An update on Real-Time scheduling on Linux

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Intel

Why deadline scheduling?

General Purpose OS

- Resource arbitration
- Resource isolation

FIFO/RR must be privileged because they violate all that.

- Misbehaving task affects other tasks
- Prio assignment is difficult and cannot easily be composed

Sporadic task model

(G)EDF scheduling provides arbitration

- Easy composition of task sets

CBS provides isolation

- Self suspending tasks
- Constrained tasks must preserve density

SCHED_DEADLINE → (G)EDF + CBS

Accounting vs Enforcement

- Budget (q) is accounted in [ns]
  - Subject to platform clock resolution
- Budget depletion is tested on 'tick'
- Budget replenishment is 0-sum

'Global' EDF

- Per logical CPU runqueue
- Push on activation
- Pull on demote/idle

Hierarchy

- pick_next_task()
  - class_stop
  - class_deadline (DEADLINE)
  - class_rt (FIFO/RR)
  - class_fair (NORMAL)
  - class_idle

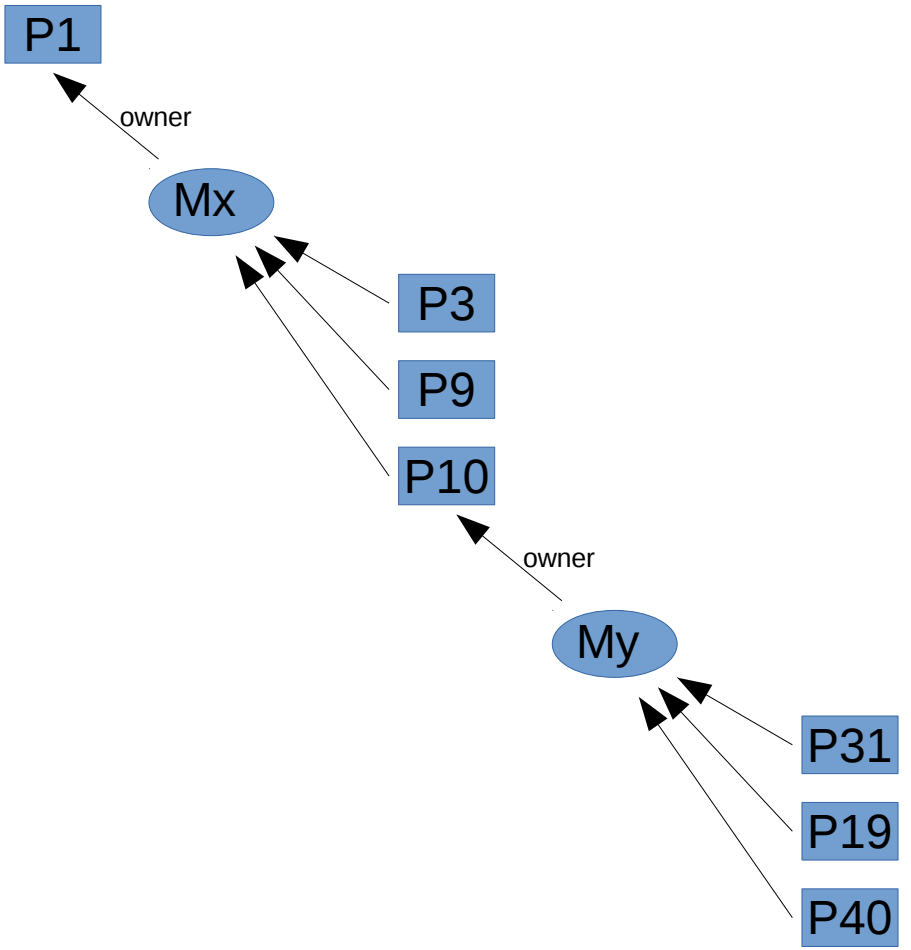
Inversion

Fixed Priority

- Priority inheritance

Dynamic Priority

- Deadline inheritance
- Bandwidth Inheritance
  - SMP?

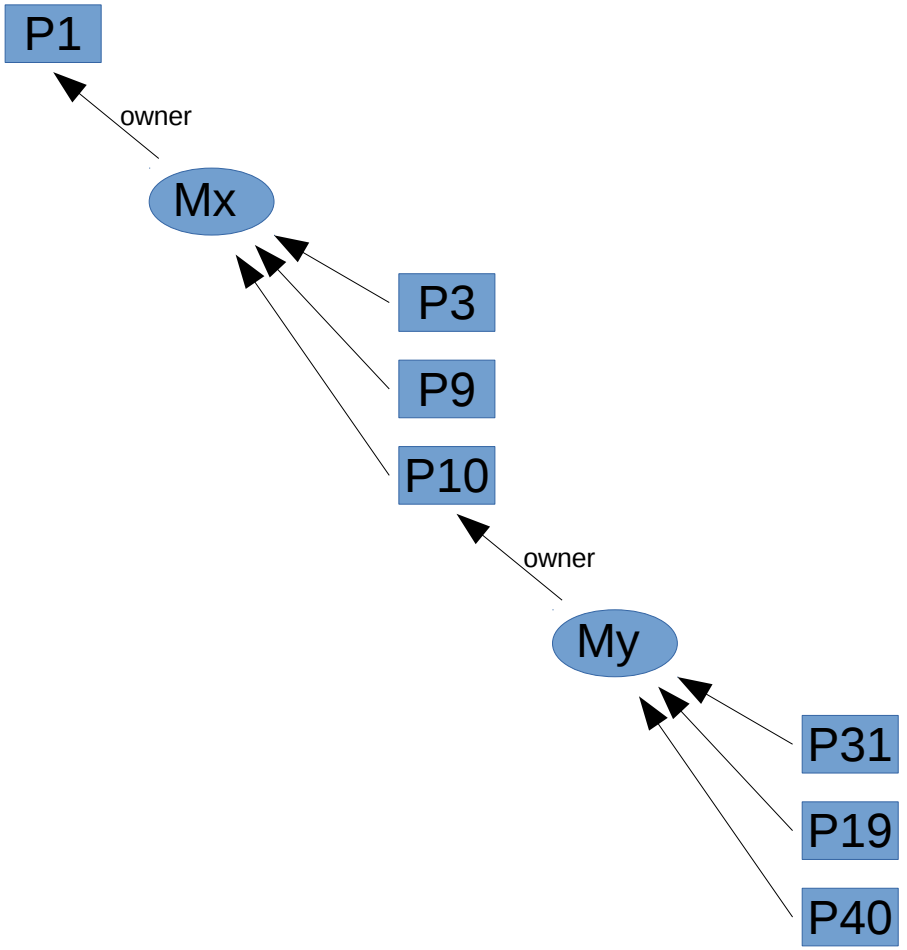


Proxy Execution

Scheduling decision function invariant.

SMP tricky...

- Easy to end up executing the same task on multiple CPUs



Admission Control

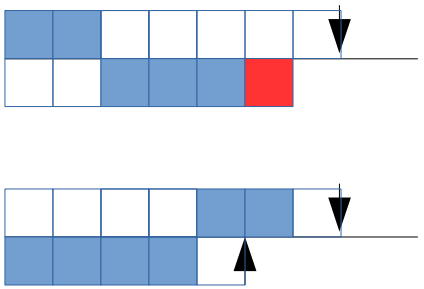
(G)EDF: U ≤ m

- Recoverable, avoids domino effect
  - Bounded tardiness
- Affinities are tricky

Proposed: $U_i = \sum_{t \cap i} \left(\frac{u_t}{w_t} \right) \leq 1$

Single CPU Affinity

- Often requested
- Expectation of UP-like behaviour
  - Mixed criticality
  - 'obvious' hierarchical EDF fails:



Mixed Criticality

EDF + LLF:

- At least 2 degrees of freedom in the model
- Laxity := { d – e; for single CPU affine tasks, otherwise inf.
- If the EDF pick can run without the LLF pick turning 0, do so, otherwise run the LLF pick.
- Has similarities to EDZL

$$t + e_{EDF} > d_{LLF} - e_{LLF}$$

Reclaim

- Soft-CBS
- Power Aware / Idle-reclaim
- GRUB (Greedy Reclaim of Unused Bandwidth)
  - Introduces active bw
    - Uact > 1 !!
  - dq = -Uact dt
  - Privileged; can consume lots of time
    - Per task / cgroup reclaim limits

Probabilistic

- Consider the per-task reclaim limit as an extension to the task model and interpret it as a measure of variance on the runtime.
- 0-sum overrun → avg, fairness
- Measurement based pWCET

Cgroups

- Cpuset → partitioning
  - AC vs partitioning broken
- Deadline
  - AC limits
  - Hierarchical CBS

Hierarchical scheduling

- CFS slack time scheduling
- FIFO servers
  - Minimal concurrency
  - Nested load-balancing
  - Arbitrary affinities are still a problem

Unprivileged

- Assume users are hostile
- Plug the BW (inheritance) hole
- DoS
  - Limits on the task model

Questions?