Linux Process Scheduling

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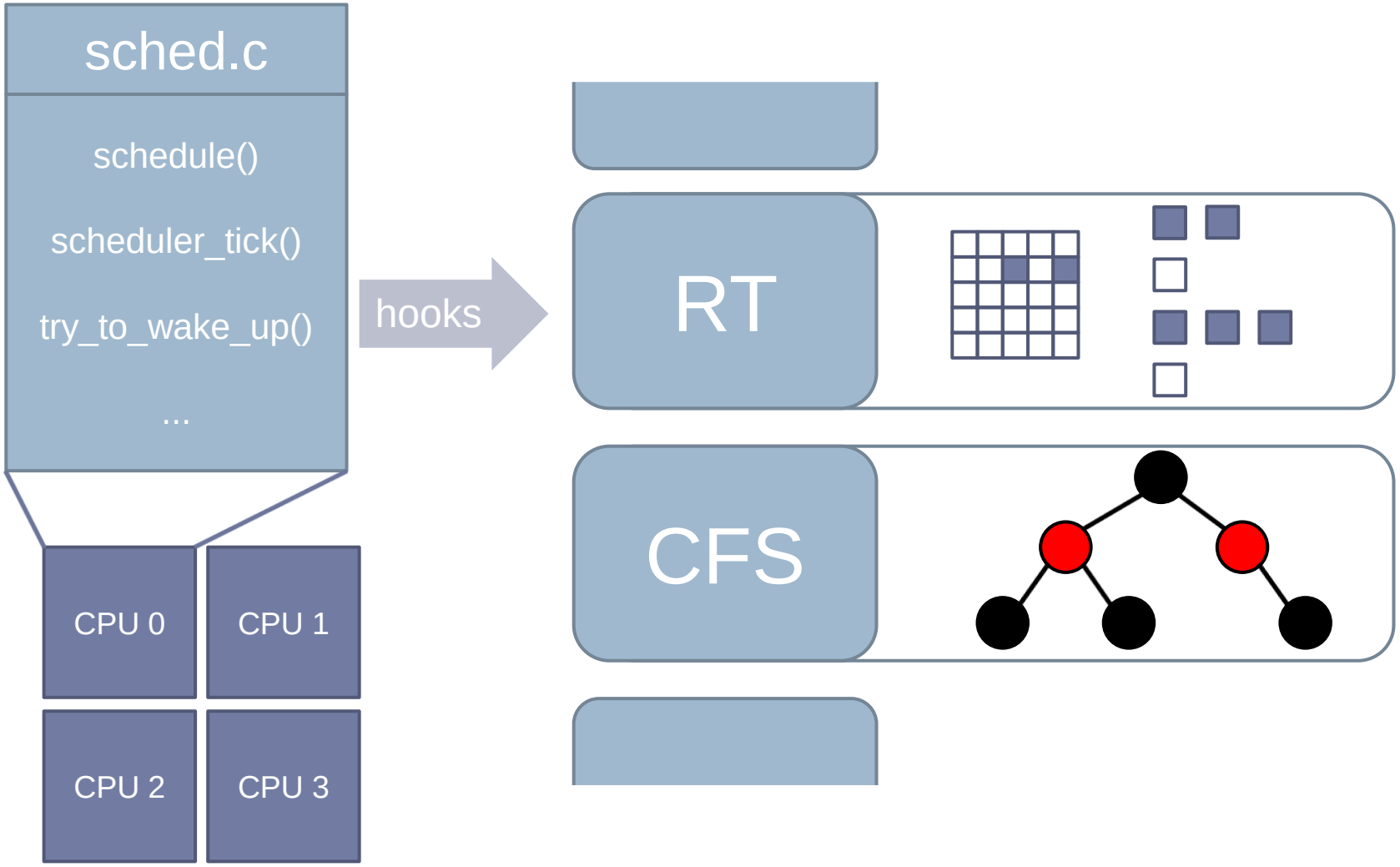

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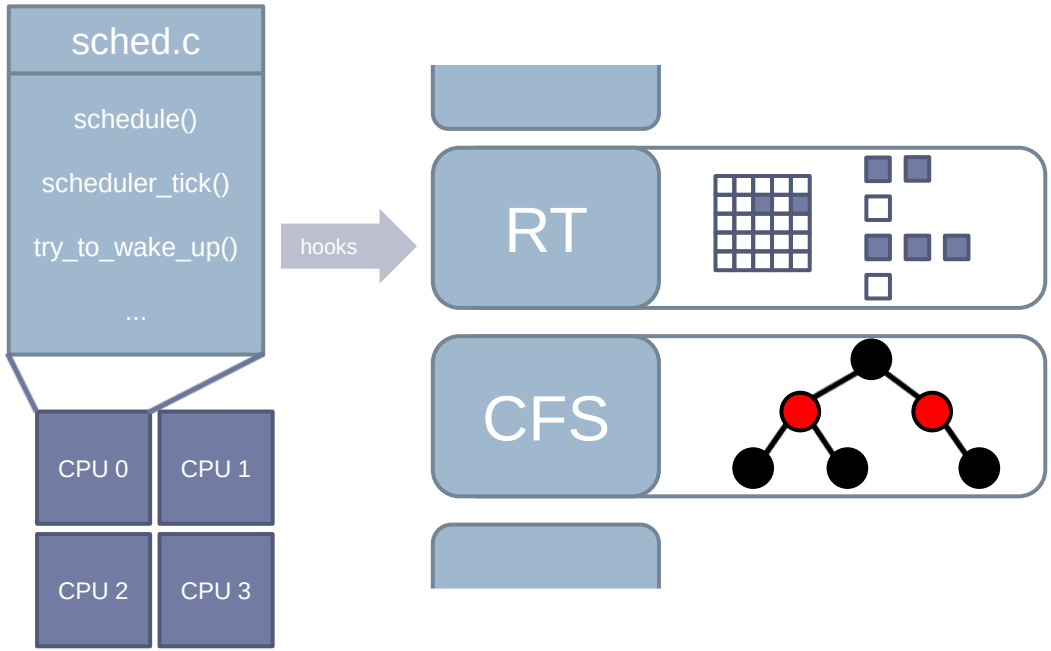
1. Task Classification
2. Scheduler Skeleton
3. Completely Fair Scheduler (CFS)
4. Real Time Scheduling (RT)
5. Load Balancing CFS
6. Load Balancing RT



1. Task Classification
Task Types

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Real Time vs Normal/Other

CPU bound vs I/O bound

- Efficient vs Responsive
- Server vs Desktop vs HPC

1. Task Classification Scheduling Classes

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include/linux/sched.h

struct sched_class

const struct sched_class *next

(*enqueue_task)
(*dequeue_task)
(*check_preempt_curr)
(*pick_next_task)
(*select_task_rq)
(*pick_next_task)
...

kernel/sched_rt.c

rt_sched_class

.next = &fair_sched_class

.enqueue_task = &enqueue_task_rt
.dequeue_task = &dequeue_task_rt
...

kernel/sched_fair.c

fair_sched_class

.next = &idle_sched_class

.enqueue_task = &enqueue_task_fair
.dequeue_task = &dequeue_task_fair
...

1. Task Classification
Scheduling Class Priorities

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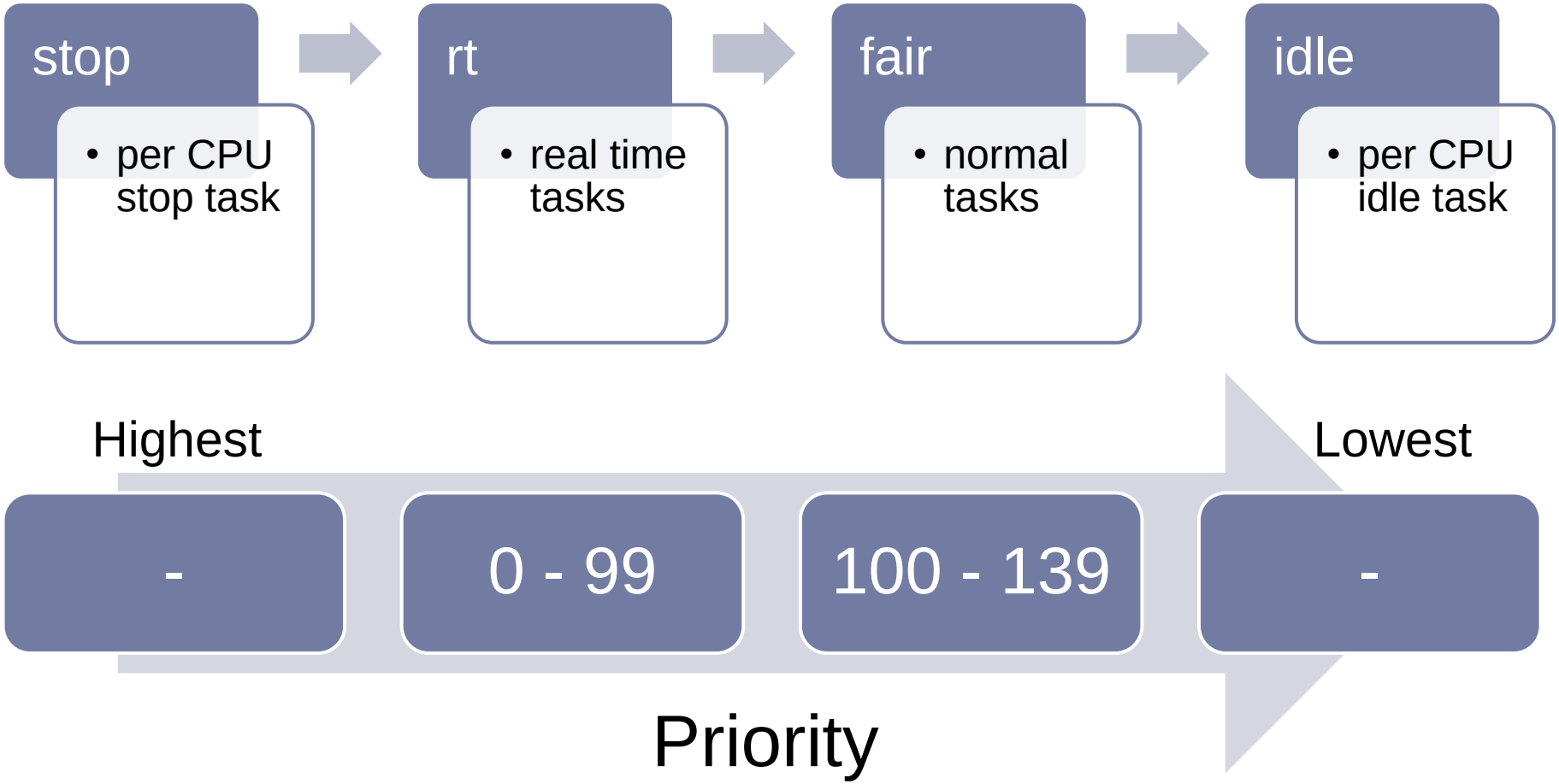

2. Scheduler Skeleton
Scheduler Entry Point

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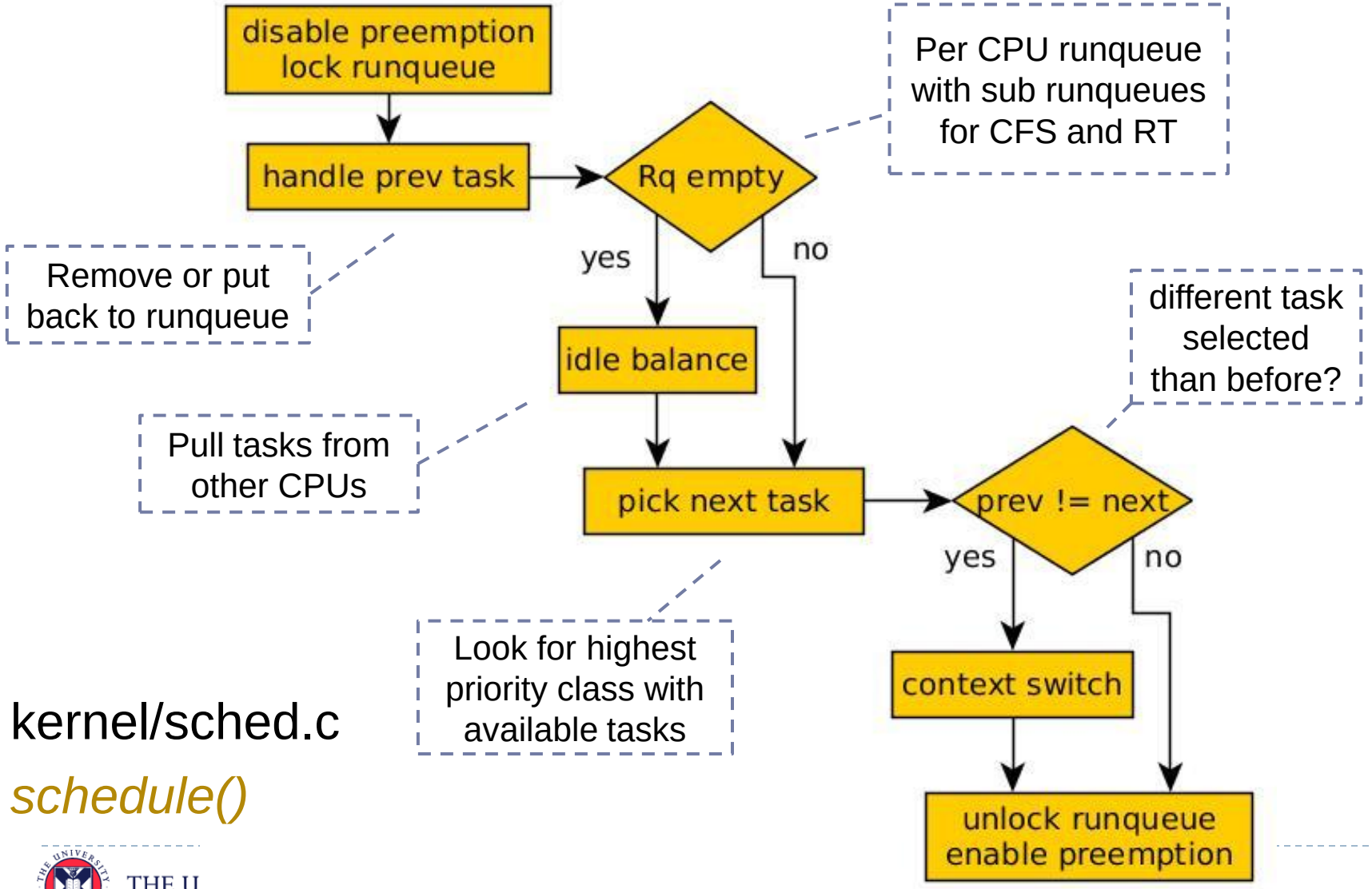

kernel/sched.c

schedule()

2. Scheduler Skeleton
Calling the Scheduler

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1. Timer Interrupt
2. Currently running task goes to sleep
3. Sleeping task wakes up

2. Scheduler Skeleton
Calling the Scheduler - Timer

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kernel/sched.c

```
scheduler_tick() {
  ...
  sched_class->task_tick()
  ...
}
```

CPU 0 | CPU 1
CPU 2 | CPU 3

kernel/sched_X.c

X_sched_class

```
task_tick_X() {
```

update task's scheduling entity

is it another task's turn yet?

Yes

Invoke scheduling

```
}
```

2. Scheduler Skeleton
Calling the Scheduler - Sleep

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```
1  /* ‘q’ is the wait queue we wish to sleep on */
2  DEFINE_WAIT(wait);
3
4  add_wait_queue(q, &wait);
5  while (!condition) { /* condition is the event that we are waiting for */
6      prepare_to_wait(&q, &wait, TASK_INTERRUPTIBLE);
7      if (signal_pending(current))
8          /* handle signal */
9      schedule();
10 }
11 finish_wait(&q, &wait);
```

2. Scheduler Skeleton
Calling the Scheduler – Wake up

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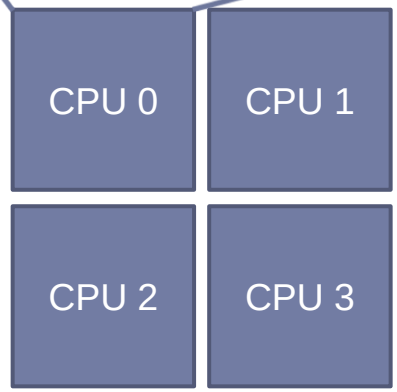
kernel/sched.c

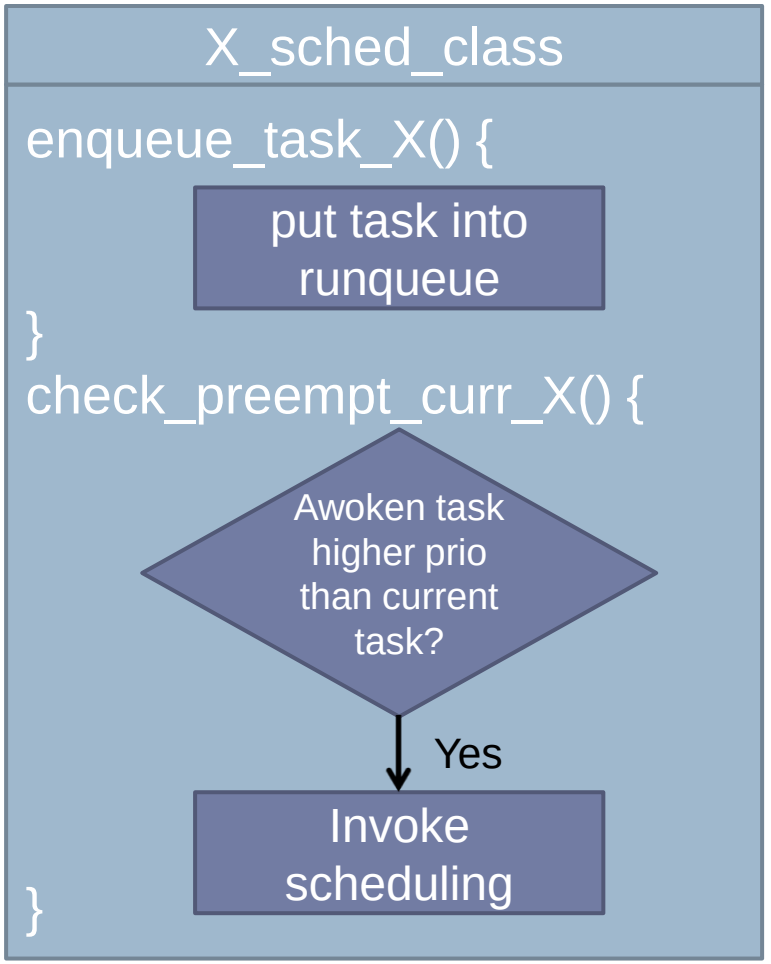
```
try_to_wake_up() {
...
sched_class->enqueue_task()

sched_class->check_preempt_curr()

task.state = TASK_RUNNING
...
}
```



kernel/sched_X.c



3. Completely Fair Scheduler Concept

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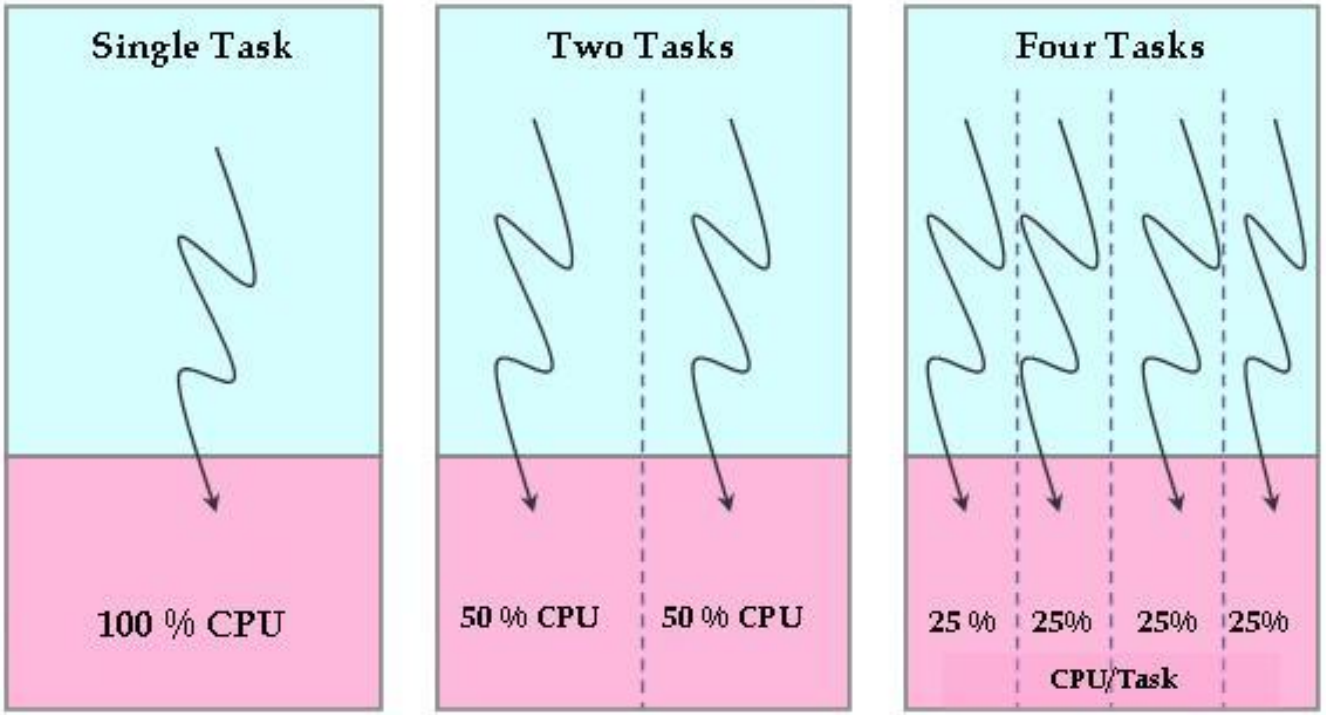

Ideal Precise Multi-tasking CPU – Each task runs in parallel and consumes equal CPU share

Virtual Runtime CFS tries to maintain an equal virtual runtime for each task in a CPU's runqueue at all time.

3. Completely Fair Scheduler Virtual Runtime

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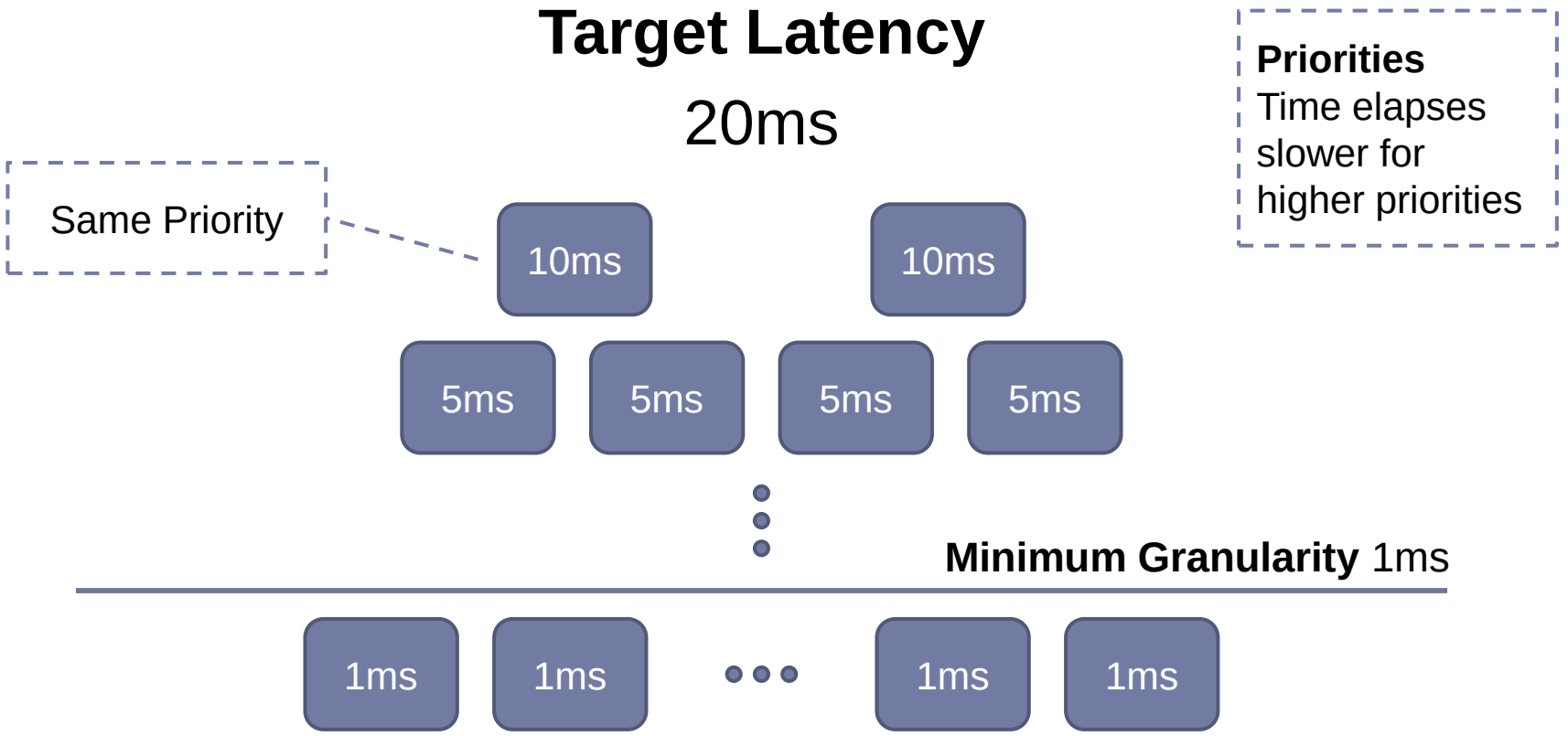

- How does it work out for I/O bound and CPU bound Tasks?

3. Completely Fair Scheduler Runqueue - Red-Black-Tree

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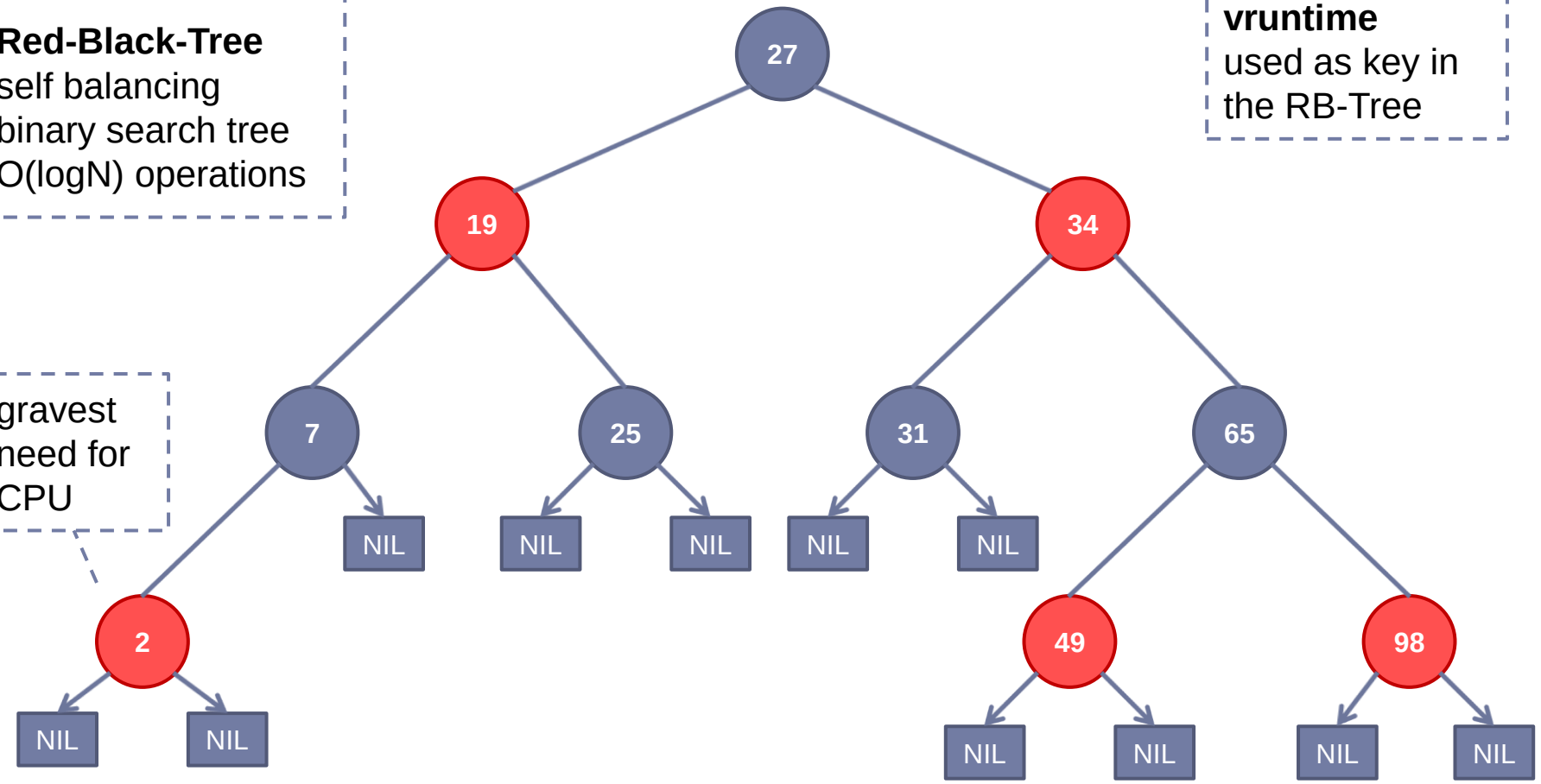
Red-Black-Tree
self balancing
binary search tree
O(logN) operations

vruntime
used as key in
the RB-Tree

gravest
need for
CPU



3. Completely Fair Scheduler Fair Group Scheduling

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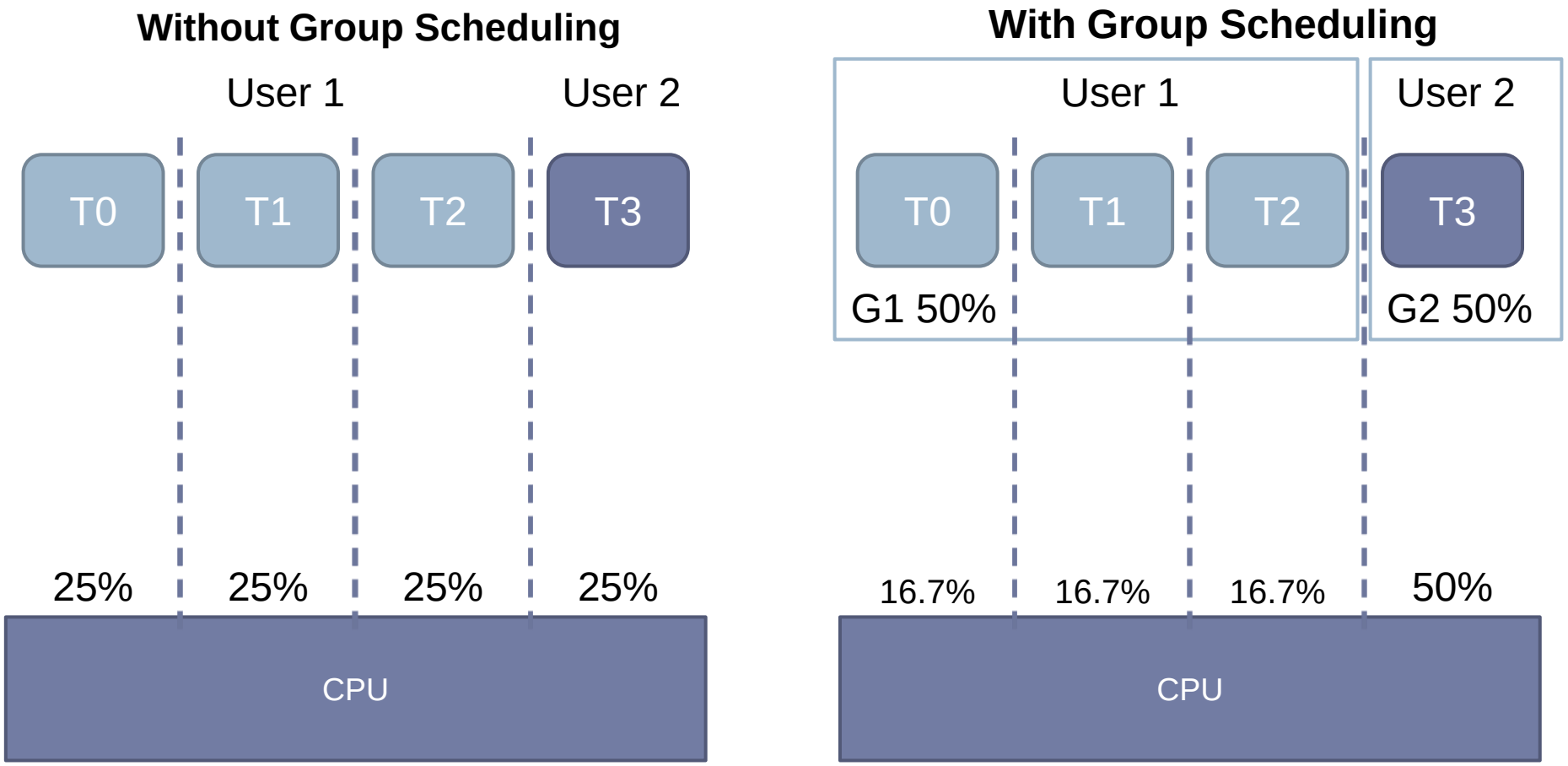

First, be fair to groups – then, be fair to tasks.

4. Soft-Real-Time Scheduling
Scheduling Modes

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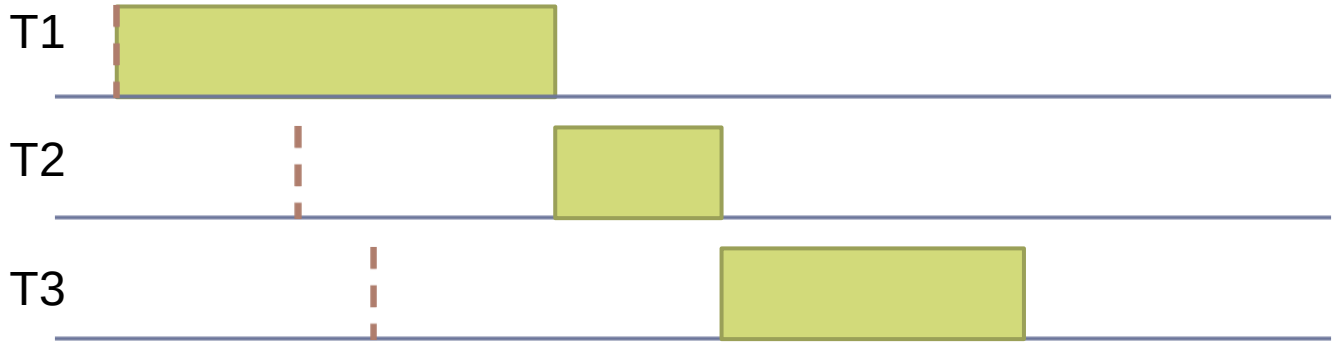
Scheduling of tasks with strict timing requirements.
RT scheduling is reliable but kernel does not guarantee that deadlines will be met.

SCHED_FIFO

no time slices

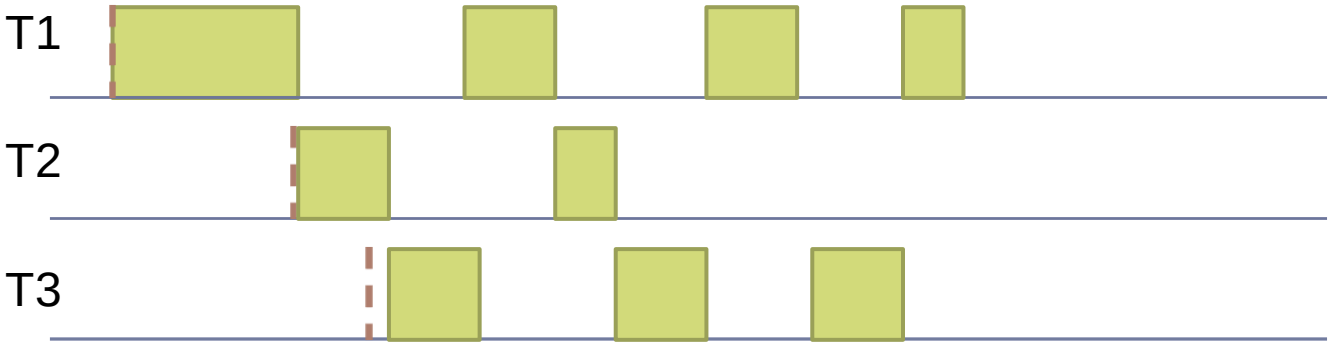
until termination or yielding CPU



SCHED_RR

fixed time slice

round robin scheduling



4. Soft-Real-Time Scheduling Runqueue – Priority Queues

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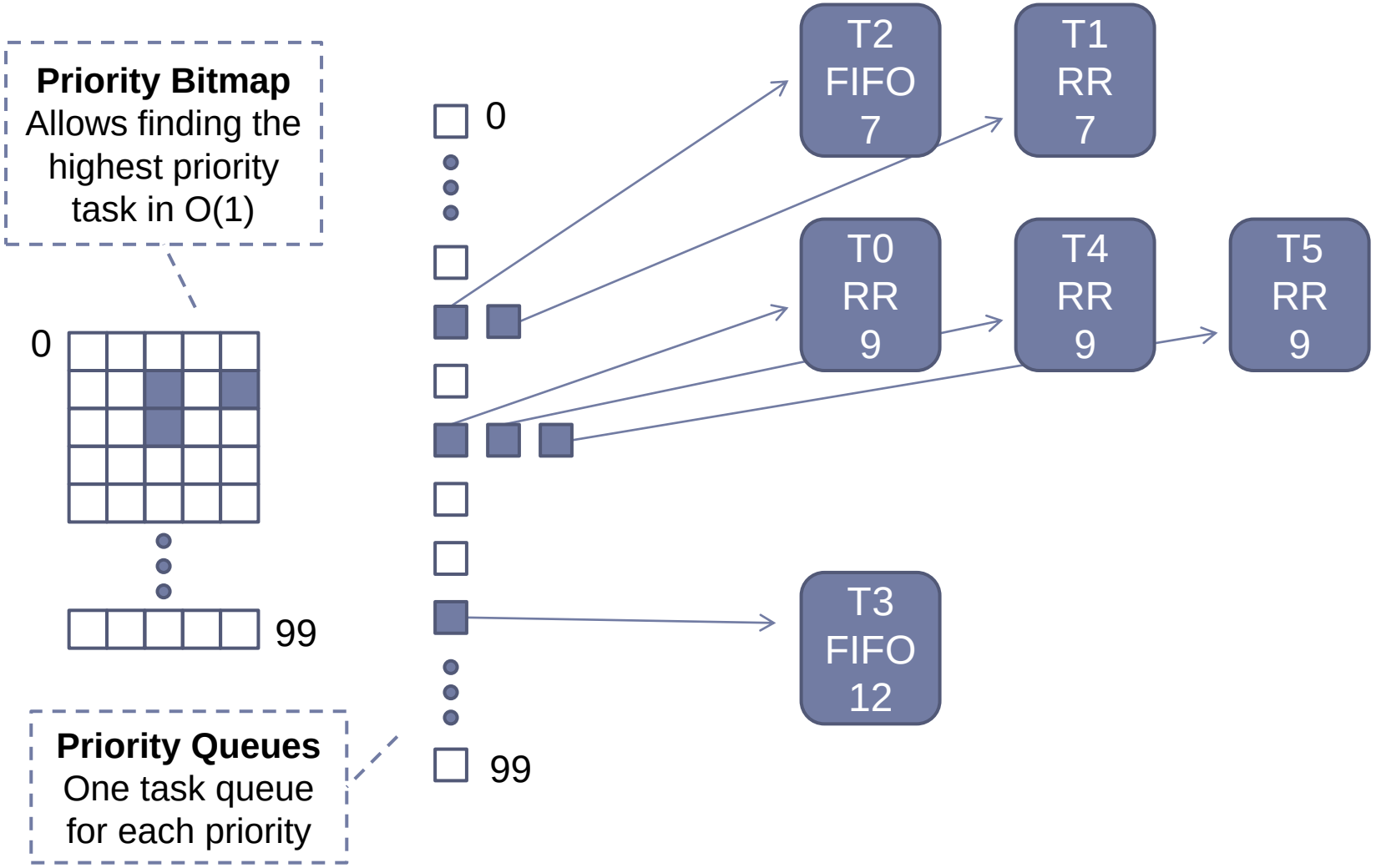

5. Load Balancing CFS Scheduling Domains

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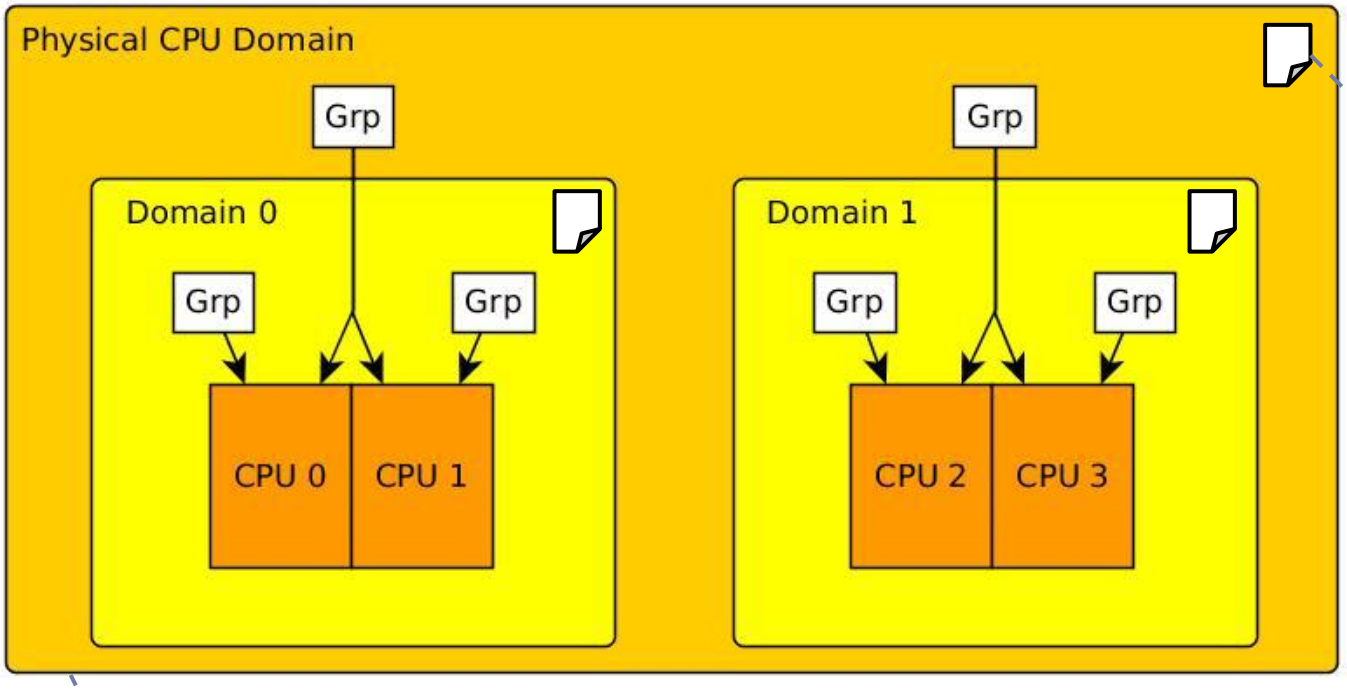
CFS load balancing is used to offload task from busy CPUs to less busy or idle ones on SMP Systems.



Domain Specific Balancing Policy

- how often to do balancing
- how far to move tasks
- how long before cache cools down
- ...

Scheduling Domains

Handle the topology variety of modern processor.

5. Load Balancing CFS
Active and Idle Balancing

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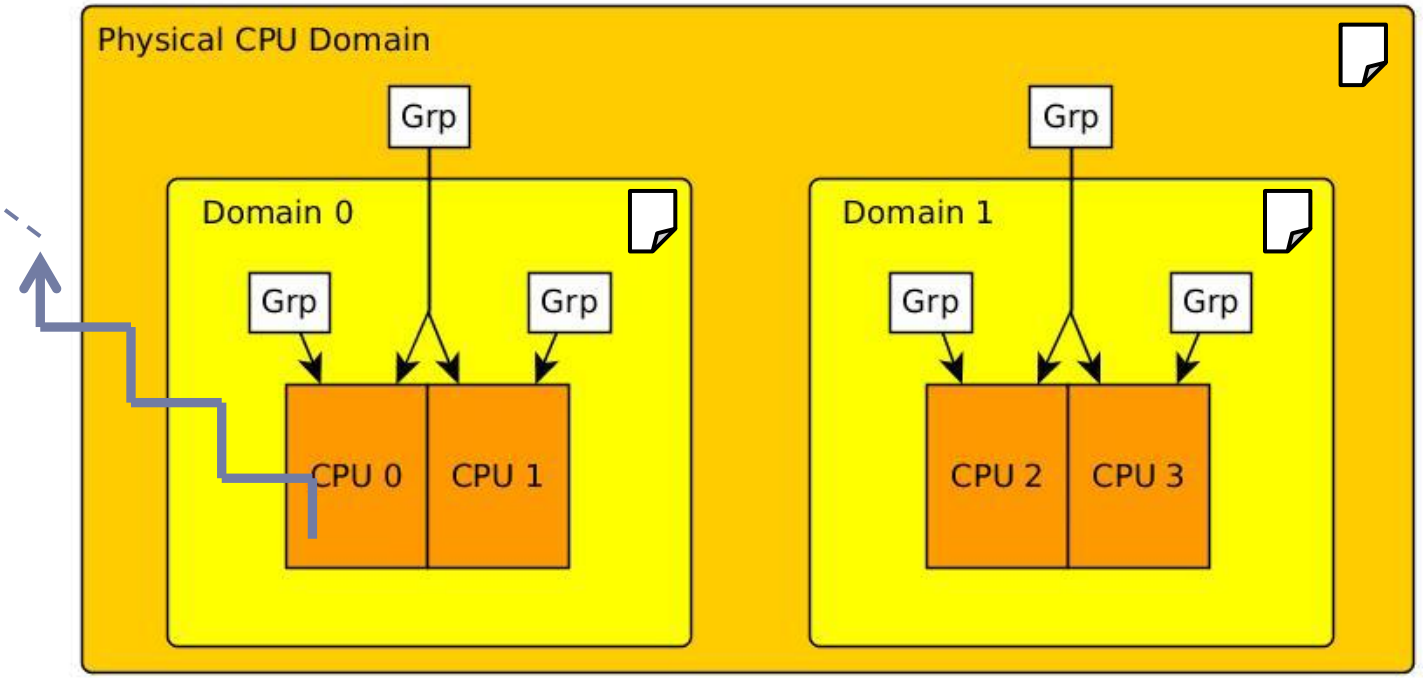
kernel/sched_fair.c

Balancing
walks up the domain hierarchy and looks for the busiest group



Active Balancing

regularly by *scheduler_tick()*

pulls tasks over from busiest group per domain

Idle Balancing

as soon as CPU goes idle in *schedule()*

checks if average idle time is larger than migration cost

pulling tasks like active balancing

5. Load Balancing CFS Where To Put a New Task

kernel/sched.c

```
select_task_rq(flag) {
  ...
   sched_class->select_task_rq(flag)
  ...
}
```

kernel/sched_fair.c

```
fair_sched_class
select_task_rq_fair(flag) {
 ...
}
```

Returns optimal CPU to put the task on

Looks for idlest CPU considering only those domains that have *flag* set in their balancing policy

SD_BALANCE_EXEC

used in *sched_exec()* upon starting a new task with exec()

SD_BALANCE_FORK

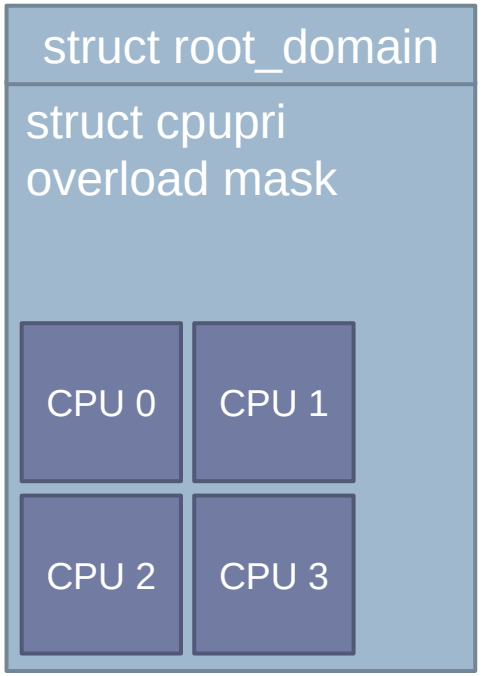
used in *wake_up_new_task()* upon a fork command

SD_BALANCE_WAKE

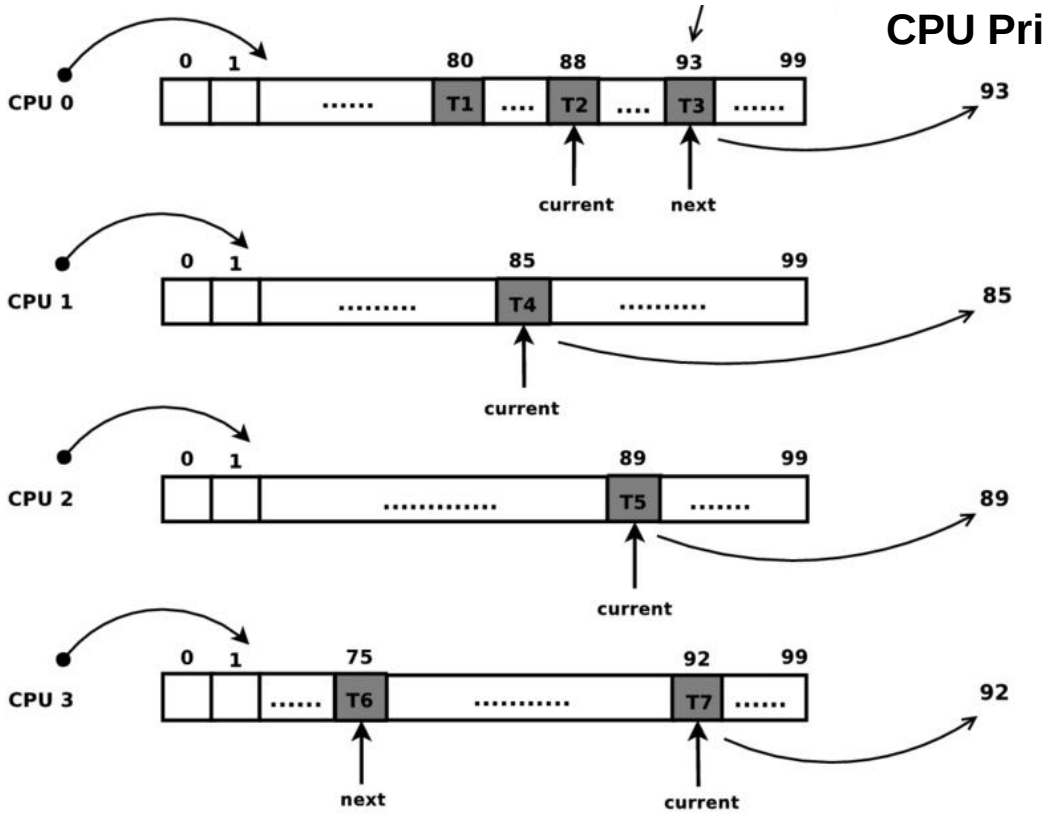
used in *try_to_wake_up()* upon waking up a task that already ran

6. Load Balancing RT
Root Domains and CPU Pri

RT load balancing aims to make sure that the N highest priority tasks on the system are running at all time where N is the number of CPUs.



Root Domain
scope for RT scheduling decisions
overall overload and priority state



6. Load Balancing RT Push

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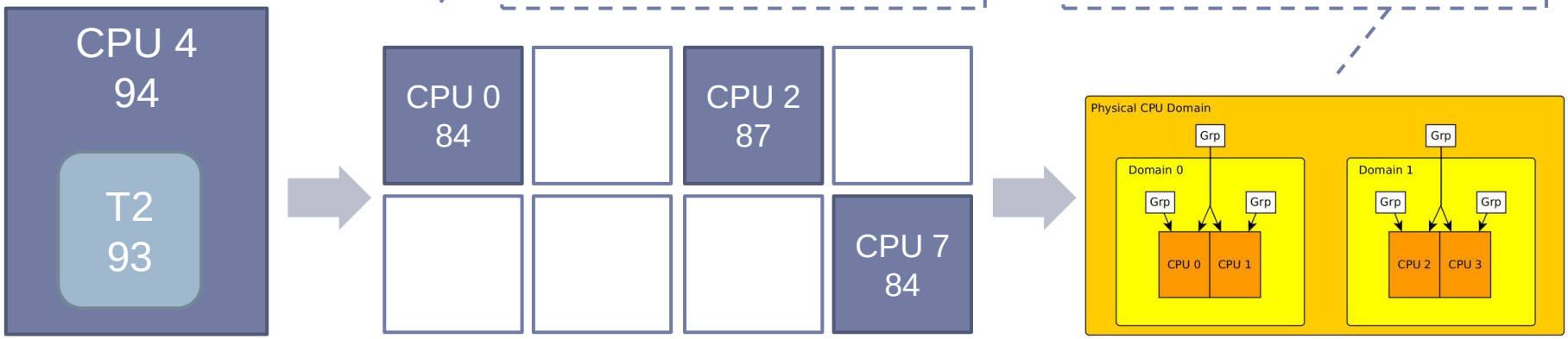
A Low Priority Task is Pushed to Another CPU If *post_schedule()*
- lower prio task wakes up on CPU with higher prio task running
- higher prio task wakes up on CPU and preempts lower prio task

T2 needs to be pushed away

get CPU Lowest Mask represents the lowest priority tasks in the system

Elect best target CPU based on cache affinity and topology



6. Load Balancing RT Pull

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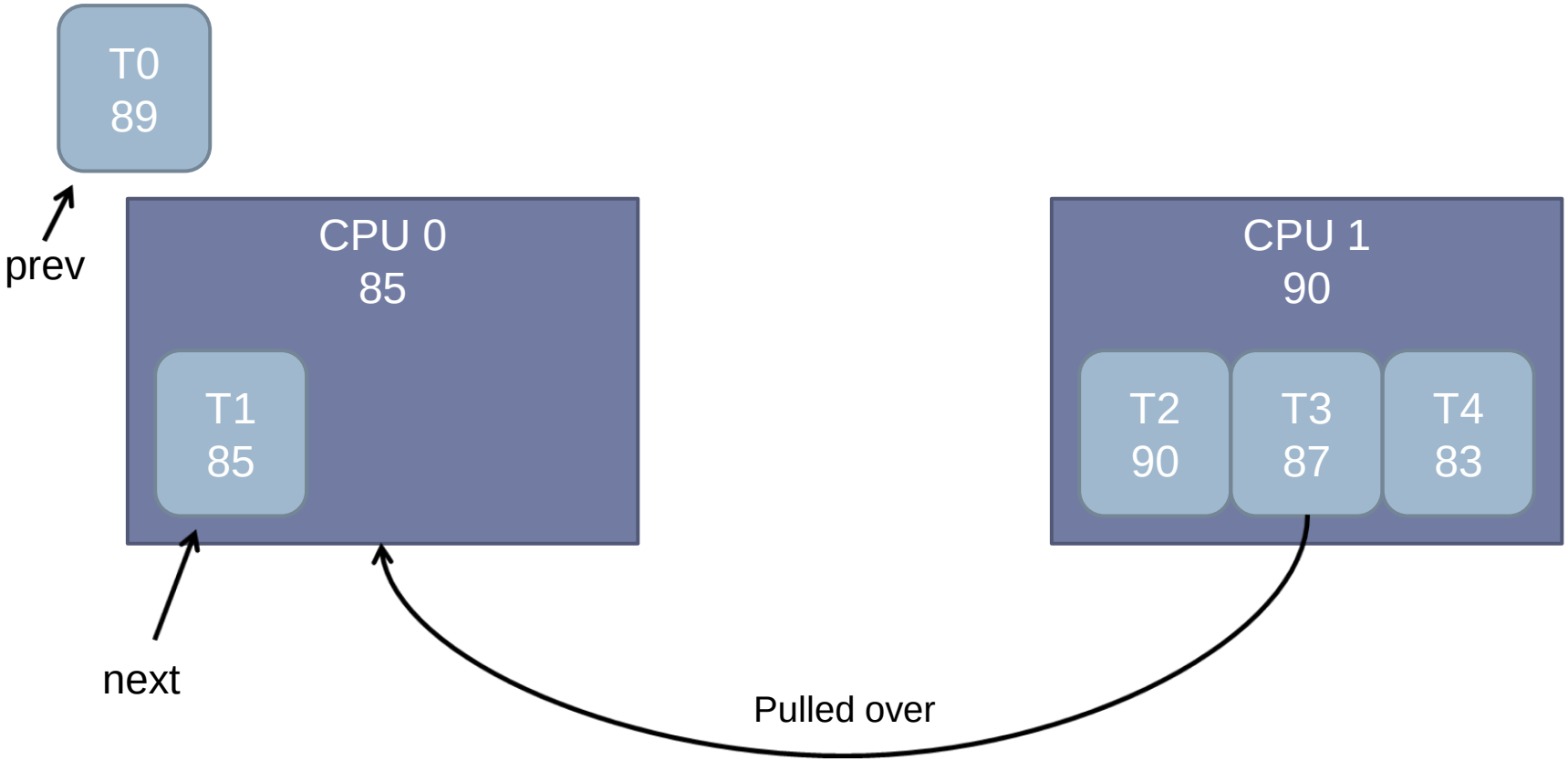
A High Priority Task is Pulled from Another CPU If *pre_schedule()*

- priority of task to be scheduled would be lower than previously one's



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Thanks, Questions?

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