MRG Realtime 1.0

Realtime Tuning Guide

1.0

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This book contains advanced tuning procedures for the MRG Realtime component of the Red Hat Enterprise MRG distributed computing platform. For installation instructions, see the MRG Realtime Installation Guide.

MRG Realtime 1.0: Realtime Tuning Guide

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Preface

Red Hat Enterprise MRG.

This book contains basic installation and tuning information for the MRG Realtime component of Red Hat Enterprise MRG. Red Hat Enterprise MRG is a high performance distributed computing platform consisting of three components:

1. *M*essaging — Cross platform, high performance, reliable messaging using the Advanced Message Queuing Protocol (AMQP) standard.

2. *R*ealtime — Consistent low-latency and predictable response times for applications that require microsecond latency.

3. *G*rid — Distributed High Throughput (HTC) and High Performance Computing (HPC).

All three components of Red Hat Enterprise MRG are designed to be used as part of the platform, but can also be used separately.

MRG Realtime.

Many industries and organizations need extremely high performance computing and may require low and predictable latency, especially in the financial and telecommunications industries. Latency, or response time, is defined as the time between an event and system response and is generally measured in microseconds (μs). For most applications running under a Linux environment, basic performance tuning can improve latency sufficiently. For those industries where latency not only needs to be low, but also accountable and predictable, Red Hat have now developed a 'drop-in' kernel replacement that provides this. MRG Realtime is distributed as part of Red Hat Enterprise MRG and provides seamless integration with Red Hat Enterprise Linux 5.1. MRG Realtime offers clients the opportunity to define, measure, configure and record latency times across their organization.

About The MRG Realtime Tuning Guide.

This book is laid out in three main sections: General system tuning, which can be performed on a Red Hat Enterprise Linux 5.1 kernel and MRG Realtime specific tuning, which should be performed on a MRG Realtime kernel in addition to the standard Red Hat Enterprise Linux 5.1 tunes. The third section is for developing and deploying your own MRG Realtime programs.

You will need to have the MRG Realtime kernel installed before you begin the tuning procedures in this book. If you have not yet installed the MRG Realtime kernel, or need help with installation issues, read the *MRG Realtime Deployment Guide*.

1. Document Conventions

Certain words in this manual are represented in different fonts, styles, and weights. This highlighting indicates that the word is part of a specific category. The categories include the following:

`Courier font`

Courier font represents `commands`, `file names and paths`, and `prompts` .
When shown as below, it indicates computer output:

```
Desktop       about.html       logs      paulwesterberg.png
Mail          backupfiles      mail      reports
```

`bold Courier font`

Bold Courier font represents text that you are to type, such as: **`service jonas start`**
If you have to run a command as root, the root prompt (#) precedes the command:

```
# gconftool-2
```

`italic Courier font`

Italic Courier font represents a variable, such as an installation directory: *`install_dir`*`/bin/`

bold font

Bold font represents **application programs** and **text found on a graphical interface**.
When shown like this: **OK** , it indicates a button on a graphical application interface.

Additionally, the manual uses different strategies to draw your attention to pieces of information. In order of how critical the information is to you, these items are marked as follows:

> **Note**
>
> A note is typically information that you need to understand the behavior of the system.

> **Tip**
>
> A tip is typically an alternative way of performing a task.

> **Important**
>
> Important information is necessary, but possibly unexpected, such as a configuration change that will not persist after a reboot.

Caution

A caution indicates an act that would violate your support agreement, such as recompiling the kernel.

Warning

A warning indicates potential data loss, as may happen when tuning hardware for maximum performance.

2. We Need Feedback!

If you find a typographical error in this manual, or if you have thought of a way to make this manual better, we would love to hear from you! Please submit a report in Bugzilla: *http://bugzilla.redhat.com/bugzilla/* against the product **Red Hat Enterprise MRG.**

When submitting a bug report, be sure to mention the manual's identifier: *Realtime_Tuning_Guide*

If you have a suggestion for improving the documentation, try to be as specific as possible when describing it. If you have found an error, please include the section number and some of the surrounding text so we can find it easily.

Before you start tuning your MRG Realtime system

MRG Realtime is designed to be used on well-tuned systems for applications with extremely high determinism requirements. Kernel system tuning offers the vast majority of the improvement in determinism. For example, in many workloads thorough system tuning improves consistency of results by around 90%. This is why we typically recommend that customers first perform the *Chapter 2, General System Tuning* of standard Red Hat Enterprise Linux before using MRG Realtime.

Things to remember while you are tuning your MRG Realtime kernel

1. Be Patient

   Realtime tuning is an iterative process; you will almost never be able to tweak a few variables and know that the change is the best that can be achieved. Be prepared to spend days or weeks narrowing down the set of tunings that work best for your system.

   Additionally, always make long test runs. Changing some tuning parameters then doing a five minute test run is not a good validation of a set of tunes. Make the length of your test runs adjustable and run them for longer than a few minutes. Try to narrow down to a few different tuning sets with test runs of a few hours, then run those sets for many hours or days at a time, to try and catch corner-cases of max latencies or resource exhaustion.

2. Be Accurate

   Build a measurement mechanism into your application, so that you can accurately gauge how a particular set of tuning changes affect the application's performance. Anecdotal evidence (e.g. "The mouse moves more smoothly") is usually wrong and varies from person to person. Do hard measurements and record them for later analysis.

3. Be Methodical

   It is very tempting to make multiple changes to tuning variables between test runs, but doing so means that you do not have a way to narrow down which tune affected your test results. Keep the tuning changes between test runs as small as you can.

4. Be Conservative

   It is also tempting to make large changes when tuning, but it is almost always better to make incremental changes. You will find that working your way up from the lowest to highest priority values will yield better results in the long run.

5. Be Smart

   Use the tools you have available. The Tuna graphical tuning tool makes it easy to change processor affinities for threads and interrupts, thread priorities and to isolate processors for application use. The `taskset` and `chrt` command line utilities allow you to do most of what Tuna does. If you run into performance problems, the `ftrace` facility in the trace kernel can help locate latency issues.

6. Be Flexible

Rather than hard-coding values into your application, use external tools to change policy, priority and affinity. This allows you to try many different combinations and simplifies your logic. Once you have found some settings that give good results, you can either add them to your application, or set up some startup logic to implement the settings when the application starts.

How Tuning Improves Performance.

Most performance tuning is performed by manipulating processors (Central Processing Units or CPUs). Processors are manipulated through:

Interrupts:

In software, an interrupt is an event that calls for a change in execution.
Interrupts are serviced by a set of processors. By adjusting the affinity setting of an interrupt we can determine on which processor the interrupt will run.

Threads:

Threads provide programs with the ability to run two or more tasks simultaneously.
Threads, like interrupts, can be manipulated through the affinity setting, which determines on which processor the thread will run.

It is also possible to set scheduling priority and scheduling policies to further control threads.

By manipulating interrupts and threads off and on to processors, you are able to indirectly manipulate the processors. This gives you greater control over scheduling and priorities and, subsequently, latency and determinism.

MRG Realtime Scheduling Policies.

Linux uses three main scheduling policies:

`SCHED_OTHER` (sometimes called `SCHED_NORMAL`)

This is the default thread policy and has dynamic priority controlled by the kernel. The priority is changed based on thread activity. Threads with this policy are considered to have a realtime priority of 0 (zero).

`SCHED_FIFO` (First in, first out)

A realtime policy with a priority range of from 1 - 99, with 1 being the lowest and 99 the highest. `SCHED_FIFO` threads always have a higher priority than `SCHED_OTHER` threads (for example, a `SCHED_FIFO` thread with a priority of *1* will have a higher priority than *any*`SCHED_OTHER` thread). Any thread created as a `SCHED_OTHER` thread has a fixed priority and will run until it is blocked or preempted by a higher priority thread.

`SCHED_RR` (Round-Robin)

`SCHED_RR` is an optimization of `SCHED_FIFO`. Threads with the same priority have a quantum and are round-robin scheduled amongst all equal priority `SCHED_RR` threads. This policy is rarely used.

General System Tuning

This section contains general tuning that can be performed on a standard Red Hat Enterprise Linux installation. It is important that these are performed first, in order to better see the benefits of the MRG Realtime kernel.

It is recommended that you read these sections first. They contain background information on how to modify tuning parameters and will help you perform the other tasks in this book:

- *Section 2.1, "Using the Tuna Interface"*
- *Section 2.2, "Setting persistent tuning parameters"*

When are you ready to begin tuning, perform these steps first, as they will provide the greatest benefit:

- *Section 2.3, "Interrupt and Process Binding"*
- *Section 2.4, "Filesystem determinism tips"*

When you are ready to start some fine-tuning on your system, then try the other sections in this chapter:

- *Section 2.5, "`gettimeofday` speedup"*
- *Section 2.6, "Don't run extra stuff"*
- *Section 2.7, "Swapping and Out Of Memory Tips"*
- *Section 2.8, "Network determinism tips"*
- *Section 2.9, "`syslog` tuning tips"*
- *Section 2.10, "The PC Card Daemon"*

When you have completed all the tuning suggestions in this chapter, move on to *Chapter 3, Realtime-Specific Tuning*

2.1. Using the Tuna Interface

Throughout this book, instructions are given for tuning the MRG Realtime kernel directly. The Tuna interface is a tool that assists you with making changes. It has a graphical interface, or can be run through the command shell.

Tuna can be used to change attributes of threads (scheduling policy, scheduler priority and processor affinity) and interrupts (processor affinity). The tool is designed to be used on a running system, and changes take place immediately. This allows any application-specific measurement tools to see and analyze system performance immediately after the changes have been made.

Although changes made in Tuna take immediate effect, changes will not be persistent across reboots. For making persistent changes, see *Section 2.2, "Setting persistent tuning parameters"*

Installing Tuna Using Yum

1. Install Tuna using the `yum` command.

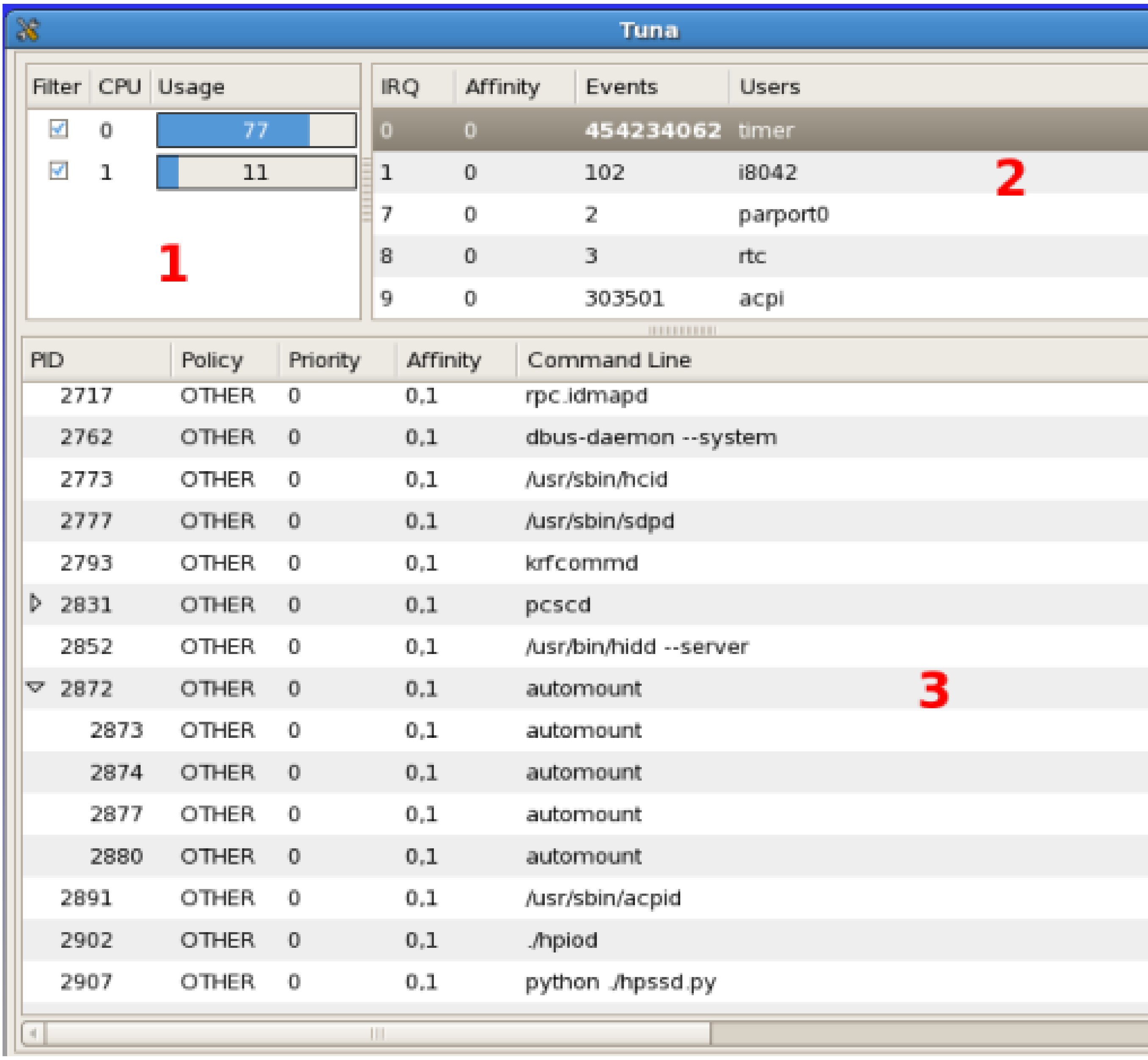
```
# yum install tuna
```

2. Once you have Tuna installed, you can view the help text to see the available options for using the tool in the command shell:

```
# tuna --help
Usage: tuna [OPTIONS]
 -h, --help                        Give this help list
 -g, --gui                         Start the GUI
 -c, --cpus=CPU-LIST               CPU-LIST affected by commands
 -f, --filter                      Display filter the selected entities
 -i, --isolate                     Move all threads away from CPU-LIST
 -I, --include                     Allow all threads to run on CPU-LIST
 -K, --no_kthreads                 Operations will not affect kernel
 threads
 -m, --move                        move selected entities to CPU-LIST
 -t, --threads=THREAD-LIST         THREAD-LIST affected by commands
 -U, --no_uthreads                 Operations will not affect user
 threads
 -W, --what_is                     Provides help about selected entities
```

3. To run the program with a graphical interface, start it from the command line. Although Tuna can be run as an unprivileged user, not all processes will be available for configuration. For this reason, in most cases you will need to run Tuna as root:

```
# tuna
```



The main Tuna window is divided into three sections. The window can be resized and the sections are divided by grab bars for adjustment. As values change, entries are shown in bold.

1. The CPU List

   This list shows all online CPUs and their current usage.

   The check-box beside the name of the CPU is used to filter the task list at the bottom of the window. Only tasks that belong to checked CPUs will be displayed.

   Right-click on a CPU to display isolation options. Selecting **Isolate CPU** will cause all tasks currently running on that CPU to move to the next available CPU. This can be chosen on one or more CPUs simultaneously, depending on how many CPUs are available on your system.

2. The IRQ List

This list shows all the active Interrupt Requests (IRQs), their process ID (PID) and policy and priority information.

The IRQ list has a right-click menu. The **Refresh IRQ list** option is provided as IRQs affinity changes may not occur until the next interrupt. Select **Set IRQ Attributes** to open the IRQ Attributes dialog box.

3. The Task List

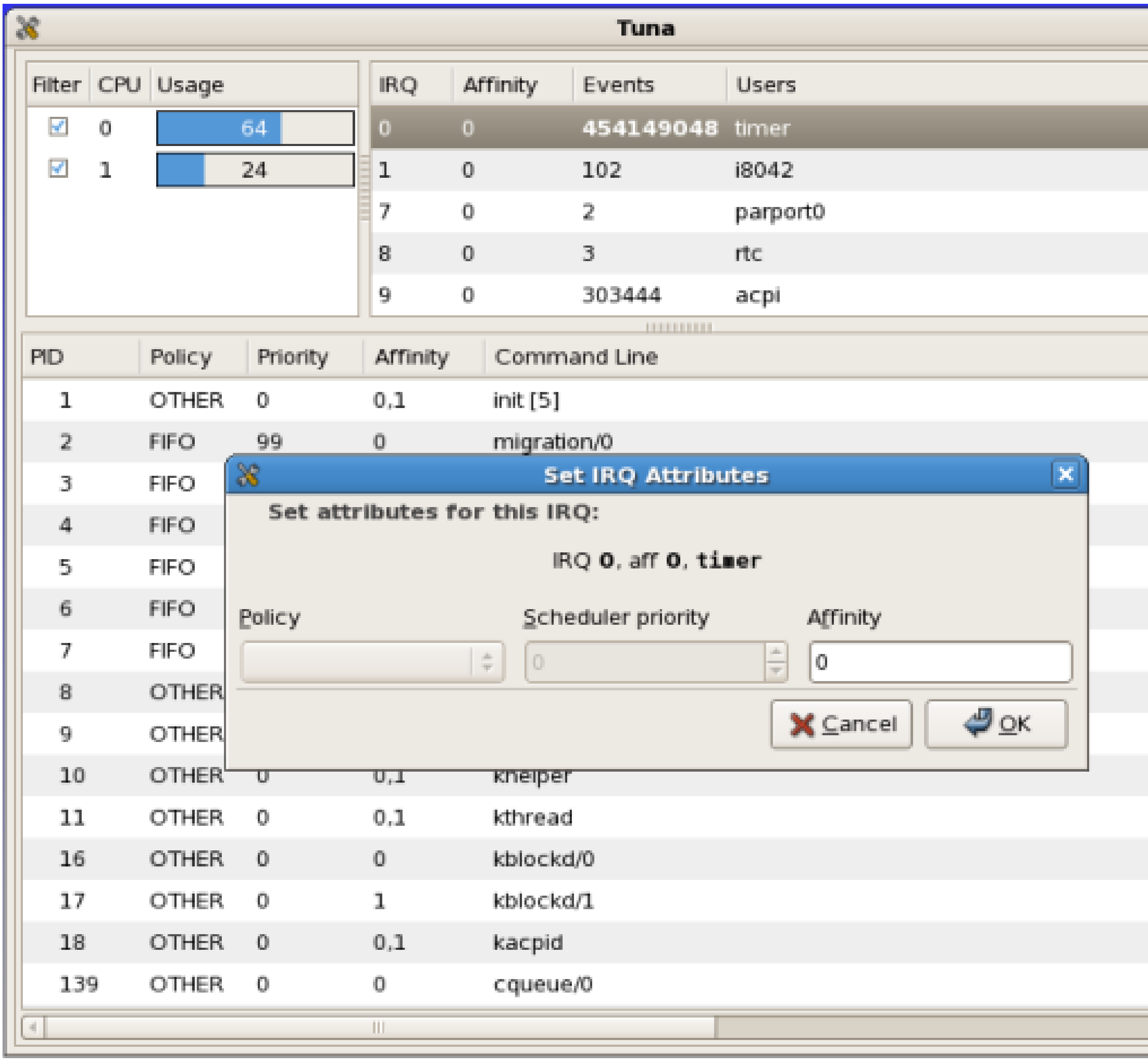
   This list shows all tasks except kernel threads.

   When a process is threaded, the task list shows the original thread with all the other threads collapsed below it. Click on the arrow to the left of the process to expand the thread.

   The right-click menu on the task list is similar to that of the IRQ list. Use **Refresh task list** will refresh the list with any changes and the **Set process attributes** will open the Set Process Attributes dialog box.

Important

Any IRQ with a PID of 0 (zero) is a NODELAY IRQ and is not implemented as a kernel thread. Setting the scheduling policy and priority for NODELAY IRQs will have no effect.



Right click on an IRQ and select **Set IRQ Attributes** to open the IRQ Attributes dialog box.

The IRQ Attributes dialog shows current information about the IRQ. It has three adjustable attributes:

1. Scheduling Policy

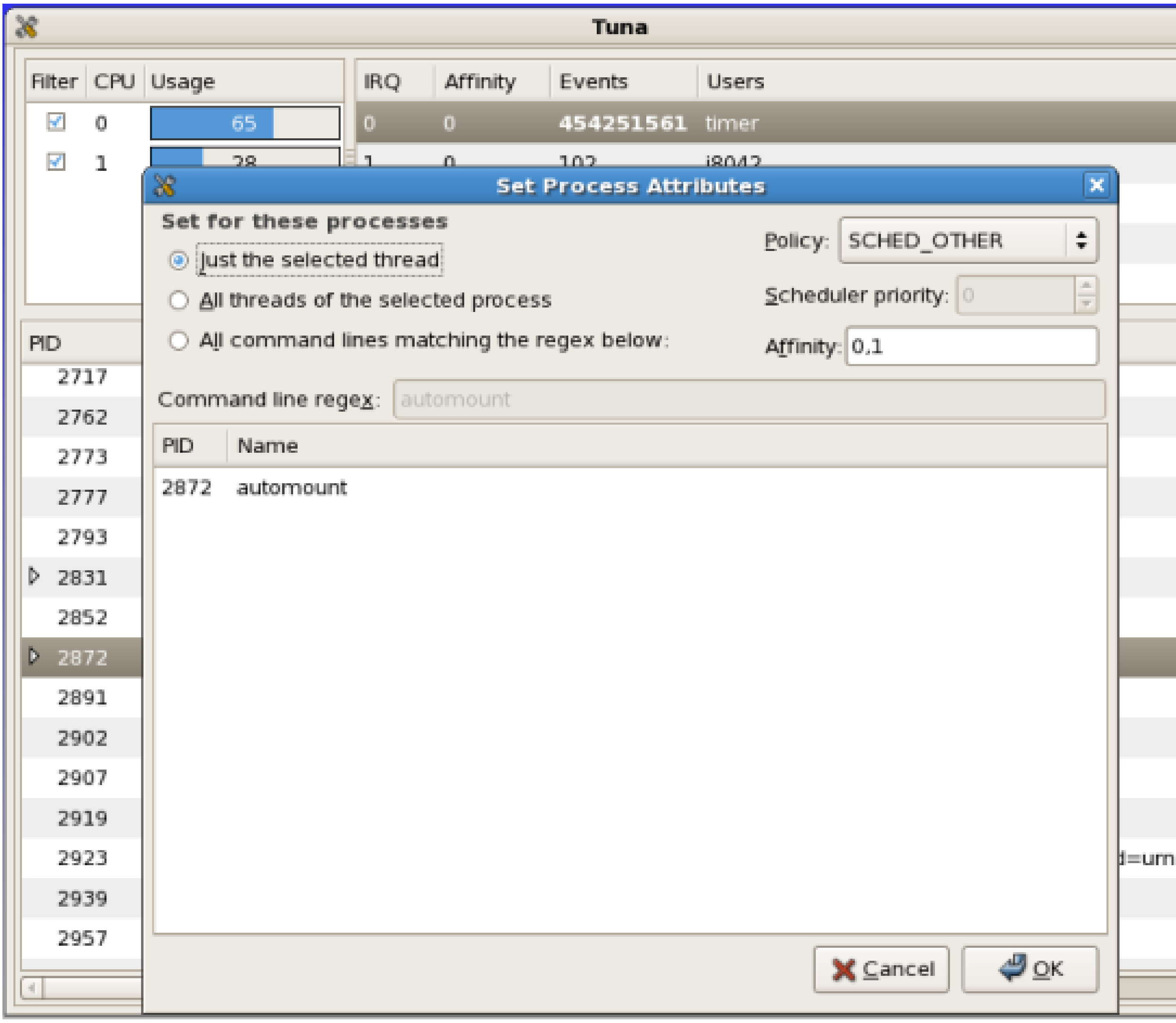
   A drop down list of the available policies.

2. Scheduler Priority

   A drop down list of the available priorities. This attribute will be disabled if the selected IRQ cannot have a set priority.

3. Affinity

A numeric list of CPUs on which the IRQ can be run. This entry can be in the form of a comma-delimited list of CPU numbers, a range using square brackets, or a combination of both. For example: `0, [2-4], 7, 8`. This would instruct the IRQ to run on CPUs 0, 2, 3, 4, 7 and 8.



Right click on a task and select **Set Process Attributes** to open the Process Attributes dialog box.

The Process Attributes dialog shows current information about the task. It allows you to set scheduling policy, scheduler priority, and CPU affinity for a task or set of tasks.

1. Thread Selection

   Just the selected thread is selected by default. If the task has more than one thread, use **All threads of the selected process** to make changes to all of the threads for that task. To use a regular expression (regex) to search for tasks, select **All command lines matching the regex below:**. This will activate the **Command line regex:** field and you can enter the regex. This field supports the "`*`" and "`?`" wildcards, and will match the entire command line. The task list will update to show only those tasks that match the regex.

2. Policy, Priority and Affinity

   The **Policy** drop down box contains the available scheduling policy options.

   The **Scheduler Priority** drop down box contains the available priorities. This attribute will be disabled if the selected tasks cannot have a set priority.

   The **Affinity** field contains a numeric list of CPUs on which the selected tasks can be run. This entry can be in the form of a comma-delimited list of CPU numbers, a range using square brackets, or a combination of both.

3. Task List

   This shows a list of the the tasks currently being adjusted based on the thread and regex selections made.

Using Tuna - An Example.

Suppose you have a system with 4 or more processors, and two applications - `Foo` and `Bar`. You want to run the applications on dedicated processors and choose processor 1 for `Foo` and processor 2 for `Bar`.

1. The first thing to do is move everything off the chosen processors. Right-click on `CPU 1` in the CPU list and select **Isolate CPU** from the menu. Repeat for `CPU 2`. The task list shows you that none of the tasks are running on those processors now.

2. Suppose that `Foo` is a single task with several threads, and you want the task and all its threads running on `CPU 1`. Find `Foo` in the process list, right-click on it and choose **Set process attributes** from the menu. In the **Set Process Attributes** dialog, select the radio button for **All threads of the selected process**. In the **Affinity** text box, change the text to `1`. You can also choose to change the scheduling policy and scheduler priority at this time. Click on **OK** to save your changes and close the dialog box.

3. Suppose that `Bar` is an application that has `--none` as its first command line argument. Right-click anywhere in the task list and choose **Set process attributes** from the menu. In the dialog, select the radio-button for **All command lines matching the regex below:**. Type `bar --none *` in the **Command line regex** text box. You will see the task list in the dialog box update to include all the matching processes (including all threads). Change the **Affinity** to `2`. Make any changes you want for the scheduler and priority. Click on **OK** to save your changes and close the dialog box.

2.2. Setting persistent tuning parameters

This book contains many examples on how to specify kernel tuning parameters. Unless stated otherwise, the instructions will cause the parameters to remain in effect until the system reboots or they are explicitly changed. This approach is effective for establishing the initial tuning configuration.

Once you have decided what tuning configuration works for your system, you will probably want those parameters to be persistent across reboots. Which method you choose depends on the type of parameter you are setting.

Editing the `/etc/sysctl.conf` file

For any parameter that begins with `/proc/sys/`, including it in the `/etc/sysctl.conf` file will make the parameter persistent.

1. Open the `/etc/sysctl.conf` file in your chosen text editor
2. Remove the `/proc/sys/` prefix from the command and replace the central "`/`" with a "`.`"
   For example: the command `echo 2 > /proc/sys/kernel/vsyscall64` will become `kernel.vsyscall64`.
3. Insert the new entry into the `/etc/sysctl.conf` file with the required parameter

```
# Enable gettimeofday(2)
kernel.vsyscall64 = 2
```

4. Run `# sysctl -p` to refresh with the new configuration

```
# sysctl -p
...[output truncated]...
kernel.vsyscall64 = 2
```

Editing files in the `/etc/sysconfig/` directory.

Files in the `/etc/sysconfig/` directory can be added for most other parameters. As files in this directory can differ significantly, instructions for these will be explicitly stated where appropriate.

Alternatively, check the *Red Hat Enterprise Linux Deployment Guide* available from the *Red Hat Documentation website*[1] for information on the `/etc/sysconfig/` directory.

Editing the `/etc/rc.d/rc.local` file

Use this option only as a last resort!

1. Adjust the command as per the *Editing the `/etc/sysctl.conf` file* intructions.
2. Insert the new entry into the `/etc/rc.d/rc.local` file with the required parameter

[1] http://redhat.com/docs

2.3. Interrupt and Process Binding

Realtime environments need to minimize or eliminate latency when responding to various events. Ideally, interrupts (IRQs) and user processes can be isolated from one another on different dedicated CPUs.

Interrupts are generally shared evenly between CPUs. This can delay interrupt processing through having to write new data and instruction caches, and often creates conflicts with other processing occurring on the CPU. In order to overcome this problem, time-critical interrupts and processes can be dedicated to a CPU (or a range of CPUs). In this way, the code and data structures needed to process this interrupt will have the highest possible likelihood to be in the processor data and instruction caches. The dedicated process can then run as quickly as possible, while all other non-time-critical processes run on the remainder of the CPUs. This can be particularly important in cases where the speeds involved are in the limits of memory and peripheral bus bandwidth available. Here, any wait for memory to be fetched into processor caches will have a noticeable impact in overall processing time and determinism.

In practice we have found that optimal performance is entirely application specific. For example, in tuning applications for different companies which perform similar functions, the optimal performance tunings were completely different. For one firm, isolating 2 out of 4 CPUs for operating system functions and interrupt handling and dedicating the remaining 2 CPUs purely for application handling was optimal. For another firm, binding the network related application processes onto a CPU which was handling the network device driver interrupt yielded optimal determinism. Ultimately, tuning is often accomplished by trying a variety of settings to discover what works best for your organization.

Important

For many of the processes described here, you will need to know the CPU mask for a given CPU or range of CPUs. The CPU mask is typically represented as a 32-bit bitmask (on 32-bit machines), but can also be expressed as a decimal or hexadecimal number. For example: The CPU mask for CPU 0 only is `00000000000000000000000000000001` as a bitmask, 1 as a decimal, and `0x00000001` as a hexadecimal. The CPU mask for both CPU 0 and 1 is `00000000000000000000000000000011` as a bitmask, 3 as a decimal, and `0x00000003` as a hexadecimal.

Disabling the `irqbalance` daemon

This daemon is enabled by default and periodically forces interrupts to be handled by CPUs in an even, fair manner. However in realtime deployments, applications are typically dedicated and bound to specific CPUs, so the `irqbalance` daemon is not required.

1. Check the status of the `irqbalance` daemon

```
# service irqbalance status
```

```
irqbalance (pid PID) is running...
```

2. If the `irqbalance` daemon is running, stop it using the `service` command.

```
# service irqbalance stop
Stopping irqbalance:                [  OK  ]
```

3. Use `chkconfig` to ensure that `irqbalance` does not restart on boot.

```
# chkconfig irqbalance off
```

Partially Disabling the `irqbalance` daemon

An alternative approach to is to disable `irqbalance` only on those CPUs that have dedicated functions, and enable it on all other CPUs. This can be done by editing the `/etc/sysconfig/irqbalance` file.

1. Open `/etc/sysconfig/irqbalance` in your preferred text editor and find the section of the file titled "FOLLOW_ISOLCPUS".

```
...[output truncated]...
# FOLLOW_ISOLCPUS
#       Boolean value.  When set to yes, any setting of
 IRQ_AFFINITY_MASK above
#       is overridden, and instead computed to be the same mask that is
 defined
#       by the isolcpu kernel command line option.
#
#FOLLOW_ISOLCPUS=no
```

2. Enable FOLLOW_ISOLCPUS by removing the # character from the beginning of the line and changing the value to *yes*.

```
...[output truncated]...
# FOLLOW_ISOLCPUS
#       Boolean value.  When set to yes, any setting of
 IRQ_AFFINITY_MASK above
#       is overridden, and instead computed to be the same mask that is
 defined
#       by the isolcpu kernel command line option.
```

```
#
FOLLOW_ISOLCPUS=yes
```

3. This will make `irqbalance` operate only on the CPUs not specifically isolated. This is most effective for machines with more than two processors, but works just as well on a dual-core machine.

Manually Assigning CPU Affinity to Individual IRQs

1. You can see which IRQ your devices are on by viewing the `/proc/interrupts` file.

```
# cat /proc/interrupts
```

   This file contains a list of IRQs. Each line shows the IRQ number, the number of interrupts that happened in each CPU, followed by the IRQ type and a description.

```
CPU0            CPU1
0:   26575949         11         IO-APIC-edge  timer
1:         14          7         IO-APIC-edge  i8042
...[output truncated]...
```

2. To instruct an IRQ to run on only one processor, `echo` the CPU mask (as a decimal number) to `/proc/interrupts`. In this example, we are instructing the interrupt with IRQ number 142 to run on CPU 0 only.

```
# echo 1 > /proc/irq/142/smp_affinity
```

3. This change will only take effect once an interrupt has occurred. To test the settings, generate some disk activity, then check the `/proc/interrupts` file for changes. Assuming that you have caused an interrupt to occur, you should see that the number of interrupts on the chosen CPU have risen, while the numbers on the other CPUs have not changed.

Binding Processes to CPUs using the `taskset` utility

The `taskset` utility uses the process ID (PID) of a task to view or set the affinity, or can be used to launch a command with a chosen CPU affinity. In order to set the affinity, `taskset` requires the CPU mask expressed as either a decimal or hexadecimal number.

1. To set the affinity of a process that is not currently running, use `taskset` and specify the CPU mask and the process. In this example, `my_embedded_process` is being instructed to use only CPU 4 (using the decimal version of the CPU mask).

```
# taskset 8 /usr/local/bin/my_embedded_process
```

2. It is also possible to set the CPU affinity for processes that are already running by using the `-p` (`--pid`) option with the CPU mask and the PID of the process you wish to change. In this example, the process with a PID of 7013 is being instructed to run only on CPU 0.

```
# taskset -p 1 7013
```

> **Note**
>
> The `taskset` utility will only work if Non-Uniform Memory Access (NUMA) is not enabled on the system. See *Section 3.6, “Non-Uniform Memory Access”* for more information on this.

Related Manual Pages.
For more information, or for further reading, the following man pages are related to the information given in this section.

- chrt(1)
- taskset(1)
- nice(1)
- renice(1)
- sched_setscheduler(2)
  For a description of the Linux scheduling scheme

2.4. Filesystem determinism tips

Journal activity can introduce latency through ordering changes and committing data and metadata. Often, journaling filesystems can do things in such a way that they slow the system down.

The most common filesystem for use on Linux machines is the third extended filesystem, or ext3, which is a journaling filesystem. Its predecessor - ext2 - is a non-journaling filesystem that is almost completely compatible with ext3. Unless your organization specifically requires journaling, consider using ext2. In many of our best benchmark results, we utilize the ext2 filesystem and consider it one of the top initial tuning recommendations.

If using ext2 is not a suitable solution for your system, consider disabling `atime` under ext3 instead. There are very few real-world situations where `atime` is neccesary, however it is enabled by default in Red Hat Enterprise Linux for longstanding legacy reasons. By disabling `atime` journal activity is avoided where it is not neccesary. It can also help with reducing power consumption as the disk is not required to do as many needless writes, giving the disk more opportunities to enter a low-power state.

Disabling `atime`

1. Open the `/etc/fstab` file using your chosen text editor and locate the entry for the root mount point.

```
LABEL=/         /        ext3     defaults         1 1
...[output truncated]...
```

2. Edit the options sections to include the terms `noatime` and `nodiratime`. `noatime` prevents access timestamps being updated when a file is read and `nodiratime` will stop directory inode access times being updated.

```
LABEL=/         /        ext3     noatime,nodiratime        1 1
```

3. The `tmpwatch` file on Red Hat Enterprise Linux is set by default to clean files in `/tmp` based on their `atime`. If this is the case on your system, then the instructions above will result in users' `/tmp/*` files being emptied every day. This can be resolved by starting `tmpwatch` with the `--mtime` option.

```
--- /etc/cron.daily/tmpwatch.orig +++ /etc/cron.daily/tmpwatch @@ -3,6
 +3,6 @@
/usr/sbin/tmpwatch 720 /var/tmp
for d in /var/{cache/man,catman}/{cat?,X11R6/cat?,local/cat?}; do
 if [ -d "$d" ]; then
- /usr/sbin/tmpwatch -f 720 "$d" + /usr/sbin/tmpwatch --mtime -f 720
 "$d"
 fi
```

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- bdflush(2)
- mkfs.ext2(8)
- mkfs.ext3(8)

- mount(8) - for information on `atime`, `nodiratime` and `noatime`
- chattr(1)

2.5. `gettimeofday` speedup

Many application workloads (especially databases and financial service applications) perform extremely frequent `gettimeofday` or similar time function calls. Optimizing the efficiency of this calls can provide major benefits.

Enable `gettimeofday` with VDSO

There is a Virtual Dynamic Shared Object (VDSO) implemented in the `glibc` runtime library. The VDSO maps some of the kernel code, which is necessary to read `gettimeofday` in the user-space. Standard Red Hat Enterprise Linux 5.1 allows the `gettimeofday` function to be performed entirely in user-space, removing the system call overhead.

1. VDSO behavior is not enabled by default and must be enabled on a global basis. You will need to `echo` a parameter of *2* to the `gettimeofday` function:

   ```
   # echo 2 > /proc/sys/kernel/vsyscall64
   ```

2. In addition to the above, the MRG Realtime kernel includes a further `gettimeofday` performance optimization. See *Section 3.2, "MRG Realtime Specific `gettimeofday` speedup"*.

> **Important**
>
> Currently the `gettimeofday` speed up is implemented only for 64 bit architectures (AMD64 and Intel 64) and is not available on x86 machines.

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- gettimeofday(2)

2.6. Don't run extra stuff

This is a common tool for improving performance, yet one that is often overlooked. Some 'extra stuff' to look for:

- Graphical desktop

  Do not run graphics there they are not absolutely required, especially on servers. To avoid running the desktop software, open the `/etc/inittab` file with your preferred text editor and locate the following line:

```
id:5:initdefault:
...[output truncated]...
```

This setting changes the runlevel that the machine automatically boots into. By default, the runlevel is 5 - full multi-user mode, using the graphical interface. By changing the number in the string to 3, the default runlevel will be full multi-user mode, but without the graphical interface.

```
id:3:initdefault:
...[output truncated]...
```

- Sendmail
  Unless you are actively using Sendmail on the system you are tuning, disable it. If it is required, ensure it is well tuned or consider moving it to a dedicated machine.
- Remote Procedure Calls (RPCs)
- Network File System (NFS)
- Mouse Services
  If you are not using Gnome, then you probably won't need a mouse either. Remove the hardware and uninstall `gpm`.

Remember to also check your third party applications, and any components added by external hardware vendors.

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- rpc(3)
- nfs(5)
- gpm(8)

2.7. Swapping and Out Of Memory Tips

Memory Swapping.

Swapping pages out to disk can introduce latency in any environment. To ensure low latency, the best strategy is to have enough memory in your systems so that swapping is not necessary. Always size the physical RAM as appropriate for your application and system. Use `vmstat` to monitor memory usage and watch the `si` (swap in) and `so` (swap out) fields. They should remain on zero as much as possible.

Out of Memory (OOM)

Out of Memory (OOM) refers to a computing state where all available memory, including swap space, has been allocated. Normally this will cause the system to panic and stop functioning as expected. There is a switch that controls OOM behavior in `/proc/sys/vm/panic_on_oom`. When set to `1` the kernel will panic on OOM.A setting of `0` instructs the kernel to call a function named `oom_killer` on an OOM. Usually, `oom_killer` can kill rogue processes and the system will survive.

1. The easiest way to change this is to `echo` the new value to `/proc/sys/vm/panic_on_oom`.

```
# cat /proc/sys/vm/panic_on_oom
1

#  echo 0 > /proc/sys/vm/panic_on_oom

# cat /proc/sys/vm/panic_on_oom
0
```

2. It is also possible to prioritize which processes get killed by adjusting the `oom_killer` score. In `/proc/`*`PID`*`/` there are two tools labelled `oom_adj` and `oom_score`. Valid scores for `oom_adj` are in the range -16 to +15. This value is used to calculate the 'badness' of the process using an algorithm that also takes into account how long the process has been running, amongst other factors. To see the current `oom_killer` score, view the `oom_score` for the process. `oom_killer` will kill processes with the highest scores first.
   This example adjusts the `oom_score` of a process with a PID of 12465 to make it less likely that `oom_killer` will kill it.

```
# cat /proc/12465/oom_score
79872

# echo -5 > /proc/12465/oom_adj

# cat /proc/12465/oom_score
78
```

3. There is also a special value of -17, which disables `oom_killer` for that process. In the example below, `oom_score` returns a value of *`0`*, indicating that this process would not be killed.

```
# cat /proc/12465/oom_score
```

```
78

# echo -17 > /proc/12465/oom_adj

# cat /proc/12465/oom_score
0
```

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- swapon(2)
- swapon(8)
- vmstat(8)

2.8. Network determinism tips

Transmission Control Protocol (TCP).

TCP can have a large effect on latency. TCP adds latency in order to obtain efficiency, control congestion, and to ensure reliable delivery. When tuning, consider the following points:

- Do you need ordered delivery?
- Do you need to guard against packet loss?
  Packet loss is not always bad. Transmitting the packet again can cause greater delays.
- If you must use TCP, consider disabling the Nagle buffering algorithm by using `TCP_NODELAY` on your socket. The Nagle algorithm collects small outgoing packets to send all at once, and can have a detrimental effect on latency.

Network Tuning

There are numerous tools for tuning the network. Here are some of the more useful:

Interrupt Coalescing

> To reduce netwrok traffic, packets can be collected and a single interrupt generated.
> Use the `-C` (`--coalesce`) option with the `ethtool` command to enable.

Congestion

> Often, I/O switches can be subject to back-pressure, where network data builds up as a result of full buffers.

Use the `-A` (`--pause`) option with the `ethtool` command to change pause parameters and avoid network congestion.

Infiniband (IB)

Infiniband is a type of communications architecture often used to increase bandwidth and provide quality of service and failover. It can also be used to improve latency through Remote Direct Memory Access (RDMA) capabilities.

Network Protocol Statistics

Use the `-s` (`--statistics`) option with the `netstat` comamnd to monitor network traffic.

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- ethtool(8)
- netstat(8)

2.9. syslog tuning tips

`syslog` forwards log messages from any number of programs over a network. The less often this occurs, the larger the pending transaction is likely to be. If the transaction very is large it can cause an I/O spike. It is recommended that the interval is kept reasonably small to prevent this occurring.

Using `syslogd` for system logging.

The system logging daemon, called `syslogd`, is used to collect messages from a number of different programs. It also collects information reported by the kernel from the kernel logging daemon `klogd`. Typically, `syslogd` will log to a local file, but it can also be configured to log over a network to a remote logging server.

1. To enable remote logging, you will first need to configure the machine that will receive the logs. `syslogd` uses configuration settings defined in the `/etc/sysconfig/syslog` and `/etc/syslog.conf` files. To instruct `syslogd` to receive logs from remote machines, open `/etc/sysconfig/syslog` in your preferred text editor and locate the `SYSLOGD_OPTIONS=` line.

```
# Options to syslogd
# -m 0 disables 'MARK' messages.
# -r enables logging from remote machines
# -x disables DNS lookups on messages recieved with -r
# See syslogd(8) for more details

SYSLOGD_OPTIONS="-m 0"
```

```
...[output truncated]...
```

2. Append the `-r` parameter to the options line:

```
SYSLOGD_OPTIONS="-m 0 -r"
```

3. Once remote logging support is enabled on the remote logging server, each system that will send logs to it must be configured to send its syslog output to the server, rather than writing those logs to the local filesystem. To do this, edit the `/etc/syslog.conf` file on each client system. For each of the various logging rules defined in that file, you can replace the local log file with the address of the remote logging server.

```
# Log all kernel messages to remote logging host.
kern.*     @my.remote.logging.server
```

   The example above will cause the client system to log all kernel messages to the remote machine at *@my.remote.logging.server*.

4. It is also possible to configure `syslogd` to log all locally generated system messages, by adding a wildcard line to the `/etc/syslog.conf` file:

```
# Log all messages to a remote logging server:
*.*     @my.remote.logging.server
```

Important

Note that `syslogd` does not include built-in rate limiting on its generated network traffic. Therefore, we recommend that remote logging on MRG Realtime systems be confined to only those messages that are required to be remotely logged by your organization. For example, kernel warnings, authentication requests, and the like. Other messages should be locally logged instead.

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- syslog(3)
- syslog.conf(5)
- syslogd(8)

2.10. The PC Card Daemon

The `pcscd` daemon is used to manage connections to PC and SC smart card (formally PCMCIA) readers. Although `pcscd` is usually a low priority task, it can often use more CPU than any other daemon. This additional background noise can lead to higher pre-emption costs to realtime tasks and other undesirable impacts on determinism.

Disabling the `pcscd` Daemon

1. Check the status of the `pcscd` daemon

```
# service pcscd status
pcscd (pid PID) is running...
```

2. If the `pcscd` daemon is running, stop it using the `service` command.

```
# service pcscd stop
Stopping PC/SC smart card daemon (pcscd):             [  OK  ]
```

3. Use `chkconfig` to ensure that `pcscd` does not restart on boot.

```
# chkconfig pcscd off
```

Realtime-Specific Tuning

Once you have completed the tunes in *Chapter 2, General System Tuning* you are ready to start MRG Realtime specific tuning. You must have the MRG Realtime kernel installed for these procedures.

> **Important**
>
> Do not attempt to use the tools in this section without first having completed *Chapter 2, General System Tuning*. You will not see a performance improvement.

When are you ready to begin MRG Realtime tuning, perform these steps first, as they will provide the greatest benefit:

- *Section 3.1, "Setting Scheduler Priorities"*

When you are ready to start some fine-tuning on your system, then try the other sections in this chapter:

- *Section 3.2, "MRG Realtime Specific `gettimeofday` speedup"*
- *Section 3.3, "Using `kdump` and `kexec` with the MRG Realtime kernel"*
- *Section 3.4, "TSC timer synchronization on Opteron CPUs"*
- *Section 3.5, "Infiniband"*
- *Section 3.6, "Non-Uniform Memory Access"*

This chapter also includes information on two performance monitoring tools:

- *Section 3.7, "Using the `ftrace` Utility for Tracing Latencies"*
- *Section 3.8, "Latency Tracing Using `trace-cmd`"*
  Section 3.9, "Using `sched_nr_migrate` to limit SCHED_OTHER processes."

When you have completed all the tuning suggestions in this chapter, move on to *Chapter 4, Application Tuning and Deployment*

3.1. Setting Scheduler Priorities

The MRG Realtime kernel allows fine grained control of scheduler priorities. It also allows application level programs to be scheduled at a higher priority than kernel threads. This can be useful but may also carry consequences. It is possible that it will cause the system to hang and other unpredictable behavior if crucial kernel processes are prevented from running as needed. Ultimately the correct settings are workload dependent.

Using `rtctl` to Set Priorities

1. Priorities are set using a series of levels, ranging from *0* (lowest priority) to *99* (highest priority). The system startup script `rtctl` initializes the default priorities of the kernel threads. By requesting the status of the `rtctl` service, you can view the priorities of the various kernel threads.

   ```
   # service rtctl status
   2    TS       - [kthreadd]
   3    FF      99 [migration/0]
   4    FF      99 [posix_cpu_timer]
   5    FF      50 [softirq-high/0]
   6    FF      50 [softirq-timer/0]
   7    FF      90 [softirq-net-tx/]
   ...[output truncated]...
   ```

2. The output is in the format:

   ```
   [PID] [scheduler policy] [priority] [process name]
   ```

   In the `scheduler policy` field, a value of `TS` indicates a policy of *normal* and `FF` indicates a policy of *FIFO* (first in, first out).

3. The `rtctl` system startup script relies on the `/etc/rtgroups` file. To make changes, open the `/etc/rtgroups` file in your preferred text editor.

   ```
   kthreads:o:0:\[.*\]$
   watchdog:f:99:\[watchdog.*\]
   migration:f:99:\[migration\/.*\]
   posix_cpu_timer:f:99:\[posix_cpu_timer\]
   hardirq:f:95:\[IRQ-.*\]
   ...[output truncated]...
   ```

4. Each line represents a process. You can change the priority of the process by adjusting the parameters. The entries in this file are in the format:

   ```
   [group name]:[scheduler policy]:[scheduler priority]:[regular
    expression]
   ```

   In the `scheduler policy` field, the following values are accepted:

o	Sets a policy of *other*. If the policy is set to o, the scheduler priority field will be set to *0* and ignored.
b	Sets a policy of *batch*.
f	Sets a policy of *FIFO*.
*	If the policy is set to *, no change will be made to to any matched thread policy.

The regular expression field matches the thread name to be modified.

5. After editing the file, you will need to restart the rtctl service to reload it with the new settings:

```
# service rtctl stop

# service rtctl start
Setting kernel thread priorities: done
```

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- rtctl(1)
- rtgroups(5)

3.2. MRG Realtime Specific gettimeofday speedup

In addition to the gettimeofday(2) speedup listed in *Section 2.5, "gettimeofday speedup"*, the MRG Realtime kernel contains a further gettimeofday performance optimization. This method caches the most recently used time value in a global system file. If another gettimeofday call is performed within the ms (hz) then it is not necessary re-read the hardware clock. As a result, applications which do not require microsecond precision benefit.

Enable the MRG Realtime gettimeofday speedup

This setting is not enabled by default. When you start it, it needs to be enabled on a global basis.

1. Firstly you will need to append the line "kernel.vsyscall64 = 2" to the /etc/sysctl.conf file. This causes the gettimeofday function to be performed entirely in user-space, removing the system call overhead.

```
echo "kernel.vsyscall64 = 2" >> /etc/sysctl.conf
```

2. To make the change effective immediately and persistent between reboots, use the `-w` option with the `sysctl` command to update the setting:

```
/sbin/sysctl -w kernel.vsyscall64=2
```

Related Manual Pages.
For more information, or for further reading, the following man pages are related to the information given in this section.

- sysctl(8)
- gettimeofday(2)

3.3. Using kdump and kexec with the MRG Realtime kernel

If `kdump` is enabled on your system, the standard boot kernel will reserve a small section of system RAM and load the `kdump` kernel into the reserved space. When a kernel panic or other fatal error occurs, `kexec` is used to boot into the `kdump` kernel. `Kexec` is a fastboot mechanism that allows the `kdump` kernel to boot without going through BIOS. The `kdump` kernel boots up using only the reserved RAM and sends an error message to the console. It will then write a dump of the boot kernel's address space to a file for later debugging. Because `kexec` does not go through the BIOS, the memory of the original boot is retained, and the crash dump is much more detailed. Once this is done, the `kdump` kernel performs a reboot, which will reset the machine and bring the boot kernel back up.

Tip

In Red Hat Enterprise Linux 5.1 there is no dedicated `kdump` kernel. It uses the main kernel instead. The MRG Realtime kernel cannot be used as a `kdump` kernel, but it supports the use of a seperate `kdump` kernel. It is recommended that you use the MRG Realtime kernel as the boot kernel, and the Red Hat Enterprise Linux 5.1 kernel as the `kdump` kernel.

There are two methods for enabling `kdump` under Red Hat Enterprise Linux 5.1. The first method adds a command line to the boot kernel, and the second uses a system configuration tool.

Enabling `kdump` with `grub.conf`

1. Firstly, you will need to check that you have the `kexec-tools` package installed.

```
# rpm -q kexec-tools
kexec-tools-1.101-194.4.el5
```

2. By default, the crash dump is saved in the `/var/crash` file. If you wish to change this, simply uncomment and adjust the `path` value in the `/etc/kdump.conf` file. This can be a local file, or on another server.

```
...[output truncated]...
#raw /dev/sda5
#ext3 /dev/sda3
#ext3 LABEL=/boot
#ext3 UUID=03138356-5e61-4ab3-b58e-27507ac41937
#net my.server.com:/export/tmp
#net user@my.server.com

path /path/to/file

#core_collector makedumpfile -c
#link_delay 60
#kdump_post /var/crash/scripts/kdump-post.sh
#extra_bins /usr/bin/lftp
#extra_modules gfs2
#default shell
```

3. Open the `/etc/grub.conf` file in your preferred text editor and add a `crashkernel` line to the boot kernel. This line takes the form:

```
crashkernel=[MB of RAM to reserve]M@[memory location]M
```

A typical `crashkernel` line would reserve 128 megabytes (128M) at 16 megabytes (16M), which is equivalant to the address 0x1000000:

```
crashkernel=128M@16M
```

A typical MRG Realtime `/etc/grub.conf` file would have the MRG Realtime kernel as the boot kernel, and the `crashkernel` line added to the Red Hat Enterprise Linux kernel:

```
default=0
timeout=5
splashimage=(hd0,0)/grub/splash.xpm.gz
hiddenmenu
title Red Hat Enterprise Linux (realtime) (2.6.21-57.el5rt)
 root (hd0,0)
```

```
 kernel /vmlinuz-2.6.21-57.el5rt ro root=/dev/HelpdeskRHEL5/Root rhgb
 quiet
 initrd /initrd-2.6.21-57.el5rt.img
title Red Hat Enterprise Linux Client (2.6.18-53.1.13.el5)
 root (hd0,0)
 kernel /vmlinuz-2.6.18-53.1.13.el5 ro root=/dev/HelpdeskRHEL5/Root
 rhgb quiet crashkernel=128M@16M
 initrd /initrd-2.6.18-53.1.13.el5.img
```

4. Once you have saved your changes, restart the system to set up the reserved memory space. You can then turn on the `kdump` init script and start the `kdump` service:

```
# chkconfig kdump on

# service kdump status
Kdump is not operational

# service kdump start
Starting kdump:                    [  OK  ]
```

5. If you want to check that the `kdump` is working correctly, you can simulate a panic using `sysrq`:

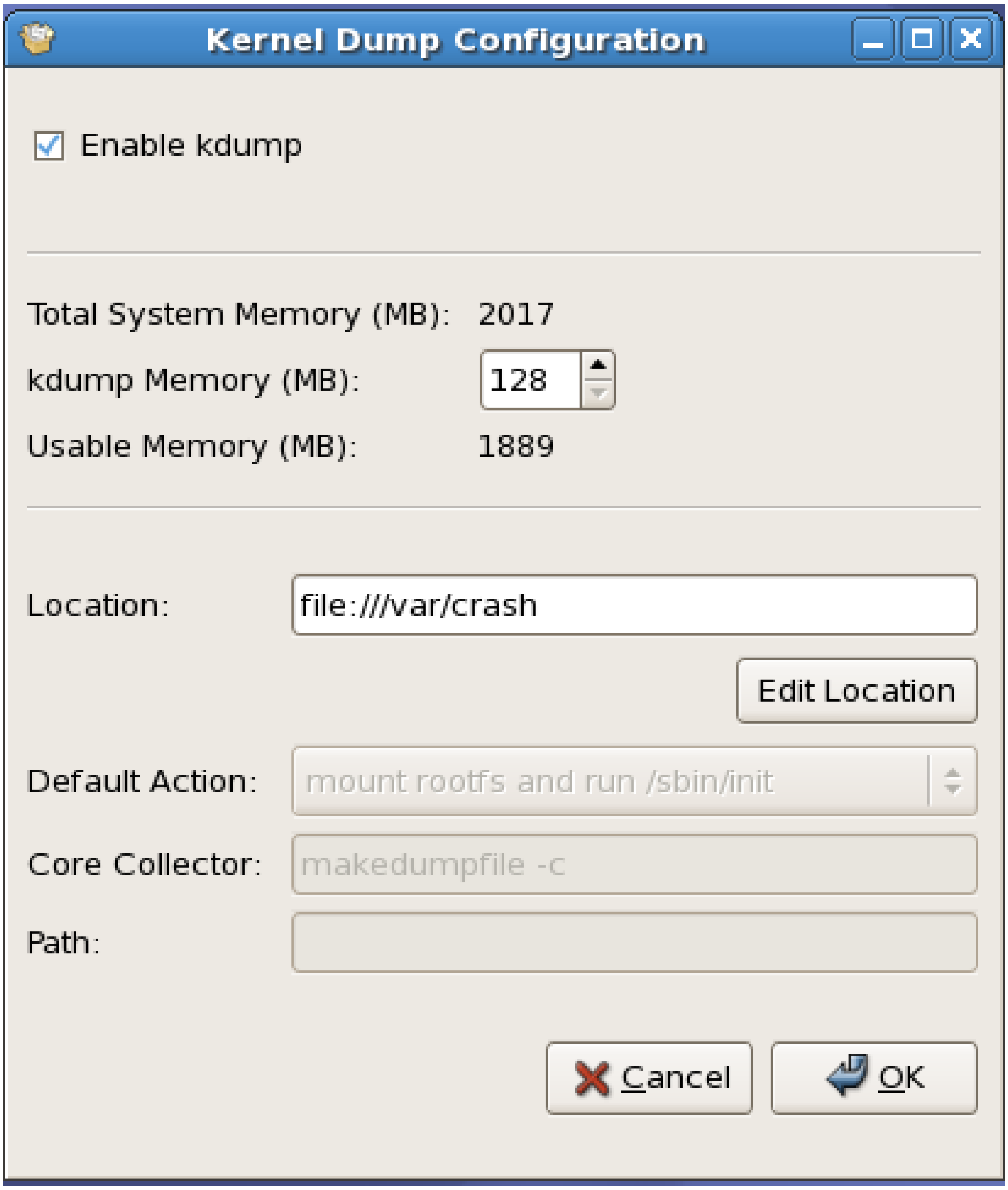
```
# echo "c" > /proc/sysrq-trigger
```

This will cause the kernel to panic and the system will boot into the `kdump` kernel. Once your system has been brought back up with the boot kernel, you should be able to check the log file at the location you specified.

Enabling `kdump` with `system-config-kdump`

1. Select the **Kdump** system tool from the **System|Administration** menu, or use the following command from the command line:

```
# system-config-kdump
```



2. Select the check box labeled **Enable kdump** and adjust the necessary settings for memory reservation and dump file location. Click **OK** to save your changes.

> **Important**
>
> Always check the `/etc/grub.conf` file to ensure that the tool has adjusted the correct kernel. The MRG Realtime kernel should be the default boot kernel and the Red Hat Enterprise Linux kernel should be used as the crash kernel.

3. If you want to check that the `kdump` is working correctly, you can simulate a panic using `sysrq`:

```
# echo "c" > /proc/sysrq-trigger
```

This will cause the kernel to panic and the system will boot into the `kdump` kernel. Once your system has been brought back up with the boot kernel, you should be able to check the log file at the location you specified.

> **Tip**
>
> Some hardware needs to be reset during the configuration of the `kdump` kernel. If you have any problems getting the `kdump` kernel to work, edit the `/etc/sysconfig/kdump` file and add `reset_devices=1` to the `KDUMP_COMMANDLINE_APPEND` variable.

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- kexec(8)
- `/etc/kdump.conf`

3.4. TSC timer synchronization on Opteron CPUs

The current generation of AMD64 Opteron processors are susceptible to a large `gettimeofday` skew when `cpufreq` is enabled while using the Time Stamp Counter (TSC). MRG Realtime provides a method to prevent this on Opteron systems by forcing all processors to simultaneously change to the same frequency. As a result, the TSC on a single processor never increments at a different rate than the TSC on another processor.

Enabling TSC timer synchronization

1. Open the `/etc/grub.conf` file in your preferred text editor and add the line `nohpet nopmtimer powernow-k8.tscsync=1` to the MRG Realtime kernel. This forces the use of TSC and enables simultaneous core processor frequency transitions.

```
...[output truncated]...
title Red Hat Enterprise Linux (realtime) (2.6.21-57.el5rt)
  root (hd0,0)
  kernel /vmlinuz-2.6.21-57.el5rt ro root=/dev/HelpdeskRHEL5/Root rhgb
 quiet nohpet nopmtimer powernow-k8.tscsync=1
  initrd /initrd-2.6.21-57.el5rt.img
```

2. You will need to restart your system for the changes to take effect.

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- gettimeofday(2)

3.5. Infiniband

Infiniband is a type of communications architecture often used to increase bandwidth and provide quality of service and failover. It can also be used to improve latency through Remote Direct Memory Access (RDMA) capabilities.

Support for Infiniband under MRG Realtime does not differ from the support offered under Red Hat Enterprise Linux 5.1

3.6. Non-Uniform Memory Access

Non-Uniform Memory Access (NUMA) is a design used to allocate memory resources to a specific CPU. This can improve access time and results in fewer memory locks. Although this appears as though it would be useful for reducing latency, NUMA systems have been known to interact badly with realtime applications, as they can cause unexpected event latencies.

As mentioned in *Binding Processes to CPUs using the `taskset` utility* the `taskset` utility will only work if NUMA is not enabled on the system. If you want to perform process binding in conjunction with NUMA, use the `numactl` command instead of `taskset`.

For more information about the NUMA API, see Andi Kleen's whitepaper *An NUMA API for Linux*[1].

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- numactl(8)

3.7. Using the `ftrace` Utility for Tracing Latencies

One of the diagnostic facilities provided with the MRG Realtime kernel is `ftrace`, which is used to determine where a desired maximum latency is being exceeded. The `ftrace` utility has a variety of options that allow you to use the utility in a number of different ways. The utility is particularly useful for identifying whether non-deterministic performance results are attributable to the kernel or to user space components. In customer deployments, the tool is most useful to differentiate whether delays are in the kernel or the application.

---

[1] http://www.halobates.de/numaapi3.pdf

The `ftrace` utility is not enabled in the production version of the MRG Realtime kernel as it creates additional overhead. If you wish to use the `ftrace` utility you will need to download and install the `trace` variant of the MRG Realtime kernel from the `mrg-beta` yum repository.

Note

For instructions on how to install kernel variants, or for more information on the `mrg-beta` yum repository, see the *MRG Realtime Installation Guide*.

Using the `ftrace` Utility

1. Once you are using the `trace` variant of the MRG Realtime kernel, you can set up the `ftrace` utility. You will need to create a `/debug` directory and then mount it to use the `debugfs` file system.

```
# mkdir /debug

# mount -t debugfs nodev /debug
```

2. To check if the `ftrace` utility is running, use the `cat` command to view the `/debug/tracing/tracing_enabled` file. A value of *1* indicates that `ftrace` is running, and *0* indicates that it is not running.

```
# cat /debug/tracing/tracing_enabled
1
```

   By default, the tracer is enabled. To turn the tracer on or off, `echo` the appropriate value to the `/debug/tracing/tracing_enabled` file.

```
# echo 0 > /debug/tracing/tracing_enabled

# echo 1 > /debug/tracing/tracing_enabled
```

3. The `ftrace` utility has a variety of options that allow you to use the utility in a number of different ways. The available options are:

`events`	Trace specific events.
`wakeup`	Record the time it takes for the highest priority RT task to wake up. If no RT tasks are running, this option will result in no output.

pre-emptoff	Record the the longest time for which pre-emption is disabled.
irqsoff	Record the the longest time for which interrupts have been disabled.
pre-emptirqsoff	Record the the longest time for which either interrupts or pre-emption have been disabled.
ftrace	Trace functions using mcount.
sched_switch	Trace tasks as they are switched by the scheduler.
none	Disable all tracing.

4. To check which options you currently have in the tracer use the `cat` command on the `/debug/tracing/available_tracers` file:

```
# cat /debug/tracing/available_tracers
```

5. To set a single option on the tracer, `echo` the option name to the `/debug/tracing/current_tracer` file.

```
# echo ftrace > /debug/tracing/current_tracer
```

Note

If you use a single > with the `echo` command, it will override any existing value in the file. If you wish to append the value to the file, use >> instead.

6. The results of any traces are saved to two files. The contents of `/debug/tracing/latency_trace` contains detailed information:

```
# cat /debug/tracing/latency_trace
```

The `/debug/tracing/trace` uses a simpler format:

```
# cat /debug/tracing/trace
```

7. There are a number of options available for changing the format of the output. These options are stored in `/debug/tracing/iter_ctrl`:

`print-parent`	Show the parent of the functions.
`sym-offset`	Add the offset into the function.
`sym-addr`	Add the address of a symbol.
`verbose`	Increase the verbosity of the tracer output.

8. Use the `cat` command to view the current configuration:

```
# cat /debug/tracing/iter_ctrl
```

To set a single option on the tracer output configuration, `echo` the option name to the `/debug/tracing/iter_ctrl` file.

```
# echo verbose > /debug/tracing/iter_ctrl
```

To disable a single option on the tracing output configuration, `echo` the option name with the test no before it to the `/debug/tracing/iter_ctrl` file.

```
# echo noverbose > /debug/tracing/iter_ctrl
```

> **Note**
>
> If you use a single > with the `echo` command, it will override any existing value in the file. If you wish to append the value to the file, use >> instead.

9. The `ftrace` utility can be filtered by altering the settings in the `/debug/tracing/set_ftrace_filter` file. If no filters are specified in the file, all processes are traced. Use the `cat` to view the current filters:

```
# cat /debug/tracing/set_ftrace_filter
```

10. To change the filters, `echo` the name of the process to be traced. The filter allows the use of a `*` wildcard at the beginning or end of a search term. Some examples of filters are:

- Trace only the `schedule` process:

```
# echo schedule > /debug/tracing/set_ftrace_filter
```

- Trace all processes that end with `lock`:

```
# echo *lock > /debug/tracing/set_ftrace_filter
```

- Trace all processes that start with `spin_`:

```
# echo spin_* > /debug/tracing/set_ftrace_filter
```

- Trace all processes with `cpu` in the name:

```
# echo *cpu* > /debug/tracing/set_ftrace_filter
```

> **Note**
>
> The `*` wildcard for the tracer filter will only work at the beginning or end of a word. For example: `spin_*` and `*lock` will work, but `spin_*lock` will not.

3.8. Latency Tracing Using trace-cmd

`trace-cmd` is a MRG Realtime function that traces all kernel function calls, and some special events. It records what is happening in the system during a short period of time, providing information that can be used to analyze system behavior.

The `trace-cmd` tool is not enabled in the production version of the MRG Realtime kernel as it creates additional overhead. If you wish to use the `trace-cmd` tool you will need to download and install either the `trace` or `debug` variants of the MRG Realtime kernel.

> **Note**
>
> For instructions on how to install kernel variants, see the *MRG Realtime Installation Guide*.

1. Once you are using either the `trace` or `debug` variants of the MRG Realtime kernel, you can install the `trace-cmd` tool using `yum`.

```
# yum install trace-cmd
```

2. You will need to create a `/debugfs` directory and then mount it to use the `debugfs` file system.

```
# mkdir /debugfs

# mount -t debugfs debugfs /debugfs
```

3. You can choose to make the `debugfs` directory mount automatically on boot. You can do this by opening the `/etc/fstab` file in your preferred text editor, and adding the following line:

```
/debugfs     /debugfs     debugfs     defaults     0     0
```

4. To start the utility, type `trace-cmd` at the shell prompt, along with the options you require, using the following syntax:

```
# trace-cmd [-f] [command]
```

The use of the *-f* option sets Function Tracing and can be used with any other trace command.

The commands instruct `trace-cmd` to trace in specific ways.

Command	Trace Type	Description
`-s`	Context switch	Traces the context switches between tasks.
`-i`	Interrupts off	Records the maximum time that an interrupt is disabled. When a new maximum is recorded, it replaces the previous maximum.
`-p`	Pre-emption off	Records the maximum time that pre-emption is disabled. When a new maximum is recorded, it replaces the previous maximum.
`-b`	Pre-emption and interrupts off	Records the maximum time that pre-emption *or* interrupts are disabled. When a new maximum is recorded, it replaces the previous maximum.
`-w`	Wakeup	Traces and records the maximum time for the highest

Command	Trace Type	Description
		priority task to get scheduled after it has been woken up.
-e	Event tracing	

5. In this example, the `trace-cmd` utility will:
   - Select the `context switch` tracing method
   - Enable the latency tracer
   - Run the `ls -la` command
   - Turn the latency tracer off again

```
# trace-cmd -s /bin/ls -la > /tmp/latency_log.txt
```

3.9. Using sched_nr_migrate to limit SCHED_OTHER processes.

If a `SCHED_OTHER` task spawns a large number of other tasks, they will all run on the same CPU. The migration task or `softirq` will try to balance these tasks so they can run on idle CPUs. The `sched_nr_migrate` option can be set to specify the number of tasks that will move at a time. Because realtime tasks have a different way to migrate, they are not directly affected by this, however when `softirq` moves the tasks it locks the run queue spinlock that is needed to disable interrupts. If there are a large number of tasks that need to be moved, it will occur while interrupts are disabled, so no timer events or wakeups will happen simultaneously. This can cause severe latencies for realtime tasks when the `sched_nr_migrate` is set to a large value.

Adjusting the value of the sched_nr_migrate variable

1. Increasing the `sched_nr_migrate` variable gives high performance from `SCHED_OTHER` threads that spawn lots of tasks, at the expense of realtime latencies. For low realtime task latency at the expense of `SCHED_OTHER` task performance, then the value should be lowered. The default value is 8.

2. To adjust the value of the `sched_nr_migrate` variable, you can `echo` the value directly to `/proc/sys/kernel/sched_nr_migrate`:

```
# echo 2 > /proc/sys/kernel/sched_nr_migrate
```

3. As this is a kernel process, you can also use the `sysctl` command.

```
# sysctl kernel.sched_nr_migrate=2
```

Application Tuning and Deployment

This page contains tips related to enhancing and developing MRG Realtime Applications.

> **Note**
>
> In general, try to use *POSIX* (Portable Operating System Interface) defined APIs. The MRG Realtime developers are compliant with POSIX standards and latency reduction in the MRG Realtime kernel is also based on POSIX.

Further Reading.

For further reading on developing your own MRG Realtime applications, start by reading the *RTWiki Article*[1].

4.1. Signal Processing in Realtime Applications

Traditional UNIX™ and POSIX signals have their uses, especially for error handling, but they are not suitable for use in realtime applications as an event delivery mechanism. The reason for this is that the current Linux kernel signal handling code is quite complex, due mainly to legacy behavior and the multitude of APIs that need to be supported. This complexity means that the code paths that may be taken when delivering a signal are not always the optimal path and quite long latencies may be experienced by applications.

The original motivation behind UNIX™ signals was to multiplex one thread of control (the process) between different "threads" of execution. Signals behave somewhat like operating system interrupts - when a thread is delivered to an application, the application's context is saved and it starts executing a previously registered signal handler. Once the signal handler has completed, the application returns to executing where it was when the signal was delivered. This can get complicated in practice.

Signals are too non-deterministic to trust them in a realtime application. A better option is to use POSIX Threads (pthreads) to distribute your workload and communicate between various components. You can coordinate groups of threads using the pthreads mechanisms of mutexes, condition variables and barriers and trust that the code paths through these relatively new constructs are much cleaner than the legacy handling code for signals.

Further Reading.

For more information, or for further reading, the following links are related to the information given in this section.

- RTWiki's *Build an RT Application*[2]
- Ulrich Drepper's *Requirements of the POSIX Signal Model*[3]

[1] http://rt.wiki.kernel.org/index.php/HOWTO:_Build_an_RT-application

4.2. Using `sched_yield` and Other Synchronization Mechanisms

The `sched_yield` system call is used by a thread allowing other threads a chance to run. Often when `sched_yield` is used, the thread can go to the end of the run queues, taking a long time to be scheduled again, or it can be rescheduled straight away, creating a busy loop on the CPU. The scheduler is better able to determine when and if there are actually other threads wanting to run.

POSIX Threads (Pthreads) have abstractions that will provide more consistent behavior across kernel versions. However, this can also mean that the system has less time to process networking packets, leading to considerable performance loss. This type of loss can be difficult to diagnose as there are no significant changes in the networking components of the system. It can also result in a change in behavior of some applications.

For more information, see Arnaldo Carvalho de Melo's paper on *Earthquaky kernel interfaces*[4].

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- pthread.h(P)
- sched_yield(2)
- sched_yield(3p)

4.3. Mutex options

Standard Mutex Creation

Mutual exclusion (mutex) algorithms are used to prevent processes simultaneously using a common resource. A fast user-space mutex (futex) is a tool that allows a user-space thread to claim a mutex without requiring a context switch to kernel space, provided the mutex is not already held by another thread.

> **Note**
>
> In this document, we use the terms *futex* and *mutex* to describe POSIX thread (pthread) mutex constructs.

1. When you initialize a `pthread_mutex_t` object with the standard attributes, it will create a private, non-recursive, non-robust and non priority inheritance capable mutex.

2. Under pthreads, mutexes can be initialized with the following strings:

[4] http://vger.kernel.org/~acme/unbehaved.txt

```
pthread_mutex_t my_mutex;

pthread_mutex_init(&my_mutex, NULL);
```

3. In this case, your application may not be benefiting of the advantages provided by the pthreads API and the MRG Realtime kernel. There are a number of mutex options that should be considered when writing or porting an application.

Advanced Mutex Options

In order to define any additional capabilities for the mutex you will need to create a `pthread_mutexattr_t` object. This object will store the defined attributes for the futex.

> **Important**
>
> For the sake of brevity, these examples do not include a check of the return value of the function. This is a basic safety procedure and one that you should always perform.

1. Creating the mutex object:

```
pthread_mutex_t my_mutex;

pthread_mutexattr_t my_mutex_attr;

pthread_mutexattr_init(&my_mutex_attr);
```

2. Shared and Private mutexes:
   Shared mutexes can be used between processes, however they can create a lot more overhead.

```
pthread_mutexattr_setpshared(&my_mutex_attr, PTHREAD_PROCESS_SHARED);
```

3. Realtime priority inheritance:
   Priority inversion problems can be avoided by using priority inheritance.

```
pthread_mutexattr_setprotocol(&my_mutex_attr, PTHREAD_PRIO_INHERIT);
```

4. Robust mutexes:
   Robust mutexes are released when the owner dies, however this can also come at a high overhead cost. `_NP` in this string indicates that this option is non-POSIX or not portable.

```
pthread_mutexattr_setrobust_np(&my_mutex_attr,
 PTHREAD_MUTEX_ROBUST_NP);
```

5. Mutex initialization:

   Once the attributes are set, initialize a mutex using those properties.

```
pthread_mutex_init(&my_mutex, &my_mutex_attr);
```

6. Cleaning up the attributes object:

   After the mutex has been created, you can keep the attribute object in order to initialize more mutexes of the same type, or you can clean it up. The mutex is not affected in either case. To clean up the attribute object, use the `_destroy` command.

```
pthread_mutexattr_destroy(&my_mutex_attr);
```

   The mutex will now operate as a regular `pthread_mutex`, and can be locked, unlocked and destroyed as normal.

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- futex(7)
- pthread_mutex_destroy(P)

  For information on `pthread_mutex_t` and `pthread_mutex_init`
- pthread_mutexattr_setprotocol(3p)

  For information on `pthread_mutexattr_setprotocol` and `pthread_mutexattr_getprotocol`
- pthread_mutexattr_setprioceiling(3p)

  For information on `pthread_mutexattr_setprioceiling` and `pthread_mutexattr_getprioceiling`

4.4. `TCP_NODELAY` and Small Buffer Writes

As discussed briefly in *Transmission Control Protocol (TCP)*, by default TCP uses Nagle's algorithm to collect small outgoing packets to send all at once. This can have a detrimental effect on latency.

Using TCP_NODELAY and TCP_CORK to improve network latency

1. Applications that require lower latency on every packet sent should be run on sockets with TCP_NODELAY enabled. It can be enabled through the setsockopt command with the sockets API:

```
# int one = 1;

# setsockopt(descriptor, SOL_TCP, TCP_NODELAY, &one, sizeof(one));
```

2. For this to be used effectively, applications must avoid doing small, logically related buffer writes. Because TCP_NODELAY is enabled, these small writes will make TCP send these multiple buffers as individual packets, which can result in poor overall performance.
   If applications have several buffers that are logically related and that should be sent as one packet it could be possible to build a contiguous packet in memory and then send the logical packet to TCP, on a socket configured with TCP_NODELAY.

   Alternatively, create an I/O vector and pass it to the kernel using writev on a socket configured with TCP_NODELAY.

3. Another option is to use TCP_CORK, which tells TCP to wait for the application to remove the cork before sending any packets. This command will cause the the buffers it receives to be appended to the existing buffers. This allows applications to build a packet in kernel space, which may be required when using different libraries that provides abstractions for layers. To enable TCP_CORK, set it to a value of *1* using the setsockopt sockets API (this is known as "corking the socket"):

```
# int one = 1;

# setsockopt(descriptor, SOL_TCP, TCP_CORK, &one, sizeof(one));
```

4. When the logical packet has been built in the kernel by the various components in the application, tell TCP to remove the cork. TCP will send the accumulated logical packet right away, without waiting for any further packets from the application.

```
# int zero = 0;

# setsockopt(descriptor, SOL_TCP, TCP_CORK, &zero, sizeof(zero));
```

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- tcp(7)
- setsockopt(3p)
- setsockopt(2)

4.5. Setting Realtime Scheduler Priorities

Using `rtctl` to set scheduler priorities is described at *Using `rtctl` to Set Priorities*. In the example given in that chapter, some kernel threads have been given a very high priority. This is to have the default priorities integrate well with the requirements of the Real Time Specification for Java (RTSJ). RTSJ requires a range of priorities from 10-89, so many kernel thread priorities are positioned at 90 and above. This avoids unpredictable behavior if a long-running Java application blocks essential system services from running.

For deployments where RTSJ is not in use, there is a wide range of scheduling priorities below 90 which are at the disposal of applications. It is usually dangerous for user level applications to run at priority 90 and above - despite the fact that the capability exists. Preventing essential system services from running can result in unpredictable behavior, including blocked network traffic, blocked virtual memory paging and data corruption due to blocked filesytem journaling.

Extreme caution should be used if scheduling any application thread above priority 89. If any application threads are scheduled above priority 89 you should ensure that the threads only run a very short code path. Failure to do so would undermine the low latency capabilities of the MRG Realtime kernel.

Setting Real-time Priority for Non-privileged Users.

Generally, only root users are able to change priority and scheduling information. If you require non-privileged users to be able to adjust these settings, the best method is to add the user to the `Realtime` group.

> **Important**
>
> You can also change user privileges by editing the `/etc/security/limits.conf` file. This has a potential for duplication and may render the system unusable for regular users. If you *do* decide to edit this file, exercise caution and always create a copy before making changes.

Further Reading.

For more information, or for further reading, the following links are related to the information given in this section.

- There is a testing utility called `signaltest` which is useful for demonstrating MRG Realtime system behavior. A whitepaper written by Arnaldo Carvalho de Melo explains this in more detail: *signaltest: Using the RT priorities*[5]

4.6. Dynamic Libraries Loading

When developing your MRG Realtime program, consider resolving symbols at startup. Although it can slow down program initialization, it is one way to avoid non-deterministic latencies during program execution.

Dynamic Libraries can be instructed to load at system startup by setting the `LD_BIND_NOW` variable with `ld.so`, the dynamic linker/loader.

The following is an example shell script. This script exports the `LD_BIND_NOW` variable with a non-null value of *1*, then runs a program with a scheduler policy of FIFO and a priority of *1*.

```
#!/bin/sh

LD_BIND_NOW=1
export LD_BIND_NOW

chrt --fifo 1 /opt/myapp/myapp-server &
```

Related Manual Pages.

For more information, or for further reading, the following man pages are related to the information given in this section.

- ld.so(8)

More Information

5.1. Reporting Bugs

> **Important**
>
> An up-to-date listing of known issues can be found on the *MRG Realtime Wiki: Known Bugs*[1]. Always check this list before reporting a new bug.

Diagnosing a Bug.

Before you a file a bug report, follow these steps to diagnose where the problem has been introduced. This will greatly assist in rectifying the problem.

1. Try reproducing the problem with the standard kernel. Check that you have the latest version of the Red Hat Enterprise Linux 5.1 kernel, then boot into it from the grub menu. Try reproducing the problem. If the problem still occurs with the standard kernel, report a bug against Red Hat Enterprise Linux 5.1 *NOT* MRG Realtime.

2. If the problem does not occur when using the standard kernel, then the bug is probably the result of changes introduced in either:

   a. The upstream kernel on which MRG Realtime is based. For example, Red Hat Enterprise Linux 5.1 is based on kernel version 2.6.18 and MRG Realtime is based on version 2.6.21

   b. MRG Realtime specific enhancements Red Hat has applied on top of the baseline (2.6.21) kernel

   To determine the problem, it is helpful to see if you can reproduce the problem on an unmodified upstream 2.6.21 kernel. For this reason, in addition to providing the MRG Realtime kernel, we also provide a `vanilla` kernel variant. The `vanilla` kernel is the unmodified upstream kernel build without the MRG Realtime additions.

Reporting a Bug.

If you have determined that the bug is specific to MRG Realtime follow these instructions to enter a bug report:

1. You will need a *Bugzilla*[2] account. You can create one at *Create Bugzilla Account*[3].

2. Once you have a Bugzilla account, log in and click on *Enter A New Bug Report*[4].

3. You will need to identify the product the bug occurs in. MRG Realtime appears under Red Hat Enterprise MRG in the Red Hat products list. It is important that you choose the correct product that the bug occurs in.

4. Continue to enter the bug information by designating the appropriate component and giving a detailed problem description. When entering the problem description be sure to include details of whether you were able to reproduce the problem on the standard Red Hat Enterprise Linux 5.1 or the supplied `vanilla` kernel.

5.2. Further Reading

- Red Hat Enterprise MRG Product Information
  - *http://1www.redhat.com/1mrg*
- Red Hat MRG Realtime Development Wiki
  - *http://1rt.et.redhat.com/1page/1Main_Page*
- For more information on the benefits of MRG Realtime and determining whether or not MRG Realtime is suitable for your organization:
  - *Red Hat News: Building An Informed Realtime Customer Base at High Performance On Wall Street*[5]
- Red Hat MRG Realtime Press Releases
  - *http://1rt.et.redhat.com/1page/1RHEL-RT_Media_Info*
- Mailing List
  - To post to the list, send mail to `<rhemrg-users-list@redhat.com>`
  - Subscribe to the mailing list at: *http://1post-office.corp.redhat.com/1mailman/1listinfo/1rhemrg-users-list*

Appendix A. Revision History

Revision History		
Revision 1.1	5 June, 2008	Lana Brindley
Completed Revision for 1.0 Release		
Revision 1.0	18 February, 2008	Lana Brindley
Initial draft		