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Scuola Superiore
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Deadline scheduling: can your mobile device last longer?

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Retis
Real-Time Systems Laboratory

Outline

- Classical Real-Time concepts
- An implementation
- Power Aware Deadline Scheduling
- Conclusions & Discussion

Classical Real-Time concepts

What's Real-Time?

- All about “**deadlines**”
- Useful result → **correct output + before its deadline**
- “Go as fast as you can” is not always the best answer
- “**Go as fast as you need to respect deadlines**”

“But not faster! Or you will spend too much energy!”

Hard vs. Soft RT

- **Hard real-time** tasks: a missed deadline may cause **catastrophic consequences.**
- **Soft real-time** tasks: timing constraints are important, but not critical **(QoS degradation)**

Resource Reservation

- Concurrent real-time tasks compete for resources (CPU time)
- **Resource Reservation** mechanism
- A task is allowed to execute for:
  - Q time units *(budget)*
  - in every interval of length P *(reservation period)*
- Allocated bandwidth is U=Q/P (a.k.a. **utilization**)

Temporal Isolation

- nothing new ?
  - CFS bandwidth control
  - RT throttling
- **Reservations**, like containers
- Each reservation has its own **dynamic deadline** (Constant Bandwidth Server)
- Reservations are scheduled by Earliest Deadline First

Temporal Isolation

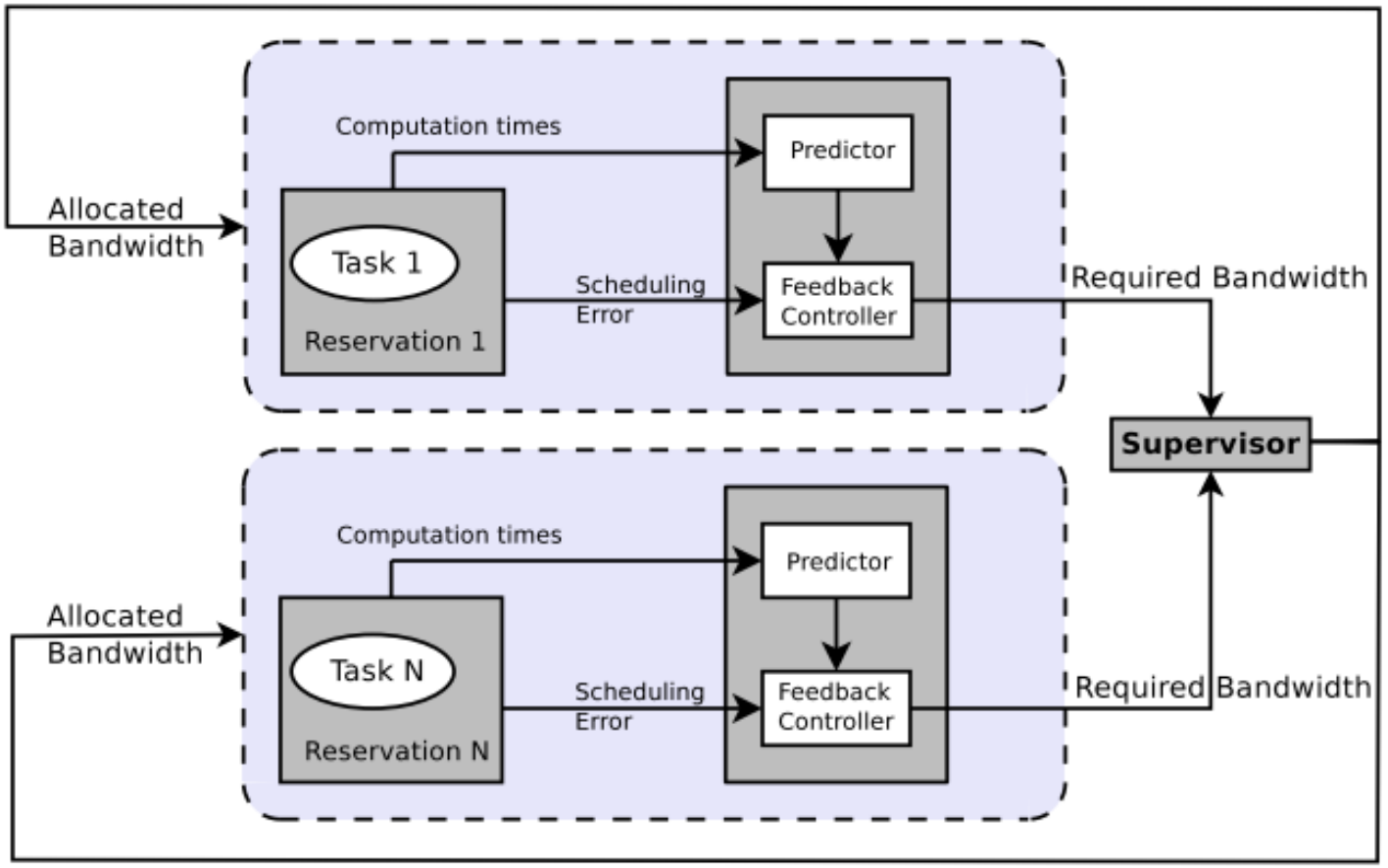
- EDF gives higher priority to more urgent tasks
- CBS slows down (or throttles) misbehaving tasks
- EDF + CBS ensures **temporal isolation**
- Admission control provides timing guarantees

$$\sum U_i \leq M$$

Choosing parameters

- **Period** is easy: P = T or P = NT
- **Budget** assignment is painful :'-(
- Hard real-time → WCET
  - calculated with tools from source code
  - estimated via benchmarks
- Soft real-time
  - measure computation time and adapt budget
  - *adaptive reservations*

Adaptive/Feedback Scheduling



Mobile Data

- Not only Multimedia
  - not strictly periodic
  - no explicit deadline
- how to cope with other data sources (e.g., Web browsing, emails, user interaction, etc.) ?
  - pack similar sources on container reservations
  - best effort (we don't care)

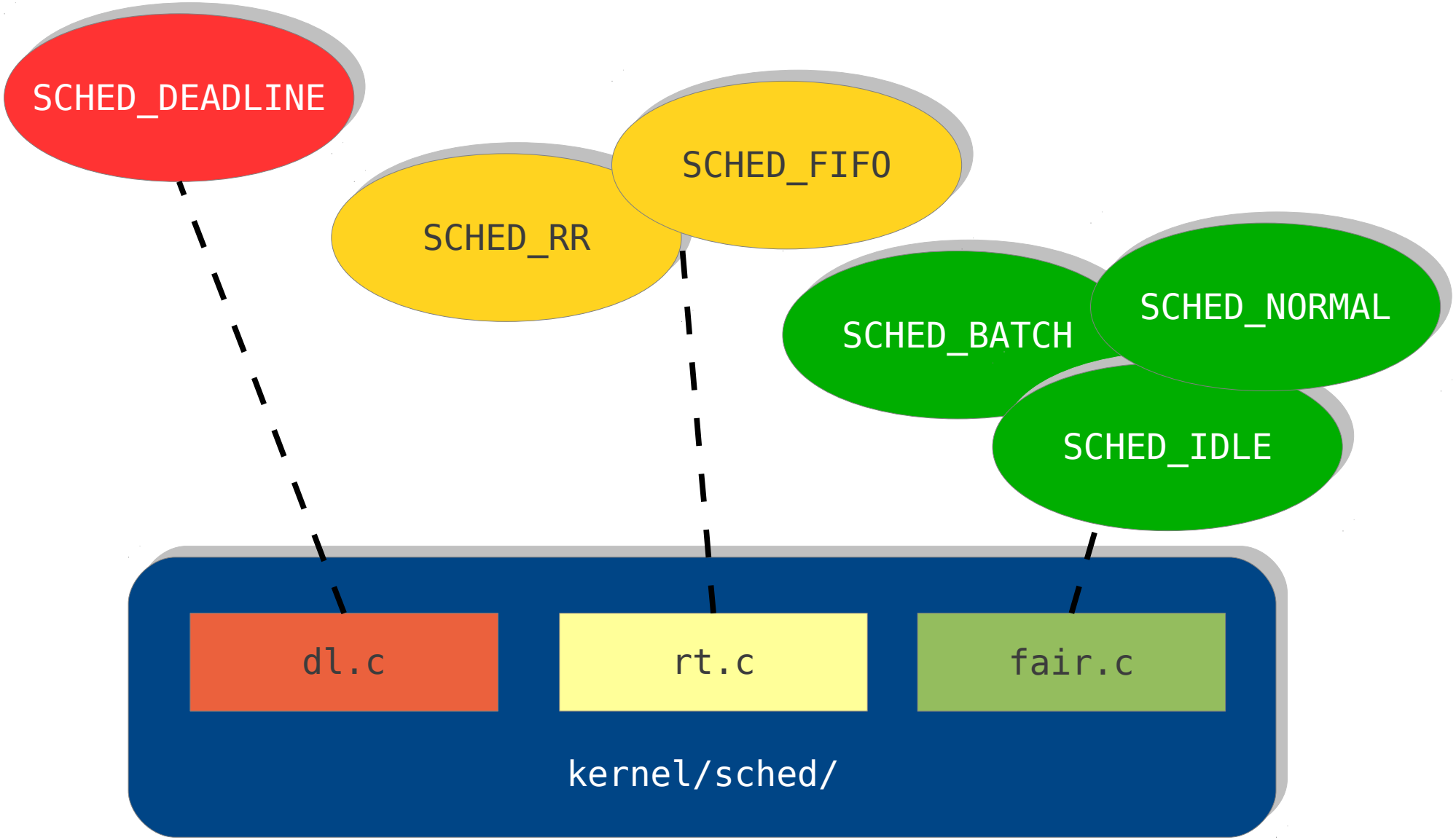
An implementation

What we already have

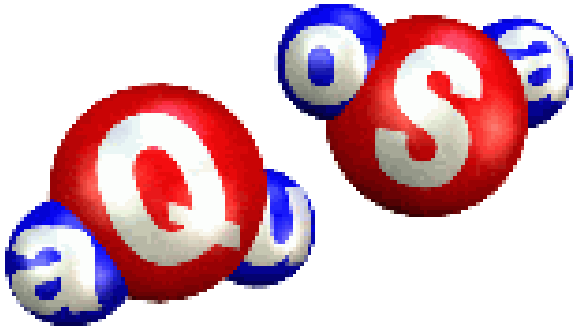
SCHED_DEADLINE

- deadline based real-time task scheduling policy
- bandwidth isolation
- each task runs inside its own reservation
- global/clustered multiprocessor scheduling through dynamic task migration

What we already have



What we already “have”



"Adaptive Quality of Service Architecture"
(for the Linux kernel)

- adaptive resource reservation layer
- dynamically adapting CPU reservation
- QoS aware applications API
- a bit outdated & UP only :-(

Power Aware Deadline Scheduling

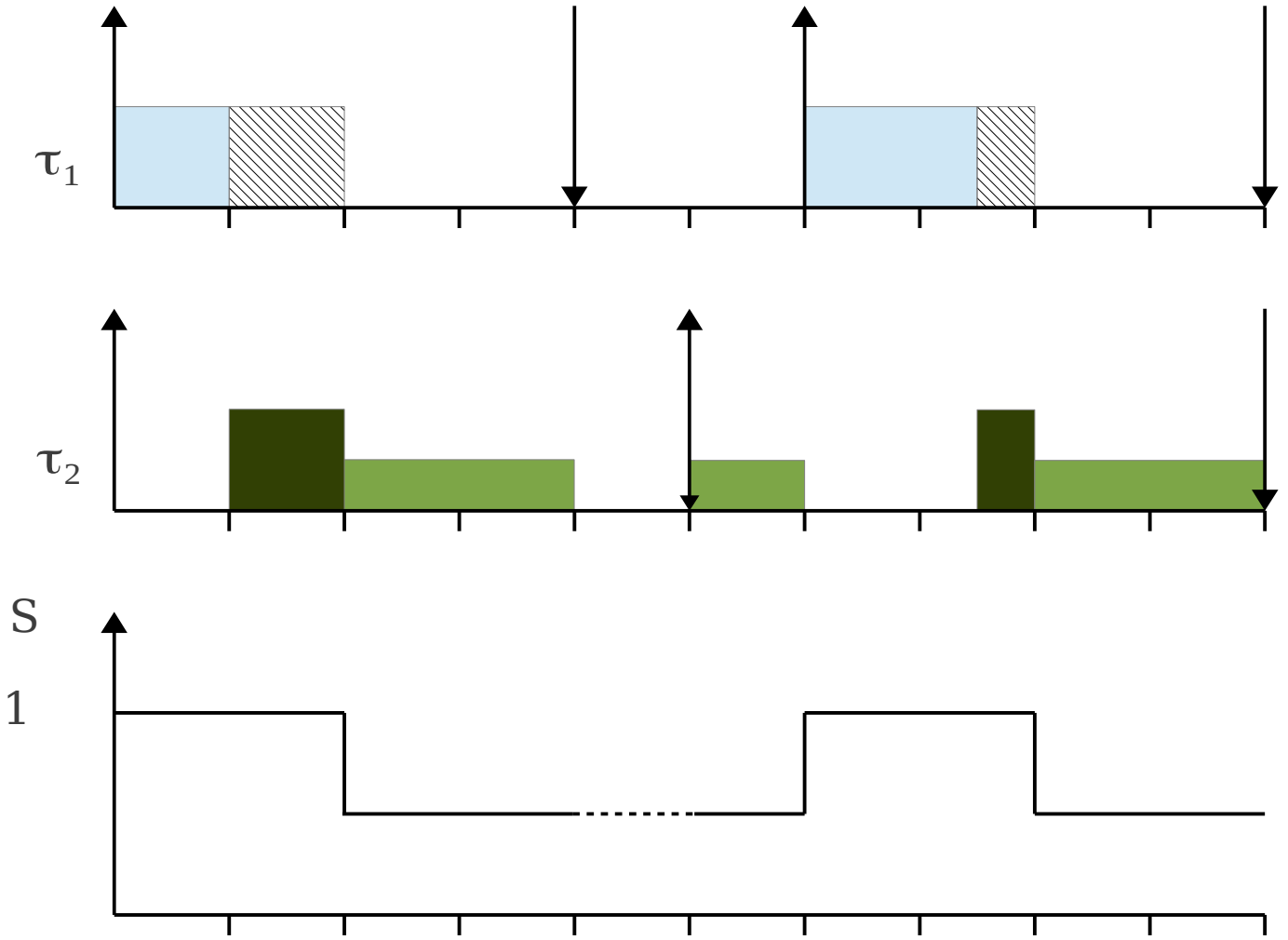
Power aware RT scheduling

- Let's bring power efficiency into the picture...
- Hardware context (simplified)
  - homogeneous / heterogenous
  - single / multiple clock domains
  - discrete operating frequencies
  - transitories to adjust to a new frequency
  - overhead for frequency scaling
  - overhead for switching a core either ON or OFF

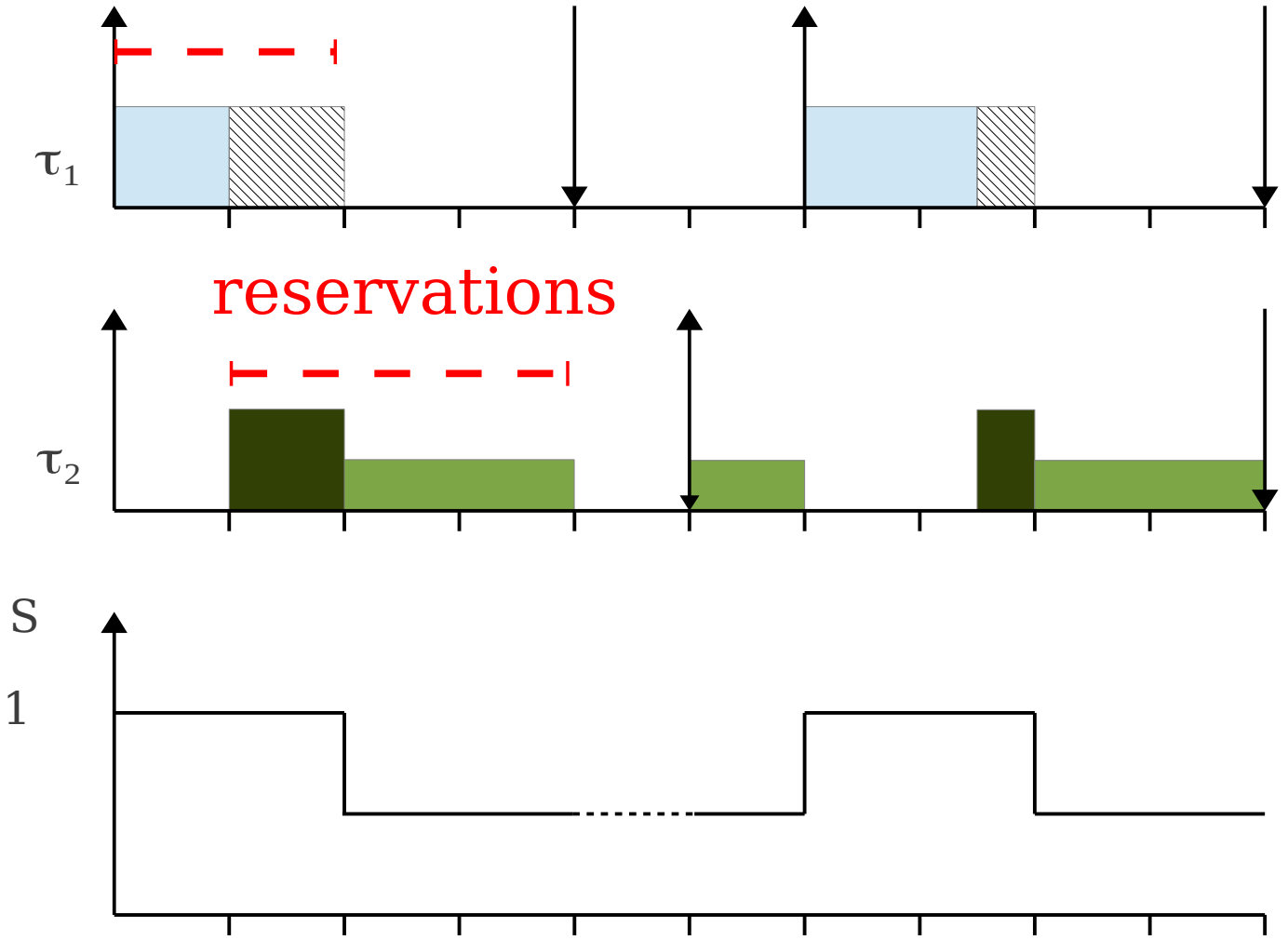
“Ideal” UP example

- Associate a *reservation* to each task
- Track actual CPU utilization (active servers contribute) → U
- Dynamically change CPU speed S to follow U
- Admission Control → don't go below U if you don't want deadline misses
- Power efficiency → slow down as much closer to U as you can to save power

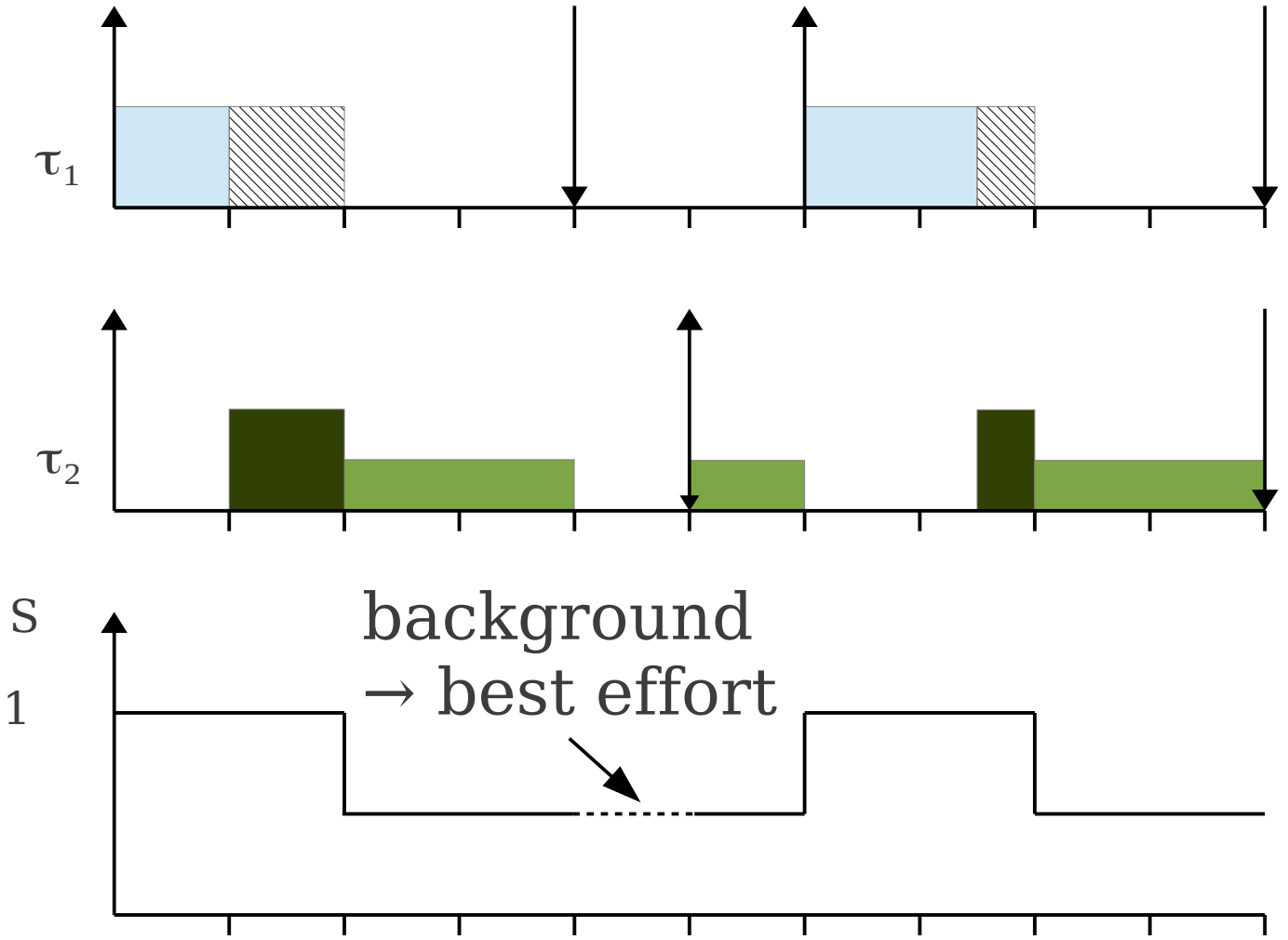
“Ideal” UP example



“Ideal” UP example



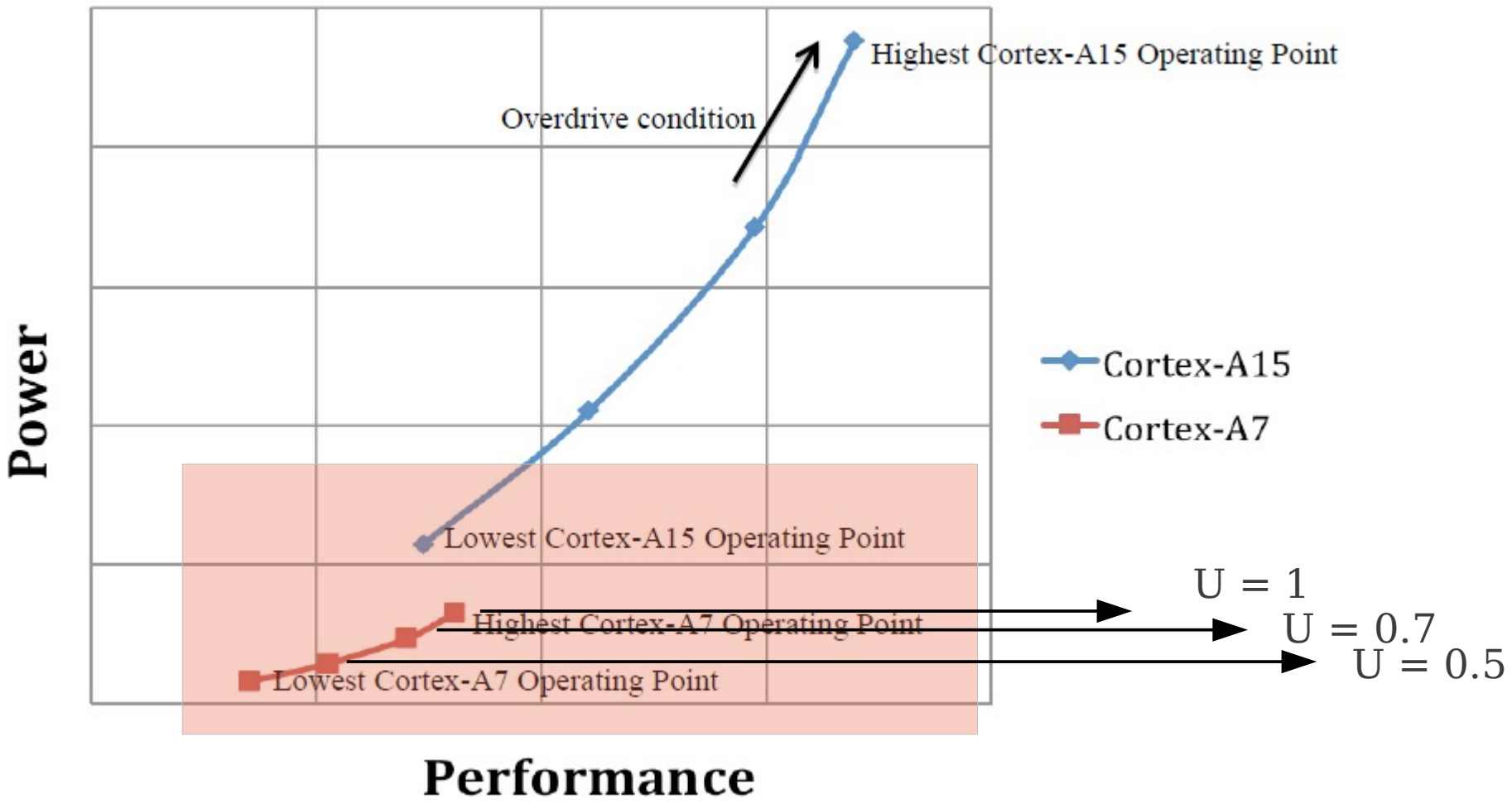
“Ideal” UP example



UP with “thresholds”

- No existing processor can vary its frequency with continuity
- set some “thresholds” on the values of the total system bandwidth
- CPU with N different frequencies
- compute N different bandwidth thresholds
- use them to know when a CPU speed change is needed, for example...

UP with “thresholds”



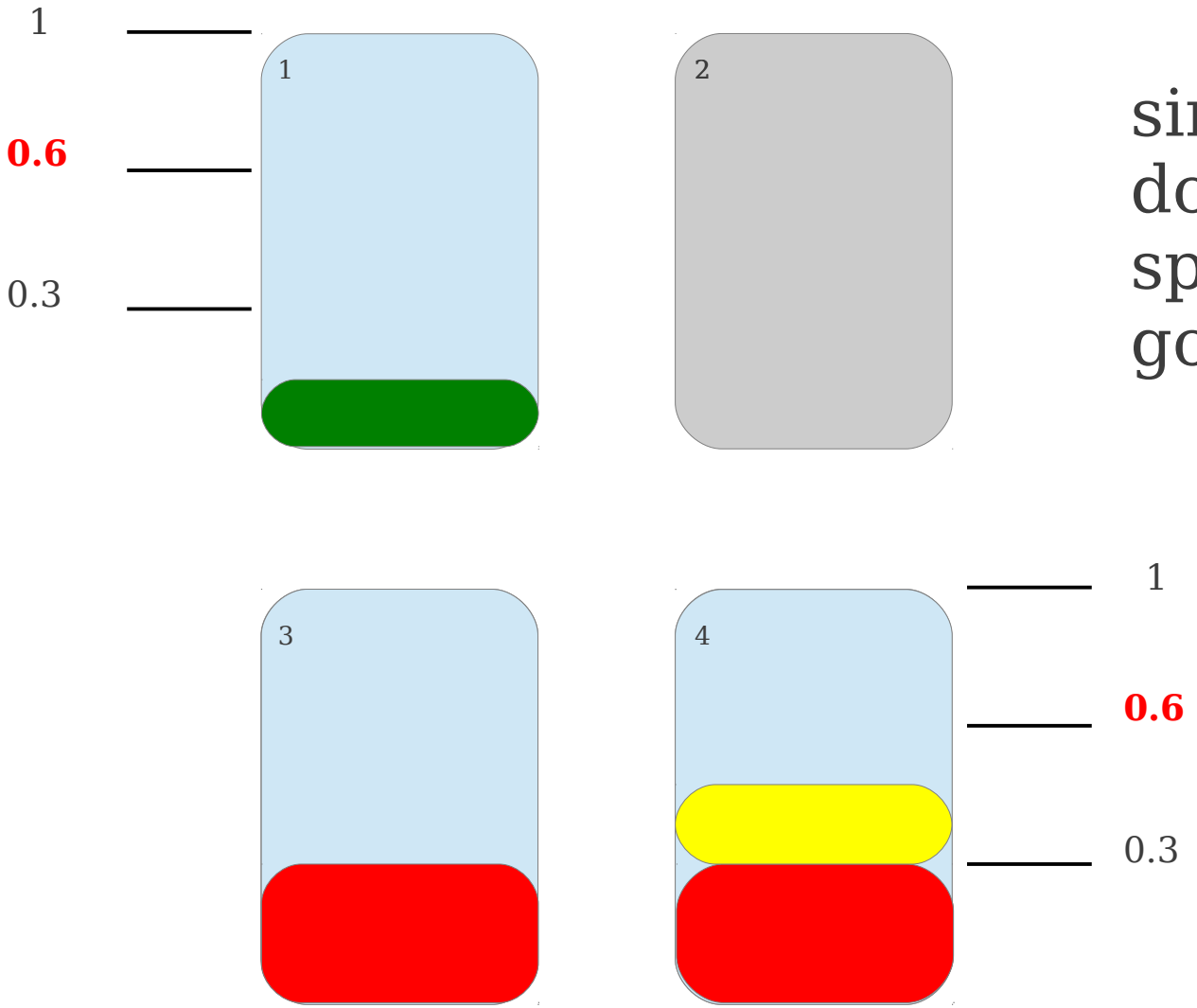
Going SMP

- SCHED_DEADLINE performs active “load-balancing” → Global-EDF
  - on a M-CPUs system the M earliest deadline ready tasks are always running
  - achieved through **push/pull** migrations (as in rt) – **deadline based decisions**

Power aware push/pull

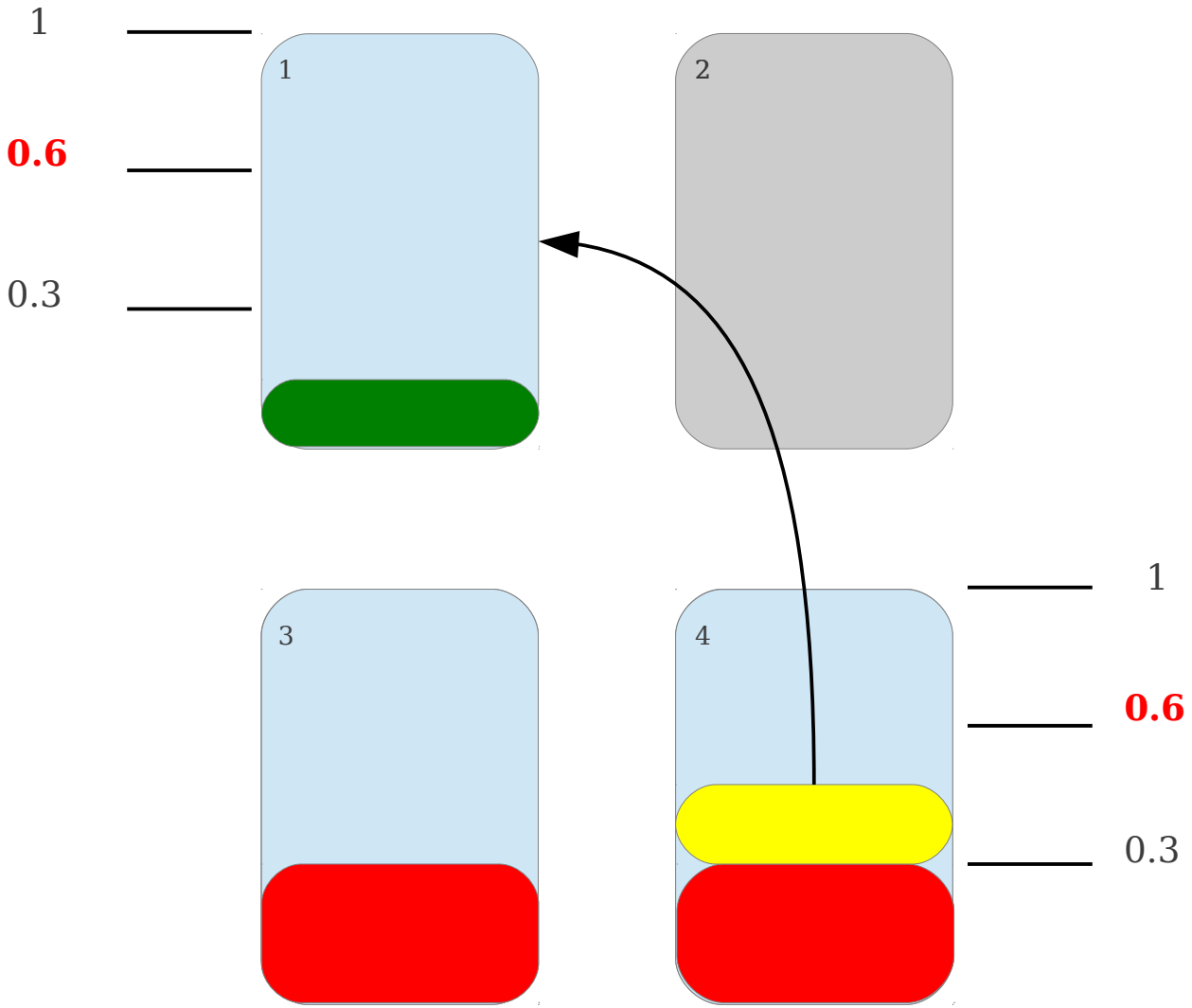
- “hybrid” scheduling
  - **EDF on each CPU**
  - **U driven migrations**
- different policies
  - single clock domain → minimize mean U
  - multiple clock domains → compact tasks to turn off CPUs as long as possible
  - big.LITTLE → compact on little core, move only big tasks on big cores ?

PA push/pull – an example

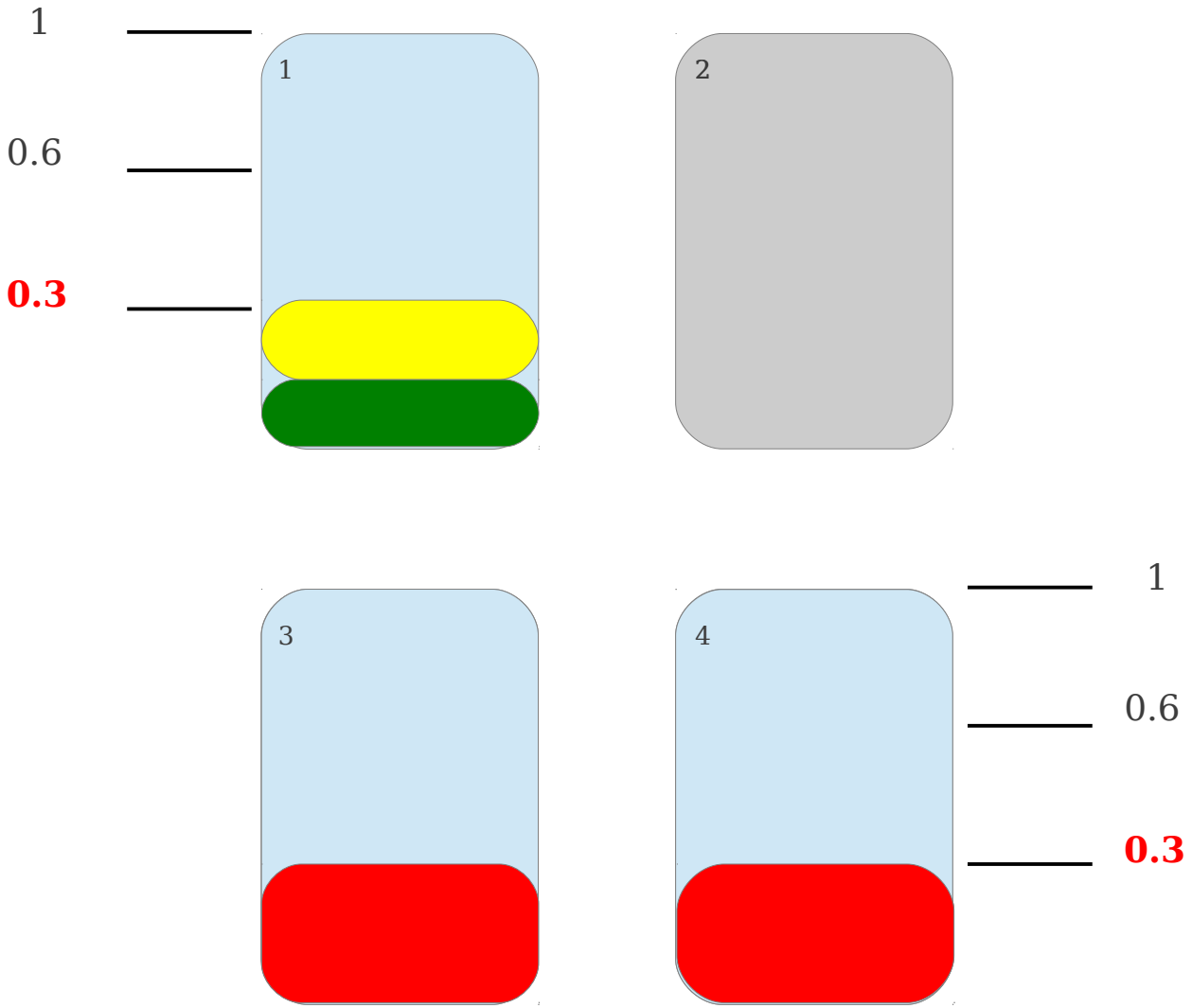


single clock domain → spread load to go slower

PA push/pull – an example



PA push/pull – an example



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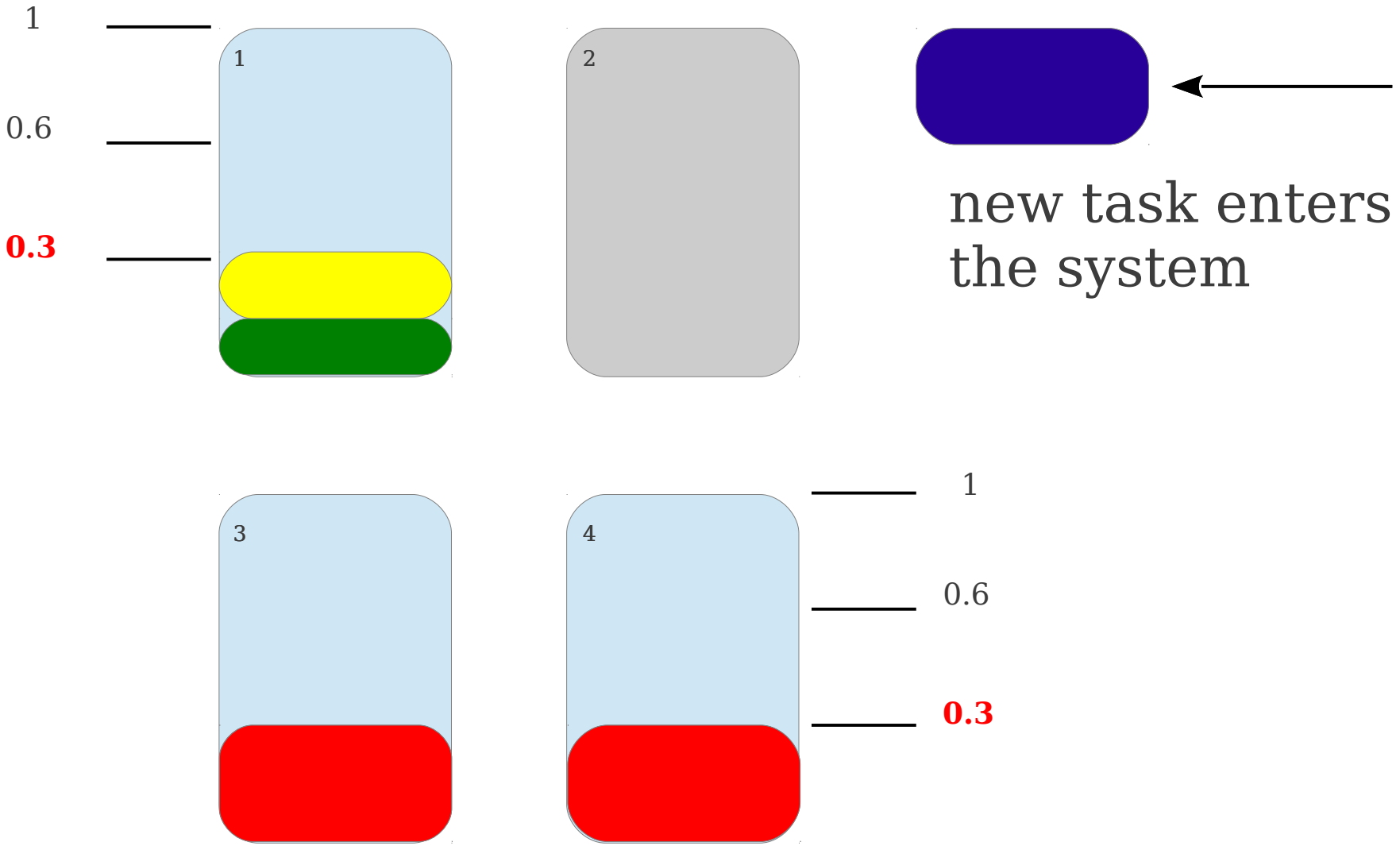

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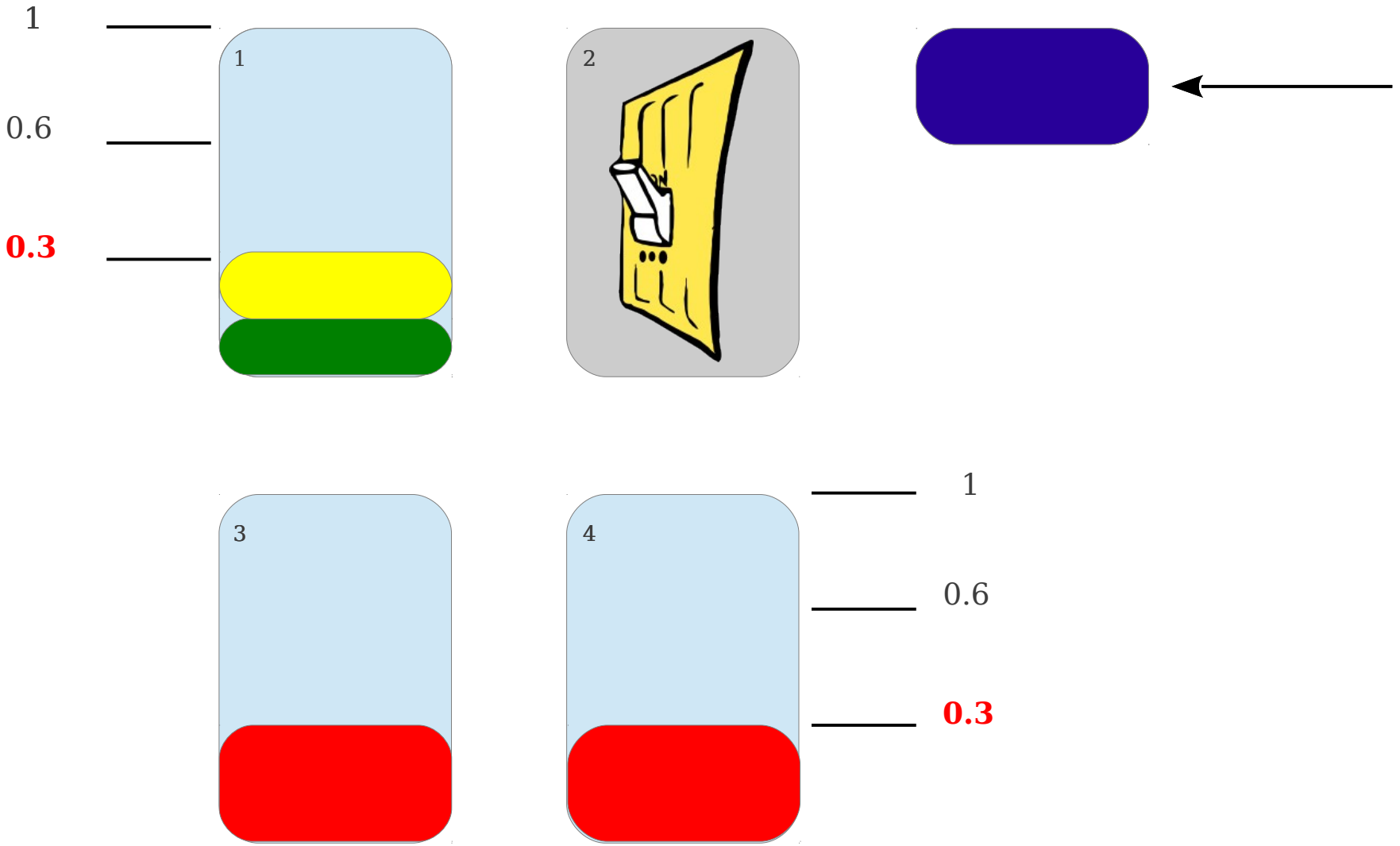

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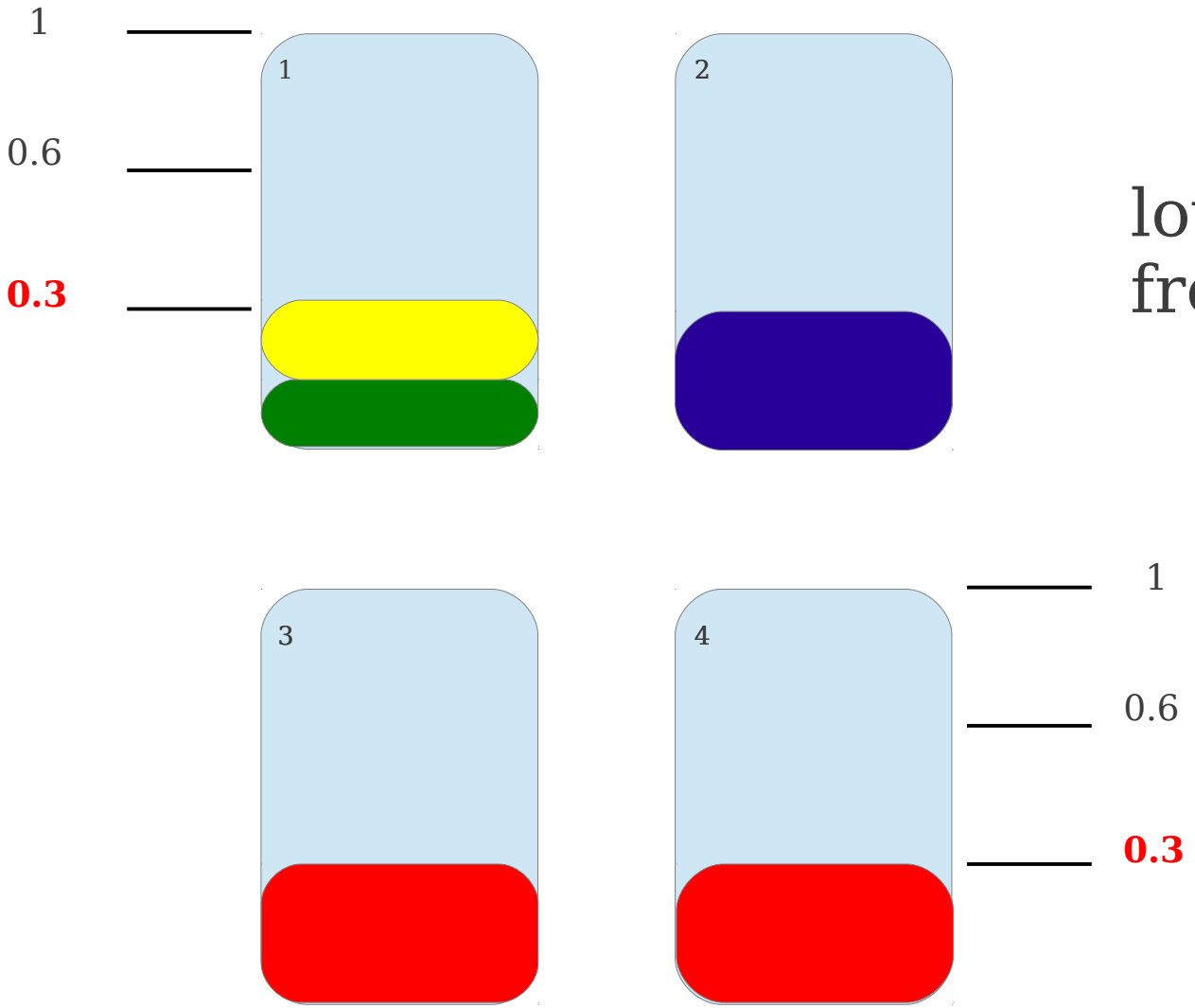
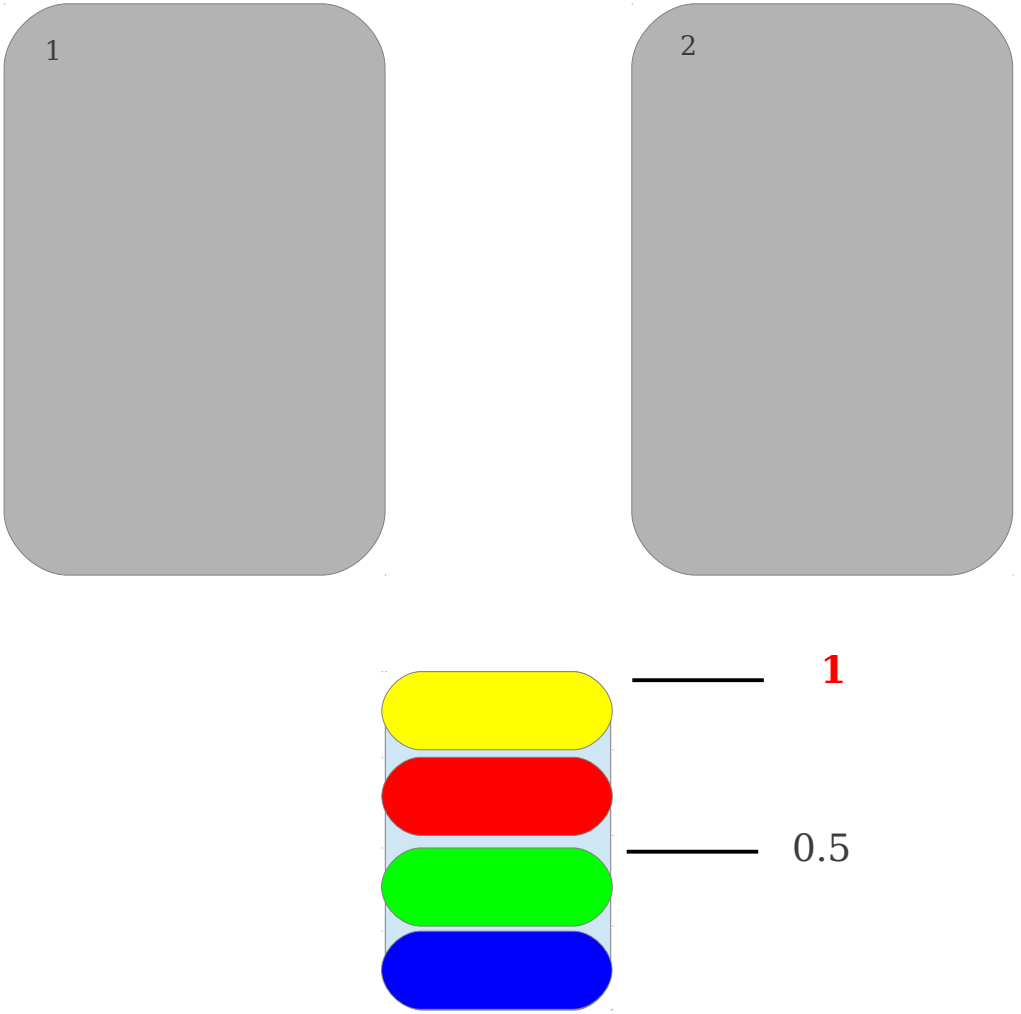
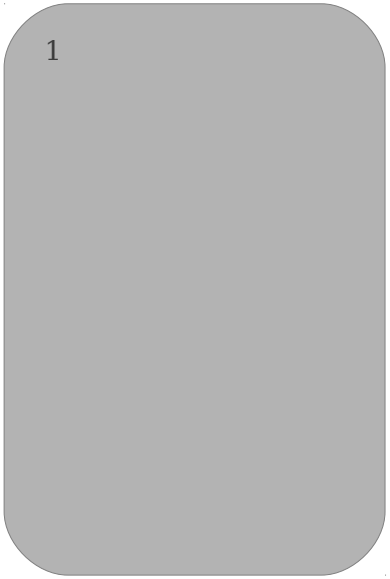


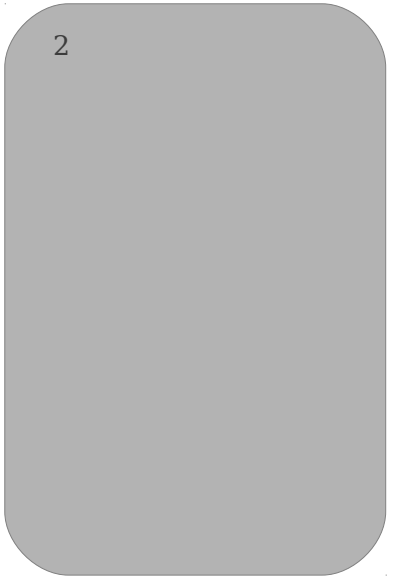
lower mean frequency

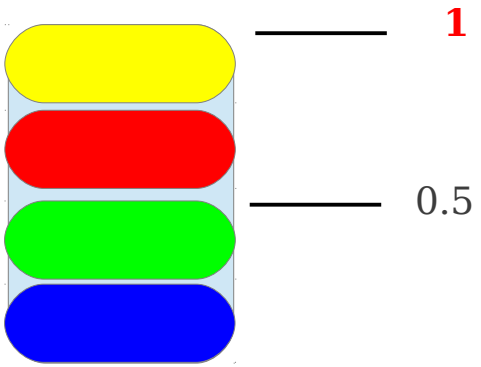
PA push/pull – Tegra like

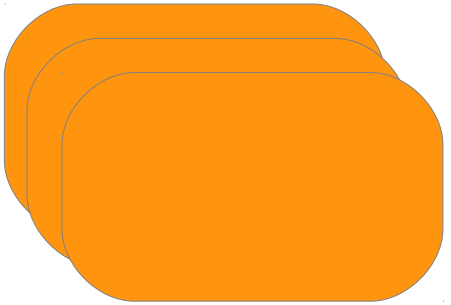


PA push/pull – Tegra like



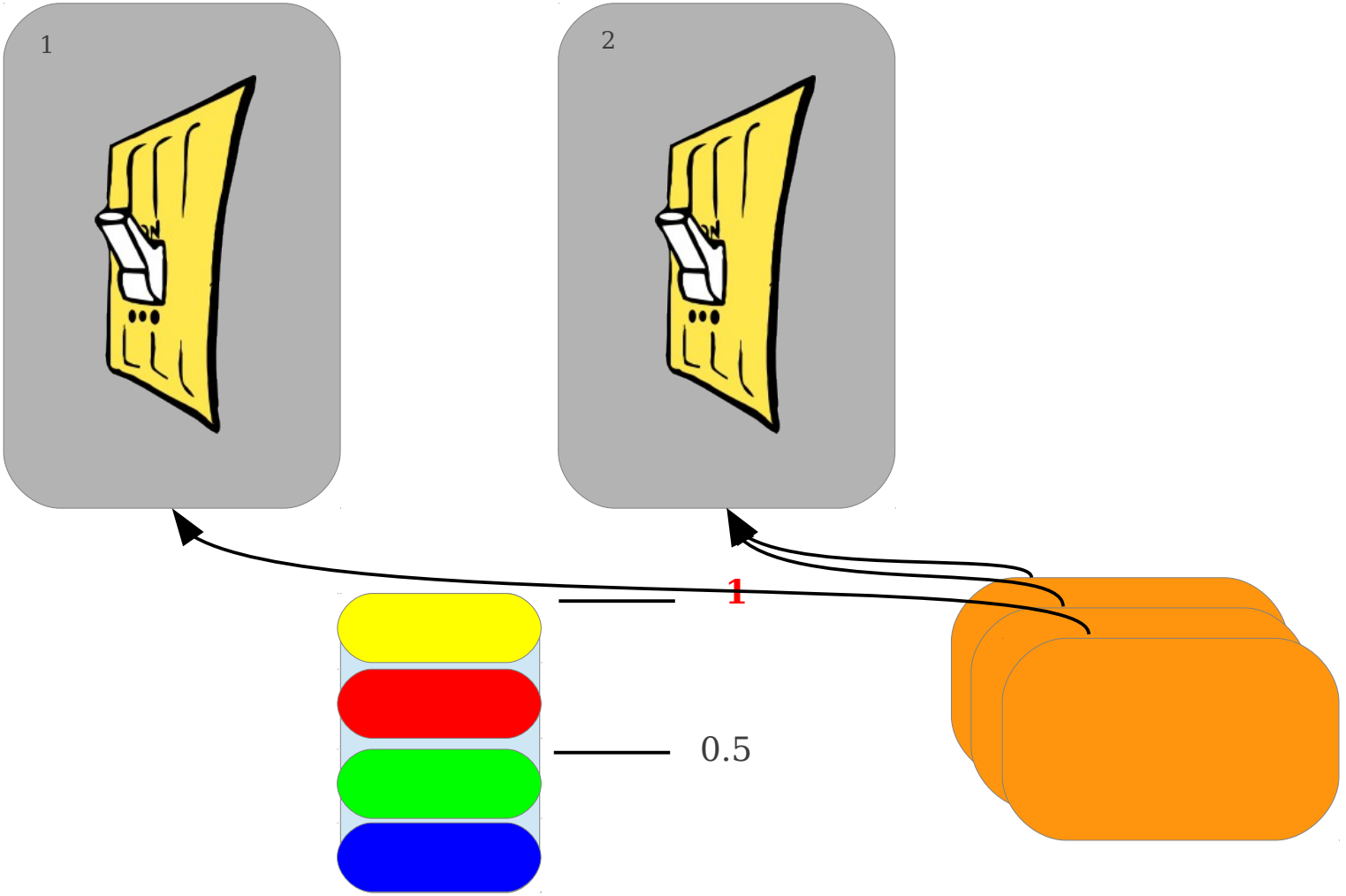






user starts
a console class
video game

PA push/pull – Tegra like



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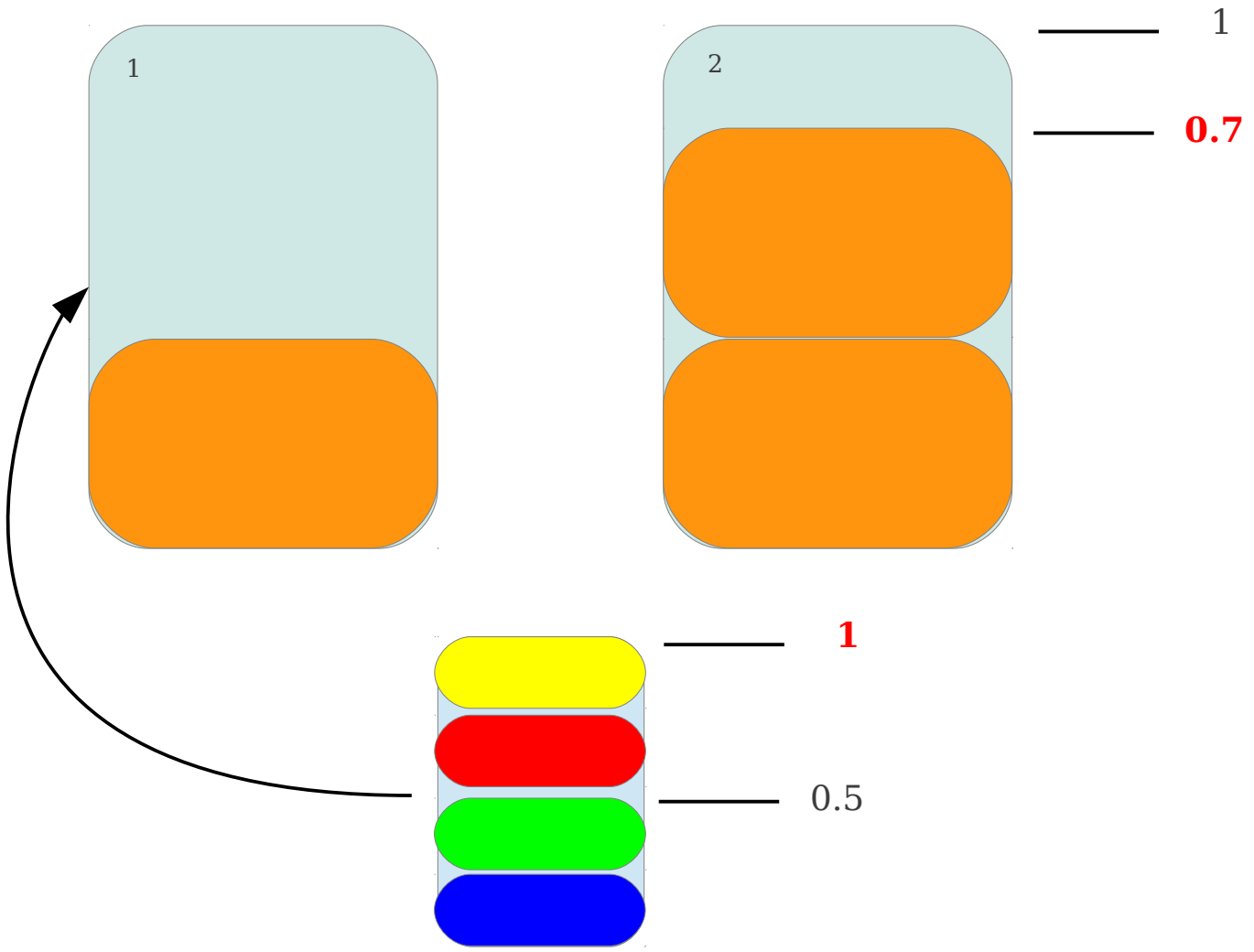

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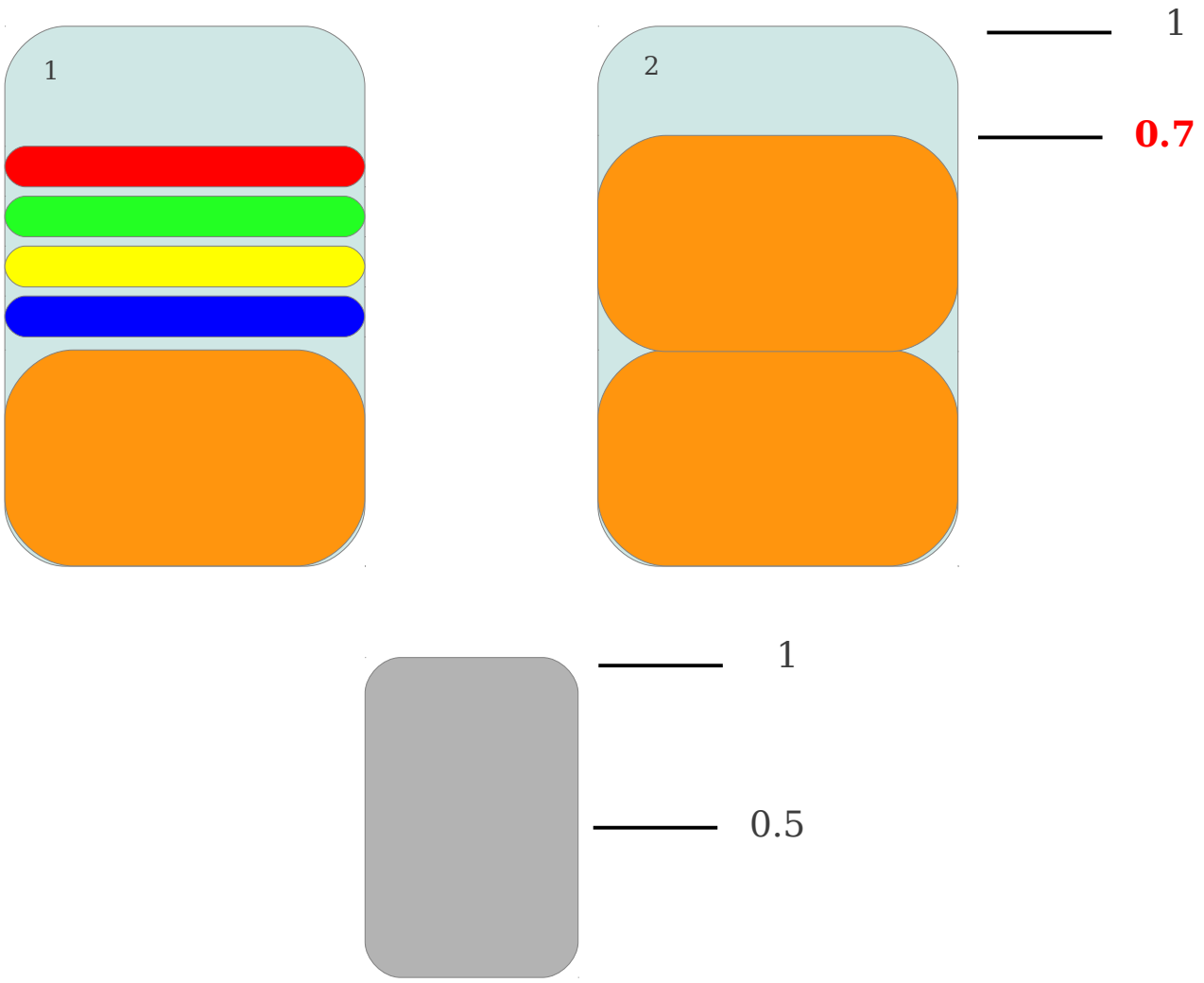

Conclusions & Discussion

Conclusions

- prototype implementation should be straightforward
  - account for runqueue actual utilization
  - modify push/pull mechanism
- integration in a real system (Android ?) could be more difficult
- the plan → start simple and then add bits one ofter the other :-)

Open Questions

- When is it worth to wake up a CPU ?
- Interaction with other components (e.g., thermal management, drivers, etc.) ?
- Test platforms ?
- add here your own concern or ...

Thanks!

Questions ?

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