SUSE

Hardware Testing and Latency for the RT Kernel in SLES

The real-time kernel in SUSE Linux Enterprise Server 16.1 provides integrated real-time capabilities. To confirm that a server can meet real-time deadlines, measure its latency with the hardware latency detector and with `cyclictest`. The hardware latency detector exposes delays caused by firmware and hardware. The `cyclictest` tool adds the scheduling overhead of the operating system to the measurement. This article explains how to prepare the platform, run both tools on SLES 16.1 and interpret the results.

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1 Understanding real-time hardware latency testing

Real-time hardware capabilities require predictable response times within a specified margin. This section explains fundamental real-time concepts and the sources of platform interference. It details how to distinguish hardware-induced delays from the scheduling overhead of the operating system using latency tools. Understanding these concepts helps you isolate low-level firmware bottlenecks before deploying production workloads.

You must distinguish between hardware-induced and operating-system-induced latencies. The hardware latency detector runs independently of the Linux kernel scheduler. It polls the CPU Time Stamp Counter (TSC) to find gaps. These gaps indicate when the hardware or firmware disturbed the CPU.

Conversely, `cyclictest` measures operating system latencies. It runs closer to a real computing situation by including operating system overhead in its results.

`cyclictest` measures a superset of what the hardware latency detector measures, plus the scheduling and interrupt handling overhead added by the operating system. On a correctly tuned system, expect `cyclictest` to report somewhat higher latencies than the hardware latency detector, because it includes this additional software overhead. If `cyclictest` reports latencies that are much higher, for example, hundreds of microseconds or more where the hardware latency detector reports only a few microseconds, this points to a source of latency in the operating system rather than in the hardware. In that case, contact SUSE for support.

2 Installing the real-time kernel

Before testing latencies, you must activate the real-time capabilities on your system. The `kernel-rt` package provides the preemption capabilities necessary for real-time operations.

PROCEDURE 1: INSTALLING AND ACTIVATING THE `kernel-rt` PACKAGE

1. Install the real-time kernel package:

   ```
   > sudo zypper install kernel-rt
   ```

2. Reboot your system.

3. Select the `kernel-rt` kernel from the boot menu to activate the real-time capabilities.

3 Preparing the hardware platform

Real-time applications require a hardware foundation configured for minimal latency. This section describes how to configure server BIOS and firmware settings. These adjustments eliminate low-level platform interference before you begin latency testing.

Before you start measuring hardware or operating system latencies, you must optimize your machine settings:

PROCEDURE 2: OPTIMIZING SERVER FIRMWARE SETTINGS

1. Access your server BIOS or firmware settings.
2. Disable power-management features that introduce variable latency, since these are common sources of SMIs and scheduling jitter. Menu labels vary by vendor, but look for and disable:
   - C-states (CPU idle power states)
   - P-states and frequency scaling (SpeedStep, Cool'n'Quiet or similar)
   - Turbo Boost or turbo core
   - Hyper-threading or SMT
   - Any other SMI-generating power management feature
3. Reduce memory patrol scrubbing to its lowest available rate or disable it, since scrubbing cycles can introduce firmware-level latency spikes.

4 Evaluating hardware latencies with the hardware latency detector

The hardware latency detector (**`hwlatdetect`**) drives the built-in `hwlat` ftrace tracer of the kernel through `tracefs`, and identifies system delays introduced directly by platform firmware and hardware, independent of the operating system scheduler.

Before you run this test, make sure that the platform firmware is optimized as described in *Section 3, "Preparing the hardware platform"*, that the system is running the `kernel-rt` kernel installed in *Section 2, "Installing the real-time kernel"*, and that you are logged in as `root` or can run commands with **`sudo`**.

PROCEDURE 3: EXECUTING `hwlatdetect`

1. Start the detector with a specified threshold:

```
> sudo hwlatdetect --threshold=10
```

   This command monitors system management interrupts (SMIs) with a minimum latency threshold of 10 microseconds.

2. Check the measured latencies.
   A run against a tuned, real-time-capable system produces output similar to the following:

```
> sudo hwlatdetect --threshold=10 --duration=120
hwlatdetect:  test duration 120 seconds
detector: hwlat
parameters:
Latency threshold: 10us
Sample window:     1000000us
Sample width:      500000us
Non-sampling period:  500000us
Output File:       None

Starting test
test finished
Max Latency: 3us
Samples recorded: 0
Samples exceeding threshold: 0
```

   `Max Latency` reports the largest gap observed between the CPU Time Stamp Counter reads, in microseconds. `Samples exceeding threshold` counts how many of those gaps were larger than the value you passed with `--threshold`.
   A hardware platform suitable for real-time workloads should report `Samples exceeding threshold: 0` over the full test duration, with `Max Latency` below the threshold you set. If `Samples exceeding threshold` is greater than zero, or `Max Latency` approaches or exceeds your threshold, the platform firmware or hardware is introducing delays your application deadline cannot tolerate. Treat this as a hardware or firmware-level failure regardless of what **`cyclictest`** reports later, and use a different hardware platform.

5 Measuring latencies with `cyclictest`

This section describes how to measure operating system latencies using the `cyclictest` tool. It guides you through installing the test suite on SUSE Linux Enterprise Server 16.1. It also details running the benchmark to generate latency histogram files.

The **`cyclictest`** command is part of the real-time kernel test suite, contained in the `rt-tests` RPM package distributed as part of SUSE Linux Enterprise Server 16.1.

Before you run this test, make sure your hardware is configured as described in *Section 3, "Preparing the hardware platform"*, and that you are logged in as `root` or can run commands with **`sudo`**.

PROCEDURE 4: RUNNING THE CYCLICTEST TOOL

1. Install the `rt-tests` package if it is not already present:

   ```
   > sudo zypper install rt-tests
   ```

2. Determine your test parameters from the **`cyclictest`** options listed in *Section 6, "`hwlatdetect` and `cyclictest` command-line options"*.

3. Start **`cyclictest`**. For example, to run 1000 cycles with a latency histogram tracked up to 1000 microseconds, execute:

   ```
   > sudo cyclictest --loops=1000 --histogram=1000
   ```

   By default, **`cyclictest`** writes the histogram data to standard output after the run. To save it to a file for later analysis instead, redirect the output:

   ```
   > sudo cyclictest --loops=1000 --histogram=1000 > histogram
   ```

4. Analyze the recorded minimal, actual, average and maximum latencies.
   A typical result on a multi-core system looks like:

   ```
   cyclictest --loops=1000 --histogram=1000
   policy: fifo: loadavg: 0.12 0.08 0.03 1/342 4821

   T: 0 ( 4822) P:99 I:1000 C:  1000 Min:      4 Act:    6 Avg:    7 Max:      31
   T: 1 ( 4823) P:99 I:1500 C:   667 Min:      3 Act:    5 Avg:    6 Max:      24
   ```

Each line reports one measurement thread (`T:`), its process ID, scheduling priority (`P:`) and interval in microseconds (`I:`). Four values matter for evaluation: `Min`, `Act` (the latency of the most recent cycle), `Avg` and `Max`. All four are reported in microseconds by default. Use `--nsec` if you need nanosecond resolution.

`Max` is the value to compare against the deadline of your application: it is the single worst-case scheduling latency observed during the run. As a rough order of magnitude, well-tuned real-time systems generally report `Max` values in the tens of microseconds. Results climbing into the hundreds of microseconds suggest an unresolved source of interference, and results in the thousands of microseconds indicate the system is not meeting real-time deadlines at all. These figures vary by hardware, workload and kernel configuration. Compare this `Max` value against the `Max Latency` reported by **`hwlatdetect`** in *Section 4, "Evaluating hardware latencies with the hardware latency detector"*. Per *Section 1, "Understanding real-time hardware latency testing"*, **`cyclictest`** is expected to report somewhat higher latencies, since it includes scheduling and interrupt handling overhead that **`hwlatdetect`** does not measure.

The `Max` value from **`cyclictest`** includes hardware latency plus kernel scheduling overhead. The `Max Latency` value from **`hwlatdetect`** does not. So **`cyclictest`** is expected to report a higher number. The two tools are not measuring the same thing.

What matters is the size of the gap. A small gap is normal software overhead. A gap of orders of magnitude points to a real problem in the operating system, not the hardware.

6 **`hwlatdetect`** and **`cyclictest`** command-line options

Real-time latency measurement tools support multiple runtime parameters. This section provides a structured reference table of the command-line options for **`hwlatdetect`** and **`cyclictest`**. These parameters help you customize sampling duration, sample windows and thread execution.

The **`hwlatdetect`** and **`cyclictest`** commands support several configuration options to modify their behavior.

TABLE 1: `hwlatdetect` OPTIONS

Option	Description
`--duration`	Run the detector logic for the specified duration.

Option	Description
`--threshold`	Specify the TSC gap used to detect an SMI.
`--hardlimit`	Define the failure limit.
`--window`	Specify the size of the sample window.
`--width`	Specify the sampling duration within the window.
`--report`	Specify the output file name of the detector report.
`--debug`	Turn on debug output.
`--quiet`	Turn off information output.
`--watch`	Print sample data to standard output as it arrives.

TABLE 2: `cyclictest` OPTIONS

Option	Description
`--nsec`	Use nanoseconds instead of microseconds for the displayed latency values.
`--loops`	Limit the number of test cycles. By default, the tool runs forever.
`--threads`	Specify the number of threads. Without a number, **`cyclictest`** runs on all available processors.
`--affinity`	Pin test threads to the processors with the same thread number.
`--histogram`	Create a histogram with the latency values up to the maximum tracking time.

7 Next steps

Completing latency benchmarks is only the first part of system preparation. This section details essential post-testing tasks to optimize your real-time server. It guides you to document your system configuration and perform regular regression testing.

Latency testing is only one step in preparing your system. After completing your measurements, analyze the results and tune your system.

Document your test environment thoroughly. Record the following:

- server model
- processor details
- firmware versions
- enabled features
- operating system version
- running kernel
- tool options
- workloads

Repeat your latency testing after making significant system changes. Regular retesting helps identify performance regressions before they affect production workloads.

8 For more information

This section lists external resources and technical documentation for real-time latency analysis. It guides you to relevant command man pages and kernel source documentation. These materials provide deeper insights into platform tuning.

To learn more about real-time latency testing and analysis, refer to the following resources:

- For more details on **`cyclictest`** options and outputs, see the man page **`man 8 cyclictest`**.
- For more information on the hardware latency detector and the `hwlat` ftrace tracer, see https://docs.kernel.org/trace/hwlat_detector.html.

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