Oracle Linux 9

Debugging the Kernel With Drgn and Corelens

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Contents

Preface

Oracle Linux 9: Debugging the Kernel With Drgn and Corelens describes how to install and use the `drgn` and `corelens` kernel debugging utilities to analyze crash logs and troubleshoot system problems.

Documentation License

Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

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About the `drgn` and `corelens` Kernel Debugging Utilities

Drgn is a tool and a programming library that can be used to extract debug information from both the live kernel of the running machine and memory crash dumps from halted systems (`vmcore`).

Drgn can be used as part of a root cause analysis to provide extra metrics that aren't already exposed through existing dashboards and interfaces.

For more information, see https://drgn.readthedocs.io/.

Corelens is provided through a separate `drgn-tools` package and provides the same functionality as Drgn, but requires no prior knowledge of the kernel implementation, data structures, or Python programming.

For more information, see the `corelens(1)` manual pages.

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(Optional) Installing DebugInfo Packages

You can optionally install `*-debuginfo` packages to add extra DWARF debugging information in generated core dumps. They're intended for development purposes only, so we recommend that you only install them in development environments.

Before installing `*-debuginfo` packages, enable the Oracle Linux 9 `debuginfo` repository by creating the `/etc/yum.repos.d/debuginfo.repo` file with root privileges and the following contents:

```
[debuginfo]
name=Oracle Linux 9 Debuginfo Packages
baseurl=https://oss.oracle.com/ol9/debuginfo/
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-oracle
gpgcheck=1
enabled=1


sudo dnf update -y
```

For more information, see Oracle Linux: Managing Software on Oracle Linux.

1. If you're running Oracle Linux with the Unbreakable Enterprise Kernel (UEK), install the `kernel-uek-debuginfo` package by using the `dnf` command:

   ```
   sudo dnf install -y kernel-uek-debuginfo-$(uname -r)
   ```

   If you're running Oracle Linux with the Red Hat Compatible Kernel (RHCK), install the `kernel-debuginfo` package instead:

   ```
   sudo dnf install -y kernel-debuginfo-$(uname -r)
   ```

   Run the install command each time the kernel is updated through the package manager. The DebugInfo package is only functional when it matches the running kernel, and it's not replaced automatically when a newer kernel version is installed on the system.

2. Use the package manager to search for DebugInfo packages to install:

   ```
   dnf search *-debuginfo
   ```

The selected `*-debuginfo` packages are installed.

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Installing `drgn`

Install the `drgn` package on Oracle Linux 9.

Before installing the `drgn` package, enable the `ol9_addons` repository:

```
sudo dnf config-manager --enable ol9_addons
```

```
sudo dnf update -y
```

For more information, see Oracle Linux: Managing Software on Oracle Linux.

1. (Optional) Install relevant DebugInfo packages on the system.

   For more information, see (Optional) Installing DebugInfo Packages.
2. Install the `drgn` package:

   ```
   sudo dnf install -y drgn
   ```

The `drgn` package is installed.

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Installing drgn-tools

Install the drgn-tools package on Oracle Linux 9.

Before installing the drgn-tools package, enable the ol9_addons repository:

```
sudo dnf config-manager --enable ol9_addons
```

```
sudo dnf update -y
```

For more information, see Oracle Linux: Managing Software on Oracle Linux.

1. (Optional) Install relevant DebugInfo packages on the system.

   For more information, see (Optional) Installing DebugInfo Packages.
2. Install the drgn-tools package:

   ```
   sudo dnf install -y drgn-tools
   ```

The drgn-tools package is installed.

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Getting Started With `drgn`

Debugging a live running kernel by using the `drgn` command.

Install the `drgn` package. For more information, see Installing `drgn`.

The `drgn` command can be used to troubleshoot system problems by analyzing the contents of system images and crash dumps.

1. To debug the running kernel, use the `drgn` command to analyze the contents of the `/proc/kcore` live system image:

   ```
   drgn
   ```

2. Type `exit()` or press the `Ctrl` + `D` keys to exit the Python shell.
3. For more information about how to use the `drgn` command, use the `-h` option:

   ```
   drgn -h
   ```

A Python shell was started, provided access to live kernel debugging information, and was then stopped.

If a matching DebugInfo package isn't installed for the running kernel, you might see an error message. Drgn can still be used on a production system to debug a kernel dump that was generated by a separate development system that has DebugInfo packages installed.

> **Note:**
>
> Kernel dumps generated on systems without DebugInfo packages installed can be debugged by using the `corelens` command, as that uses Common Type Format (CTF) debug information when DWARF debug information isn't present. For more information, see Getting Started With `corelens`.

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drgn Command Reference

This table provides information about the drgn command.

Action	Command	Description
Start a Python shell to analyze the contents of the /proc/kcore live system image.	sudo drgn	Provides information for debugging the running live kernel.
Start a Python shell to analyze the contents of a different dump file for a running kernel or vmcore crash dump.	sudo drgn -c *path/to/dumpfile*	Provides information for debugging a running kernel or generated crash dump.
Start a Python shell to analyze the contents of a dump file and specify the vmlinux and module symbols.	sudo drgn -c *path/to/dumpfile* -s *path/to/vmlinux*	Provides information for debugging a running kernel, or generated crash dump, filtered by relevant kernel modules.
Review further options provided with the drgn command.	sudo drgn -h	Provides a listing of command line options for the drgn command.

> **Note:**
>
> Type exit() or press the Ctrl + D keys to exit the Python shell.

For example, to debug /proc/kcore for a live kernel and specify kernel drivers, run the following command:

```
sudo drgn  -c /proc/kcore -s /usr/lib/debug/lib/modules/$(uname -r)/vmlinux \
   -s /lib/modules/$(uname -r)/kernel/net/netfilter/xt_comment.ko.xz
```

To perform the same operation on a vmcore crash dump file:

```
sudo drgn -c /var/crash/127.0.0.1-2023-06-02-09:33:07/vmcore \
 -s /usr/lib/debug/lib/modules/5.15.0-101.103.2.1.el9uek.x86_64/vmlinux \
 -s /lib/modules/5.15.0-101.103.2.1.el9uek.x86_64/kernel/net/netfilter/
xt_comment.ko.xz
```

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Using the drgn Library With Python

Debug live kernels and vmcore crash dumps in a Python shell, and Python scripts, by importing the drgn library.

Before you can start using drgn with Python scripts, ensure that Python is correctly installed on the system. For more information, see Oracle Linux 9: Installing and Managing Python.

If the script runs on Python 3.9, also install the drgn package. For more information, see Installing drgn.

> **Note:**
>
> To import the drgn library in scripts that run on newer versions of Python 3, enable the ol9_addons repository, then specify the version in the package name.
>
> For example, you could install the python3.12-drgn package to import the drgn library in a script that runs on Python 3.12:
>
> ```
> sudo dnf config-manager --enable ol9_addons
> ```
>
> ```
> sudo dnf install python3.12-drgn
> ```
>
> If no matching packages are available in the ol9_addons yum repository, then that Python version might no longer be supported. For more information, see Oracle Linux: Product Life Cycle Information.
>
> You can optionally run the drgn command with Python 3.12 as the interpreter by running the following command:
>
> ```
> python3.12 -m drgn
> ```

Unlike the crash utility, Drgn wasn't originally designed to be a standalone kernel debugging tool. Drgn is a Python programming library that exposes debugging information for scripting and review purposes.

1. The prog array variable contains the information about the kernel that you're debugging. For example, to return the data collected for slab_caches, run the following statements in the drgn shell:

   ```
   prog["slab_caches"]
   ```

   ```
   (struct list_head){
           .next = (struct list_head *)0xffff8b831d972260,
   ```

```
        .prev = (struct list_head *)0xffff8b8007c02060,
}
```

2. Standard python structures can also be used to iterate through debug information:

```
slab_caches = prog["slab_caches"]
```

```
slab_caches.next
```

```
*(struct list_head *)0xffff8b831d972260 = {
        .next = (struct list_head *)0xffff8b831d972460,
        .prev = (struct list_head *)slab_caches+0x0 = 0xffffffff836e3da0,
}
```

3. For more information about the `drgn` API and script syntax, see https://drgn.readthedocs.io/. Or, run the following command in the Python shell:

```
help(drgn)
```

The Python script loaded an array of kernel debugging information and crash data.

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Getting Started With `corelens`

Debug a running kernel or `vmcore` crash dump file by using the `corelens` command.

Install the `drgn-tools` package. For more information, see Installing `drgn-tools`.

The `corelens` command requires kernel debugging information to function. That can be provided by installing a kernel DebugInfo package. For more information, see (Optional) Installing DebugInfo Packages.

> **Note:**
>
> If no DebugInfo packages are installed, for example because the system being debugged is deployed in a production environment, the `corelens` command instead uses the more lightweight Common Type Format (CTF) debugging information if that's available.
>
> CTF is available if the system is running Oracle Linux 9 with the Unbreakable Enterprise Kernel (UEK).

The `corelens` command can be used to troubleshoot system problems by analyzing the contents of system images and crash dumps.

1. To debug `/proc/kcore` for a live kernel, run the following command:

   ```
   sudo corelens /proc/kcore
   ```

2. For more information about how to use the `corelens` command, use the `-h` option:

   ```
   corelens -h
   ```

A brief summary of the system state is provided as output from the `corelens` command.

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corelens Command Reference

This table provides information about the corelens command.

Action	Command	Description
Review a summary of the system state for a running kernel or vmcore crash dump.	sudo corelens *path/to/dumpfile*	Provides information for debugging the running live kernel or generated crash dump.
Run a corelens module to analyze the contents of a running kernel or vmcore crash dump, and then review the results.	sudo corelens *path/to/dumpfile* -M *module*	Provides information for debugging a running kernel or generated crash dump filtered by module.
Review a list of modules that can be specified.	corelens -L	Provides a listing of module filters for use with the -M option.
Create a report based on the output from the corelens command.	sudo corelens *path/to/dumpfile* -a -o report	Generates a diagnostic report containing all the debugging information captured by the corelens command.
Review further options provided with the corelens command.	corelens -h	Provides a listing of command line options for the drgn command.

For example, to debug /proc/kcore for a live kernel, run the following command:

```
sudo corelens /proc/kcore
```

To perform the same operation on a vmcore crash dump file:

```
sudo corelens /var/crash/127.0.0.1-2024-06-28-09:33:07/vmcore
```

Selecting Modules for corelens Command Output

Use the -M option to filter the output from corelens commands.

The corelens command can also filter output based on the parts of the system that require diagnosis by using the -M option. For example, to reproduce the full output for a live kernel, activate the sys module:

```
sudo corelens /proc/kcore -M sys
```

Similarly, to display a list of I/O requests that are still in progress, activate the `inflight-io` module:

```
sudo corelens /proc/kcore -M inflight-io
```

More than one module can be specified by reusing the `-M` option for each module. For example, to reproduce the full output for a live kernel and all the mounted directories that are now present, activate the `sys` and `mounts` modules:

```
sudo corelens /proc/kcore -M sys -M mounts
```

Example output follows:

```
warning: Running corelens against a live system.
         Data may be inconsistent, or corelens may crash.

 ====== MODULE sys ======
MODE        : Live kernel
DATE        : Fri Jul 12 18:21:34 2024
NODENAME    : oracle-example-ol9
RELEASE     : 5.15.0-206.153.7.el9uek.x86_64
VERSION     : #2 SMP Thu May 9 15:59:05 PDT 2024
MACHINE     : x86_64
UPTIME      : 1 day, 19:47:22
LOAD AVERAGE: 0.08  ,  0.02 ,  0.01
JIFFIES     : 4452309417
MEMORY      : 7.49 GiB
TASKS       : 251 R:1 D:0 S:167 I:83
PLATFORM    : QEMU Standard PC (i440FX + PIIX, 1996), BIOS 1.6.6 08/22/2023
X86_HYPER_KVM
CPU VENDOR: AuthenticAMD
MODEL NAME: AMD EPYC 7763 64-Core Processor
CPU FAMILY: 25
CPUS      : 2
CPUS NUMA0: 0-1
MICROCODE : 0x1000065
CSTATES   : 9

====== MODULE mounts ======
DEVNAME                     TYPE        DIRNAME
-------                     ------      -------
none                        rootfs      /
proc                        proc        /proc
sysfs                       sysfs       /sys
devtmpfs                    devtmpfs    /dev
securityfs                  securityfs  /sys/kernel/security
tmpfs                       tmpfs       /dev/shm
devpts                      devpts      /dev/pts
tmpfs                       tmpfs       /run
cgroup2                     cgroup2     /sys/fs/cgroup
pstore                      pstore      /sys/fs/pstore
efivarfs                    efivarfs    /sys/firmware/efi/efivars
bpf                         bpf         /sys/fs/bpf
configfs                    configfs    /sys/kernel/config
```

```
/dev/mapper/ocivolume-root  xfs         /
rpc_pipefs                  rpc_pipefs  /var/lib/nfs/rpc_pipefs
selinuxfs                   selinuxfs   /sys/fs/selinux
systemd-1                   autofs      /proc/sys/fs/binfmt_misc
debugfs                     debugfs     /sys/kernel/debug
hugetlbfs                   hugetlbfs   /dev/hugepages
mqueue                      mqueue      /dev/mqueue
tracefs                     tracefs     /sys/kernel/tracing
none                        ramfs       /run/credentials/systemd-
sysctl.service
none                        ramfs       /run/credentials/systemd-tmpfiles-
setup-dev.service
fusectl                     fusectl     /sys/fs/fuse/connections
/dev/mapper/ocivolume-oled  xfs         /var/oled
/dev/sdb2                   xfs         /boot
/dev/sdb1                   vfat        /boot/efi
none                        ramfs       /run/credentials/systemd-tmpfiles-
setup.service
tmpfs                       tmpfs       /run/user/983
tmpfs                       tmpfs       /run/user/1000
```

To see a full list of all the modules that can be specified, run the `corelens` command with the `-L` option:

```
corelens -L
```

For more information about what each `corelens` module does, use the `-h` option after specifying each of them with the `-M` option:

```
corelens -M module -h
```

For example, to learn more about the `dentrycache` module that outputs the kernel directory entry cache, use the following command:

```
corelens -M dentrycache -h
```

The following output might be displayed:

```
usage: dentrycache [-h] [--limit LIMIT] [--negative] [--detailed]

List dentries from the dentry hash table

optional arguments:
  -h, --help show this help message and exit
  --limit LIMIT, -l LIMIT
                        list at most <number> dentries, 50 by default
  --negative, -n list negative dentries only, disabled by default
  --detailed, -d include inode, super, file type, refcount
```

Generating Reports With `corelens`

Use the provided `corelens` command options to generate reports for later review.

To generate a report from the `corelens` command, use the `-o` option and specify the output directory for that report. For example, to generate a report for the live kernel and output that report into a folder called `report` in the current working directory, use the following command:

```
sudo corelens /proc/kcore -a -o report
```

If you don't explicitly specify modules by using the `-M` option, use the `-a` option to generate a report using standard modules, or the `-A` option to generate the report using detailed modules.

> **Note:**
>
> If you generate a report using every module, the final report might contain warnings that some modules couldn't be run. This is expected behavior, because some `corelens` modules require a core dump or can only function when specific kernel modules are loaded.

Diagnostic information is stored in a plain-text file for each module that was active when the `corelens` command was run. For example, to review the mounted directories that were output from the `mounts` module, view the contents of the `report/mounts` file:

```
cat report/mounts
```

Example output follows:

```
DEVNAME                     TYPE        DIRNAME
-------                     ------      -------
none                        rootfs      /
proc                        proc        /proc
sysfs                       sysfs       /sys
devtmpfs                    devtmpfs    /dev
securityfs                  securityfs  /sys/kernel/security
tmpfs                       tmpfs       /dev/shm
devpts                      devpts      /dev/pts
tmpfs                       tmpfs       /run
cgroup2                     cgroup2     /sys/fs/cgroup
pstore                      pstore      /sys/fs/pstore
efivarfs                    efivarfs    /sys/firmware/efi/efivars
bpf                         bpf         /sys/fs/bpf
configfs                    configfs    /sys/kernel/config
/dev/mapper/ocivolume-root  xfs         /
rpc_pipefs                  rpc_pipefs  /var/lib/nfs/rpc_pipefs
selinuxfs                   selinuxfs   /sys/fs/selinux
systemd-1                   autofs      /proc/sys/fs/binfmt_misc
hugetlbfs                   hugetlbfs   /dev/hugepages
mqueue                      mqueue      /dev/mqueue
debugfs                     debugfs     /sys/kernel/debug
tracefs                     tracefs     /sys/kernel/tracing
fusectl                     fusectl     /sys/fs/fuse/connections
none                        ramfs       /run/credentials/systemd-
sysctl.service
none                        ramfs       /run/credentials/systemd-tmpfiles-
```

```
setup-dev.service
/dev/mapper/ocivolume-oled  xfs         /var/oled
/dev/sda2                   xfs         /boot
/dev/sda1                   vfat        /boot/efi
none                        ramfs       /run/credentials/systemd-tmpfiles-
setup.service
tmpfs                       tmpfs       /run/user/0
tmpfs                       tmpfs       /run/user/982
tmpfs                       tmpfs       /run/user/1000
```