CPU Scheduling with the RT Kernel

Real-time CPU scheduling in SUSE Linux Enterprise Server is the kernel mechanism that controls task execution timing and processor placement to provide deterministic, low-latency performance. By combining real-time policies such as `SCHED_FIFO` and `SCHED_RR` with CPU affinity through `systemd`, **`chrt`** and **`taskset`**, administrators can eliminate thread migration overhead, preserve cache locality and guarantee bounded dispatch latency for critical workloads.

Prerequisites

- The `util-linux` package installed for **`chrt`** and **`taskset`**
- A real-time kernel installed and running on SUSE Linux Enterprise Server

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1 What is CPU scheduling?

CPU scheduling is the kernel mechanism that allocates execution time on processor cores among competing processes and threads. Because a system typically has far more running tasks than physical or logical CPU cores, the kernel scheduler arbitrates execution by deciding which thread executes, when it executes, how long it runs, and on which CPU core it is eligible to run.

The primary objective of the kernel is to provide predictability, determinism, and bounded dispatch latency. To achieve this, real-time CPU scheduling controls two complementary dimensions of thread execution: *timing* and *placement* (on which CPU core a task runs).

The timing dimension is controlled through real-time *scheduling policies* and priority levels. These settings ensure that whenever a time-critical task is ready to execute, the real-time scheduler immediately preempts lower-priority workloads.

However, real-time priority alone does not restrict a task to a specific processor. By default, the scheduler may migrate a running thread between available CPU cores to balance the overall system load. In real-time environments, this migration introduces unwanted latency through context switching, cache invalidation, and non-uniform memory access (NUMA) penalties.

To eliminate migration overhead and guarantee deterministic execution, scheduling policies must be paired with *CPU affinity*. Scheduling policies determine task preemption rights on a given core. CPU affinity rules pin tasks to dedicated cores to preserve cache locality and isolate critical execution paths from the rest of the operating system.

2 Real-time CPU scheduling policies

The Linux kernel's scheduler allocates processor execution time to running threads according to process-level CPU scheduling policies.

The Linux kernel scheduler can use the following policies:

`SCHED_FIFO`

> **First In, First Out**: A running thread continues executing until it blocks on an I/O request, explicitly yields execution, or is preempted by a higher-priority real-time thread. Priority levels range from 1 (lowest) to 99 (highest).

`SCHED_RR`

Round Robin: Similar to `SCHED_FIFO`, but threads of identical priority receive fixed time slices to prevent a single thread from monopolizing execution on a core.

In production real-time environments, there are three primary ways to set these policies depending on whether control belongs to the system administrator, a startup script, or the developer:

- **Persistently using `systemd` unit files**: The policy is set in a `.service` unit file. For details, refer to *Section 2.1, "Configuring policies using `systemd`"*.
- **Temporarily using `chrt`**: For details, refer to *Section 2.2, "Managing policies using `chrt`"*.
- **Programmatically within the application code**: Real-time applications can configure their own policies internally using POSIX API calls.

2.1 Configuring policies using `systemd`

To configure a scheduling policy or set a scheduling priority for a service, edit the specific `.service` unit file:

```
[Service]
CPUSchedulingPolicy=fifo
CPUSchedulingPriority=42
ExecStart=PATH_TO_APP_BINARY
```

Alternatively, configure the policy and priority dynamically using **`systemd-run`**:

```
> sudo systemd-run --property=CPUSchedulingPolicy=fifo --
property=CPUSchedulingPriority=42 PATH_TO_APP_BINARY
```

2.2 Managing policies using **chrt**

You can change the policy and priority of processes on the fly using the **chrt** command. The command interacts directly with the `sched_setscheduler()` system call and operates independently of cgroup configurations. Use the command to perform the following tasks:

- Display valid system priority ranges for supported scheduling policies:

```
> sudo chrt -m
```

- Query the active policy and real-time priority of a running process (for example, PID 1437):

```
> sudo chrt -p 1437
```

- Set a running process to `SCHED_FIFO` with priority 42:

```
> sudo chrt --fifo -p 42 1437
```

- Launch a new application under `SCHED_RR` with priority 20:

```
> sudo chrt --rr 20 PATH_TO_APP_BINARY
```

For more details about **chrt**, refer to the chrt(1) man page (https://man7.org/linux/man-pages/man1/chrt.1.html)↗.

3 Managing CPU affinity

CPU affinity binds a process or thread to a specified subset of logical CPU cores. You can manage affinity ad hoc at the individual process level using the **taskset** command from the `util-linux` package, or configure it declaratively for services using `systemd`.



Note

A process cannot execute on CPU cores outside the boundaries defined by its parent cgroup's `cpuset.cpus` attribute. This restriction applies equally whether affinity is managed imperatively using **taskset** or declaratively using `systemd`.

3.1 Managing CPU affinity with `taskset`

To set a specific logical CPU core for a process, use **`taskset`** with the `-c` option. See the examples below:

- Display the current CPU affinity list of a running process (for example, PID 1437):

```
> sudo taskset -c -p 1437
```

- Bind a running process to logical CPU cores #1 and #3:

```
> sudo taskset -c -p 1,3 1437
```

- Launch a new command bound exclusively to CPU cores #0 through #2:

```
> sudo taskset -c 0-2 PATH_TO_APP_BINARY
```

3.2 Configuring CPU affinity using `systemd`

When configuring services in `systemd`, two distinct directives interact with CPU assignment:

`CPUAffinity=`
: Sets CPU affinity at the individual process level. The effective set of CPU cores is the *intersection* of the requested cores and the parent cgroup's allowed cores. If there is no overlap (for example, requesting CPU 3 inside a cgroup limited to CPUs 0–2), the kernel rejects the request with an `Invalid argument` error, and `systemd` fails to start the unit.

`AllowedCPUs=`
: Configures cgroup-level resource limits directly in the `cpuset.cpus` control file. Because cgroups v2 strictly enforces a top-down hierarchy, a service or child slice cannot be assigned CPUs that its parent slice does not possess.



Tip

For details on isolating dedicated CPU cores and creating custom slices for real-time tasks, refer to the Shielding Linux Resources on SUSE Linux Enterprise Server (https://documentation.suse.com/sles/16.1/html/SLES-RT-cpu-scheduling/) article.

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