CS614: Linux Kernel Programming

Scheduling in Linux

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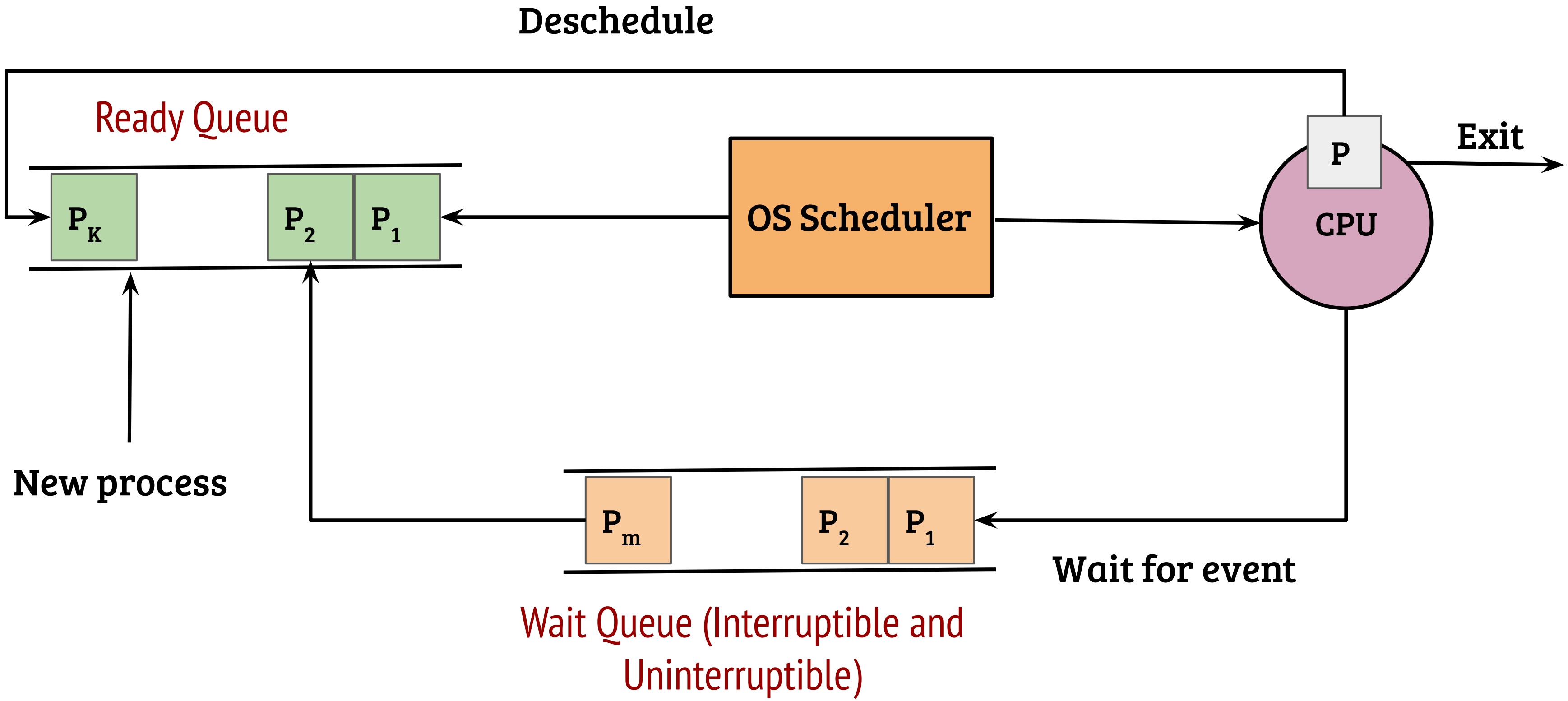
Scheduler overview



Scheduling: preemptive vs. non-preemptive

- There are scheduling points which are triggered because of the current process execution behavior (non-preemptive)
  - Process termination
  - Process explicitly yields the CPU
  - Process waits/blocks for an I/O or event

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  - Process termination
  - Process explicitly yields the CPU
  - Process waits/blocks for an I/O or event
- The OS may invoke the scheduler in other conditions (preemptive)
  - Return from system call
  - After handling an interrupt (specifically timer interrupt)

Scheduling: preemptive kernels

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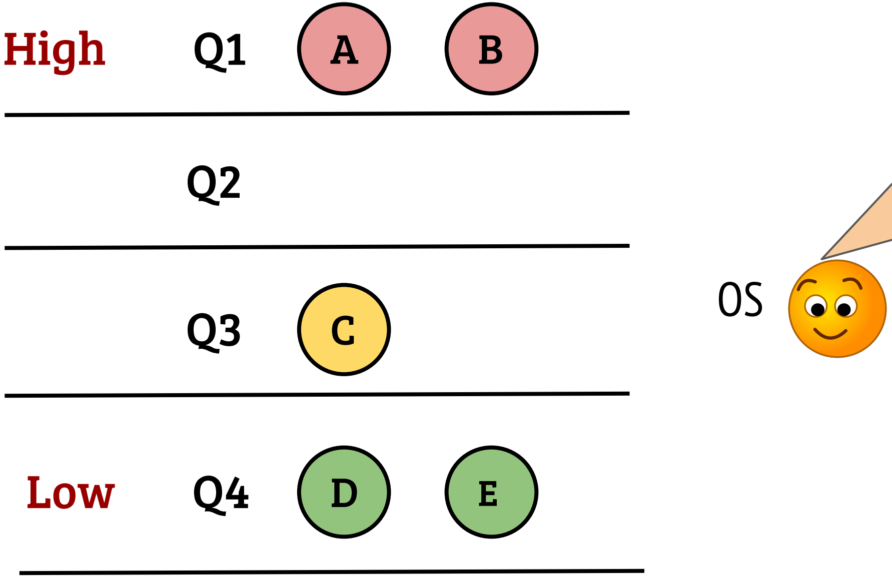
- What happens when a user thread executing in kernel more holds on to CPU for long time?
- Non-preemptive kernel: The OS should be designed to explicitly invoke the scheduler – simple to implement, inflexible because of the static nature of design
- Preemptive kernel: The OS can schedule out a kernel-mode execution thread – flexible, restrictions to context switch points need to be considered (IRQ handlers, disabled preemption execution segments etc.)

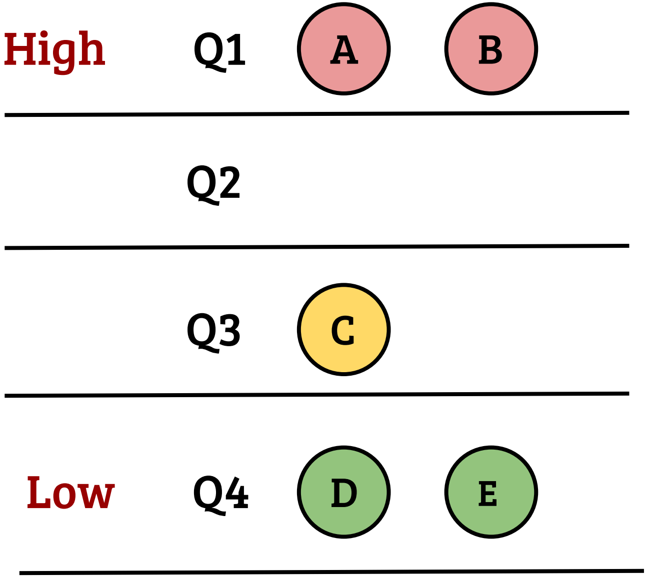
Recap: Multilevel feedback queue



Dynamically adjust priorities such that

1. Interactive applications are responsive
2. Short jobs do not suffer
3. No starvation
4. No user can trick the scheduler

Multilevel feedback queue



OS

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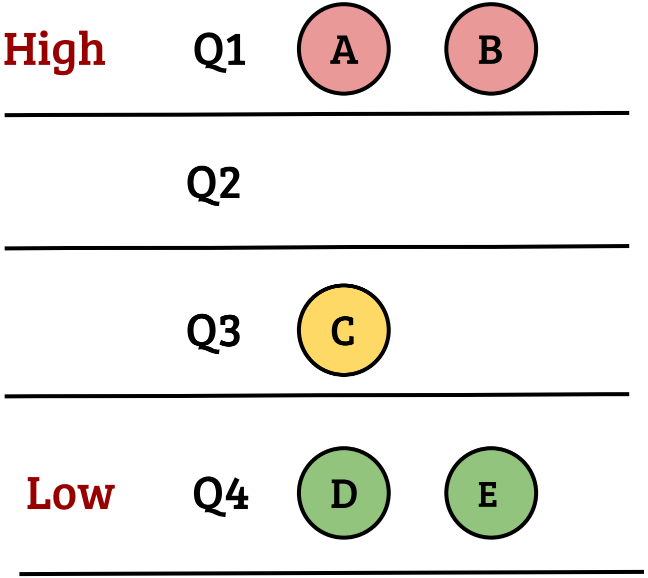
- Basic multi-level strategy
  - Pick a process from highest priority queue
  - Within a queue, apply RR

Multilevel feedback queue: Dynamic priorities



- A process is assigned the highest priority when it is created
- If the process consumes the slice (scheduler invoked because of timer), its priority is reduced
- If the process relinquishes the CPU (I/O wait etc.), its priority remain the same

MLFQ: Starvation and other issues

- Long running processes may starve with the proposed scheme
- Additionally, permanent demotion of priority hurts processes which change their behavior
  - Example: A process performing a lot of computation only at start gets pushed to a low priority queue permanently
- How to avoid the above issues?

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  - Example: A process performing a lot of computation only at start gets pushed to a low priority queue permanently
- How to avoid the above issues?
  - Periodic priority boost: all processes moved to high priority queue
  - Priority boost with aging: recalculate the priority based on scheduling history of a process

Scheduling is much more complex in a real OS!

- Scheduling requirement of different processes in the system are different
  - Real-time processes: Should meet strict deadlines
  - Interactive processes: Responsive scheduling
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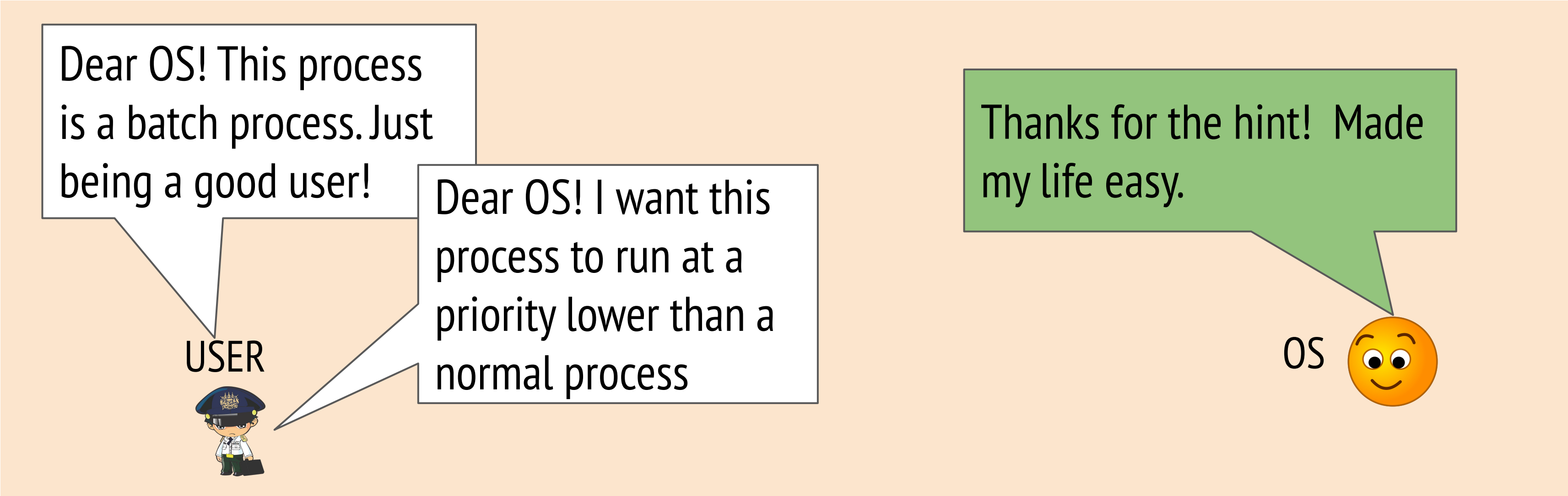

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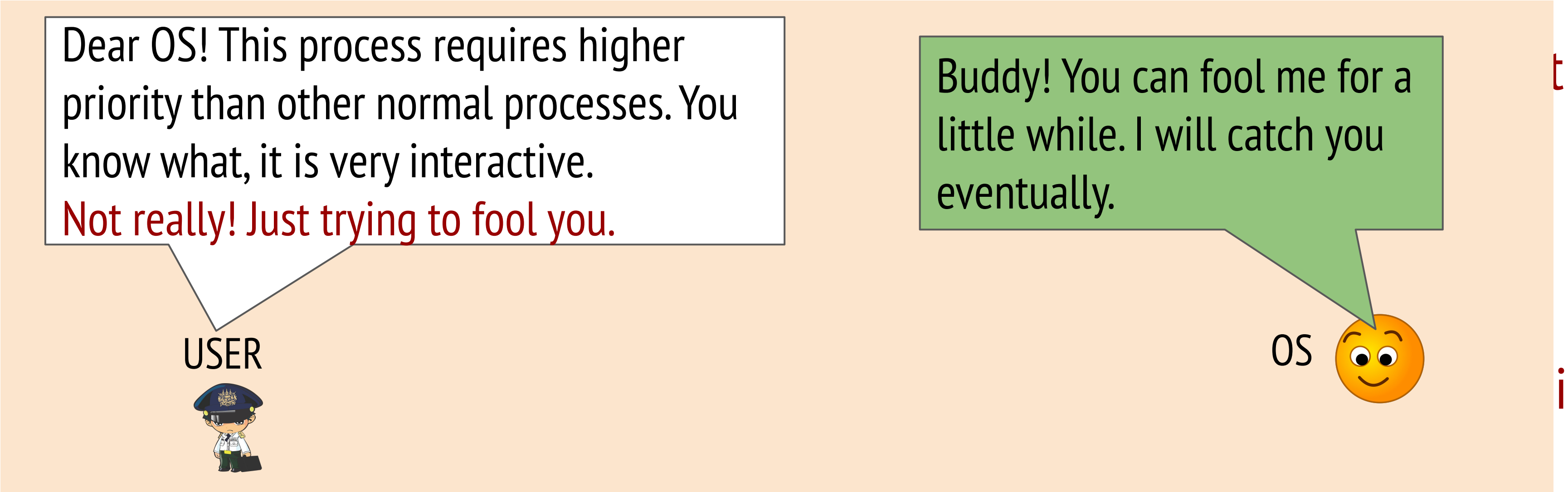

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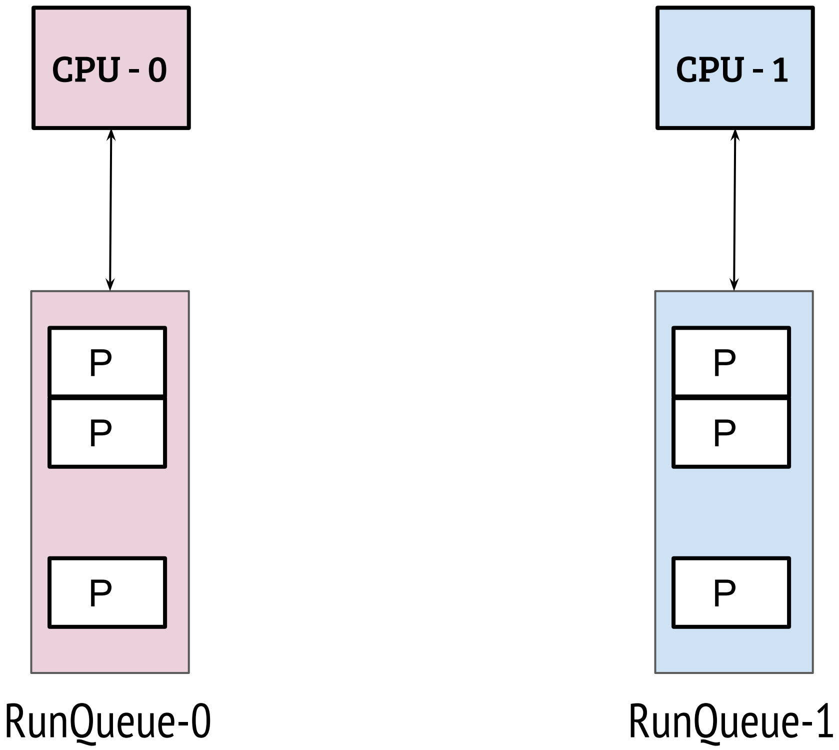
- Conclusion: OS scheduling should provide flexibility while being auto-tuning in nature

Overview of kernel scheduling design



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- How to balance the run queues in a dynamic manner?

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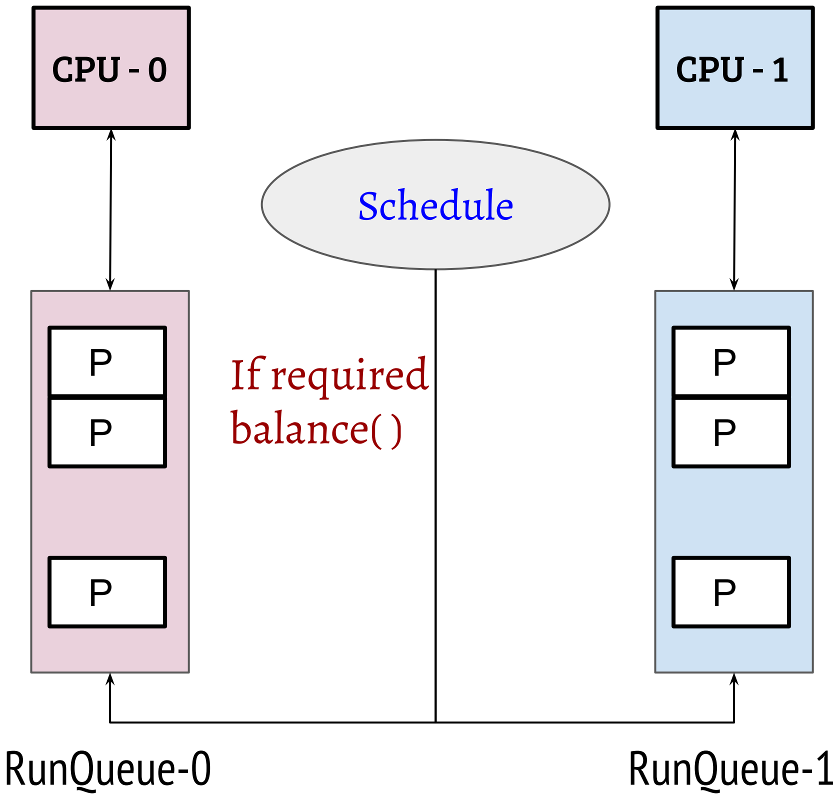

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- How to balance the run queues in a dynamic manner?
- The scheduler can balance the queues based on certain events
- How is multiple types of scheduling policies realized?

Linux scheduling classes

- There is a single stop task in every runqueue, scheduled when some extreme conditions occur (e.g., stop machine)

Linux scheduling classes

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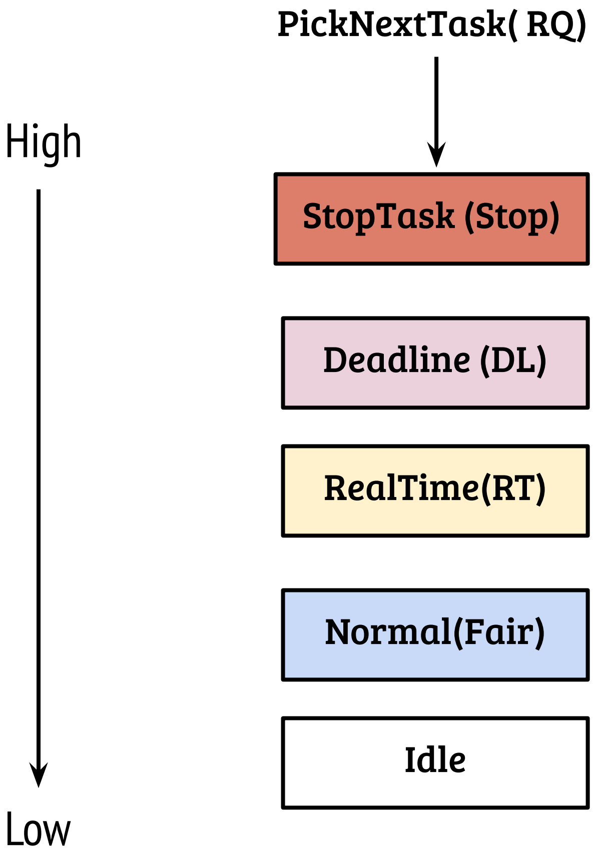
- Normal (a.k.a fair) scheduling class: Tries to achieve fair scheduling using scheduling policies such as CFS
- There is a single idle task in every runqueue, used when no process is ready

Selecting the next task



- A task is picked from the non-empty highest priority queue
- Each class implements handlers for important scheduler functions such as
  - pick_next_task
  - balance
  - update_curr
  - task_tick
  - task_fork
  - ...

Normal processes: Design objectives

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Not a easy problem to solve!

Linux: Support for priorities

- 40 priority levels (100 to 139)
- Every process starts with a default priority of 120
- Linux provides *nice* system call to adjust the static priority
  - *nice(int x)*, where x is between 19 to -20
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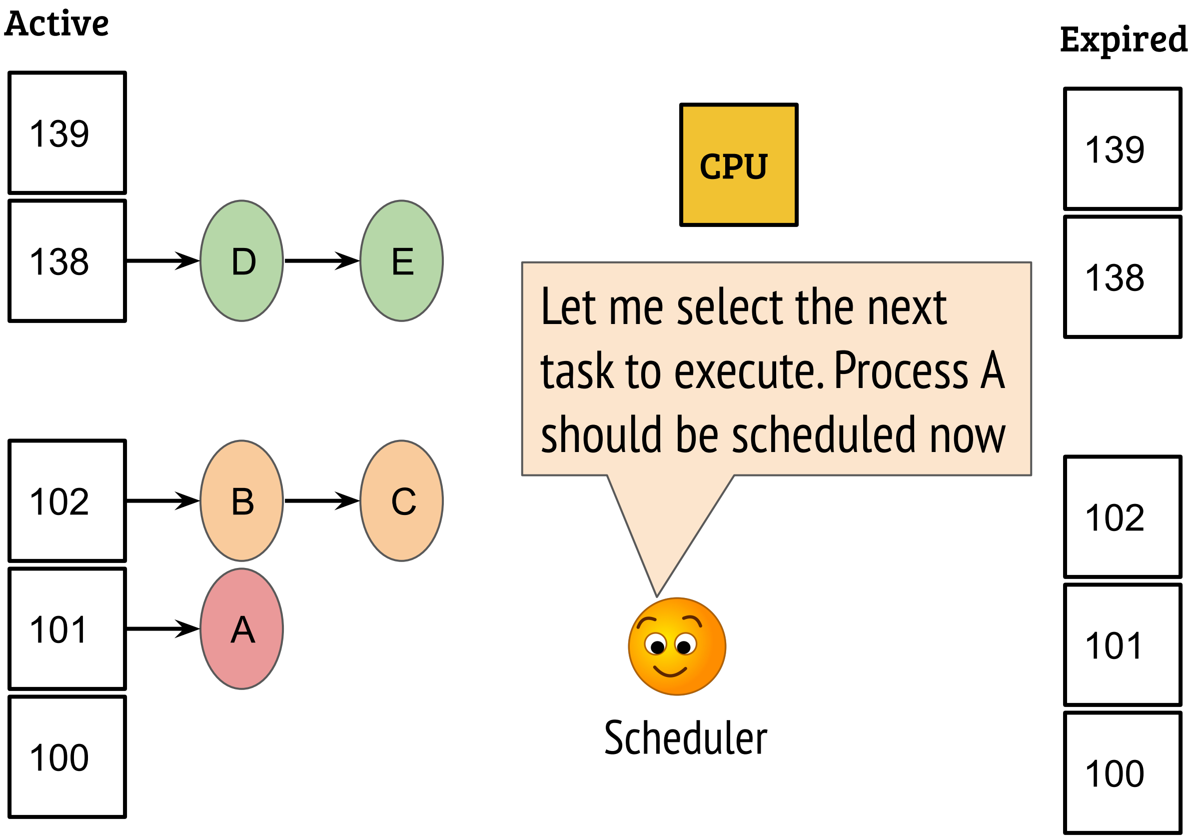
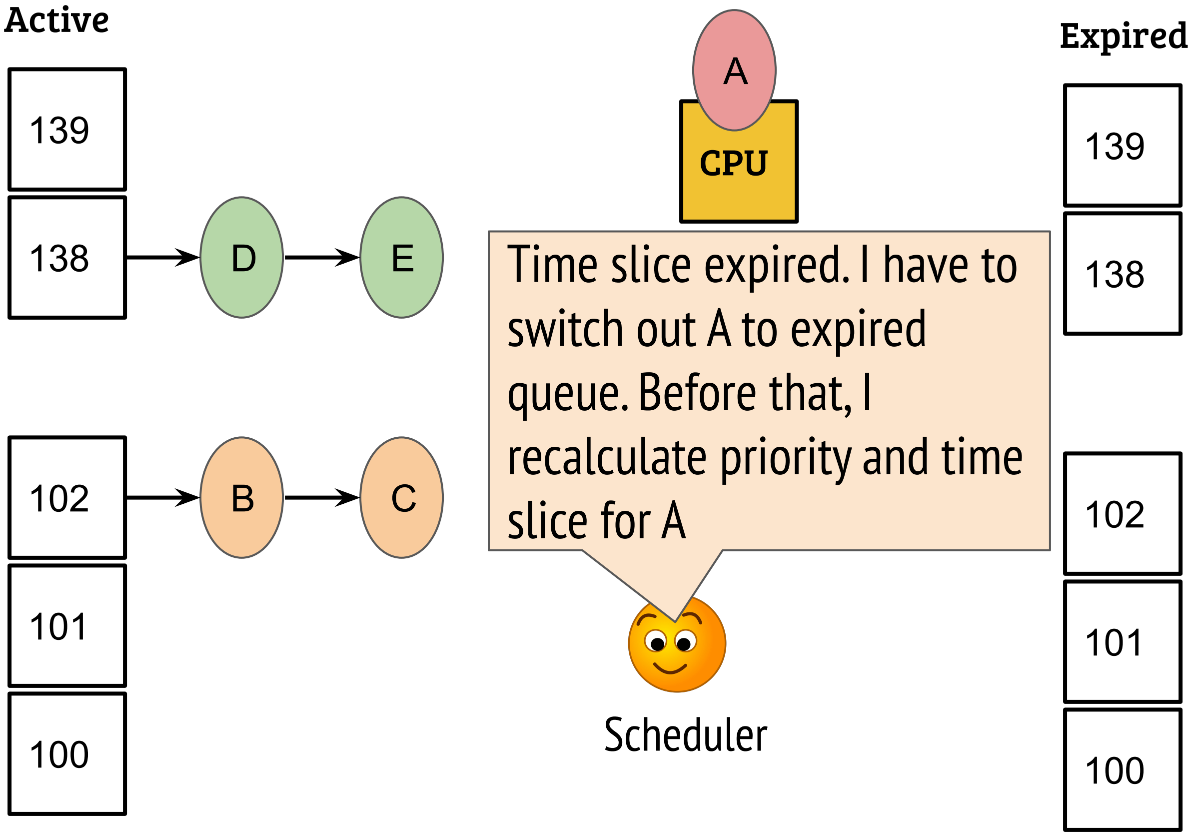
- Dynamic priority is calculated by the Linux kernel considering the interactiveness of the process
  - More interactive processes move towards the priority level 100

Linux O(1) scheduler (legacy)



Linux O(1) scheduler



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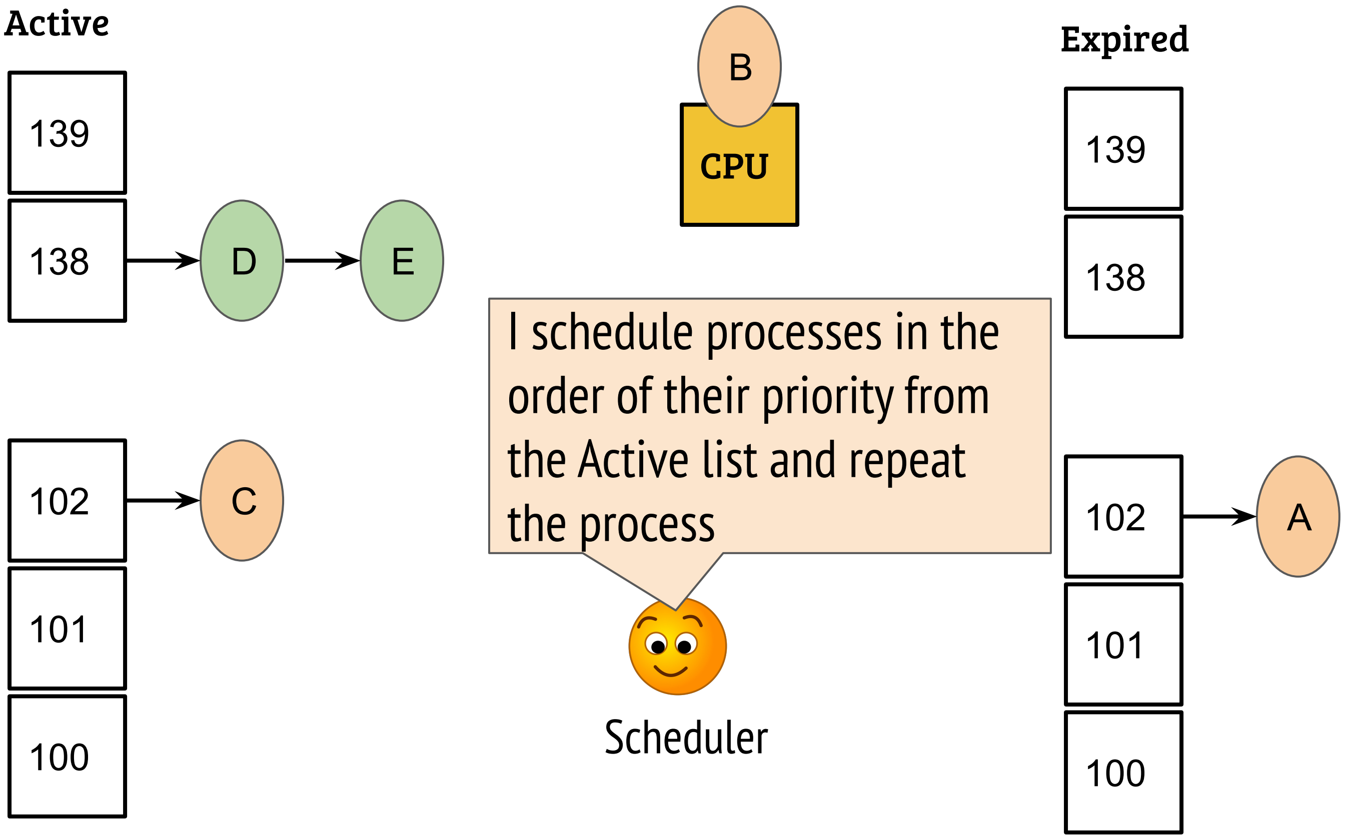

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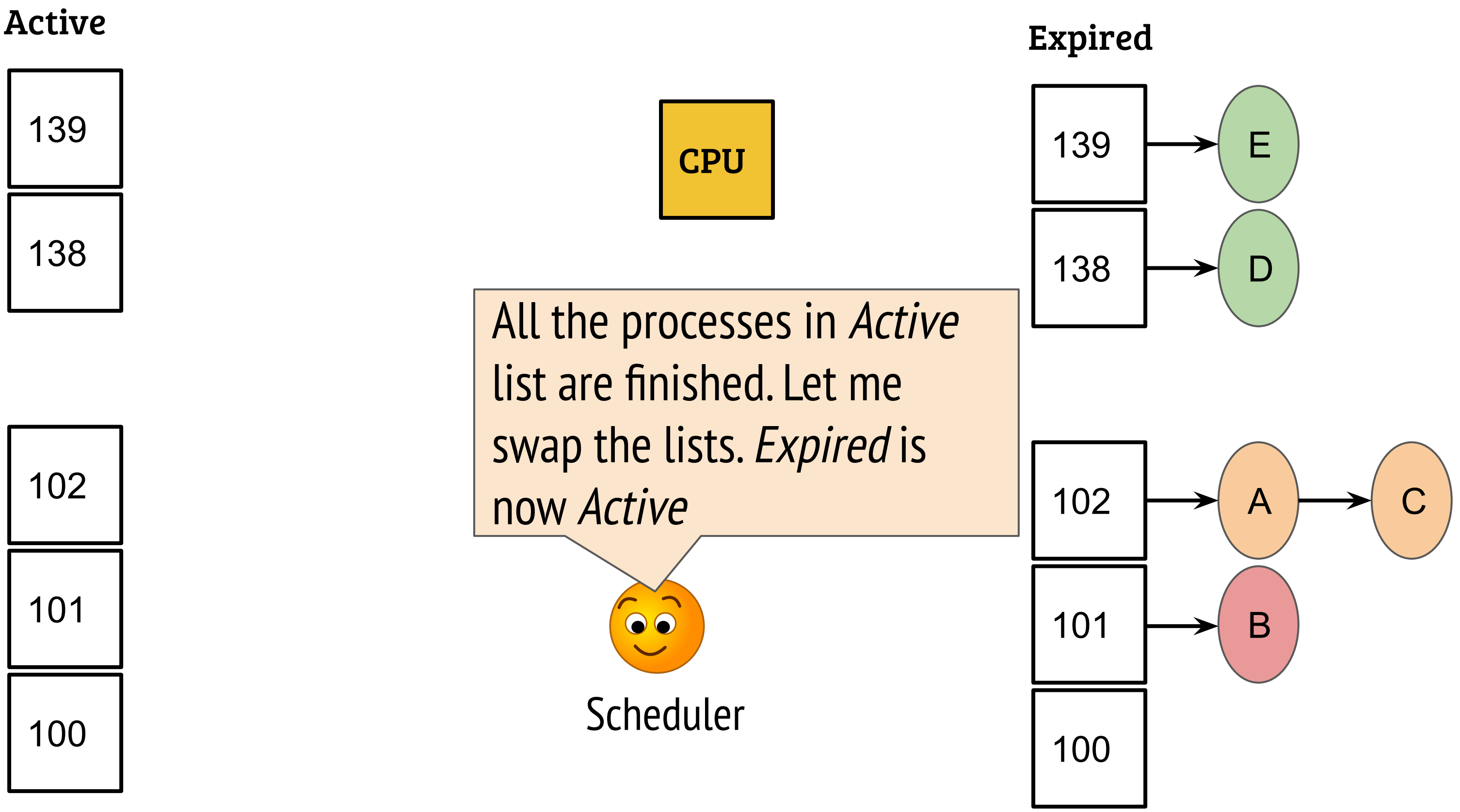

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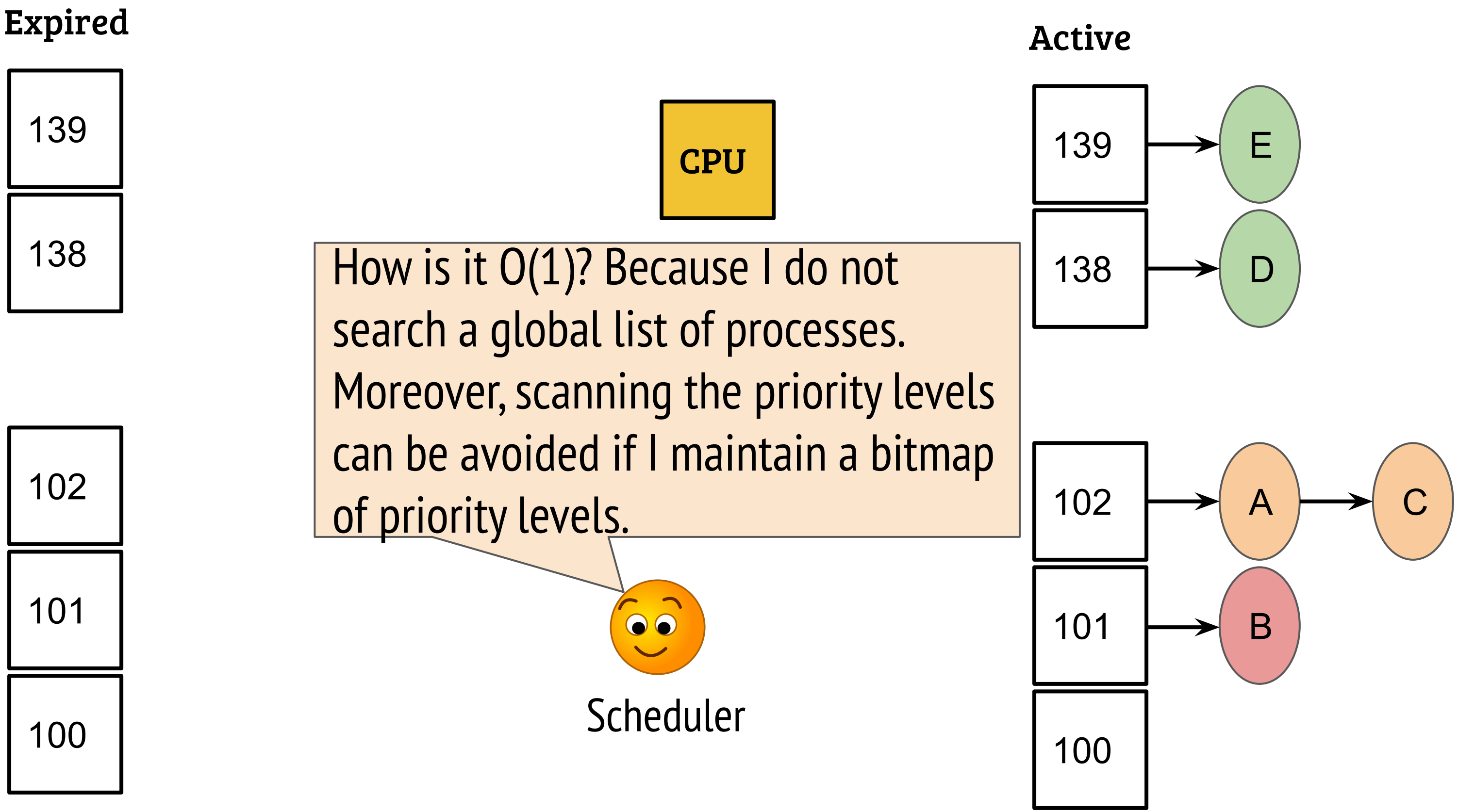

O(1) scheduler: value of time slice

- Objective: reduce timer interrupts (tickless system)
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- Low priority processes are given small time slices
  - Should not starve the interactive applications
- With many interactive (high priority) processes, low priority processes execute less frequently (but not starve) resulting in few timer interrupts
- Issues:
  - (1) More interrupts when many CPU intensive processes dominate the system (2) Priority penalty may lead to fairness issues

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  - Maintain history about runtimes, check against ideal, schedule to bridge the gap between ideal fairness and the current fairness
  - Implemented by maintaining "virtual run-time" for each task which represents the CPU share of the task
- Reality is little complicated with priorities and dynamic number of tasks