SCHED_DEADLINE desiderata

... and slightly crazy ideas

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Cisco audio-group developer says 'it made the whole "look at all the tasks and make sure no-one is killing audio" a lot easier'

Topics

- Non-root usage
- Better Priority Inheritance (AKA proxy execution)
- Cgroups support
- Re-working RT Throttling to use DL servers
- Schedulability improvements
- Better support for tracing

Non-root usage

Non-root usage

To: linux-rt-users@xxxxxxxxxxxxxxx

Subject: SCHED_DEADLINE as user

From: <xxxxxxxxxxxxxxx>

Date: Wed, 15 Aug 2018 14:08:20 +0800

...

i wonder, what's the preferred way to obtain SCHED_DEADLINE privileges
as non-root user?
for SCHED_RR/SCHED_FIFO i'm typically using pam_limits/limits.conf, but
i haven't found any resources on how SCHED_DEADLINE can be obtained ...

... it's a showstopper for using it in audio applications, which are running
as user.

Non-root usage

- Only ROOT can `sched_setattr()` to `SCHED_DEADLINE`
- Lack of a sane and safe Priority Inheritance mechanism
  - Today: deadline inheritance w/o runtime enforcement
  - We need: bandwidth inheritance w/ enforcement (proxy exec.)
- Better/finer-grained interface to manage non-root bandwidth
  - pam_limits ?
  - cgroups ?

- Lack of `libc` interface (pthreads wrapper)
  https://sourceware.org/ml/libc-alpha/2018-08/msg00474.html

Better Priority Inheritance (AKA proxy execution)

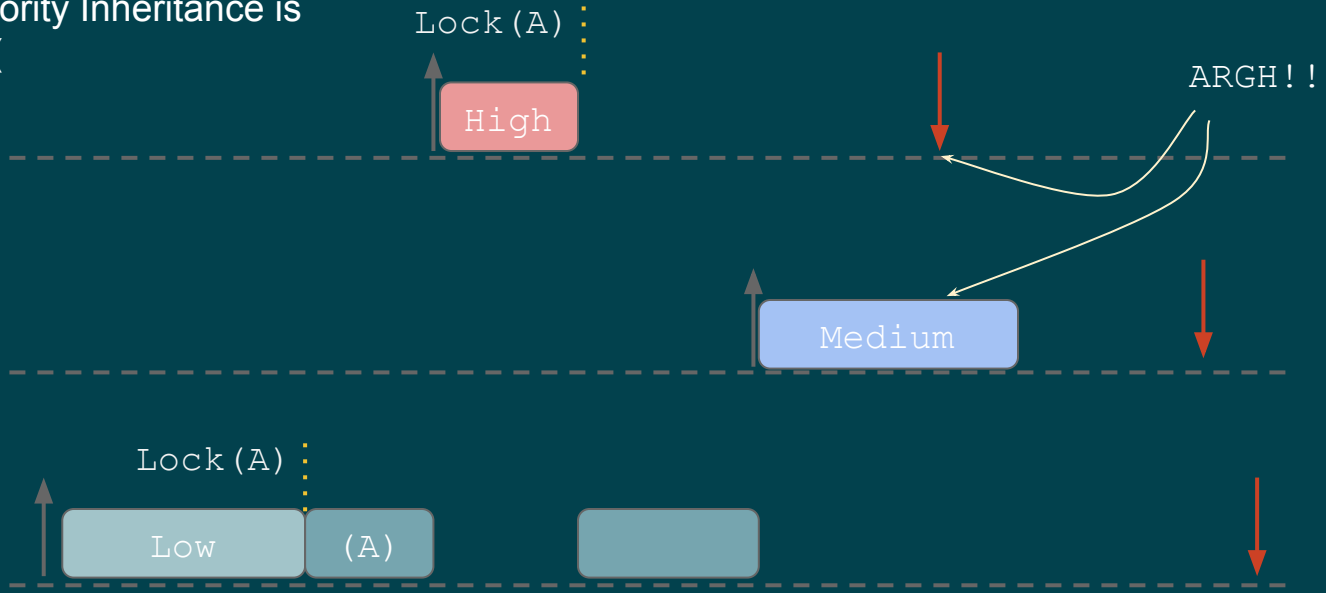
Proxy execution

- What's the problem ?
- Current Priority Inheritance mechanism is not safe for !root
  - Deadline inheritance (... also slightly incorrect)
  - Priority boosted tasks are outside runtime enforcement

- We would need to **inherit donors' bandwidth** (runtime/period)
- And keep **runtime enforcement on** while doing that
- Basically let the mutex owner **execute using the scheduling context** of a (several) donor(s)

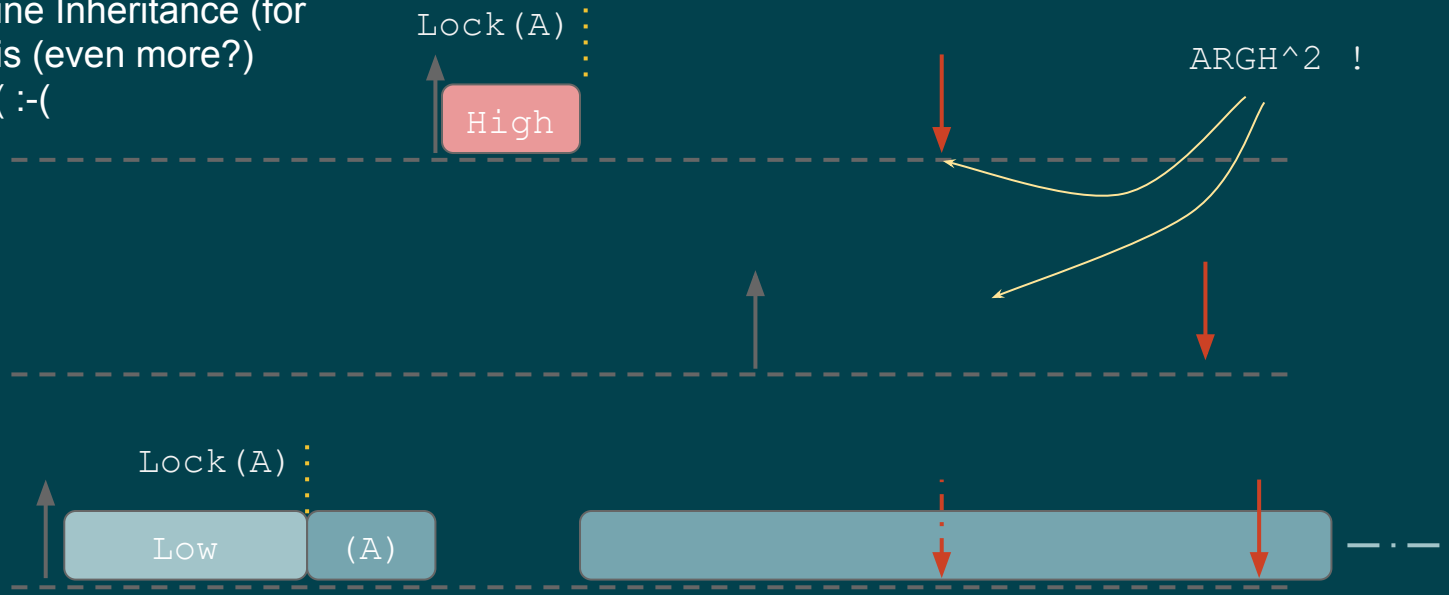
Proxy execution

No Priority Inheritance is bad :-(



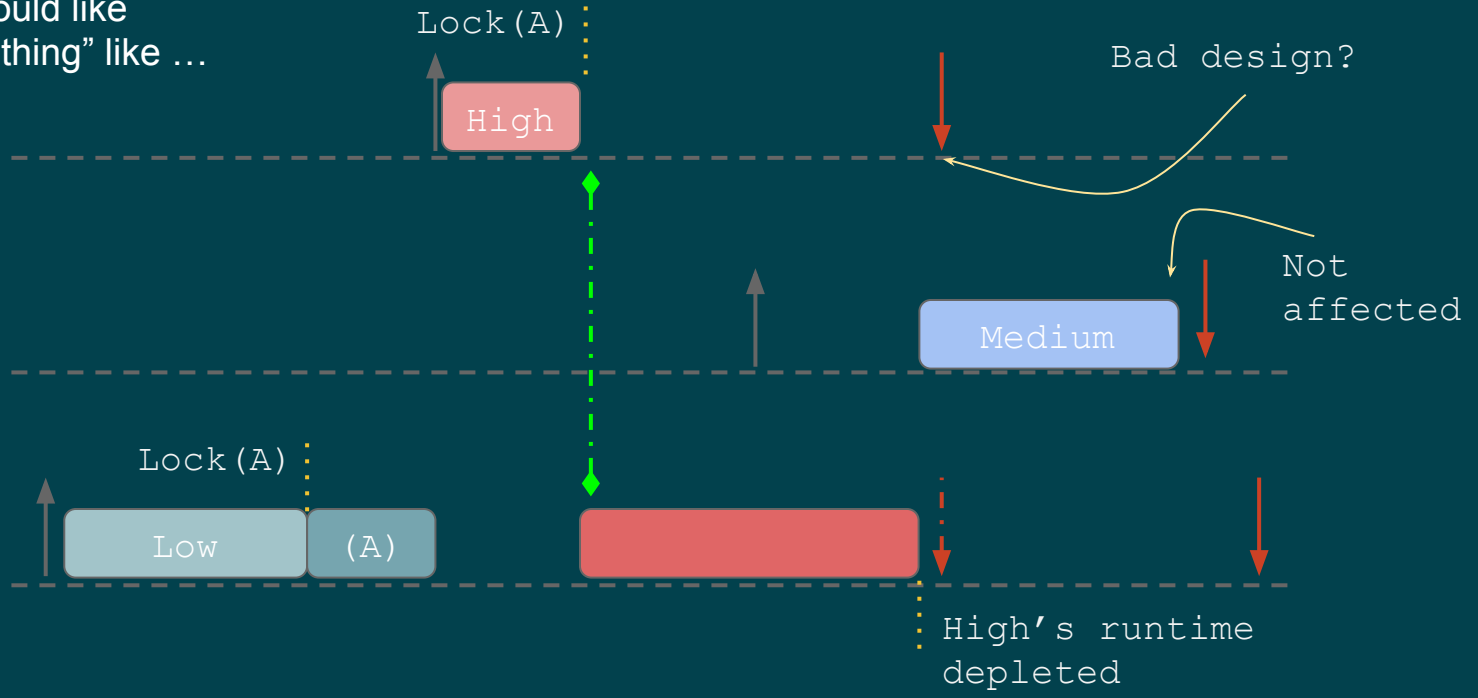
Proxy execution

Deadline Inheritance (for !root) is (even more?) bad :-(:-(



Proxy execution

We would like
“something” like …



Proxy execution

High's task_struct

SCHEDULING

Info for implementing a policy, e.g.

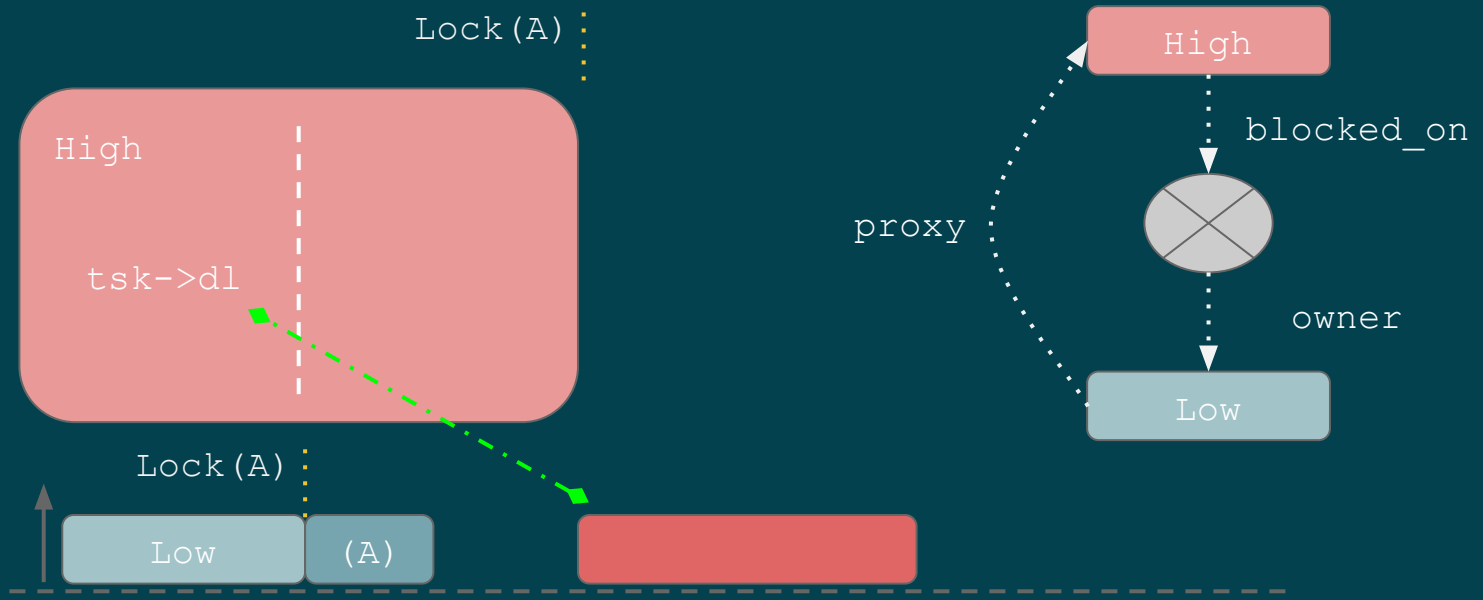
- tsk->se
- tsk->rt
- tsk->dl

EXECUTION

Info for running the task, e.g.

- affinity

Proxy execution



Proxy execution

- **More general** than Priority Inheritance for SCHED_DEADLINE
- Could be applied to **other synch mechanisms** (e.g., cond. var., yield_to like calls)
- “Boosted” task could inherit **additional properties**, e.g.
  - NICE
  - RT prio
  - Utilization clamping values
  - ...

Cgroups support

Cgroups support

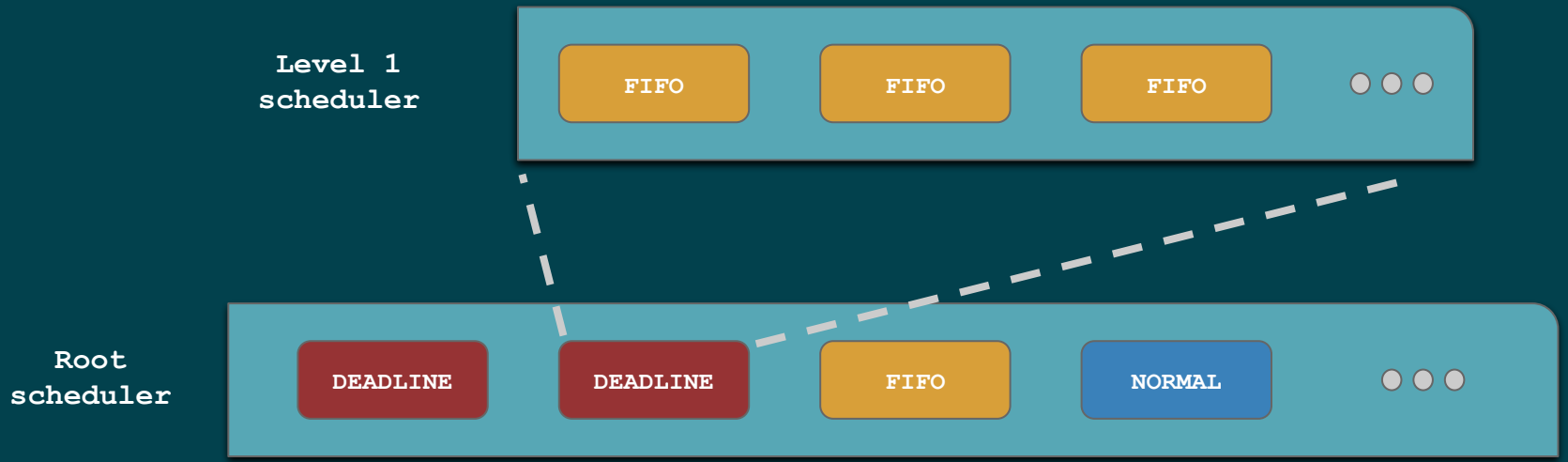
- Cgroups based bandwidth management
- Hierarchical scheduling

Cgroups support

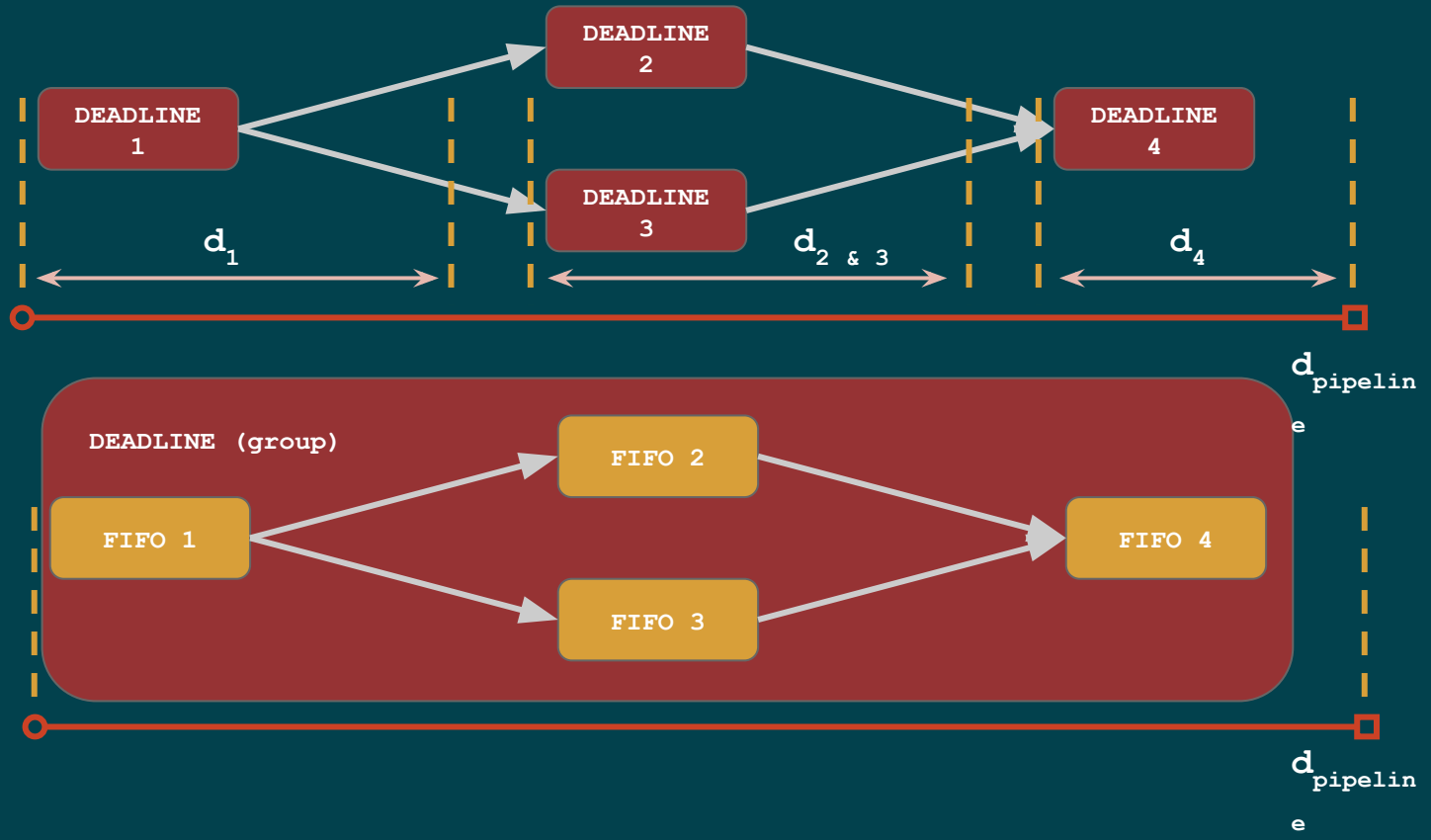
- Cgroups based bandwidth management
  - System administrator could reserve a fraction of total bandwidth to users
  - Not hierarchical - DEADLINE entities still scheduled by “root scheduler”
  - `DEADLINE_GROUP_SCHED` (requires `RT_GROUP_SCHED`)
    - Is `RT_GROUP_SCHED` actually used/useful ?
  - DEADLINE and RT share bandwidth
    - `cpu.rt_{runtime,period}_us`
    - `cpu.dl_bw` - maximum available bandwidth
    - `cpu.dl_total_bw` - currently allocated bandwidth

Cgroups support

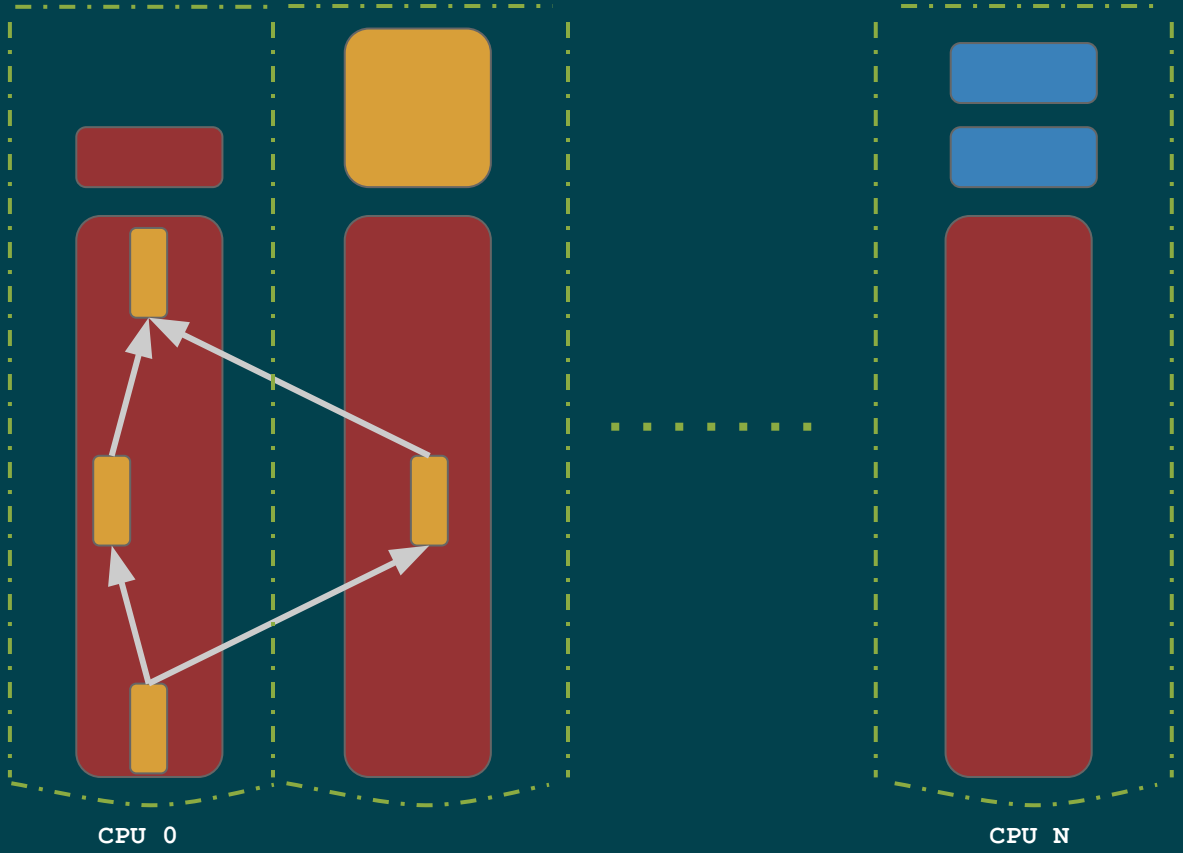
- Hierarchical scheduling - Hierarchical Constant Bandwidth Server (H-CBS)
  - Nest SCHED_{FIFO,RR} entities within SCHED_DEADLINE



Cgroups support



Cgroups support



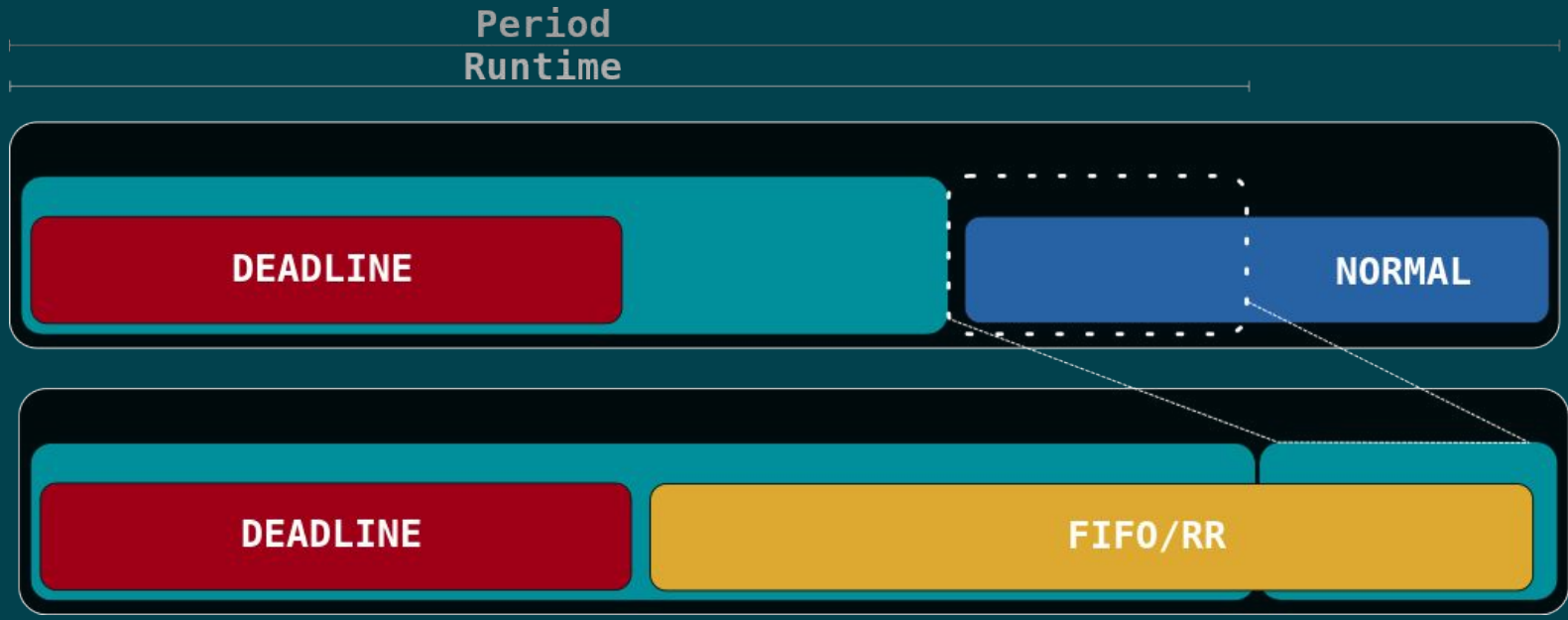
Re-working RT Throttling to use DL servers

RT Throttling

- The real-time throttling mechanism is a safeguard for misbehaving real-time tasks
- The idea is to avoid real-time tasks starving non-rt tasks
- By default, real-time tasks can run:
  - kernel.sched_rt_runtime_us / kernel.sched_rt_period_us
    - 950000 / 1000000

RT Throttling

- For SMP, it is also possible to share runtime among the runqueues of the same sched domain (RT_RUNTIME_SHARE).



Everything works!

No?

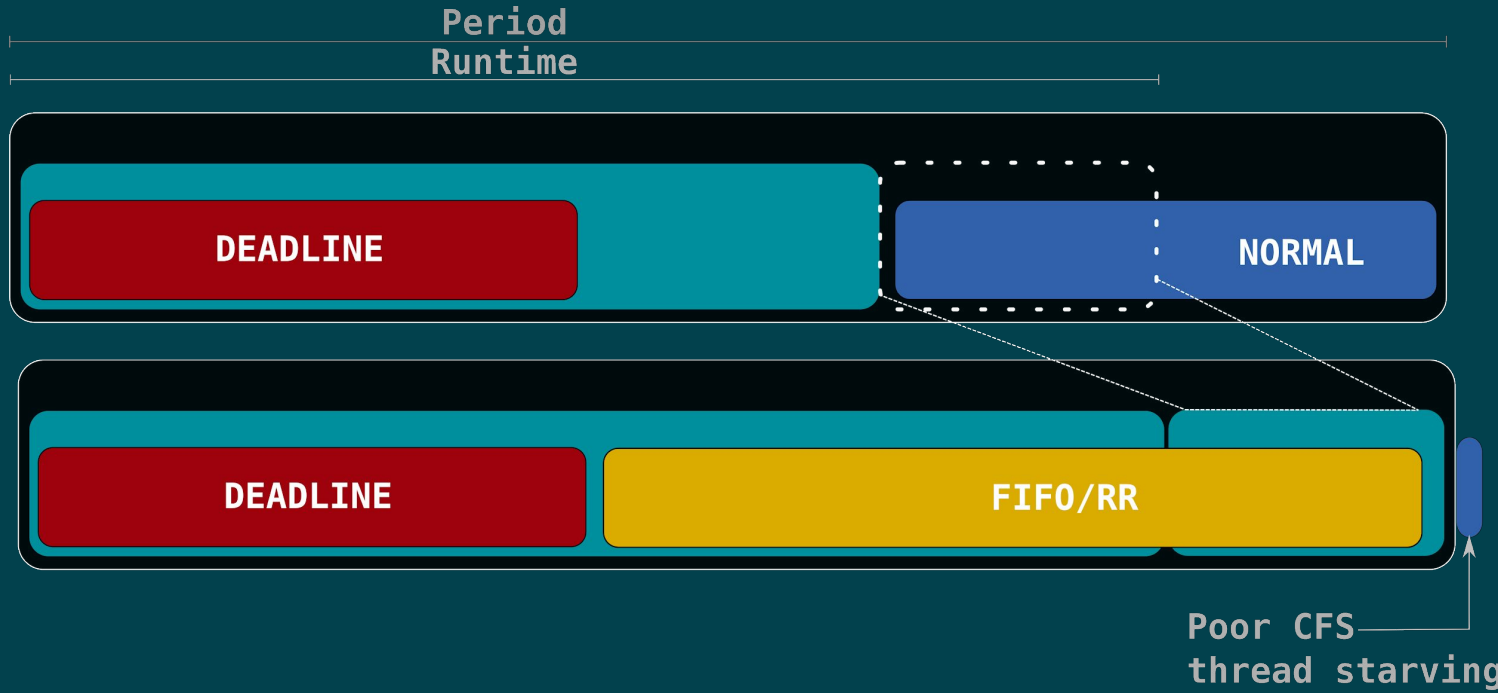
What is the deal?

RT Throttling Pitfalls

- In the absence of normal tasks:
  - Single core or NO_RT_RUNTIME_SHARE

RT Throttling Pitfalls

- In the presence of per-cpu kernel threads:
  - RT_RUNTIME_SHARE

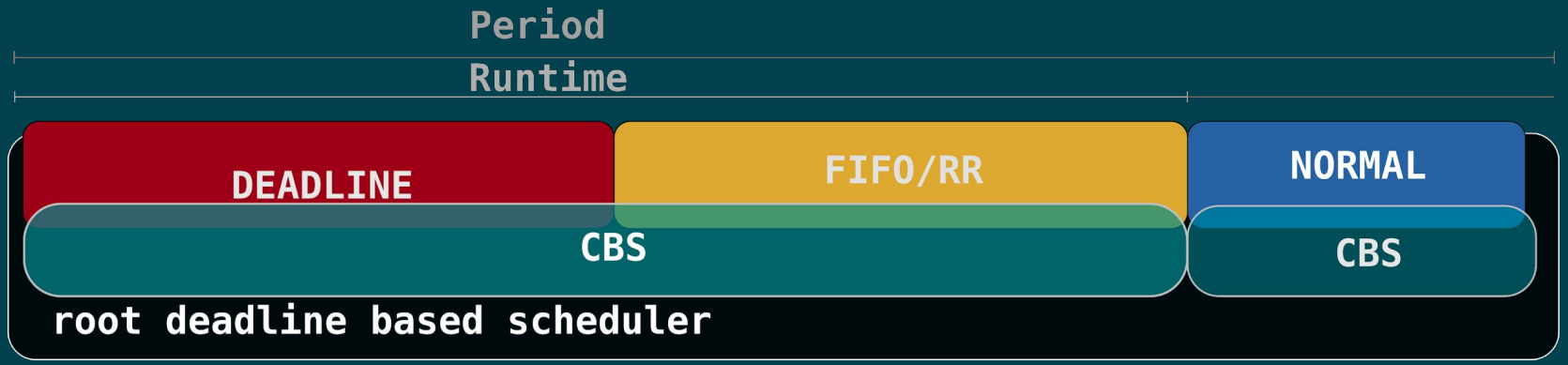


RT Throttling rework

- Change the way we implement RT Throttling
- Instead of throttling, provide bandwidth (a reservation) for RT and NON-RT schedulers:
  - RT/DL schedulers: 950/1000 ms
  - Non-rt schedulers: 50/1000 ms
  - Per-cpu schedulers (partitioned)
- Prioritize the servers according to the timing behavior

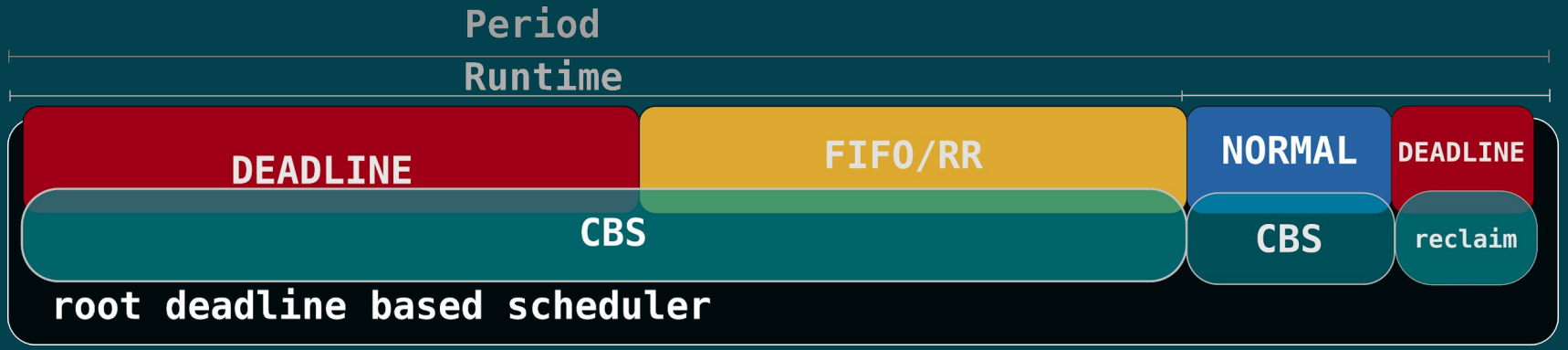
DL Server

- Suggestion from upstream is to have
  - A CBS Server scheduled for DL and RT (950ms/1000ms)
  - A CBS to normal (50ms/1000ms)
  - scheduling by the deadline:

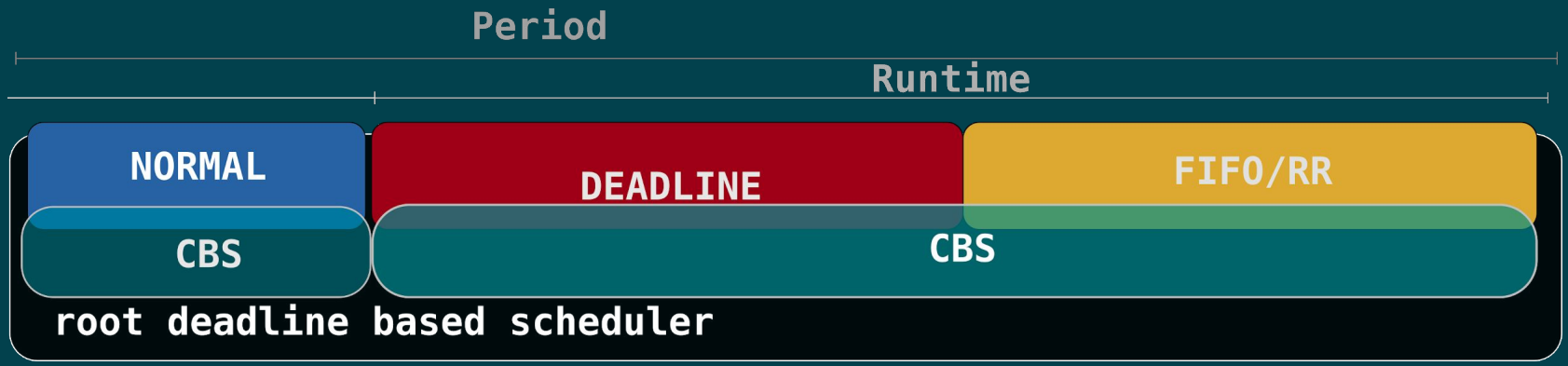


DL Server + Reclaiming

- We also need to implement reclaiming



Thinks are not that simple



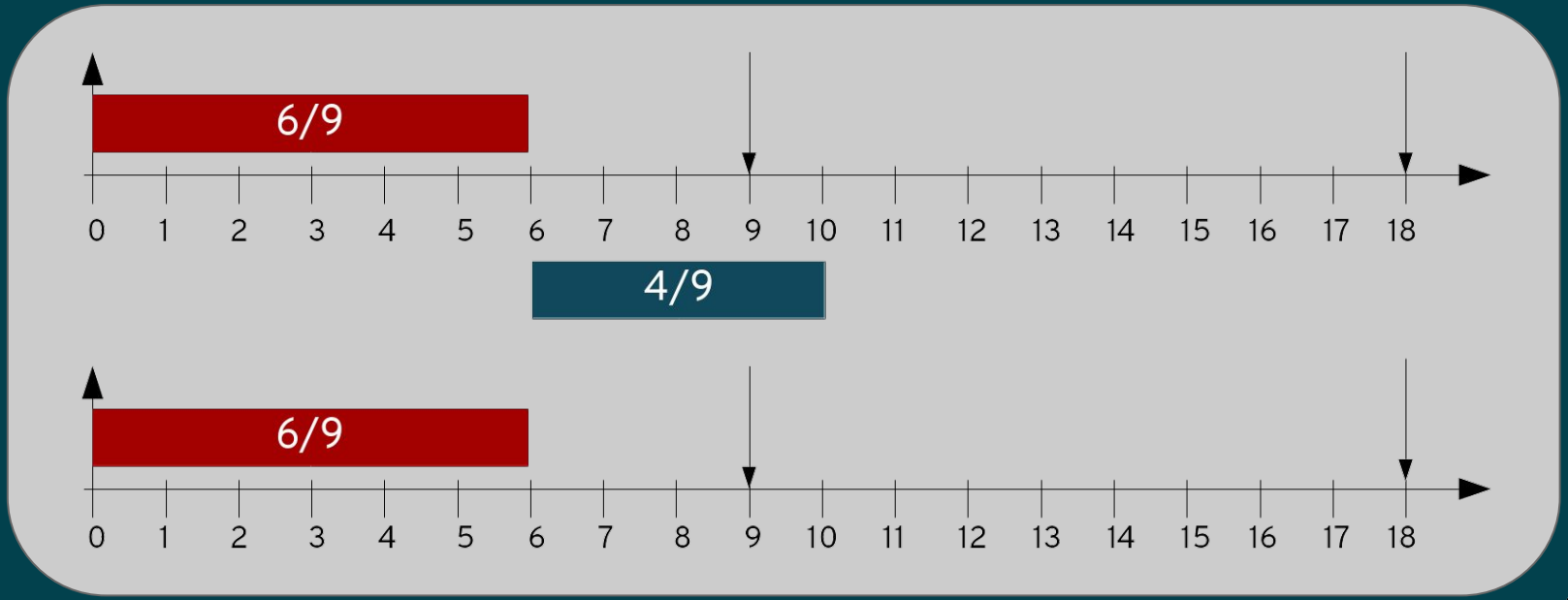
More studies required

- Pure SCHED_DEADLINE does not apply:
  - Constrained deadline is dangerous
- GRUB also does not directly apply:
  - GRUB is fair:
    - Can cause the NORMAL reservation to use more than runtime/period in the presence of suspending RT tasks.
- Points to explore:
  - Use EDZL?
  - Two level EDF?
    - Demotion in case of the end of the budget

Schedulability improvements

The semi-partitioned scheduler

There are some cases in which a feasible task set is not scheduled by neither global or partitioned schedulers. For instance:

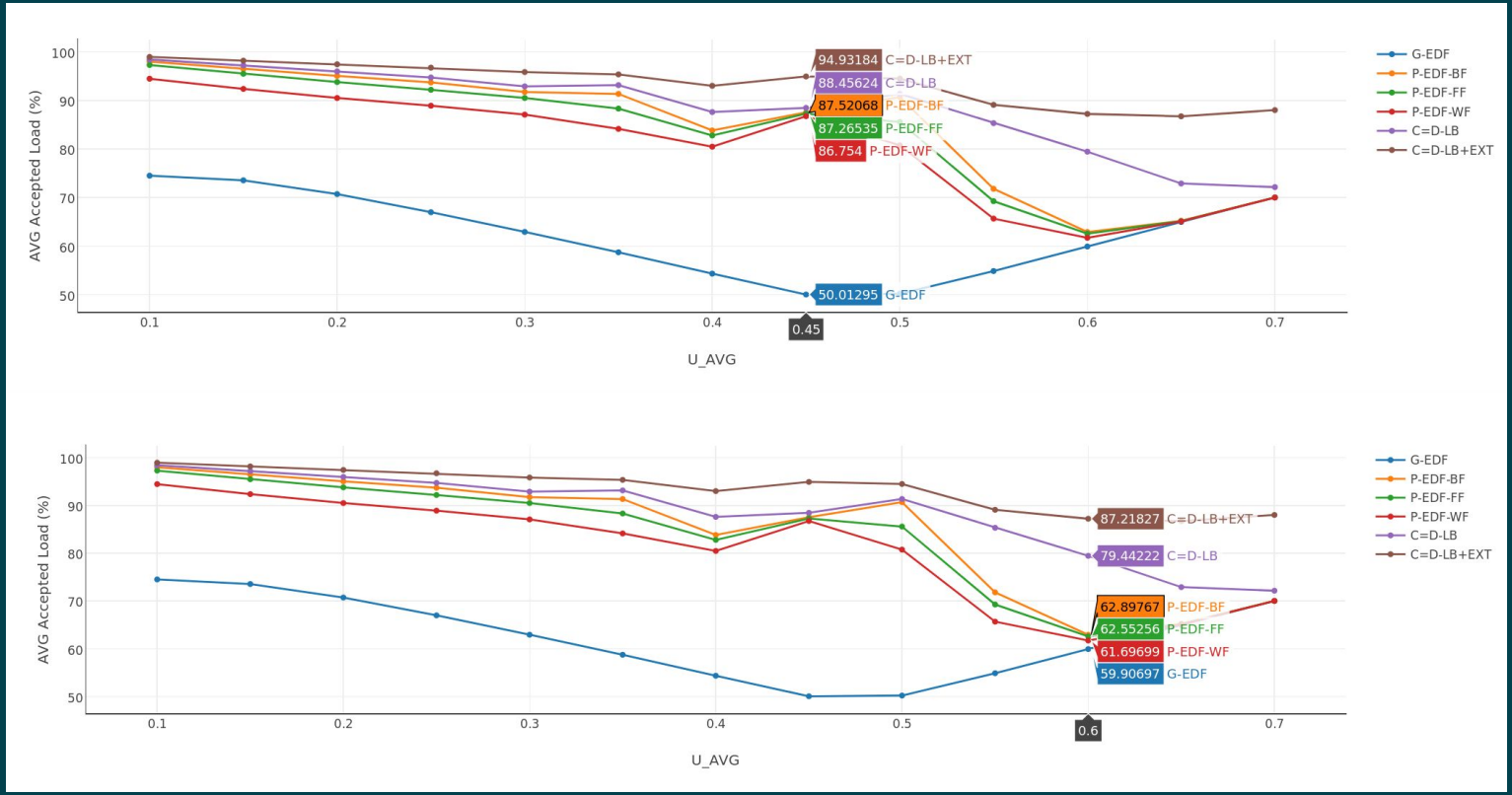


What does the academy have to say about it?

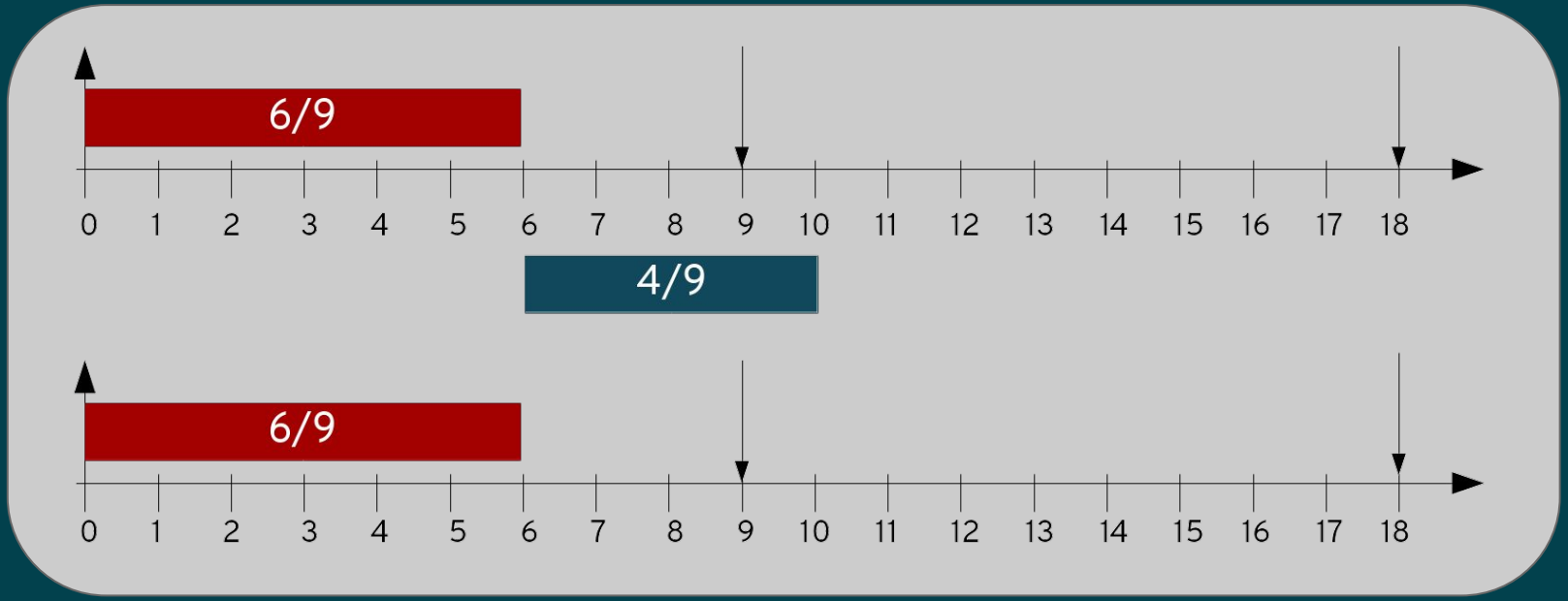
- B. Brandenburg and M. Gül, “Global Scheduling Not Required: Simple, Near-Optimal Multiprocessor Real-Time Scheduling with Semi-Partitioned Reservations” shows that:
  - “usually ≥ 99% schedulable utilization — can be achieved with simple, well-known and well-understood, low-overhead techniques (+ a few tweaks).”
  - This work, however, is not applicable for Linux because the workload is static

- D. Casini, A. Biondi, G. Buttazzo, “Semi-Partitioned Scheduling of Dynamic Real-Time Workload: A Practical Approach Based on Analysis-Driven Load Balancing.”
  - This paper relaxes the first, to be able to deal with dynamic workload.

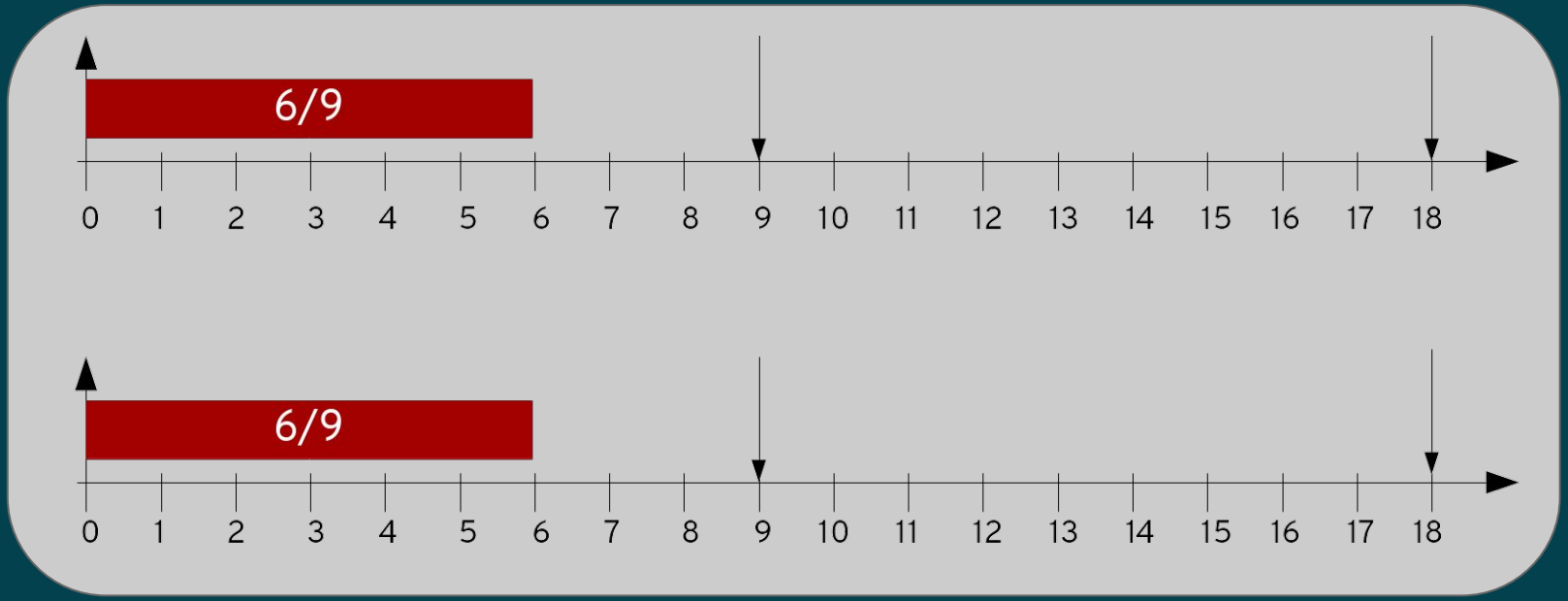
How good is this online semi-partitioned scheduler?



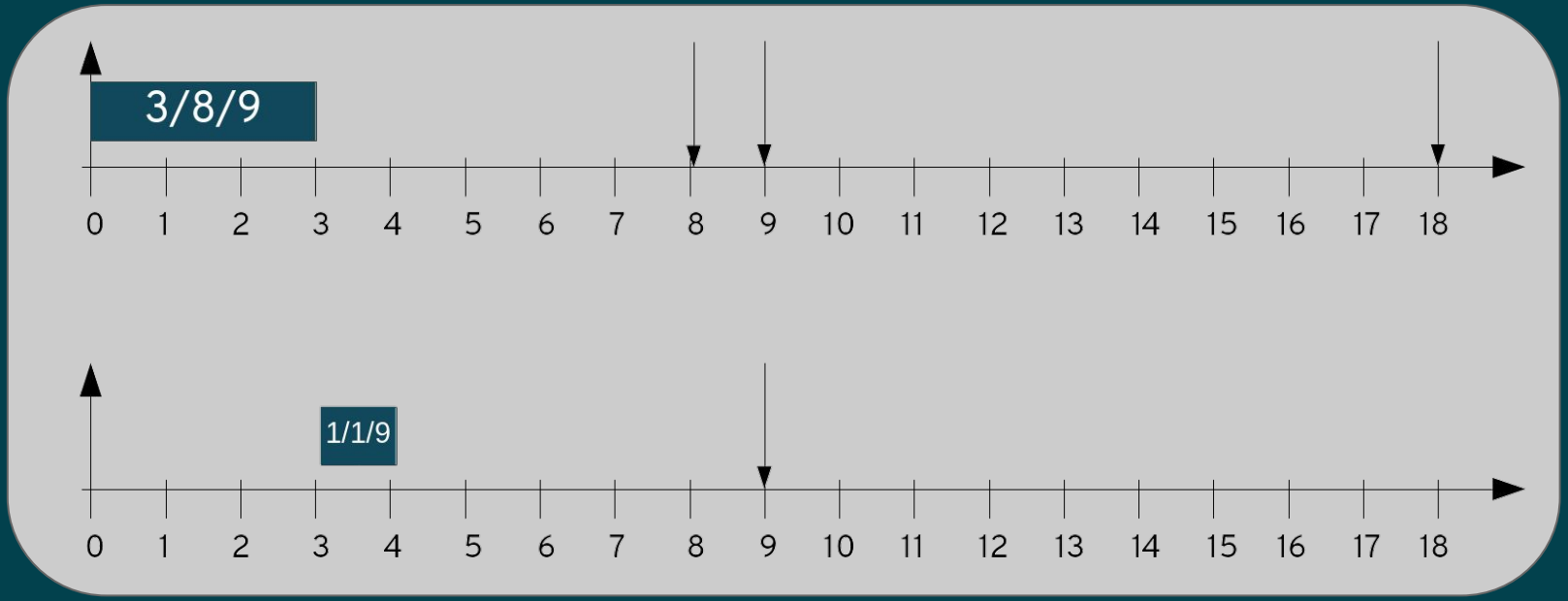
How does semi-partitioned place tasks?



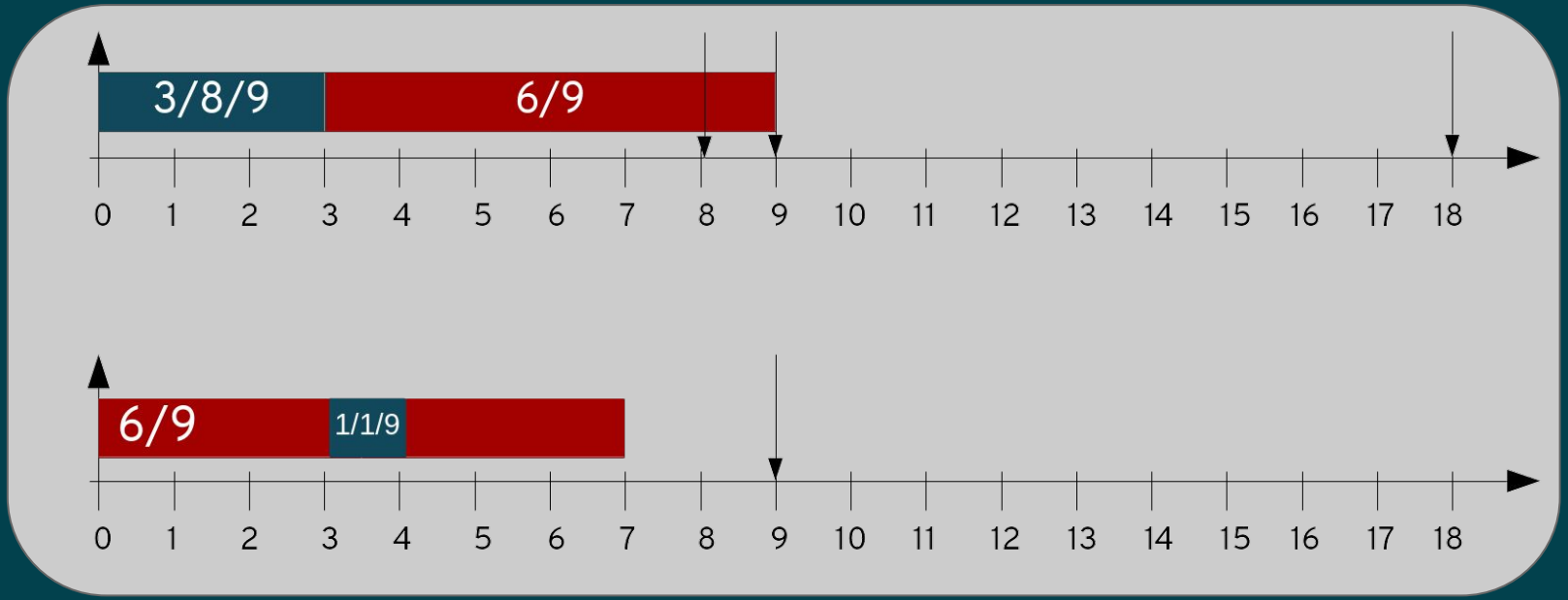
Pin as much task as possible



When it is not possible to pin, it splits a task.



Voilà!


3/8/9
6/9
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
6/9
1/1/9
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Semi-partitioned benefits

- Good points:
  - The majority of problems are reduced to single-core!
  - Less overhead:
    - The heuristics run only when setting attr/affinity/hotplug
    - There is no need to pull tasks, just push!
    - Migrations are bounded to M, for the system!
  - Tasks are mostly pinned to a single CPU!
  - Affinities come for FREE! YAY!
- Things we need to “think more”
  - The - real - admission control must to run in the kernel
  - The design of the scheduler considers implicit deadline - likewise the current... so.

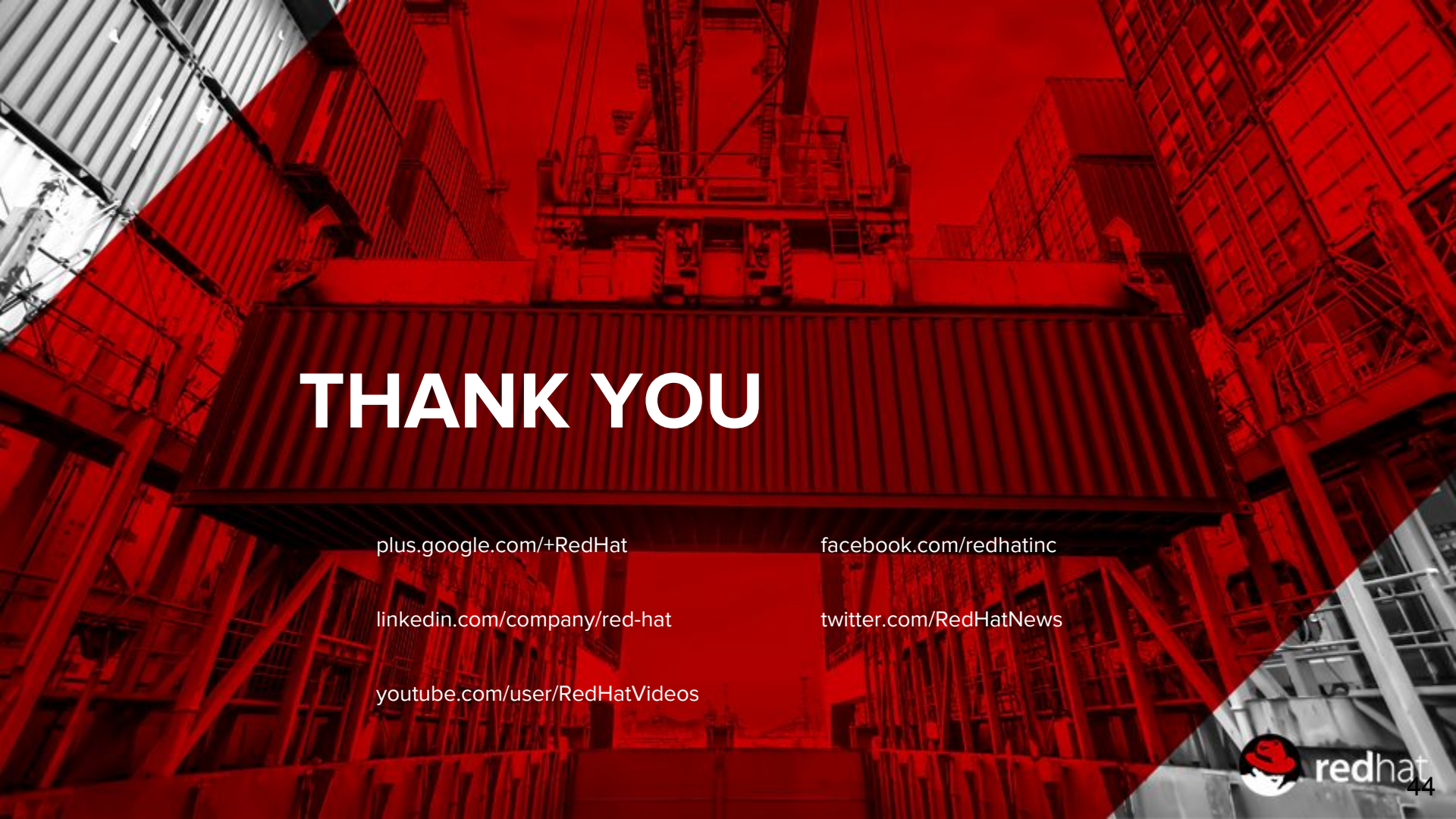
Better support for tracing

Better tracing support

```
From: Daniel Bristot de Oliveira <bristot@redhat.com>
Subject: [PATCH V2 3/3] sched/deadline: Tracepoints for deadline scheduler
Date: Mon, 28 Mar 2016 13:50:51 -0300

Deadline tasks behave differently of other tasks because deadline
task's also depend on their period, deadline and runtime.

Hence, the well known sched:sched_wakeup and sched:sched_switch
tracepoints are not always enough to precisely explain the behavior of a
deadline task with respect to the task's period, deadline, and runtime
consumption and replenishment.

In order to provide more precise information about the scheduling of
deadline tasks, this patch implements the following tracepoints:
```

Better tracing support

- No tracepoints will be added for a specific scheduler
  - But, often, we need some kind of view from -in kernel structures during the execution
  - Compiling a debug kernel is not always an option
  - Re-doing scripts that add dynamic tracepoints is... beh.
- Other things were suggested:
  - Adding trace events that are not exported as tracepoints
  - Change the kernel code to have function calls in the places were we want to trace
- But...
  - We have nothing of this so far.
- How to proceed?


THANK YOU
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redhat