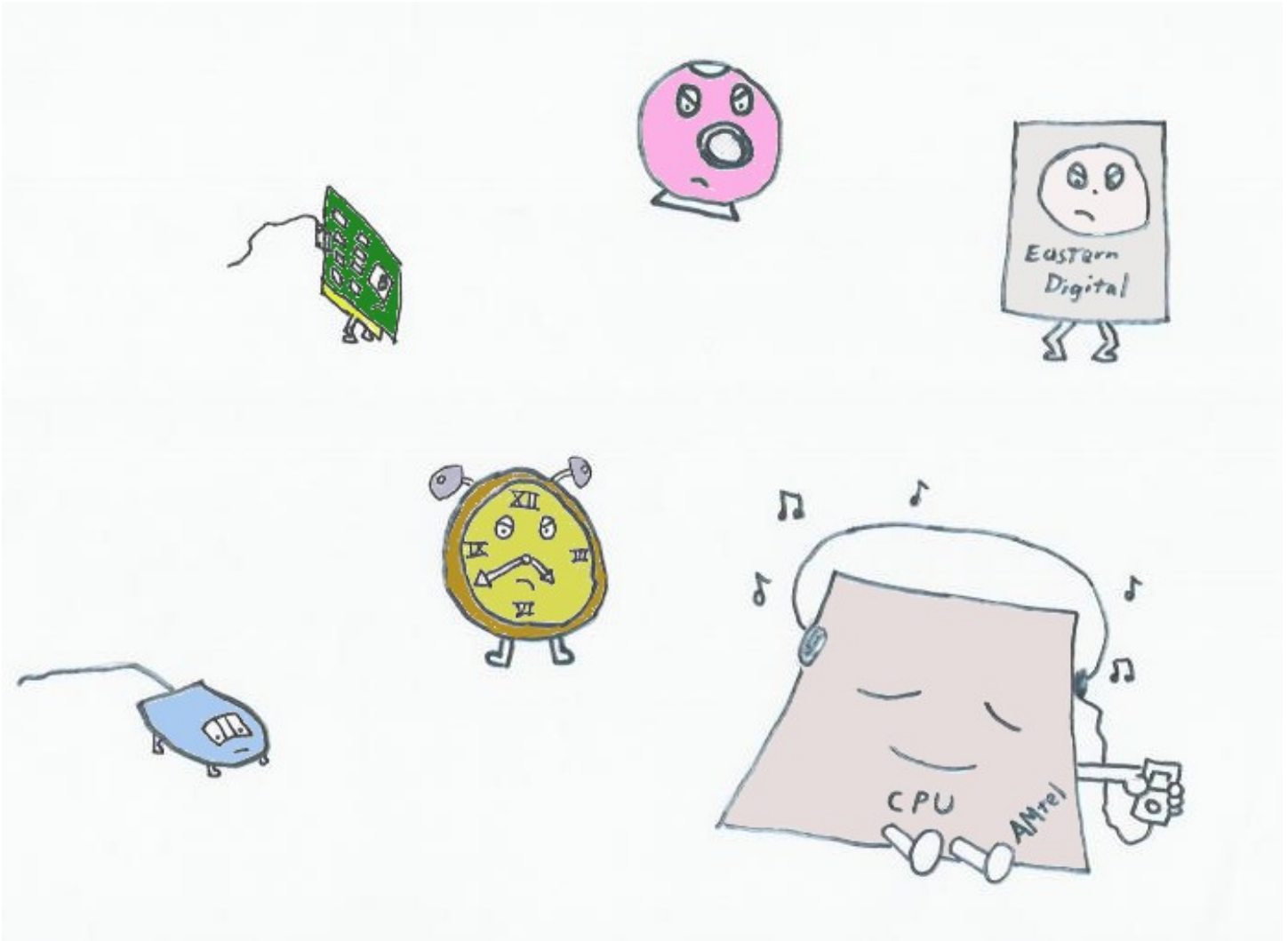

Priority Inversion
unbounded
(HIGH)
(MEDIUM)
(LOW)
TAKE
TAKE
GIVE
GIVE
t1
t2
t3
t4
t5
t6
t7
t8
Time

IRQ Handling

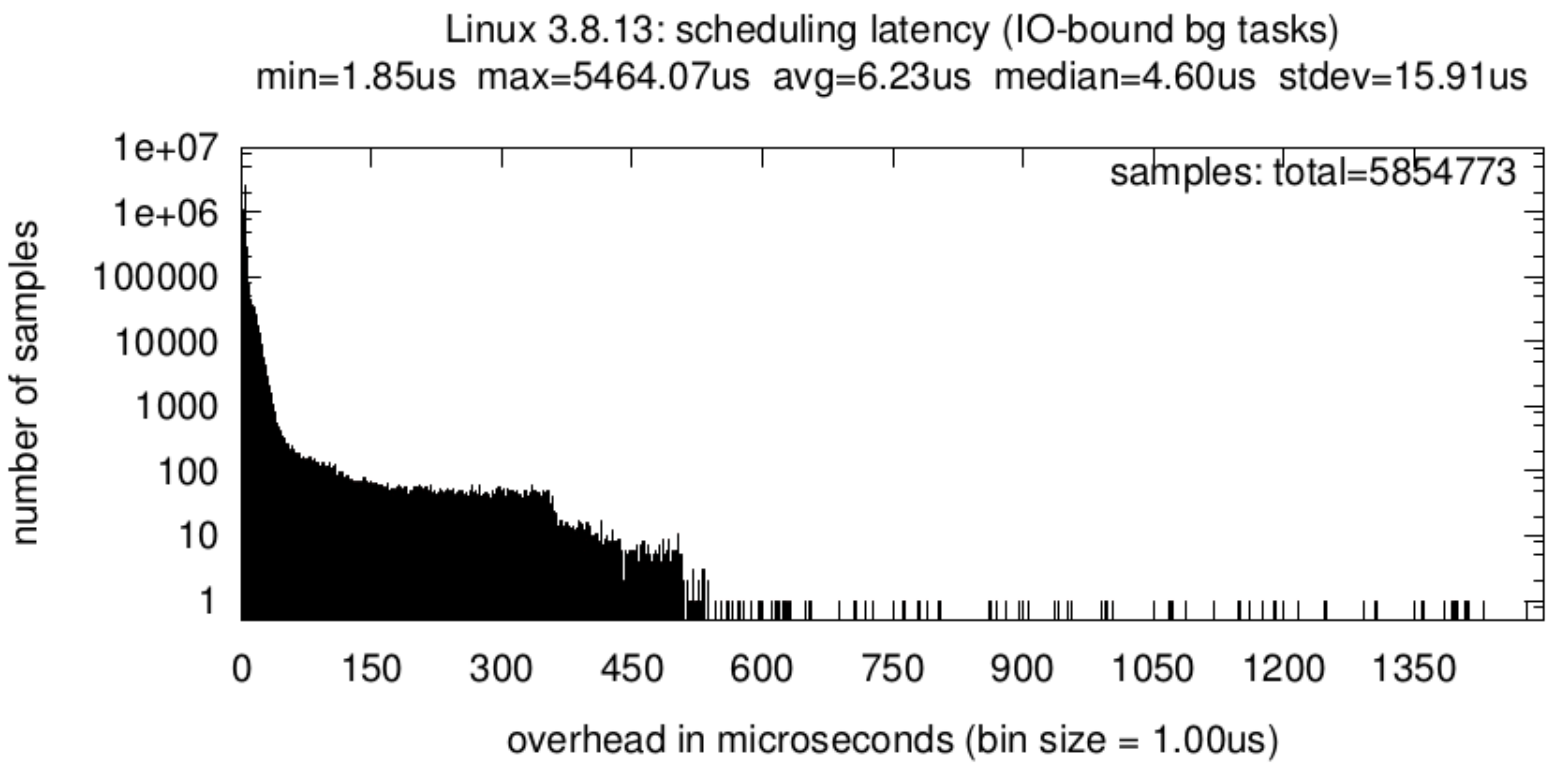

ME
ME
STOP
BOTHERING
ME
ME
CPU
AMtel
Eastern
Digital
ME
ME

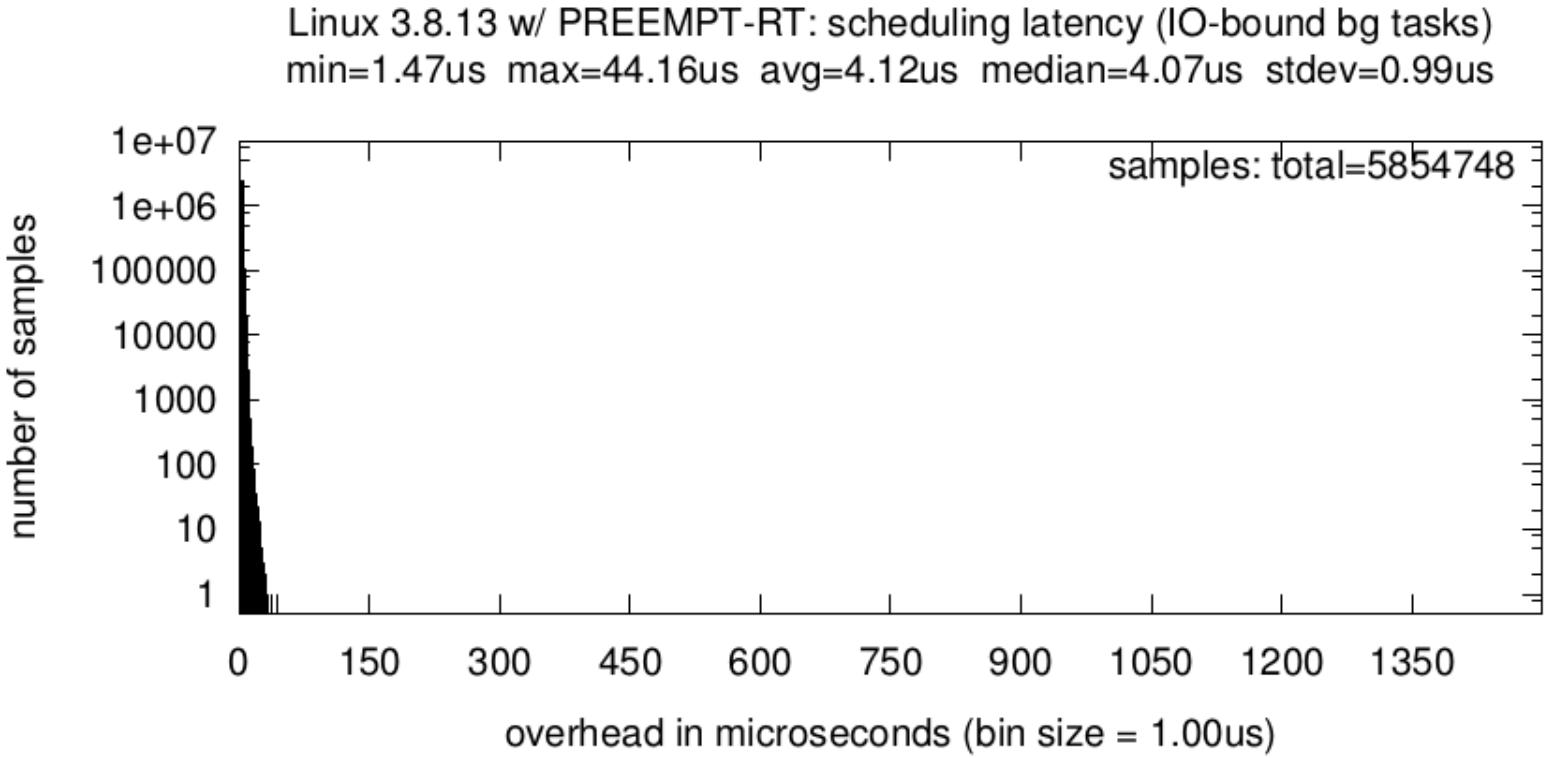

High priority task
Interrupt Handler


High priority task
Interrupt Handler


Eastern
Digital
CPU
Intel

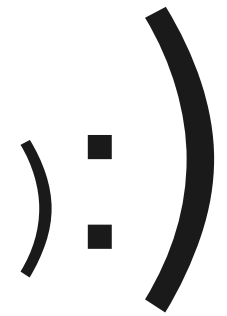
How good is PREEMPT_RT Today?


Linux 3.8.13: scheduling latency (IO-bound bg tasks)
min=1.85us max=5464.07us avg=6.23us median=4.60us stdev=15.91us
samples: total=5854773
number of samples
1e+07
1e+06
100000
10000
1000
100
10
1
0
150
300
450
600
750
900
1050
1200
1350
overhead in microseconds (bin size = 1.00us)


Linux 3.8.13 w/ PREEMPT-RT: scheduling latency (IO-bound bg tasks)
min=1.47us max=44.16us avg=4.12us median=4.07us stdev=0.99us
samples: total=5854748
number of samples
1e+07
1e+06
100000
10000
1000
100
10
1
0
150
300
450
600
750
900
1050
1200
1350
overhead in microseconds (bin size = 1.00us)

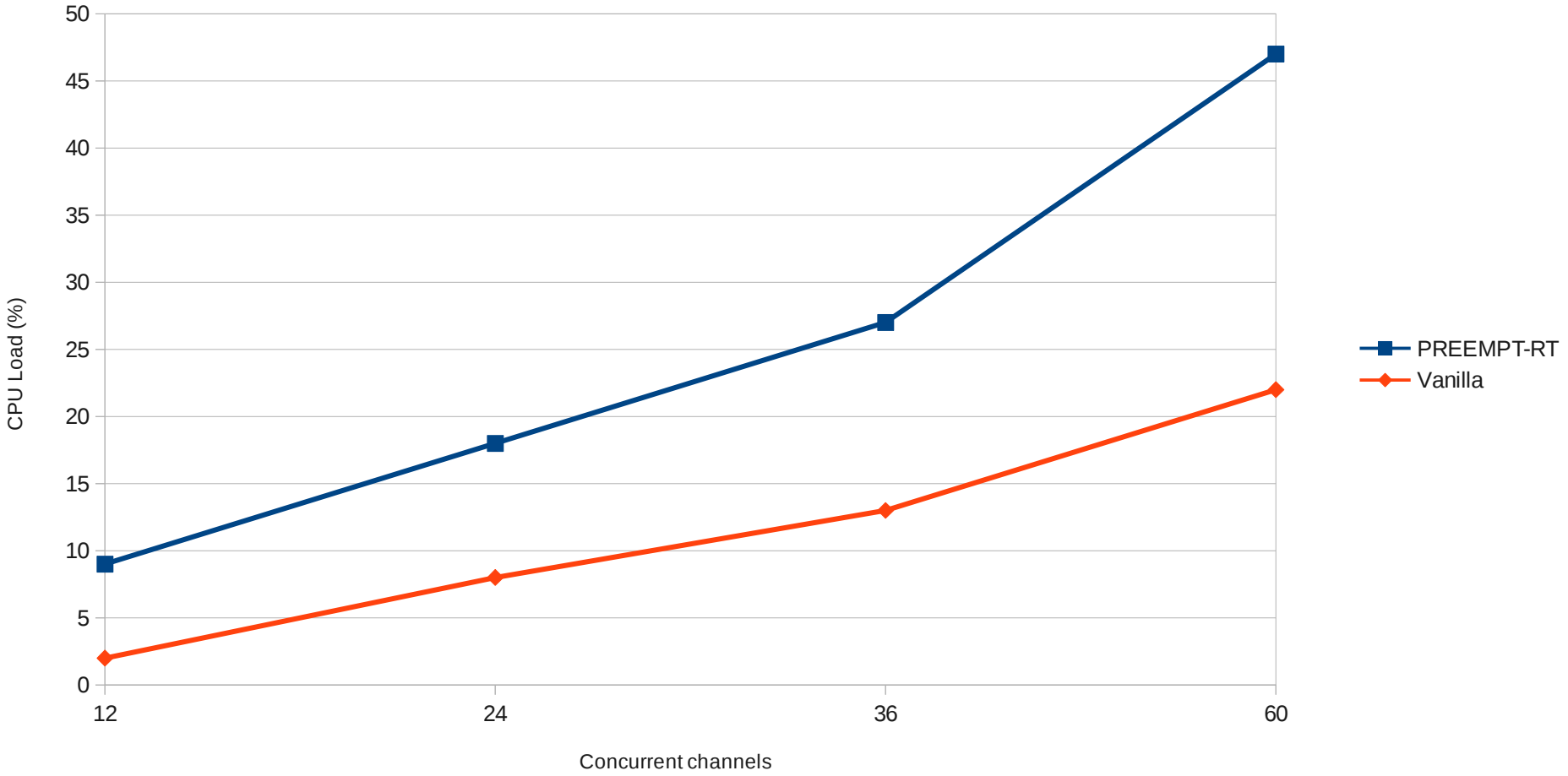
PREMPT-RT is WONDERFULL!

Let's use everywhere!!!



This is another bipolar emoticon, but more happy than another...

How expensive is PREEMP-RT?


50
45
40
35
30
25
20
15
10
5
0
CPU Load (%)
12
24
36
60
Concurrent channels
PREEMPT-RT
Vanilla

LITMUS^{RT}

A testbed for multiprocessor scheduling in Real-Time Systems

(Partitioned|Global|Clustered) EDF

Partitioned Fixed-Priority

PD2 (PFAIR)

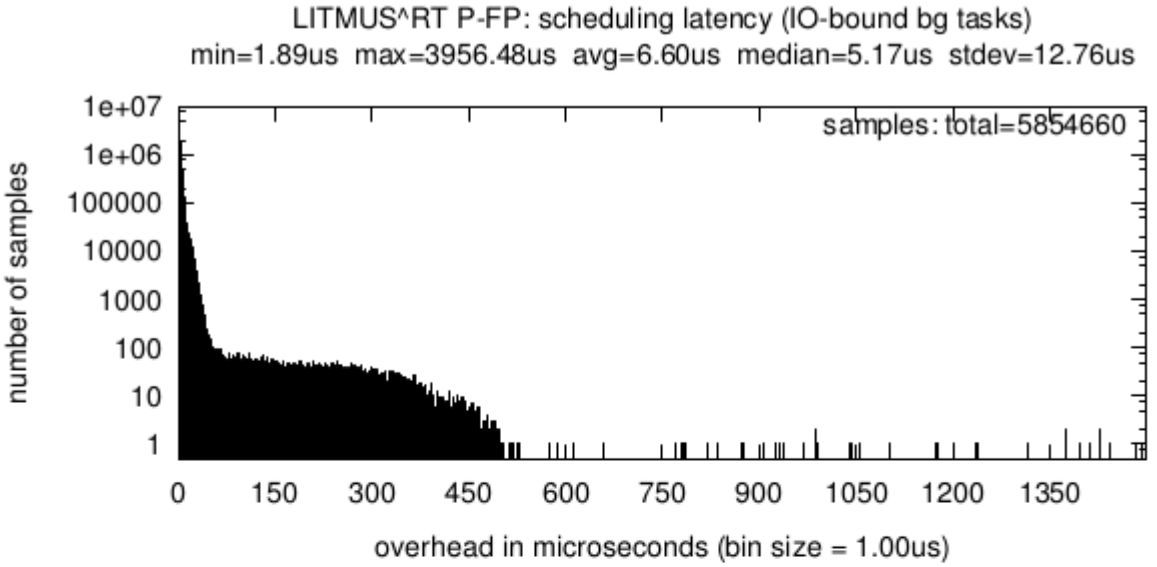
Mutual Exclusion

Interrupt Handling

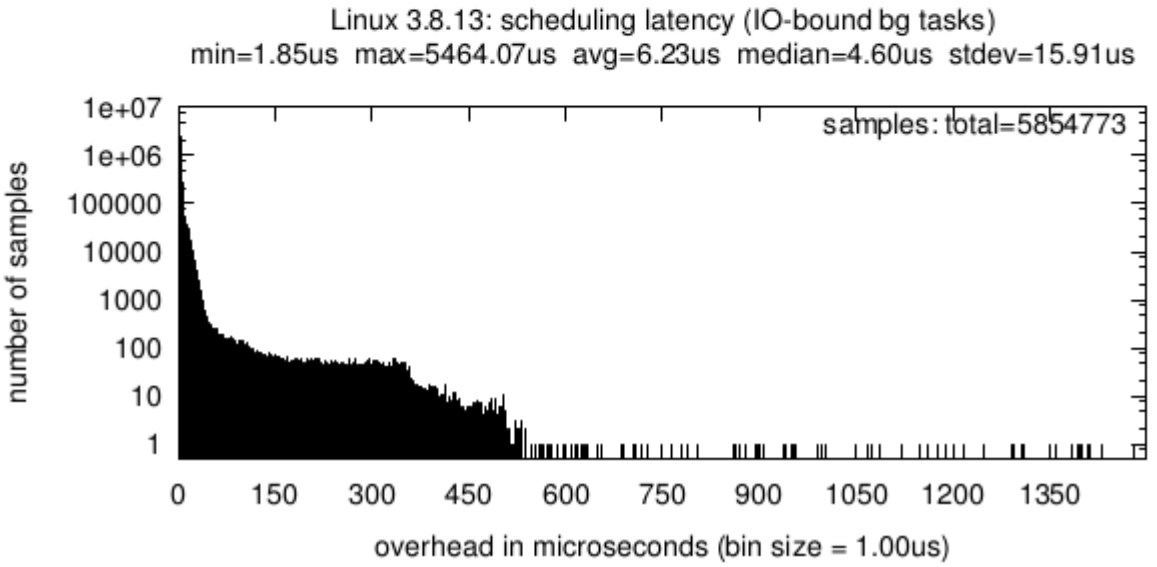
Real-Time GPU Management

Tracing Tools

How good is Litmus RT?



(a) LITMUS$^{\mathrm{RT}}$ with the P-FP scheduler plugin



Litmus RT

=

a way to pick next task

with a RT API.

A little bit of my MS Degree dissertation...

Questions?