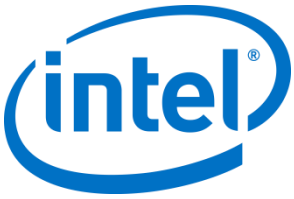

Intel® Cache Acceleration Software for Linux* v3.5.1 (GA).

Administrator Guide

February 2018

Document Number: 328496-019US

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Contents

1 Introduction

This guide offers the quickest way to install and begin using Intel® Cache Acceleration Software (Intel® CAS) for Linux* v3.5.1. This guide assumes users have a basic knowledge of storage and application management, as well as basic Linux system administration.

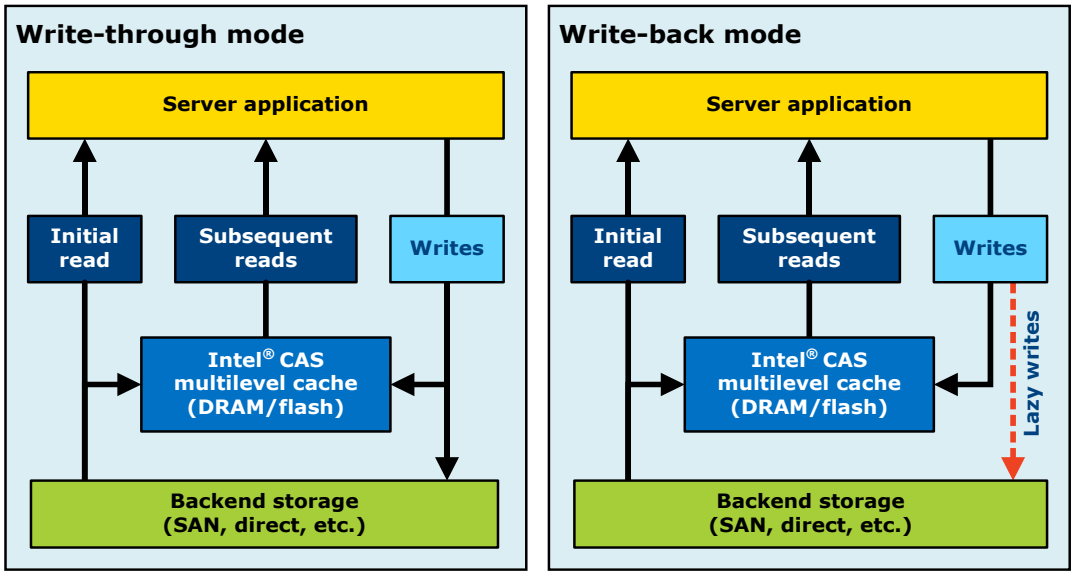
1.1 Intel® CAS Overview

Intel CAS accelerates Linux applications by caching active (*hot*) data to a local flash device inside servers. Intel CAS implements caching at the server level, using local high-performance flash media as the cache drive media within the application server, thus reducing storage latency.

Intel CAS installs into the Linux operating system as a kernel module. The nature of the integration provides a cache solution that is transparent to users, applications, and your existing storage infrastructure. No storage migration or application changes are required.

As shown in Figure 1, initial read data is retrieved from backend storage and copied to the Intel CAS cache. A second read promotes data to system memory. Subsequent reads are returned at high-performance RAM or flash speed. In Write-through mode, all data is written synchronously to both the backend storage and the cache. In Write-back mode, all data is written to the cache then eventually flushed to the backend storage. When the cache is full, newly identified active data evicts stale data from the cache, utilizing the Intel CAS proprietary eviction algorithm.

Figure 1: Block Diagram (write-through and write-back modes)



Intel CAS for Linux, by default, employs a block-based caching architecture that caches all of the activity on the selected core device.

1.2 New Features in this Release

The 3.5.1 release introduces the following new feature:

- **CAS Startup and Udev rules interaction -** The intelcas service was retired in favor of using udev rules to handle startup of caching. CAS is now enabled by default. Udev rules survey block devices in the system; if one or more of those devices is configured for caching, Udev rules perform actions to activate those devices. Also, handling of broken/failed devices has been improved.

The 3.5 release introduced the following features:

- **TRIM Support -** TRIM is enabled by default and supported by Intel CAS for Intel SSDs. This helps improve performance especially in WB (write-back) mode because Intel CAS does not have to flush the data that is no longer needed to the backend storage.
- **Atomic Writes -** Allows Intel CAS to write user data and cache metadata in one write request reducing number of writes to cache devices. This has a positive impact on performance and drive endurance. This feature is available only for Intel Data Center SSDs.
- **Warm Cache** - Provides faster recovery after an un-planned shutdown. In previous versions, the user had to recover the cache and then start the cache without any data cached. See Running Intel® CAS on page 22 for further details.

IMPORTANT: Note the following changes and update any user-created scripts accordingly:

- --load option has replaced --recovery option while starting CAS.
- -I and -X options have been removed. This option allowed caching of a specific file or files.
- Support for use of expect utility and password-less ssh login for remote installation of Intel CAS will be discontinued in future releases of Intel CAS as this poses security issues. Please see section 12.1 for details on the current support of this capability.

1.3 Documentation Conventions

The following conventions are used in this manual:

- `Courier font` - code examples, command line entries.
- *Italic* - user interface items, filenames, etc.
- **< > -** denotes mandatory commands
- **[ ] -** denotes optional commands

1.4 References

Refer to the resources and tools listed in the following table for assistance with Intel CAS testing and operations, or to learn more about caching and application I/O performance management.

Table 1: Reference Documents

Name	Location
DT generic data testing program	http://www.scsifaq.org/RMiller_Tools/dt.html
FIO	https://github.com/axboe/fio
Vdbench	http://vdbench.sourceforge.net

1.5 Revision History

Revision Number	Description	Date
001B	Initial Beta release of document.	November 2012
001	Initial public release of document.	February 2013
002	Document updates for Linux v2.1	May 2013
003	Document updates for Linux v2.5	August 2013
004	Document updates for Linux v2.6	December 2013
005	Document updates for Linux v2.6.1	April 2014
006	Document updates for Linux v2.7	May 2014
007	Document updates for Linux v2.7 GA	July 2014
008	Document updates for Linux v2.8 GA	December 2014
009	Document updates for Linux v2.9 GA	June 2015
010	Document updates for Linux v3.0 GA	January 2016
011	Document updates for Linux v3.1 GA	July 2016
012	Document updates for Linux v3.5 Beta (QEMU update)	February 2017
013	Document updates for Linux v3.5 GA (QEMU update)	April 2017
014	Document updates for Linux v3.5 Beta	June 2017
015	Document updates for Linux v3.5 GA	July 2017
016	Document updates for Linux v3.5 GA	September 2017
017	Document updates for Linux v3.5.1 Beta	December 2017
018	Document updates for Linux v3.5.1 GA	January 2018
019	Document updates for Linux v3.5.1 GA (Solid Driver/RPM Update)	February 2018

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2 Product Specifications and System Requirements

2.1 Supported Operating Systems

The following table lists the platforms for 64-bit processors that Intel CAS supports.

Table 2: Supported Operating Systems

Operating System	Kernel
Red Hat* Enterprise Linux* (RHEL*) 6.7	x86_64, Kernel 2.6.32-573
Red Hat* Enterprise Linux* (RHEL*) 6.8	x86_64, Kernel 2.6.32-642
Red Hat* Enterprise Linux* (RHEL) 7.2	x86_64, Kernel 3.10.0-327
Red Hat* Enterprise Linux* (RHEL) 7.3	X86_64, kernel 3.10.0-514
CentOS* 6.7	x86_64, Kernel 2.6.32-573
CentOS* 6.8	x86_64, Kernel 2.6.32-642
CentOS* 7.2	x86_64, Kernel 3.10.0-327
CentOS* 7.3	x86_64, Kernel 3.10.0-514
SUSE* Linux* Enterprise Server (SLES*) Version 12 SP2	x86_64, Kernel 4.4.74-92.38
Ubuntu Server 14.04.5	x86_64, Kernel 4.4.0-59
Ubuntu Server 16.04	x86_64, Kernel 4.4.0-28
Other distros - Intel CAS will install and compile from source on other distros and other kernels, but the user may be required to reproduce any issues on a validated distro & kernel to receive support.	Other kernels

The following table lists the hypervisor/OS combinations that Intel CAS supports.

Table 3: Supported Hypervisor/OS Combinations

Hypervisor	Supported Configuration	Notes
Xen*	Supported in hypervisor or guest.	Paravirtualized drivers are not supported.
KVM*	Supported in hypervisor or guest.	
VMWare*	Supported in guest.	

2.2 System Requirements

The following table lists system requirements for Intel CAS.

Table 4: Intel CAS System Requirements

Memory	RAM requirement is approximately 1GiB + 2% cache device capacity * 4KiB/<selected cache line size>. For example, when using 4KiB (default) cache line size, RAM requirement is approximately 1GiB + 2% cache device capacity.
CPU Overhead	Intel CAS consumes minimal CPU bandwidth (less than 10% in most cases). Ensure that Intel CAS has adequate CPU capacity to function optimally.
Flash/SSD	Any Linux flash device (SAS, SATA, PCIe*, Fibre Channel, RAID) is supported, and can be direct attached, expander attached, or attached via SAN (with a single worker). Additionally, the following Intel SSDs have been fully qualified: • Intel® SSD DC S3700 Series • Intel® SSD DC P3700 Series Cache device logical block size must be smaller than or equal to the logical block size of the core storage device. 60GB or larger capacity is recommended. ***Note:*** Older firmware on some SSDs lose their format after reboot and cause data loss. We highly recommend that you upgrade to the latest recommended firmware and boot loader versions for your devices. For example, as of the writing of this document, the firmware versions (8DV101H0 for firmware & 8B1B0133 for bootloader) should be used for Intel SSD DC P3700 Series drives.
Storage	Primary storage devices: Any device that appears as a local block device. For example, local disk, RAID, SAN iSCSI (via Fibre Channel, Infiniband, Ethernet), etc. Core device (HDD) logical block size must be 512 bytes or larger. Operating system must be on separate partition or drive than the core storage device to be cached.
File Systems	The following file systems are supported for primary storage or core storage: • ext3 (limited to 16TiB volume size). This is an ext3 file system limitation. • ext4 • xfs **NOTE:** For best performance, core device file system block size should match the core device partition logical block size. **NOTE:** For best performance, I/O request sizes in multiples 4KiB are recommended.
Software	The following prerequisite software must be installed prior to Intel® CAS installation: • bzip2 • tar • sed • make • gcc • kernel-devel • kernel-headers • python2 The following software is optional. If desired, it must be installed prior to Intel® CAS installation: • dkms (http://linux.dell.com/dkms/)
Power Management	Power Management Suspend (S3) and Hibernate (S4) states must be disabled.

3 Installing Intel® CAS

This section describes how to perform a typical installation of Intel CAS. The installation package consists of loadable kernel modules that provide the caching layer and a management CLI that controls caching behavior.

3.1 Disabling Sleep States

Before configuring Intel CAS, you must disable Power Management Suspend (S3) and Hibernate (S4) states on your OS. Consult your OS documentation for how to accomplish this on your particular OS.

3.2 Configuring the Flash Device

Before configuring Intel CAS, you must have a flash device installed. The flash device can be any solid state drive (SSD) or any PCIe* flash drive supported by the Linux operating system (see Table 4 for details).

Follow the instructions in the installation guide included with the flash device, and make note of the device's serial number or WWN so you can identify it once the system is up and running. All devices to be used for Intel CAS should be un-mounted and any auto-mount procedures disabled. When using a partition of a device as cache space, make sure the partition is aligned to the device's physical sector size for best performance.

For best performance, it is recommended to use the *noop* IO scheduler on the cache device (SSD). Initially, the intelcas virtual block device that is created when caching is enabled will inherit the IO scheduler of the primary storage device. If desired, the user can change the IO schedulers of the virtual block device and primary storage device independently after the virtual block device is created.

Note: Mounting file systems by label, such as in */etc/fstab*, should not be used in older SysV based operating systems (RHEL 6.x, CentOS 6.x, Ubuntu 14) because it interferes with proper startup of Intel CAS services. This is due to the fact that the file system will already be mounted by the operating system when the Intel CAS service tries to start.

3.3 DKMS Installation

Intel CAS for Linux will automatically recompile from source via DKMS upon any kernel update when DKMS is installed prior to Intel CAS installation and opted into during Intel CAS installation.

The latest DKMS build can be obtained at http://linux.dell.com/dkms/

Note: DKMS installation is optional and Intel CAS automatic recompile via DKMS is opt-in at the time of Intel CAS installation.

Note: Using DKMS to automatically recompile Intel CAS is strongly recommended. If the user chooses not to install DKMS or not to opt-in for automatic recompile, then whenever a kernel update occurs, Intel CAS will be disabled until the user manually re-installs it.

3.4 Local Server Installation

Before you begin installation, log on as an administrator or verify that you have the requisite privileges to install software. You must have “root” privileges or login as “root” in order to proceed.

Note: If Intel CAS 3.1 or newer is already installed, you can perform an in-flight upgrade to install the latest version without stopping I/O to cached devices (see Upgrading Intel® CAS on page 13 for details).

Note: If Intel CAS 3.0 or older is already installed, you must first uninstall the Software prior to Installation (see Section 3.6 Uninstalling the Software for details).

1. Download or copy the Intel CAS installer file to a directory on the target Intel CAS server. The installation instructions use the example of ~ or ~/ (equivalent of $HOME) on the server file system. The installer file name is in the format:

   `installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run`

   where: *XX.XX.XX.XXXXXXXX* is the version information. For example:

   `installer-Intel-CAS-03.05.00.07200700.run`

   Note: Be sure to copy/transfer the installer files in binary format. The installer will not work if it is transferred in ASCII or non-binary format.

   Note: Installer automatically detects the correct distribution of Linux.

2. Navigate to the directory with the Intel CAS installation file.

3. Make the installer file executable:

   ```
   # chmod u+x installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run
   ```

4. Launch the installation:

   ```
   #./installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run
   ```

   Note: For more information on the installer, type:

   ```
   #./installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run --help
   ```

5. Read and accept the end-user license agreement (EULA) to proceed with the installation.

   Upon accepting the license agreement the following text should appear confirming the successful installation of Intel CAS:

```
Checking for validated GNU/Linux distribution              [  OK  ]
Checking for validated kernel                              [  OK  ]
Verifying installation dependencies...
- Looking for bzip2...                                     [  OK  ]
- Looking for tar...                                       [  OK  ]
- Looking for sed...                                       [  OK  ]
- Looking for gcc...                                       [  OK  ]
- Looking for make...                                      [  OK  ]
- Looking for bash...                                      [  OK  ]
- Looking for kernel-devel...                              [  OK  ]
- Looking for Linux kernel headers in
   /lib/modules/3.10.0-123.13.2.el7.x86_64/build/...       [  OK  ]
Building userspace management utility...                   [ DONE ]
Compiling kernel module...
[================================================]100%    [ DONE ]
Verifying build products...                                [ DONE ]
- Looking for dkms...                                      [  OK  ]
Intel(R) CAS installer has detected presence of DKMS on your GNU/Linux
operating system.
```

```
The installer can configure DKMS to recompile Intel(R) CAS after each Linux
kernel version upgrade. By accepting, you acknowledge that CAS may cease to
work properly if your new kernel version is not compatible with the software as
validated against supported configurations. By declining, you acknowledge that
Intel(R) CAS won't load after any Linux kernel upgrade until you manually
reinstall the software.

Do you want to configure DKMS for Intel(R) CAS? [y/N]
y
Installing casadm utility...                                [ DONE ]
Setting up DKMS on a machine...                             [ DONE ]
Installing DKMS module... (this may take up to few minutes)[ DONE ]
Configuring service...                                      [ DONE ]
Module intelcas loaded successfully!
Setting module autoload
Installation successful!
Starting intelcas (via systemctl):                          [  OK  ]
```

3.5 Upgrading Intel® CAS

Intel CAS features in-flight upgrade capability. This capability allows the user to upgrade to a newer version of Intel CAS without stopping I/O to the cached devices or rebooting the system. This maintainability feature is especially useful in software defined storage environments since the user does not have to stop the cluster to perform the upgrade.

If, however, one or more cache instances are in an incomplete state (e.g. one or more cores are inactive), uninstallation and in-flight upgrade will be blocked. The user must bring all running instances into a healthy state prior to performing the in-flight upgrade.

Additionally, in order to correctly start all configured cache instances following a reboot, all caches should be running during the in-flight upgrade. If one or more caches are stopped during the in-flight procedure, the stopped cache needs to be manually started in order to have it properly startup after reboot.

Note: If Intel CAS 3.0 or older is already installed, you must first uninstall the Software prior to Installation (see Section 3.6 Uninstalling the Software for details).

To perform an in-flight upgrade:

1. Make the installer file executable:

   ```
   # chmod u+x ./installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run
   ```

2. Execute the Intel CAS installer with the --reinstall option:

   ```
   # ./installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run --reinstall
   ```

3.6 Uninstalling the Software

Before uninstalling the software, it is important to first stop Intel CAS, as described in Stopping Cache Instances on page 222.

Also, close all applications, unmount all file systems, and remove any existing LVM volumes that use Intel CAS before uninstalling the software. The uninstallation process will not start if Intel CAS is in use.

To uninstall the software locally, navigate to the directory containing the Intel CAS installer for the version you are uninstalling. The following steps will uninstall the software: but will leave configuration information on the system for the new installation of Intel CAS.

1. Make the installer file executable:

   ```
   # chmod u+x ./installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run
   ```

2. Launch the uninstaller:

   a. If you wish to leave the Intel CAS configuration files on the system:

      ```
      # ./installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run --uninstall
      ```

   b. If you wish to remove all Intel CAS files including the configuration files:

      ```
      # ./installer-Intel-CAS-XX.XX.XX.XXXXXXXX.run --purge
      ```

   The following text should appear confirming that Intel CAS has been successfully uninstalled:

   ```
   Checking Intel(R) CAS configuration [ DONE ]
   Stopping intelcas service [ DONE ]
   Cleaning up... [ DONE ]
   Unloading kernel module... [ DONE ]
   Removing DKMS configuration... [ DONE ]
   Removing files... [ DONE ]
   Running depmod... [ DONE ]
   Uninstallation successful
   ```

3.7 Advanced Installation Options

The Intel CAS installer has the ability to perform automated installation across a distributed environment. For details on this type of installation, see Remote Installer Parameters on page 52.

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4 Configuring Intel® CAS

4.1 CAS Configuration File - /etc/intelcas/intelcas.conf

Once CAS has been installed, the next stop for the CAS administrator should be the intelcas.conf. This file is the primary point for system cache and core device configuration and is essential to correct CAS operation.

The file is read by system Udev rules upon startup. For each block device that appears in the system, rules check to see if the device is in the intelcas.conf, and take action accordingly. The file is divided into two main sections:

1. `Caches configuration section`
2. `Core devices configuration`

The `Caches configuration section` specifies:

1. Cache ID. This indicates the ID used for starting a cache instance on a given device.
2. path to the NVMe or other cache device(s). The recommended cache device is a Non-volatile Memory Express (NVMe) solid state drive. CAS has been engineered to take advantage of the high speed and low latency of even the latest NVMe drives.
3. desired cache mode.
4. extra fields, such as the full path to the custom IO Classification file.

The `Core devices configuration` section specifies:

1. Cache ID. Specifies which cache device each core corresponds to.
2. Core ID. Indicates the ID used for core device(s) corresponding to a specific cache within the system.
3. path to the core device(s).

Example of `caches` and `cores` configuration in an operational intelcas.conf file:

```
## Caches configuration section
[caches]
## Cache ID  Cache device                    Cache mode   Extra fields (optional)
1           /dev/disk/by-id/nvme-INTEL_SSD  WT     ioclass_file=/etc/intelcas/ioclass-config.csv

## Core devices configuration
[cores]
## Cache ID     Core ID         Core device
1               1       /dev/disk/by-id/wwn-0x50014ee0aed22393
1               2       /dev/disk/by-id/wwn-0x50014ee0042769ef
1               3       /dev/disk/by-id/wwn-0x50014ee00429bf94
1               4       /dev/disk/by-id/wwn-0x50014ee0aed45a6d
1               5       /dev/disk/by-id/wwn-0x50014ee6b11be556
1               6       /dev/disk/by-id/wwn-0x50014ee0aed229a4
1               7       /dev/disk/by-id/wwn-0x50014ee004276c68
```

Further details are available in the complete default /etc/intelcas/*intelcas.conf* file:

```
version=3.5.1
# Version tag has to be first line in this file

#
```

```
#              |          |  (R)
#  o        --+--        |
#  .  . .-.    |    .-.   |        .--  --.   .--
#  |  |/   \   |   /   )  |       /        \ (
#  |  |     '  |   |.-'   |      (      ----  '-.
#  |  |     |  |   \      |       \    (   |     )
#  '- '     '  '--  '--'  '--      '--  --' ' --'

# Intel(R) CAS configuration file - for reference on syntax
# of this file please refer to appropriate documentation

# NOTES:
# 1) It is highly recommended to specify cache/core device using path
# that is constant across reboots - e.g. disk device links in
# /dev/disk/by-id/, preferably those using device WWN if available:
#   /dev/disk/by-id/wwn-0x123456789abcdef0
# Referencing devices via /dev/sd* may result in cache misconfiguration after
# system reboot due to change(s) in drive order.

## Caches configuration section
[caches]
## Cache ID     Cache device                              Cache mode      Extra fields
(optional)
## Uncomment and edit the below line for cache configuration
1              /dev/disk/by-id/nvme-INTEL_SSDP..       WT

## Core devices configuration
[cores]
## Cache ID     Core ID         Core device
## Uncomment and edit the below line for core configuration
1              1               /dev/disk/by-id/wwn-0x123456789abcdef0

## To specify use of the IO Classification file, place content of the following line in the
## Caches configuration section under Extra fields (optional)
## ioclass_file=/etc/intelcas/ioclass-config.csv
```

Here is an explanation of each of the fields:

- *<Cache ID>* is a numeric value between 1 and 16,384 (valid cache instance numbers).
- *<Core ID>* is a numeric value between 0 and 4095 (valid core instance numbers)
- Cache and core devices must point to existing HDD and SSD devices, preferably referenced by the by-id name (`ls -l /dev/disk/by-id`). Core devices should reference the WWN identifier, while Cache devices should use model/SN. Alternatively, devices may be referenced by device name (eg. /dev/sdb) such as when running casadm commands.
- Mode determines the cache mode, either write-through, write-back, write-around, or pass-through
- *Optional:* Extra flags allow extra settings for the cache and core devices and are comma separated.
    - *ioclass_file* allows the user to load a file that specifies an IO class policy for this cache
    - *cleaning_policy* allows the user to specify the cache cleaning policy to be used for this cache, either alru or nop.

Note: During an upgrade, intelcas.conf files with earlier formats will automatically be converted to the new format.

4.2 The CAS Configuration Utility - casadm

Intel CAS provides a user-level utility called casadm to allow for configuration and management of the caching software. The utility is installed by default in the */sbin* directory.

In using casadm, it is important to understand certain restrictions:

- You must be logged on as root or have root privileges to start, stop, or configure Intel CAS.
- You cannot accelerate the partition that the operating system resides on.

Note: If a super user promotes you to root, there is no guarantee that the /sbin directory will be in your $PATH environment variable. If casadm is not accessible, check this variable first. Use the command's full path (that is, /sbin/casadm).

If you launch the configuration utility via casadm -H, a list of command line options and arguments is returned. For more detailed information on the different command line options, see Configuration Tool Details section of this document.

For Intel CAS configuration, note that the term "cache device" refers to the SSD/NVMe device or RAM disk that is used for caching data from a slower device, while the term "core device" refers to the slower device to be cached.

4.3 Using the Configuration Utility

While configuration of CAS via the intelcas.conf file is highly recommended, the following sections detail how to manually configure CAS options using *casadm*. For more details on available commands for the *casadm* utility, see Configuration Tool Details section.

The following is assumed for the subsequent instructions:

- The cache device (SSD) is */dev/sdc*. The cache device is either a raw block device or ram disk accessed as a block device. Ensure that the cache device does not have a file system and is not mounted.

  Note: Back up all data on your cache device before completing these steps as all data will be overwritten.

- The core device (primary storage) to be cached is */dev/sdb*.

  The core device may contain a filesystem (with or without data) or may be a raw block device. See System Requirements on page 10 for specific file system types and limitations for Intel CAS. Ensure that the device is not mounted.

- If necessary, perform an *ls -l* or *ll* on the */dev/disk/by-uuid* or */dev/disk/by-id* directory to ensure the correct devices are being configured.
- Core device (HDD) logical block size must be 512 bytes or larger.
- Cache device logical block size must be smaller than or equal to the logical block size of the core storage device.
- Ensure that both devices are removed from /etc/fstab and any other mechanism that auto mounts either the cache device or core device.

If the Intel CAS module is not loaded, follow the installation instructions in Section 3. If the Intel CAS installation fails, contact customer support.

4.4 Manual Configuration for Write-through Mode

In write-through mode, the caching software writes data to the flash device and simultaneously writes the same data "through" to the core device (disk drives). Write-through ensures the core device is 100% in sync with the cache and its data is always available to other servers sharing that storage. However, this type of cache will accelerate only read intensive operations.

1. Ensure that the core device (*/dev/sdb*) is not mounted and that the cache device (*/dev/sdc*) is not mounted and contains no data to be saved. Entering the following command will display all mount points:

   ```
   # mount
   ```

2. Start a new cache with an ID of "1":

   ```
   # casadm -S -i 1 -d /dev/sdc
   ```

   You may notice a brief delay after entering the *casadm -S* command. Typically, this is less than 60 seconds, but can be longer.

   If the cache device is formatted or a file system already exists, you will need to use the "-f" force flag (for example, *casadm -S -d /dev/sdc -f*).

   Note: All information on the cache device will be deleted if the -f option is used. Please ensure all data has been backed up to another device (see Configuration Tool Details section for further details).

3. Pair the core device to this new cache:

   ```
   # casadm -A -i 1 -d /dev/sdb
   ```

   The *add-core* command creates a new device in the */dev* directory with the following name format:

   `intelcas<cache ID>-<core #>` for example: */dev/intelcas1-1.*

   This new device can be treated as a regular block device.

4.5 Manual Configuration for Write-back Mode

In write-back mode, the caching software writes the data first to the cache and acknowledges to the application that the write is completed, before the data is written to the core device. Periodically, those writes are "written back" to the disk opportunistically. While write-back caching will improve both write and read intensive operations, there is a risk of data loss if the cache device fails before the data is written to the core device.

Write-back mode is enabled when starting a new cache device with the option "*-c wb*":

```
# casadm -S -i 1 -d /dev/sdc -c wb
```

Pairing of a core device is similar to step 3 in the previous Manual Configuration for Write-through Mode section.

4.6 Manual Configuration for Write-around Mode

In write-around mode, the caching software writes data to the flash device if and only if that block already exists in the cache and simultaneously writes the same data "through" to the core device (disk drives). Write-around is similar to write-through in that it ensures the core device is 100% in sync with the cache and in that this type of cache will accelerate only read intensive operations. However, write-around further optimizes the cache to avoid cache pollution in cases where data is written and not often subsequently re-read.

Write-around mode is enabled when starting a new cache device with the option "*-c wa*":

```
# casadm -S -i 1 -d /dev/sdc -c wa
```

Pairing of a core device is similar to step 3 in the Manual Configuration for Write-through Mode section.

4.7 Manual Configuration for Pass-through Mode

In pass-through mode, the caching software will bypass the cache for all operations. This allows the user to associate all their desired core devices to be cached prior to actually enabling caching. Once the core devices are associated, the user would dynamically switch to their desired caching mode.

Pass-through mode is enabled when starting a new cache device with the option "*-c pt*":

```
# casadm -S -i 1 -d /dev/sdc -c pt
```

Pairing of a core device is similar to step 3 in the Manual Configuration for Write-through Mode section.

4.8 Switching Caching Modes

You can switch between different caching modes any time without rebooting or restarting Intel CAS. For example, you can switch from WT mode to PT mode to stop caching during maintenance or for testing purposes.

To switch from WB to any other mode, you must specify whether dirty data should be flushed now or later using the --flush-cache option. Depending on the --flush-cache option used, switching from WB to other caching modes may require time to complete before caching mode is changed.

The following example places Intel CAS into PT mode for cache id 1.

```
# casadm --set-cache-mode --cache-mode pt --cache-id 1
```

or

```
# casadm -Q -c pt -i 1
```

4.9 Automatic Partition Mapping

If the core device to be accelerated has existing partitions, selecting the parent device as the core device to be accelerated (e.g. /dev/sdc as in the previous examples) will accelerate all of the underlying partitions with a single command.

Intel CAS will automatically hide the existing core device partitions (ex. /dev/sdc1, /dev/sdc2, etc.) from the Operating System, create partitions on the exported device (e.g. /dev/intelcas1-1p1, /dev/intelcas1-1p2, etc.), and make the exported device a child of the core device.

Table 5: Comparison of logical device layout before and after Intel CAS acceleration

Before	After
/dev/sdc /dev/sdc1 /dev/sdc2 /dev/sdc3 /dev/nvme0n1	/dev/sdc /dev/intelcas1-1 /dev/intelcas1-1p1 /dev/intelcas1-1p2 /dev/intelcas1-1p3 /dev/nvme0n1

This scheme ensures compatibility with existing object storage device creation and activation scripts from common software defined storage systems (e.g. Ceph).

4.10 Mounting an Intel® CAS Device as a Data Volume

For some applications, a storage system or cluster may require the CAS exported device to be mounted to the file system to allow for its use as a data volume.

The file system should be created directly on the core device before it is added to the cache instance. It's not recommended to run mkfs commands on the exported device (intelcasX-Y) as the process can be very slow.

Format the core device as ext4
mkfs.ext4 /dev/sdb1

Format the core device as xfs
mkfs.xfs -f /dev/sdb1

Once the cache instance has been started and core devices added, the CAS exported name can be used for the mount function. The device designation of `intelcasX-Yp1` will be used for mounting since the file system partition on the exported device is required to mount into the file system directory.

As a reminder, a directory must already exist in order to mount the exported device. In this example, the device is `/dev/intelcas1-1p1` and the mount point directory is `/mnt/cache1`. Create the mount point directory if it does not exist.

Mount a CAS exported device:

```
# mount -t xfs /dev/intelcas1-1p1 /mnt/cache1
```

Note: Intel CAS ensures that no changes are required to the application; it can use the same file system mount point (for example, */local/data*) as the core device previously used.

Note: If your application uses the raw device directly (for example, some installations of Oracle*), then you must configure the application to use the exported device (e.g. intelcas1-1) instead.

Note: To take advantage of the new TRIM functionality, the file system must be mounted with additional options. Please see the TRIM section for further details.

It may be necessary to change ownership and/or permissions for the mount point directory to grant applications access to the cache. Modify as required to allow access.

Persistent mounting of the CAS exported device(s)

After the caching devices have been created and CAS is running, you can use the /etc/fstab file to ensure persistent mounts of your mounted volumes. Use of the fstab file as follows assumes that CAS is active and that exported devices have been configured to agree with the contents of the fstab.

```
# cat /etc/fstab
...
/dev/intelcas1-1p1 /mnt/cache1 xfs defaults 0 0
/dev/intelcas1-2p1 /mnt/cache2 xfs defaults 0 0
```

5 Running Intel® CAS

This chapter describes how to perform typical administrative activities with Intel CAS.

5.1 Initial configuration of Cache instances

If CAS is installed, but no cache instances are configured and running, the user can easily configure and start cache instances as follows:

1. Edit and configure caches and cores in the /etc/intelcas/intelcas.conf file
2. Execute the following:

```
# intelcas init
```

5.2 Startup of Cache instances

In order to start all cache instances which are configured in the intelcas.conf file, the user should execute the following:

```
# intelcas start
```

Use of the `intelcas start` command assumes that the configured cache instances were previously running.

5.3 Rebooting, Power Cycling, and CAS Autostart

Once the /etc/intelcas/intelcas.conf file is configured correctly to include the cache and core devices, Intel CAS devices will automatically become available for use after a restart of the system. That is, CAS defaults to being enabled within the system, checks the intelcas.conf file for device configuration, and performs the appropriate actions.

If the user does not wish to start CAS caching after reboot, it will be necessary to comment out the cache/core devices in the intelcas.conf file. This will effectively disable CAS and prevent autostart of the devices following a system restart.

If the intelcas.conf file is not yet configured, and CAS devices were previously manually started/added, a system reboot will require another manual restart of the cache and addition of the cores to the cache device.

1. Start Intel CAS using the following command syntax:

```
# casadm -S -i <cache_id> -d <cache_device> -c <cache_mode>
# casadm -A -i <cache_id> -d <core_device>
```

5.4 Stopping Cache Instances

Prior to any shutdown or reboot of your system, it is recommended to cleanly stop Intel CAS.

In order to stop all cache instances which are configured in the intelcas.conf file, the user should execute the following:

```
# intelcas stop
```

5.5 Disabling Intel® CAS

In order to disable intelcas on one or more devices, the user should perform the following operations:

1. Stop cache or remove cores using casadm -T or casadm -R commands.
2. Remove or comment out devices from the intelcas.conf file followed by a system restart.

5.6 Handling an Unplanned Shutdown

An unplanned shutdown is any time Intel CAS devices are not shutdown properly as described in the previous section. This can include power cycling the system, or a power loss to the system, without properly shutting down Intel CAS devices.

After an unplanned shutdown, there are two options for restarting caching. The first option is to start the cache in load mode (-l option), which will utilize the dirty data currently in cache for faster recovery, and no flushing of cache will be done. When using atomic writes, the load option will utilize all the current data (clean/dirty) in the cache. The clean cache data means that the data in cache is in sync with the backend storage, such as hard disk drives. Dirty cache data refers to data that has not yet been written to the backend storage. Therefore Atomic writes provide better performance after recovery because they have more data in the cache.

The second option is to reinitialize the cache with new metadata, which will clear the cache, resulting in the loss of all dirty data that is currently in the cache. See the following options for details.

Caution: If the file system changes while caching is not running, data loss may occur. Do not issue any IO to the core device until caching has been restarted using one of the methods below.

5.6.1 Recovering the Cache

To start Intel CAS with recovery enabled, enter the following command. All previously attached cores will be reattached to the cache after this command.

```
# casadm -S -d /dev/sdc -l
```

For more details, see '-S | --start-cache'.

5.6.2 Reinitializing the Cache

To clear the cache (invalidate the entire cache), do the following:

1. Log on as root.
2. Start the cache including the `-f` parameter (and omitting the `-l` parameter), as shown below:

```
# casadm -S -d /dev/sdc -f
# casadm -A -i 1 -d /dev/sdb
```

This reinitializes the cache instead of loading the old state.

Reinitializing the cache with new metadata will destroy all write-cached data that has not yet been flushed to the disk. In addition, reinitializing the cache with the -force (-f) option is still valid and will destroy all existing cache data.

Intel CAS maintains state across a reboot. If the system is rebooted without starting the caching subsystem, then the state of the cache data may become out of sync with the data in primary storage (core device). In this case, restarting the cache system without clearing the cache may result in data corruption.

5.7 Device I/O Error Handling

In the event of a read or write I/O error from either the cache device (SSD) or the core device (HDD), Intel CAS will intelligently handle the error and, if possible, will return the requested data and continue processing I/O in certain cases.

Cases where Intel CAS will ***return data*** and ***continue processing I/O*** include ***cache device I/O errors*** when attempting to:

- Read clean data from the cache
- Write data to the cache on a read operation (attempting to cache the data that was read)
- Write data to the cache in Write-Through or Write-Around modes on a write operation

Cases where Intel CAS will ***return an error*** to the calling application and ***stop processing I/O*** for any exported devices (e.g. intelcas1-1) served by the cache SSD on which the I/O error occurred include ***cache device I/O*** errors when attempting to:

- Read dirty data from the cache
- Write data to the cache in Write-Back mode

Cases where Intel CAS will ***return an error*** to the calling application and ***continue processing I/O*** include ***core device I/O errors*** when attempting to:

- Read data from the core device
- Write data to the core device

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6 I/O Classification

6.1 I/O Class Configuration

Intel CAS provides the ability to control caching of your data at a finer granularity than ever before. Intel CAS for Linux can analyze every IO on the fly to determine whether the requested block is filesystem metadata or data and, if it is data, the total size of file I/O requested. Using this information the administrator can determine the best I/O class configuration settings for the typical workload and can set which I/O classes to cache and which not to cache, and set a priority level for each I/O class. Then, when it becomes necessary to evict a cache line, the software will evict cache lines of the lowest available priority first (an improvement compared to traditional LRU eviction).

1. To enable I/O classification and selective allocation, first look at the provided example IO class configuration file and edit to suit your needs:

   ```
   # vi /etc/intelcas/ioclass-config.csv
   ```

   The example IO class configuration file format is as follows:

Table 6: I/O Class Configuration File Fields

Field	Description
IO class id	Unique ID for the IO class. Values in this field are fixed and should not be modified. (eg. ID for Metadata must always be 1)
IO class name	String name of the IO class. The user can use any string to represent IO class, however the meaning of the particular class will remain the same (e.g. IO class ID 1 will always represent Metadata regardless of the string assigned in this field)
Eviction priority	Sets the priority number for the IO class. Priority range is 0-255 with zero having the highest priority. The I/O classes with the lowest priority will be evicted first.
Allocation	Boolean value that allows the user to decide whether data of this IO class will be cached or not. 0=do not cache, 1=cache.

```
IO class id,      IO class name,      Eviction priority,      Allocation
0,                Unclassified,       22,                     1
1,                Metadata,           0,                      1
11,               <=4KiB,             10,                     1
12,               <=16KiB,            11,                     1
13,               <=64KiB,            12,                     1
14,               <=256KiB,           13,                     1
15,               <=1MiB,             14,                     1
16,               <=4MiB,             15,                     1
17,               <=16MiB,            16,                     1
18,               <=64MiB,            17,                     1
19,               <=256MiB,           18,                     1
20,               <=1GiB,             19,                     1
21,               >1GiB,              20,                     1
22,               O_DIRECT,           21,                     1
23,               Misc,               22,                     1
```

2. After you have completed your changes to the IO class configuration and saved the file, you must load the configuration for your cache device with ID number represented by <ID> from file <FILE>:

   ```
   # casadm --io-class --load-config --cache-id <ID> -f <FILE>
   ```

3. Verify that the configuration file was successfully loaded:

   ```
   # casadm --io-class --list --cache-id <ID>
   ```

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7 Advanced Options

7.1 Many-to-one Option

You can add multiple core devices to the single cache device.

1. Add more core devices to the existing caching framework (associated with `<cache_id> = "1"`) by entering the following:

   ```
   # casadm -A -i 1 -d /dev/sd<n>
   ```

   where *<n>* is any unique core drive and/or partition letter. (For example: *casadm -A -i 1 -d /dev/sdd*.)

2. Repeat the step 1 for each unique core drive to be added to the many-to-one caching framework.

   For each new core device added, a cache-core pair will be created with the following naming format:

   <cache_id> =1, first core device.
   (For example: */dev/sdd*.)

   /dev/intelcas1-2 will be created associated with *<cache_id>=1*, second core device.
   (For example: */dev/sdf*)

   and so on.

3. Confirm the creation of each device with one of the following commands:

   ```
   # ls /dev/intelcas<cache_id>-<core_id>
   ```

   or

   ```
   # casadm -L
   ```

   or

   ```
   # casadm -P -i 1
   ```

In some instances, like sequential read on a newly created cache device, the cache device may become overloaded, causing slower performance, and the queue may increase, consuming system buffers. To avoid this issue, it may be necessary to manually force an optimal queue size for the cache write queue specific to a use case. The default *max_writeback queue_size* value is 65,536. Another parameter may also be used to determine the unblock threshold for this queue: *writeback_queue_unblock_size* (default value is set at 60,000). You can use the following command to overwrite this default value and set a custom *max_writeback queue_size* or alter the *writeback_queue_unblock_size* threshold:

```
# modprobe intelcas max_writeback_queue_size=<size>
writeback_queue_unblock_size=<size>
```

or

```
# insmod intelcas max_writeback_queue_size=<size>
writeback_queue_unblock_size=<size>
```

Note: The above examples are each a single line. Intel CAS is now enabled on the system and files to be accelerated can be written to */mnt/cache1*.

Keep in mind that the modinfo command only displays the default values of these parameters. To check the actual values of the parameters that you have modified, you can do so by examining /sys/modules/intelcas/parameters/* files:

```
/sys/modules/intelcas/parameters/max_writeback_queue_size
/sys/modules/intelcas/parameters/writeback_queue_unblock_size.
```

If you are not seeing the correct values in the sysfs files, it is most likely because you have not unloaded the Intel CAS module prior to running modprobe. The modprobe command does not return any errors when you try to run it against a module that is already loaded.

7.2 Multi-Level Caching

Intel CAS for Linux supports multi-level caching. For example, this enables the user to cache warm data from slow HDD media to faster SSD media, and then cache hot data from the SSD to an even faster media such as a RAMdisk. In this case, a fixed portion of DRAM will be allocated for buffering, and the SSD will remain as a fully inclusive cache so DRAM cache data will always be available on the SSD.

To set up a RAMdisk-based cache level, do the following:

1. Create a RAMdisk (100 MB or larger).

   In RHEL, for example, the default RAMdisk size is 8 MB so it must be configured to be equal or greater than 40 MB.

   a. For kernels prior to 3.0, modify *grub.conf* and change the *ramdisk_size* parameter to the desired capacity in KiB. Example highlighted below in **red**:

```
# grub.conf generated by anaconda
#
# Note that you do not have to rerun grub after making changes to this file
# NOTICE:  You have a /boot partition.  This means that
#          all kernel and initrd paths are relative to /boot/, eg.
#          root (hd0,0)
#          kernel /vmlinuz-version ro root=/dev/hda5
#          initrd /initrd-version.img
#boot=/dev/hda
default=0
timeout=10
splashimage=(hd0,0)/grub/splash.xpm.gz
title Red Hat Linux (2.4.20-20.9)
          root (hd0,0)
        kernel /vmlinuz-2.4.20-20.9 ro root=LABEL=/ hdc=ide-scsi
        ramdisk_size=102400
        initrd /initrd-2.4.20-20.9.img
```

   b. For kernels 3.0 or newer, issue the following command to increase the RAMdisk size to 100 MB:

```
# modprobe brd rd_size=102400
```

Note: Do not format or create a file system or mount the RAMdisk, at this time.

Note: Do not use */dev/ram0* since it is reserved by the kernel. Use any available RAMdisk */dev/ram1* or greater. We will use */dev/ram1* in this example.

2. Reboot the system and start a fresh Intel CAS install, if necessary.
3. Create the SSD caching framework, where */dev/sdc* is your SSD cache device:

   ```
   # casadm -S -d /dev/sdc
   ```

4. Add a core device (*/dev/sdb*) mapping to the SSD caching framework:

   ```
   # casadm -A -i 1 -d /dev/sdb
   ```

5. Create the RAMdisk caching framework:

   ```
   # casadm -S -d /dev/ram1 -i 2
   ```

6. Add the tiered core device (*/dev/intelcas1-1*) mapping to the RAMdrive caching framework:

   ```
   # casadm -A -i 2 -d /dev/intelcas1-1
   ```

7. Create the file system from the newly created tiered cache drive:

   ```
   # mkfs -b 4096 -t ext3 /dev/intelcas2-1
   ```

   or

   ```
   # mkfs.ext4 -b 4096 /dev/intelcas2-1
   ```

   or

   ```
   # mkfs.xfs -f -i size=2048 -b size=4096 -s size=4096 /dev/intelcas2-1
   ```

8. Create a cache directory and mount the cache to it:

   ```
   # mkdir -p /mnt/cache1
   # mount /dev/intelcas2-1 /mnt/cache1
   ```

The newly created and mounted cache drive */mnt/cache1* is ready for use.

By default, any RAMdisk tiered buffering setup is volatile and will need to be set up again following a system restart. Any data should remain in the SSD following a clean restart. See Stopping Cache Instances for details on stopping Intel CAS.

Caution: If the RAMdisk cache tier is started in write-back mode and there is a dirty shutdown, data loss may occur.

7.3 Linux* LVM support

Intel CAS supports LVM in two ways.

1. LVM physical volumes can be created directly on Intel CAS devices. This allows creation of volume groups thereon, and later creation of logical volumes on those groups.

   Note: With older versions of LVM, you must first create a partition on the core device (eg. if the core device is /dev/sdc, you must create /dev/sdc1) prior to accelerating that device with Intel CAS device and creating the physical volume or creation of the logical volume will fail. If you see the following warning: *"WARNING: Ignoring duplicate config node: types (seeking types); Found duplicate PV"*, then you must use this workaround.

2. LVM logical volumes can be used as core devices, just like regular partitions.

LVM must be configured in the system before using it with Intel CAS, which is outside of the scope of this document.

Ensure Intel CAS devices are listed as acceptable block device types in */etc/lvm/lvm.conf* by adding the following line to the advanced settings:

```
# Advanced settings.
# List of pairs of additional acceptable block device types found
# in /proc/devices with maximum (non-zero) number of partitions.
types = [ "inteldisk", 16 ]
```

After the LVM is configured and an Intel CAS device has been created (see Configuring Intel® CAS starting on page 15 for further details) a physical volume can be created thereon:

```
# pvcreate /dev/intelcas1-1
```
(or `#pvcreate /dev/intelcas1-1p1` if creating the physical volume from a partition on the Intel CAS device)

After the physical volume is created, the user can create a volume group, for example: *vg_cas*, and then a logical volume on it, for example: *lv_cas*:

```
# vgcreate vg_cas /dev/intelcas1-1
# lvcreate -n lv_cas -l 100%FREE vg_cas
```

Create and mount LVM filesystem to "*vfs_cas*":

```
# mkfs.ext4 <-b 4096> /dev/vg_cas/lv_cas
# mkdir -p /mnt/vfs_cas
# mount /dev/vg_cas/lv_cas /mnt/vfs_cas
```

To remove the LVM device, use the following steps:

```
# umount /mnt/vfs_cas
# vgchange -an vg_cas
# casadm -R -i <cache_id> -j <core_id>
# casadm -T -i 1
```

Dynamic logical volume reduction or extension is not automatically supported (e.g. *vgreduce* or *vgextend*). The user must remove the Intel CAS device (e.g. *intelcas1-1*) as the physical volume, perform the necessary size changes and then recreate the physical volume based on the Intel CAS device. Consult Intel CAS LVM man pages and web wikis for details on how to use and manage LVMs.

7.4 Using Custom Setup Files (Advanced Config)

You can further configure Intel CAS by using a special setup file. This file is created by the administrator and must be stored in the */etc/intelcas* directory.

The */etc/intelcas* directory contains example files after a fresh installation; we recommend reviewing them before proceeding with the steps described in this admin guide.

One example of the setup file would be a user-created script named *installation_setup_file.* This file can automate remote installation and configuration using local config files.

7.4.1 Format of Setup Files

The *installation_setup_file* script has the following format and syntax:

```
# Comments begin with hash symbol
config: </etc/intelcas/intelcas.conf>
<IP Address of system A>
```

```
<IP Address of system B>
<IP Address of system N>

# Empty lines are ignored
```

Example of an *installation_setup_file*:

```
# INSTALL_SETUP_FILE
# Sample installation_setup_file for nodes 192.168.1.101 through
# 192.168.1.112

config: /etc/intelcas/intelcas.conf
192.168.1.101
192.168.1.102
...
192.168.1.112
```

Each config file to be copied to the machines in a particular group must be listed in the `config:` line (delimited by space) for that group. All machines whose addresses are listed in a particular group will receive the config files listed in the group header. End of group is indicated with a new configuration group header or an end of file.

7.4.2 Installing with installation_setup_file

The remote installation utility (see Remote Installation section) supports batch configuration on multiple target systems, by automatically copying (via *ssh* to multiple system IP addresses) previously created config files to appropriate remote target systems.

Note: The remote installation utility requires that the remote machine supports *ssh* connections and file transfer from the installation system/server.

The configuration procedure goes as follows:

Note: The same `installation_setup_file` is used for both installation and configuration (as well as for uninstallations).

Note: Installation and setup are two separate steps that can be performed independently of each other (i.e. a target system can be pre-configured even though there may be no existing installation of Intel CAS on it).

1. After you complete all the steps from Remote Installation on page 54, do the following to place configuration files on a single target system one at time:

   ```
   # ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run
    --setup --one-machine <IP ADDRESS> </etc/intelcas/intelcas.conf>
   ```

2. Alternatively, you can implement the same two steps above by including them in to an *installation_setup_file* script and typing the following:

   ```
   # ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run
    --setup --use-config <path>/installation_setup_file
   ```

Note: Ensure the files listed in group headers in the installation config file point to existing files in the filesystem, otherwise they will not be copied.

Note: After Intel CAS has been properly installed and configured on a system, ensure that the config files contain valid information before restarting that system.

Note: For your reference, your installation package includes example files named *<filename>.example* under the */etc/intelcas* directory (placed in that directory as part of the normal install process - no additional user steps are required) for each of the setup and config files referred to in this chapter. You may want to consult these files for further examples of correct syntax and formatting.

7.5 Trim Support

The trim command (known as TRIM in the ATA command set, and UNMAP in the SCSI command set) allows an operating system to inform an SSD which blocks of data are no longer considered in use and can be wiped internally. TRIM is enabled by default and supported by Intel CAS for Intel SSDs. When a user or application deletes data, Intel CAS will free the cache lines associated with that data when TRIM is used. This avoids the time required to flush that data to the backend storage such as hard drives.

In order to take advantage of this feature, the Linux file system has to be configured so TRIM requests are properly sent to Intel CAS for processing. The configuration consist of mounting the file system with the discard option, which applies to most file systems, such as ext4 or xfs.

The following command is an example:

```
# mount -o discard /dev/intelcas1-1 /mnt
```

7.6 Atomic Writes

Intel Data Center SSDs have an Extended LBA feature. Intel CAS takes advantage of this feature to write user data and cache metadata in one write request reducing number of writes to cache devices, therefore enhancing performance and increasing drive endurance.

The performance improvements are especially useful in Write-Back (WB) mode, which requires two writes (one for user data and the second one for metadata updates). During a recovery procedure, Intel CAS makes use of this metadata to recover user data (for example, in case of power-failures).

To take advantage of this feature, the Intel SSD must be properly formatted prior to using with Intel CAS.
The command syntax is:

```
# casadm -N -F <MODE> -d <DEVICE> [option. . .]
```

Or

```
# casadm --nvme --format <MODE> --device <DEVICE> [option. . .]
```

For example:

```
# casadm -N -F atomic -d /dev/nvme0n1
```

Note: To use this feature, the Intel SSD used for caching must be dedicated to Intel CAS only. In other words, the SSD cannot be partitioned to be used for other purposes such as Ceph journals, etc.

Note: Atomic writes are only available for RHEL/CentOS 7.3 or Ubuntu 16.04.

Important Note: You must ensure that you reboot the server after formatting the NVMe* devices and before any further changes are made to the system.

7.7 Kernel Module Parameters

The following is a list of available system and kernel parameters that can be modified in order to further improve the performance of certain applications. These parameters should not be modified without advanced tuning expertise and a thorough knowledge of the workload. Please contact Intel support for further details.

The parameters are: unaligned_io, seq_cut_off_mb, metadata_layout, and use_io_scheduler.

- **Unaligned_io:** This parameter enables user to specify how I/O requests unaligned to 4KiB should be handled. This parameter should be changed if caching such requests cause performance drop.

  Possible values: 0 - handle unaligned requests using PT mode, or 1 - handle unaligned requests using current cache mode (default)

- **seq_cut_off_mb:** This parameter enables user to specify a threshold for sequential cut off feature. Value is expressed in **megabytes**. Sequential cut off disables caching of sequential I/O requests. If Intel CAS detects sequential data with size above value controlled by this parameter it stops caching this data.

  Possible values: 0 - sequential cut off is disabled, 1 or larger - sequential cut off threshold in megabytes (default is 1)

- **metadata_layout:** This parameter enables user to specify layout of metadata on SSD. This is an advanced parameter for **controlling** Intel CAS internal metadata layout.

  Possible values: 0 - striping (default), or 1 - sequential

- **use_io_scheduler:** This parameter enables user to specify how I/O requests are handled - if I/O scheduler will be used or not. **User** can disable I/O scheduler on Intel CAS device if there is another block device with its own scheduler on top of it (for example LVM). This parameter has no effect for WB (Write-Back) mode.

  Possible values: 0 - handle I/O requests in application context, thus omit I/O scheduler, or 1 - handle I/O using I/O scheduler (default)

The parameters can only be changed during module loading and must be added to the system startup so they would take effect upon reboots. To change the values of these parameters without modifying Intel CAS startup files, you can create a configuration file in /etc/modprobe.d directory. For example, on a Redhat 7.3 system create the file /etc/modprobe.d/intelcas.conf with the following content, then restart Intel CAS or reboot the system:

```
# cat /etc/modprobe.d/intelcas.conf
options intelcas unaligned_io=0 seq_cut_off_mb=10
```

Note: The example above may not apply to your specific Operating System. Please see the appropriate documents for your operating system for properly modifying these parameters.

§

8 Monitoring Intel® CAS

There are a number of performance counters available for viewing. These counters are accessible using the `casadm -P -i <cache_id>` command. This section contains a brief description of data included in the *stats* command line option.

```
# casadm --stats --cache-id <ID>
```

or

```
# casadm -P -i <ID>
```

See the '-P | --stats' section for details.

The output of this command contains three tables that describe the activities in the caching system:

- **Usage statistics**
- **Inactive Usage statistics**
- **Request statistics**
- **Block statistics**
- **Error statistics**

Entries are in the form: stat, actual number, percent of overall, units.

You can use these statistics to learn about your data usage. For example, looking at the sequential versus random read statistics reveals how your data is used.

The following tables list the statistics (counters) that Intel CAS records:

Table 7: Usage Statistics

Statistic	Description
Occupancy	Number of cached blocks
Free	Number of empty blocks in the cache
Clean	Number of clean blocks (cache data matches core data)
Dirty	Number of dirty blocks (block written to cache but not yet synced to core)

Table 8: Inactive Usage Statistics

Statistic	Description
Inactive Occupancy [4KiB Blocks]	Number of inactive cached blocks
Inactive Clean [4KiB Blocks]	Number of inactive clean blocks (cache data matches core data)
Inactive Dirty [4KiB Blocks]	Number of inactive dirty blocks (block written to cache but not yet synced to core)

Table 9: Request Statistics

Statistic	Description
Read hits	Number of reads that were cache hits
Read partial misses	Number of reads that spanned both data that was in the cache and data that was not in the cache

Statistic	Description
Read full misses	Number of reads that were cache misses
Read total	Total number of reads
Write hits	Number of writes that were cache hits
Write partial misses	Number of writes that spanned both data that was in the cache and data that was not in the cache
Write full misses	Number of writes that were cache misses
Write total	Total number of writes
Pass-through reads	Number of read requests sent directly to the core device (not cached by CAS). This statistic is incremented when the request is handled while the cache is in pass-through mode (see -Q | --set-cache-mode for details).
Pass-through writes	Number of write requests sent directly to the core device (not cached by CAS). This statistic is incremented when the request is handled while the cache is in pass-through mode (see -Q | --set-cache-mode for details).
Serviced requests	Total number of IO requests serviced (that did not bypass the cache)
Total requests	Total number of IO requests (both serviced and bypassed requests)

Percentages are calculated as percentage of total requests. (e.g. Read Hits % = 100*(# read hits / total requests)).

Table 10: Block Statistics

Statistic	Description
Reads from core(s)	Number of blocks read from core device(s)
Writes to core(s)	Number of blocks written to core device(s)
Total to/from core(s)	Total number of blocks read from or written to core device(s)
Reads from cache	Number of blocks read from cache device
Writes to cache	Number of blocks written to cache device
Total to/from cache	Total number of blocks read from or written to cache device
Reads from exported object(s)	Number of blocks read from exported object(s) (eg. intelcas1-1)
Writes to exported object(s)	Number of blocks written to exported object(s)
Total to/from exported object(s)	Total number of blocks read from or written to exported object(s)

Table 8: Error Statistics

Statistic	Description
Cache read errors	Number of read errors to the cache device
Cache write errors	Number of write errors to the cache device
Cache total errors	Total number of read or write errors to the cache device
Core read errors	Number of read errors to the core device(s)
Core write errors	Number of write errors to the core device(s)
Core total errors	Total number of read or write errors to the core device(s)
Total errors	Total number of read or write errors to the cache or core devices

8.1 Viewing Cache Statistics

Usage example for cache-level statistics:

```
# casadm -P -i 1
```

Returned output:

```
Cache Id                  1
Cache Size                12055031 [4KiB Blocks] / 45.99 [GiB]
Cache Device              /dev/nvme0n1p1
Core Devices              3
Write Policy              wt
Eviction Policy           lru
Cleaning Policy           alru
Cache line size           4 [KiB]
Metadata Memory Footprint 639.1 [MiB]
Dirty for                 0 [s] / Cache clean

Metadata Mode             normal
Status                    Running
```

Usage statistics	Count	%	Units
Occupancy	12055001	100.0	4KiB blocks
Free	30	0.0	4KiB blocks
Clean	12055001	100.0	4KiB blocks
Dirty	0	0.0	4KiB blocks

Request statistics	Count	%	Units
Read hits	50532296	32.8	Requests
Read partial misses	202850	0.1	Requests
Read full misses	48537517	31.5	Requests
Read total	99272663	64.4	Requests
Write hits	31762847	20.6	Requests
Write partial misses	436	0.0	Requests
Write full misses	16197432	10.5	Requests
Write total	47960715	31.1	Requests
Pass-Through reads	2779876	1.8	Requests
Pass-Through writes	4027209	2.6	Requests
Serviced requests	147233378	95.6	Requests
Total requests	154040463	100.0	Requests

Block statistics	Count	%	Units
Reads from core(s)	471298381	57.4	4KiB blocks
Writes to core(s)	349624858	42.6	4KiB blocks
Total to/from core(s)	820923239	100.0	4KiB blocks
Reads from cache	140451806	16.5	4KiB blocks
Writes to cache	713000302	83.5	4KiB blocks
Total to/from cache	853452108	100.0	4KiB blocks
Reads from exported object(s)	611750187	63.6	4KiB blocks
Writes to exported object(s)	349624858	36.4	4KiB blocks
Total to/from exported object(s)	961375045	100.0	4KiB blocks

Error statistics	Count	%	Units
Cache read errors	0	0.0	Requests
Cache write errors	0	0.0	Requests
Cache total errors	0	0.0	Requests
Core read errors	0	0.0	Requests
Core write errors	0	0.0	Requests
Core total errors	0	0.0	Requests
Total errors	0	0.0	Requests

Usage example for core-level statistics:

```
# casadm -P -i 1 -j 1
```

Returned output:

```
Core Id          1
Core Device      /dev/sdd1
Exported Object /dev/intelcas1-1
Core Size        36620800 [4KiB Blocks] / 139.70 [GiB]
Dirty for        0 [s] / Cache clean
```

Usage statistics	Count	%	Units
Occupancy	4363950	36.2	4KiB blocks
Free	1	0.0	4KiB blocks
Clean	4363950	100.0	4KiB blocks
Dirty	0	0.0	4KiB blocks

Request statistics	Count	%	Units
Read hits	21075939	29.7	Requests
Read partial misses	77109	0.1	Requests
Read full misses	18448305	26.0	Requests
Read total	39601353	55.9	Requests
Write hits	17240919	24.3	Requests
Write partial misses	105	0.0	Requests
Write full misses	9972336	14.1	Requests
Write total	27213360	38.4	Requests
Pass-Through reads	983305	1.4	Requests
Pass-Through writes	3053282	4.3	Requests
Serviced requests	66814713	94.3	Requests
Total requests	70851300	100.0	Requests

Block statistics	Count	%	Units
Reads from core	156393665	57.0	4KiB blocks
Writes to core	118061392	43.0	4KiB blocks
Total to/from core	274455057	100.0	4KiB blocks
Reads from cache	49888641	17.7	4KiB blocks
Writes to cache	231251909	82.3	4KiB blocks
Total to/from cache	281140550	100.0	4KiB blocks
Reads from exported object	206282306	63.6	4KiB blocks
Writes to exported object	118061392	36.4	4KiB blocks
Total to/from exported object	324343698	100.0	4KiB blocks

Error statistics	Count	%	Units
Cache read errors	0	0.0	Requests
Cache write errors	0	0.0	Requests
Cache total errors	0	0.0	Requests
Core read errors	0	0.0	Requests
Core write errors	0	0.0	Requests
Core total errors	0	0.0	Requests
Total errors	0	0.0	Requests

Usage example for IO class-level statistics:

```
# casadm -P -i 1 -j 1 -d
```

Returned output:

```
IO class ID          1
IO class name        Metadata
Eviction priority    0
Selective allocation Yes
```

Usage statistics	Count	%	Units
Occupancy	864660	7.2	4KiB blocks
Free	0	0.0	4KiB blocks
Clean	864660	100.0	4KiB blocks
Dirty	0	0.0	4KiB blocks

Request statistics	Count	%	Units
Read hits	8097835	11.4	Requests
Read partial misses	0	0.0	Requests
Read full misses	17	0.0	Requests
Read total	8097852	11.4	Requests
Write hits	414587	0.6	Requests
Write partial misses	104	0.0	Requests
Write full misses	273056	0.4	Requests
Write total	687747	1.0	Requests
Pass-Through reads	2	0.0	Requests
Pass-Through writes	5517	0.0	Requests
Serviced requests	8785599	12.4	Requests
Total requests	8791118	12.4	Requests

Block statistics	Count	%	Units
Blocks reads	8097854	3.9	4KiB blocks
Blocks writes	9007260	7.6	4KiB blocks

Note: This command will output the above format for each defined IO class.

Usage example for IO class-level statistics output in csv format and saved to file

```
# casadm -P -i 1 -j 1 -d -o csv > stats.txt
```

Returned output:

```
IO class ID,IO class name,Eviction priority,Selective allocation,Occupancy [4KiB
blocks],Occupancy [%],Free [4KiB blocks],Free [%],Clean [4KiB blocks],Clean [%],Dirty [4KiB
blocks],Dirty [%],Read hits [Requests],Read hits [%],Read partial misses [Requests],Read
partial misses [%],Read full misses [Requests],Read full misses [%],Read total
[Requests],Read total [%],Write hits [Requests],Write hits [%],Write partial misses
[Requests],Write partial misses [%],Write full misses [Requests],Write full misses [%],Write
total [Requests],Write total [%],Pass-Through reads [Requests],Pass-Through reads [%],Pass-
Through writes [Requests],Pass-Through writes [%],Serviced requests [Requests],Serviced
requests [%],Total requests [Requests],Total requests [%],Blocks reads [4KiB blocks],Blocks
reads [%],Blocks writes [4KiB blocks],Blocks writes [%]
0,Unclassified,22,Yes,0,0.0,97,100.0,0,0.0,0,0.0,0,0.0,0,0.0,82,0.0,82,0.0,0,0.0,0,0.0,0,0.0,
0,0.0,1,0.0,0,0.0,82,0.0,83,0.0,83,0.0,0,0.0
1,Metadata,0,Yes,864660,7.2,0,0.0,864660,100.0,0,0.0,8068949,11.4,0,0.0,17,0.0,8068966,11.4,4
13037,0.6,104,0.0,273056,0.4,686197,1.0,2,0.0,5517,0.0,8755163,12.4,8760682,12.4,8068968,3.9,
8979669,7.6
```

Note: This command will output the above format for each defined IO class.

Note: Any of the previously referenced examples can be output to csv format as well.

8.2 Resetting the Performance Counters

The performance counters are automatically reset every time the cache is started. To manually clear the performance counters, use the `casadm -Z -i <cache_id> -j <core_id>` command line option.

§

9 Configuration Tool Details

The Intel CAS product includes a user-level configuration tool that provides complete control of the caching software. The commands and parameters available with this tool are detailed in this chapter.

To access help from the CLI, type the *-H* or *--help* parameter for details. You can also view the man page for this product by entering the following command:

```
# man casadm
```

9.1 -S | --start-cache

Usage: `casadm --start-cache --cache-device <DEVICE> [option...]`

Example:

```
# casadm --start-cache --cache-device /dev/sdc
```

or

```
# casadm -S -d /dev/sdc
```

Description: Prepares a block device to be used as device for caching other block devices. Typically the cache devices are SSDs or other NVM block devices or RAM disks. The process starts a framework for device mappings pertaining to a specific cache ID. The cache can be loaded with an old state when using the *-l* or *--load* parameter (previous cache metadata will not be marked as invalid) or with a new state as the default (previous cache metadata will be marked as invalid).

Required Parameters:

[-d, --cache-device <DEVICE>] : Caching device to be used. This is an SSD or any NVM block device or RAM disk shown in the */dev* directory. <device> needs to be the complete path describing the caching device to be used, for example `/dev/sdc`.

Optional Parameters:

***[-i, --cache-id <ID>]*:** Cache ID to create; <1 to 16384>. The ID may be specified or by default the command will use the lowest available number first.

[-l, --load]: Load existing cache metadata from caching device. If the cache device has been used previously and then disabled (like in a reboot) and it is determined that the data in the core device has not changed since the cache device was used, this option will allow continuing the use of the data in the cache device without the need to re-warm the cache with data.

Caution: You must ensure that the last shutdown followed the instructions in Stopping Cache Instances on page 22 of this document. If there was any change in the core data prior to enabling the cache, data would be not synced correctly and will be corrupted.

***[-f, --force]*:** Forces creation of a cache even if a file system exists on the cache device. This is typically used for devices that have been previously utilized as a cache device.

Caution: This will delete the file system and any existing data on the cache device.

[-c, --cache-mode <NAME>]: Sets the cache mode for a cache instance the first time it is started or created. The mode can be one of the following:

wt: (default mode) Turns write-through mode on. When using this parameter, the write-through feature is enabled which allows the acceleration of only read intensive operations.

wb: Turns write-back mode on. When using this parameter, the write-back feature is enabled which allows the acceleration of both read and write intensive operations.

Caution: A failure of the cache device may lead to the loss of data that has not yet been flushed to the core device.

wa: Turns write-around mode on. When using this parameter, the write-around feature is enabled which allows the acceleration of reads only. All write locations that do not already exist in the cache (i.e. the locations have not be read yet or have been evicted), are written directly to the core drive bypassing the cache. If the location being written already exists in cache, then both the cache and the core drive will be updated.

pt: Starts cache in pass-through mode. Caching is effectively disabled in this mode. This allows the user to associate all their desired core devices to be cached prior to actually enabling caching. Once the core devices are associated, the user would dynamically switch to their desired caching mode (see '-Q | --set-cache-mode' on page 41 for details).

[-x, --cache-line-size <SIZE>]: Set cache line size {4 (default), 8, 16, 32, 64}. The cache line size can only be set when starting the cache and cannot be changed after cache is started.

9.2 -T | --stop-cache

Usage: `casadm --stop-cache --cache-id <ID> [option...]`

Example:

```
# casadm --stop-cache --cache-id 1
```
or
```
# casadm -T -i 1
```

Description: Stops all cache-core pairs associated with the cache device.

Required parameters:

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>.

Optional parameters:

[-n, --no-data-flush]: Do not flush dirty data on exit (UNSAFE). This parameter will not allow the flushing of dirty data from the cache device to the core device upon the stopping of the cache. This will significantly reduce the time needed to stop the cache to allow for activities such as a fast reboot. The core device should not be used until the cache is started again with the `--load` parameter. Then the Intel CAS device can be used as normal.

Caution: Data on the core device will not be complete or in sync with the cache device upon stopping the device. If the core device is used without starting Intel CAS cache it will lead to data corruption or data loss.

Note: The user may interrupt the blocking --stop-cache operation by pressing CTRL-C. When dirty data exists, interrupting the operation prior to the cache being fully stopped will result in the cache continuing to run. If the desire is to stop the cache without flushing the dirty data, use the --no-data-flush command.

9.3 -Q | --set-cache-mode

Usage: `casadm --set-cache-mode --cache-mode <NAME> --cache-id <ID> --flush-cache <yes/no>`

Example:

```
# casadm --set-cache-mode --cache-mode wb --cache-id 1 --flush-cache yes
```

or

```
# casadm -Q -c wb -i 1 -f yes
```

Description: Allows users to dynamically change cache modes while the cache is running.

Required Parameters:

[-c, --cache-mode <NAME>]:

- **wt -** switch from the current cache mode to write-through mode.
- **wb -** switch from the current cache mode to write-back mode.
- **wa -** switch from the current cache mode to write-around mode
- **pt -** switch from the current cache mode to pass-through mode.

Note: Dynamically switching to pass-through mode is useful in preventing cache pollution when the system is undergoing maintenance operations, for example.

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>

***[-f, --flush-cache]*: (required only when switching from write-back mode)**

Caution: You should carefully consider the following choices.

- **yes** - Flush cache contents immediately to core drive before switching to new cache mode.

  When choosing *yes* to flush the cache immediately, the operation may take a long time to complete depending on number of dirty blocks. I/O to the device will continue at reduced performance until flush completes.

- **no** - Begin transition to new cache mode immediately, but flush cache contents opportunistically.

  When choosing *no*, I/O to the device will continue at normal performance, but you must be aware that the cache will be in a transition state, and not yet in the newly chosen state until the cache is fully flushed. The transition to the new state will take longer than choosing the *yes* option. Current cache state and flush % can be checked using the casadm -L command.

9.4 -A | --add-core

Usage: `casadm --add-core --cache-id <ID> --core-device <DEVICE> [option...]`

Example:

```
# casadm --add-core --cache-id 1 --core-device /dev/sdb
or
# casadm -A -i 1 -d /dev/sdb
```

Description: Adds/maps a core device (either the full device or a partition) to the framework associated with a specified cache ID. This command can be repeated using the same *cache-id* number to map multiple cores to the same cache device.

Required Parameters:

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>.

***[-d, --core-device <DEVICE>]*:** Location of the HDD storage/core device.
You must use the complete device path in the /dev directory, for example `/dev/sdb`.

Optional Parameters:

[-j, --core-id <ID>]: Unique identifier for core <0 to 4095>.

9.5 -R | --remove-core

Usage: `casadm --remove-core --cache-id <ID> --core-id <ID>`

Example:

```
# casadm --remove-core --cache-id 1 --core-id 1
or
# casadm -R -i 1 -j 1
```

Description: Deletes the cache/core device mapping, which is one way to disable caching of a device.

Required Parameters:

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>

***[-j, --core-id <ID>]*:** Unique identifier for core <0 to 4095>.
You can identify the assigned value for a particular core device using the *casadm -L* command.

Caution: Before using *casadm -R*, stop all I/O to the mapped core device, ensure it is not in use, and unmount it.

Note: You can interrupt the blocking --remove-core operation by pressing CTRL-C. When dirty data exists, interrupting the operation prior to the core being fully removed will result in the core continuing to be cached.

Note: Although legal core ID range starts with 0, Intel CAS engine would resort to assigning core ID value of 0 only if all other core IDs within cache instance are used. In other words the order of core assignment is as follows: 1, 2, 3, ..., 4094, 4095, 0.

Optional parameters:

[-f, --force]: Do not flush dirty data while removing the core device.

9.6 | --remove-detached

Usage: `casadm --remove-detached -d | --device <DEV_NAME>`

Example:

```
# casadm --remove-detached --device /dev/sda
```

Description: Removes a device from the core pool. A device is in the core pool when it's listed in intelcas.conf as a core in a configured cache instance, and this cache instance is not yet started (for example, missing the NVMe drive). This command does not currently have a short form.

Required Parameters:

-d | --device <DEV_NAME>

Where DEV_NAME is a device name from the core pool

9.7 -L | --list-caches

Usage: `casadm --list-caches`

Example:

```
# casadm --list-caches
```
or
```
# casadm -L
```

Description: Displays each cache instance with the following details:

- Flash/SSD cache ID used in the instance
- Storage device used in the instance
- Status of the instance
- Write Policy of the instance (write-through by default)

Also displays the associated core devices with the following details:

- Core Pool label
- Numeric ID and disk name
- Status
- CAS exported device ID
- Placement within the core pool

Example output:

```
type    id   disk                                status      write policy   device
cache   1    /dev/nvme0n1p1                      Incomplete  wt             -
+core   1    /dev/disk/by-id/wwn-0x500....-part1  Inactive    -              /dev/intelcas1-1
+core   2    /dev/sdc1                           Active      -              /dev/intelcas1-2
```

9.8 -P | --stats

Usage: `casadm --stats --cache-id <ID> [option...]`

Example:

```
# casadm --stats --cache-id 1
```
or
```
# casadm -P -i 1
```

Description: Prints performance and status counters for a specific cache instance. Section 8.1 Viewing Cache Statistics shows the detailed output.

Required Parameters:

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>.

Optional Parameters:

[-j, --core-id <ID>]: Unique identifier for core <0 to 4095>. Display statistics for a specific core device.

[-d, --io-class-id <ID>]: Unique identifier for io class <0 to 23>. Display statistics for a specific IO class.

Note: <ID> is optional. When the --io-class-id parameter is specified without specifying an <ID>, statistics will be displayed for each individual IO class.

[-f, --filter <filter-spec>]: Comma separated list of filters (eg. --filter=conf, req). Filter statistics output to only the requested statistics.

- ***all:*** (default mode) Displays all available cache statistics.
- ***conf:*** Displays cache and core configuration information and dirty timestamp.
- ***usage:*** Displays statistics on occupancy, free, clean, and dirty.
- ***req:*** Displays IO request level statistics.
- ***blk:*** Displays block level statistics.
- ***err:*** Displays I/O error statistics.

[-o, --output-format <format>]: Sets desired output format for statistics.

- ***table:*** (default mode) Displays a table of the statistics information.
- ***csv:*** Outputs a comma separated list of statistics information. This output can be piped to a file and easily parsed or opened in a spreadsheet editor.

Example output:

```
# casadm -P -i 1

Cache Id                 1
Cache Size               43708 [4KiB Blocks] / 0.17 [GiB]
Cache Device             /dev/nvme0n1p1
Core Devices             2
Inactive Core Devices    1
Write Policy             wt
Eviction Policy          lru
Cleaning Policy          alru
Cache line size          4 [KiB]
Metadata Memory Footprint 19.6 [MiB]
Dirty for                0 [s] / Cache clean
Metadata Mode            normal
Status                   Incomplete

+==================+=======+=======+=============+
| Usage statistics | Count |   %   |   Units     |
+==================+=======+=======+=============+
| Occupancy        |   164 |   0.4 | 4KiB blocks |
```

Free	43544	99.6	4KiB blocks
Clean	164	100.0	4KiB blocks
Dirty	0	0.0	4KiB blocks

Inactive usage statistics	Count	%	Units
Inactive Occupancy	82	0.2	4KiB blocks
Inactive Clean	82	50.0	4KiB blocks
Inactive Dirty	0	0.0	4KiB blocks

Request statistics	Count	%	Units
Read hits	328	99.7	Requests
Read partial misses	0	0.0	Requests
Read full misses	0	0.0	Requests
Read total	328	99.7	Requests
Write hits	0	0.0	Requests
Write partial misses	0	0.0	Requests
Write full misses	0	0.0	Requests
Write total	0	0.0	Requests
Pass-Through reads	1	0.3	Requests
Pass-Through writes	0	0.0	Requests
Serviced requests	328	99.7	Requests
Total requests	329	100.0	Requests

Block statistics	Count	%	Units
Reads from core(s)	1	100.0	4KiB blocks
Writes to core(s)	0	0.0	4KiB blocks
Total to/from core(s)	1	100.0	4KiB blocks
Reads from cache	82	100.0	4KiB blocks
Writes to cache	0	0.0	4KiB blocks
Total to/from cache	82	100.0	4KiB blocks
Reads from exported object(s)	83	100.0	4KiB blocks
Writes to exported object(s)	0	0.0	4KiB blocks
Total to/from exported object(s)	83	100.0	4KiB blocks

Error statistics	Count	%	Units
Cache read errors	0	0.0	Requests
Cache write errors	0	0.0	Requests
Cache total errors	0	0.0	Requests
Core read errors	0	0.0	Requests
Core write errors	0	0.0	Requests

```
| Core total errors  |     0 | 0.0 | Requests |
+--------------------+-------+-----+----------+
| Total errors       |     0 | 0.0 | Requests |
+====================+=======+=====+==========+
```

9.9 -Z | --reset-counters

Usage: `casadm --reset-counters --cache-id <ID> --core-id <ID>`

Example:

```
# casadm --reset-counters --cache-id 1 --core-id 1
```
or
```
# casadm -Z -i 1 -j 1
```

Description: Resets performance and status counters for a specific cache/core pair.

Required Parameters:

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>.

***[-j, --core-id <ID>]*:** Unique identifier for core <0 to 4095>. You can identify the assigned value for a particular core device using the *casadm -L* command.

9.10 -F | --flush-cache

Usage: `casadm --flush-cache --cache-id <ID>`

Example:

```
# casadm --flush-cache --cache-id 1
```
or
```
# casadm -F -i 1
```

Description: Flushes all dirty data from the cache device to all the associated core devices.

Required Parameters:

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>.

Note: You can interrupt the blocking --flush-cache operation by pressing CTRL-C. When dirty data exists, interrupting the operation prior to the cache being fully flushed will result in some dirty data remaining in the cache. The dirty data will be flushed opportunistically as normal. I/O to the device will continue with reduced performance during cache flushing.

9.11 -E | --flush-core

Usage: `casadm --flush-core --cache-id <ID> --core-id <ID> [option...]`

Example:

```
# casadm --flush-core --cache-id 1 --core-id 2
```
or
```
# casadm -E -i 1 -j 2
```

Description: Flushes all dirty data from the specified cache device to the specified associated core device.

Required parameters:

***[-i, --cache-id <ID>]*:** Unique identifier for cache <1 to 16384>.

***[-j, --core-id <ID>]*:** Unique identifier for core <0 to 4095>.

Note: You can interrupt the blocking --flush-core operation by pressing CTRL-C. When dirty data exists, interrupting the operation prior to the cache being fully flushed will result in some dirty data remaining in the cache. The dirty data will be flushed opportunistically as normal. I/O to the device will continue with reduced performance during cache flushing.

9.12 -D | --flush-parameters

Usage: `casadm --flush-parameters --cache-id <ID> --cleaning-policy-type <NAME> [option...]`

Example:

```
# casadm --flush-parameters --cache-id 1 --cleaning-policy-type alru --wake-up 20 --staleness-time 120 --flush-max-buffers 100 --activity-threshold 10000
```

or

```
# casadm -D -i 1 -c alru -w 20 -s 120 -b 100 -t 10000
```

Description: This command allows the customization of various behaviors for flushing of dirty data.

Caution: A deep understanding of caching concepts must be understood before using this command. A change from the default settings could have a negative effect on caching performance.

Required Parameters:

[-i, --cache-id <ID>]: Unique identifier for cache <1 to 16384>.

[-c, --cleaning-policy-type <NAME>]: This parameter specifies the flushing policy to be utilized for the cache specified. The default is `alru` which is a modified least recently used method that will flush dirty data periodically. The only other option is `nop` which simply disables cache flushing except as needed for cache line replacement.

Optional Parameters:

[-w, --wake-up <NUM>]: This is the wake up period for the flushing thread, in seconds. The default is 20 seconds.

[-s, --staleness-time <NUM>]: The amount of time, in seconds, that must pass after the last write operation before a block in the cache can be scheduled to be flushed. The default is 120 seconds.

[-b, --flush-max-buffers <NUM>]: The maximum number of dirty cache blocks that will be flushed in one flush cycle. The default is 100.

[-t, --activity-threshold <NUM>]: The amount of time, in milliseconds, that has to pass from the last I/O operation before the cleaning thread can start. Default is 10000 ms.

9.13 -H | --help

Usage: `casadm --help` or `casadm --<command> --help`

Examples:

```
# casadm -help
or
# casadm -H

# casadm --start-cache --help
or
# casadm -S -H
```

Description: Displays a list of *casadm* commands along with a brief description. Use this command to also get more information on specific commands.

9.14 -V | --version

Usage: `casadm --version`

Example:

```
# casadm --version
or
# casadm -V
```

Description: Reports the Intel CAS kernel module and command line utility version numbers.

Optional parameters:

[-o, --output-format <format>]: Sets desired output format of the IO class configuration.

table: (default mode) Displays a table of the IO class configuration.

csv: Outputs a comma separated list of the IO class configuration. This output can be piped to a file and easily parsed or opened in a spreadsheet editor.

9.15 -C | --io-class

9.15.1 -C | --load-config

Usage: `casadm --io-class --load-config --cache-id <ID> --file <file_path>`

Example:

```
# casadm --io-class --load-config --cache-id 1 --file /etc/intelcas/ioclass-
config.csv
or
# casadm -C -C -i 1 -f /etc/intelcas/ioclass-config.csv
```

Description: Loads I/O class configuration settings for the selected cache.

Required parameters:

[-i, --cache-id <ID>]: Unique identifier for cache <1 to 16384>.

[-f,--file]: Specifies the IO class configuration csv file to load.

9.15.2 -L | --list

Usage: `casadm --io-class --list --cache-id <ID>`

Example:

```
# casadm --io-class --list --cache-id 1 --file /etc/intelcas/my-config.csv
or
# casadm -C -L -i 1 -f /etc/intelcas/ioclass-config.csv
```

Description: Displays the current IO class configuration settings for the specified cache ID. Optionally exports those settings to a file.

Required parameters:

[-i, --cache-id <ID>]: Unique identifier for cache <1 to 16384>.

Optional parameters:

[-o, --output-format <format>]: Sets desired output format of the IO class configuration.

table: (default mode) Displays a table of the IO class configuration.

csv: Outputs a comma separated list of the IO class configuration. This output can be piped to a file and easily parsed or opened in a spreadsheet editor.

9.16 -N | --nvme

Usage: `casadm --nvme --format <MODE> --device <DEVICE> [options]`

Example:

```
# casadm --nvme --format atomic --device /dev/nvme0n1
Or
# casadm -N -F atomic -d /dev/nvme0n1
```

Description: Formats the SSD to take advantage of Atomic Writes capability of Intel SSDs.

Required parameters:

[-F, --format, <atomic | normal>]: Sets the formatting to “atomic” to use for atomic writes, or normal which does not use this feature.

[-d, --device <DEVICE>] : Caching device to be used. This is an NVMe block device listed in the */dev* directory. <device> needs to be the complete path describing the caching device to be used, for example /dev/sdg. Formating of non-NVMe devices are not supported.

Optional parameters:

[-f, --force]: Forces the SSD format, for example in case device has a file system, outdated Intel CAS metadata or partition table.

§

10 Installer Parameters

The Intel CAS installer and remote installer have several options that can make installation more convenient. The different options are detailed below.

10.1 -al | --accept-license

It is required to accept the user license prior to installing Intel CAS. This option is for the automatic acceptance of the license which requires no further interaction to complete installation. This option can be useful for scripting the installation of Intel CAS.

By using this flag you state that you have read and accept the license!

10.2 -am | --accept-unsupported-module

Auto-accepts setting the allow_unsupported_modules flag.

This parameter updates the "unsupported module flag" in `etc/modprobe.d/unsupported-modules` on SLES 11 and newer environments. Once the flag is set, it will remain so and will apply to any other modules. Having this flag set to 1 is critical for starting Intel CAS in the SLES 11 environment.

This option has no affect if installing on non-SLES 11 systems.

By using this flag you state that you accept setting this flag by the installation script.

10.3 -ad | --accept-dkms

This flag indicates that the administrator has installed DKMS and would like Intel CAS software installed with DKMS support. This enables the automatic rebuild of the Intel CAS kernel module upon the each OS kernel version update.

10.4 -rd | --reject-dkms

This flag indicates that the administrator wants Intel CAS software installed without DKMS support.

NOTE: If this flag is specified, the administrator will be required to manually re-install Intel CAS after any OS kernel version update.

10.5 -as | --auto-start

This option will force automatic Intel CAS service startup once installation has completed if Intel CAS configuration files are found.

Caution: By running with this option Intel CAS might overwrite hard drives which are mentioned as caching devices in the config file.

10.6 -d | --display-license

This option displays the end-user license agreement without launching the installer.

10.7 -p | --purge

Uninstalls Intel CAS and removes all the configuration files stored in */etc/intelcas*. This would be used for the complete removal of Intel CAS.

10.8 -f | --force

Setting this flag will ignore all system checks for Intel CAS installation. This will include the -am flag setting as well.

10.9 -h | --help

This option displays a listing of the installer options along with a short description.

10.10 -l | --list

This option displays list of files installed by the package. It is useful in ensuring that all the files in the package are installed properly.

10.11 -t | --try-run

Setting this flag will only run and report the system checks performed during a normal installation.

10.12 -r | --reinstall

Perform an in-flight upgrade to a new version of Intel CAS (or in-flight reinstall of the existing version) without stopping I/O to cached devices.

10.13 -u | --uninstall

Uninstalls files for Intel CAS, but retains configuration for future use. Typically used when uninstalling an old version of Intel CAS to install a newer version.

§

11 Remote Installer Parameters

The Intel CAS remote installer has several options that can make installation more convenient. The different options are detailed below.

11.1 -al | --accept-license

It is required to accept the user license prior to installing Intel CAS. This option is for the automatic acceptance of the license which requires no further interaction to complete installation. This option can be useful for scripting the installation of Intel CAS.

By using this flag you state that you have read and accept the license.

11.2 -am | --accept-unsupported-module

Auto-accepts setting the allow_unsupported_modules flag.

This parameter updates the "unsupported module flag" in `etc/modprobe.d/unsupported-modules` on SLES 11 and newer environments. Once the flag is set, it will remain so and will apply to any other modules. Having this flag set to 1 is critical for starting Intel CAS in the SLES 11 environment.

This option has no affect if installing on non-SLES 11 systems.

By using this flag you state that you accept that the installer will set this flag on all remote systems to which you are installing Intel CAS.

11.3 -ad | --accept-dkms

This flag indicates that the administrator has installed DKMS and would like Intel CAS software installed with DKMS support. This enables the automatic rebuild of the Intel CAS kernel module upon the each OS kernel version update.

11.4 -rd | --reject-dkms

This flag indicates that the administrator wants Intel CAS software installed without DKMS support.

Note: If this flag is specified, the administrator will be required to manually re-install Intel CAS after any OS kernel version update.

11.5 -as | --auto-start

This option will force automatic Intel CAS service startup once installation has completed if Intel CAS configuration files are found.

Caution: By running with this option Intel CAS will automatically overwrite any data on devices which are selected as cache devices in the config file.

11.6 -d | --display-license

This option displays the end-user license agreement without launching the installer.

11.7 -f | --force

Setting this flag will ignore all system checks for Intel CAS installation. This will include the -am flag setting as well.

11.8 -h | --help

This option displays a listing of the installer options along with a short description of each.

11.9 -r | --reinstall

Perform an in-flight upgrade to a new version of Intel CAS (or in-flight reinstall of the existing version) without stopping I/O to cached devices.

11.10 -u | --uninstall

Uninstalls files for Intel CAS, but retains configuration for future use. Typically used when uninstalling an old version of Intel CAS to install a newer version.

11.11 -1 | --one-machine

Performs remote installation on a single machine.

11.12 -c | --use-config

Specifies the path to the remote installer config file.

11.13 -s | --setup

Specifies the path to a single Intel CAS config file to be uploaded to remote machine

11.14 -S | --use-sudo

Allows non-root user to run installer and performs remote tasks using sudo.

Note: This method is not recommended. The preferred method is to run the remote installer as root user.

Note: When installing on RHEL 7.x or CentOS 7.x, you must remove the following directive from the sudoers file in order for --use-sudo to work: `Defaults requiretty`.

§

12 Advanced Installation Methods

12.1 Remote Installation

This step is an alternative to the installation method described in Local Server Installation on page 12; however, the same assumptions apply as the ones described in notes at the beginning of that section.

Note: The use of the expect utility and passwordless ssh pose security threats and therefore this functionality will be removed in future releases of CAS. This is due to the fact that the root password needs to be stored in the remote installer script and passed to the expect utility. This method could potentially expose the root password to other users on a server. In addition the root password is also sent over the network and could be prone to network attacks.

To execute a remote installation, you must define two separate entities:

- *Installation server* (or system) - machine (or virtual machine) on which the installation utilities are launched.
- *Installation clients* (or target systems) - machines on which Intel CAS is to be installed and/or configured.

The remote installation scripts can be executed as follows:

1. With passwordless *ssh* logins on all of the installation clients on which you are installing Intel CAS.

   In this case, the user will not be prompted for the root password during installation. To mitigate this security risk, using *ssh-keygen* to make a secured key pairing (with public and private keys) between both the installation server and each installation client is highly recommended. Details of how to implement *ssh-keygen* is beyond the scope of this document (this information is freely available on the internet), however a short generic example of how to generate and distribute *ssh* keys generated by this method is provided in Appendix B. *This is the recommended remote installation method.*

   Note: If using ssh-keygen method of installation, before the remote installation starts, ensure that you can *ssh* from the installation server/system to all the installation clients as root without being prompted for a password.

2. Without passwordless *ssh* logins, but with the *expect* utility program installed on the installation server.

   In this case the Intel CAS remote installer will prompt the user for the root password once per installation client.

3. Without passwordless *ssh* logins and without the *expect* utility program installed.

   In this case, the Intel CAS remote installer will prompt the user for the root password each time an activity is performed on an installation client (approximately 4 times per installation client machine).

To begin remote installation:

1. Download or copy the Intel CAS remote installer file to your home directory on the target Linux server or VM guest.

   The installation instructions use the example of `~` (equivalent of `$HOME`) on the server file system. The installer file name is in the format: `installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run` where *XX.XX.XX.XXXXXXXX* is the version information.

2. Make the installer file executable:

   ```
   # chmod u+x ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run
   ```

There are two options available for remote installation:

- Install to a single remote machine.
- Install to multiple remote machines.

Note: For more information about the remote installer, you can access help by typing:

```
# ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run --help
```

12.1.1 Installation to a Single Remote Machine

To install Intel CAS on one remote host, do the following:

1. Type the following:

   ```
   # ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run
    --one-machine <IP ADDRESS>
   ```

2. Read and accept the end-user license agreement (EULA) to proceed with the installation.
3. To confirm that remote installation was successful, *ssh* to the remote machine and at the Intel CAS shell, type the following:

   ```
   # casadm -H
   ```

   If the help command is successful and you are able see the help listing, your remote installation of Intel CAS has been successful. Additionally, you will find an installation log file in the same directory as the install after the installation is complete.

12.1.2 Batch Installation to Multiple Remote Machines

Installing to multiple remote machines requires an `installation_setup_file` (see Using Custom Setup Files (Advanced Config) for detailed information on setup and config file formats and syntax).

1. After your `installation_setup_file` is ready, type the following command to start the batch remote installation process:

   ```
   # ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run
    --use-config installation_setup_file
   ```

   Note: If a current or earlier version of Intel CAS already exists on a remote host, the installer will automatically detect that and skip to the next system.

   Note: Paths to the config files cannot be relative; you must specify an absolute path.

2. Read and accept the end-user license agreement (EULA) to proceed with the installation.
3. Confirm that remote batch installation was successful.

   ssh to each of the remote machines and at the Linux shell, type the following:

   ```
   # casadm -H
   ```

   If the help command is successful and you are able see the help listing, your remote installation of Intel CAS has been successful. Additionally, you will find an installation log file in the same directory as the install after the installation is complete.

12.1.3 Remote Uninstallation

To uninstall the software remotely, do the prerequisites steps described in Section 3.6 Uninstalling the Software, then do the following:

To uninstall from a *single* remote host, type the following:

```
# ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run
--uninstall --one-machine <IP ADDRESS>
```

To batch uninstall from *multiple* remote hosts, type the following:

```
# ./installer-remote-Intel-CAS-XX.XX.XX.XXXXXXXX.run
--uninstall --use-config installation_setup_file
```

Note: The *installation_setup_file* mentioned in the batch uninstall is the same file used to install the software.

§

13 Intel® CAS QEMU*

13.1 Introduction

QEMU* is an open source hypervisor used for hardware virtualization and can be used with KVM* to run virtual machines at near-native speeds. However, client virtual machines require access to the storage on the servers, which relies on server performance as well as a robust network infrastructure. To speed up application and user response times, Intel CAS QEMU can provide improved I/O performance on the client virtual machines, which could also reduce network traffic. This section describes Intel CAS QEMU functionality and usage.

13.2 Supported Operating System

Table 12 Supported Platforms

Operating System	Kernel	QEMU
CentOS* 7.2	x86_64, Kernel 3.10.0-327	QEMU 2.1.2
Other distros - Intel CAS will install and compile from source on other distros and other kernels, but the user may be required to reproduce any issues on a validated distro & kernel to receive support.	Other kernels	

13.3 Intel® CAS QEMU* Installation

To install Intel CAS QEMU*, you must first install the QEMU sources and all dependencies needed to build and run QEMU. Then install the Intel CAS QEMU patch. The following example shows the proper steps.

1. Install the QEMU dependencies:

   ```
   # yum install cyrus-sasl-devel libpng-devel glib2-devel pixman-devel texinfo
   libcap-devel libattr-devel
   ```

2. Download QEMU 2.1.2 sources from http://download.qemu-project.org/qemu-2.1.2.tar.xz

3. Unpack sources in a directory.

   ```
   # tar xvf qemu-2.1.2.tar.xz
   # cd qemu-2.1.2
   ```

4. Apply the Intel CAS QEMU patch to the source directory.

   Note: In the following example, the Intel CAS QEMU patch is located in /tmp

   ```
   # patch -p1 < /tmp/Intel-CAS-QEMU-03.05.00.03244400.patch
   ```

5. Configure, build and install QEMU (configure switches may vary, depending on your needs). QEMU will be installed under /usr/local directory. You can adjust target directory to your needs in configure -prefix switch.

```
# ./configure --target-list=x86_64-softmmu --disable-qom-cast-debug --
disable-werror --disable-xen --disable-virtfs --enable-kvm --disable-fdt --
disable-sdl --disable-debug-tcg --disable-sparse --disable-brlapi --disable-
bluez --disable-vde --disable-curses --enable-vnc-sasl --disable-spice --
enable-vnc-png --disable-vnc-jpeg --enable-uuid --disable-vhost-scsi --
enable-guest-agent --enable-virtfs --prefix=/usr/local --enable-linux-aio --
enable-modules --enable-vnc --disable-smartcard-nss --extra-cflags="-fPIC -
Wformat -Wformat-security" --extra-ldflags="-z noexecstack -z relro -z now"
--enable-pie --disable-debug --disable-debug-info --enable-stack-protector -
-disable-curl --enable-virtio-blk-data-plane

# make

# make install
```

13.4 Configuring and Starting Intel® CAS QEMU*

This section includes instructions on how to start and configure Intel CAS QEMU after the installation. The following example shows the command that will pair the core devices (HDDs) with cache devices (NVMe) and start the caching.

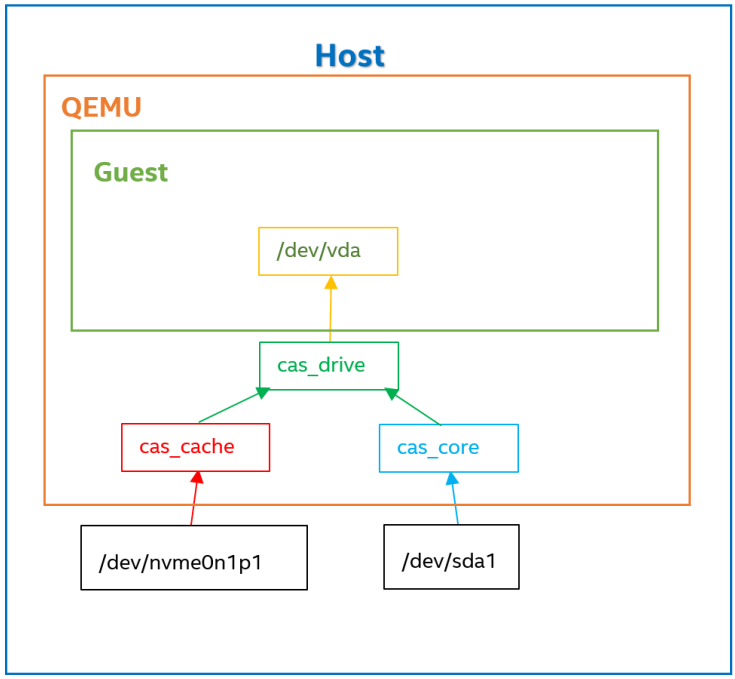
In this example, the core device is /dev/nvme0n1p1 (cas_cache) and the core device is /dev/sda1 (cas_core). The guest OS uses /dev/vda that is being cached by Intel CAS QEMU. The NVMe SSD (/dev/nvme0n1) device has been partitioned into one large partition p1. The HDD (/dev/sda) has also been partitioned to one large partition /dev/sda1 encompassing the whole drive capacity.

In this example, the default cache line size of 4KiB is used in write-through caching mode. However, all other cache line sizes listed in this document can also be used upon cache startup. The example shows the additional options required to add to your normal QEMU startup command.

```
# qemu-system-x86_64 (……)

-drive file=/dev/nvme0n1p1,format=raw,cache=none,if=none,id=cas_cache,aio=threads \
-drive file=/dev/sda1,format=raw,cache=none,if=none,id=cas_core,aio=threads \
-drive format=intelcas,cache-drv=cas_cache,core-drv=cas_core,cache-mode=wt,cache-
line-size=4,cache=none,if=none,id=cas_drive,aio=threads \
-device=virtio-blk,drive=cas_drive,scsi=off,config-wce=off
```

Figure 2: Intel CAS in QEMU Architecture




```
-device virtio-blk,drive=cas_drive,scsi=off,\
config-wce=off
```

```
-drive format=intelcas,cache-drv=cas_cache,core-
drv=cas_core,cache-mode=wt,cache-line-size=4\
cache=none,if=none,id=cas_drive,aio=threads
```

```
 -drive
 file=/dev/sda1,format=raw,cache=none\
 ,if=none,id=cas_core,aio=threads
```

```
-drive
file=/dev/nvmeon1p1,format=raw,cache=one\
,if=none,id=cas_cache,aio=threads
```

13.4.1 Enabling the TRIM Command

If you want the virtual Intel CAS device (/dev/vda) to be capable of TRIM, you must replace this line:

```
-device virtio-blk,drive=cas_drive,scsi=off,config-wce=off
```

with this line:

```
-device virtio-scsi-pci -device scsi-hd,drive=cas_drive
```

For example:

```
# qemu-system-x86_64 (…..)
-drive file=/dev/nvme0n1p1,format=raw,cache=none,if=none,id=cas_cache,aio=threads \
-drive file=/dev/sda1,format=raw,cache=none,if=none,id=cas_core,aio=threads \
-drive format=intelcas,cache-drv=cas_cache,core-drv=cas_core,cache-mode=wt,cache-
line-size=4,cache=none,if=none,id=cas_drive,aio=threads \
-device virtio-scsi-pci -device scsi-hd,drive=cas_drive
```

When the cache volume drive receives TRIM request, Intel CAS will invalidate mapped cache lines corresponding to the LBA range of TRIM request.

13.5 Configuration Guidelines

You should consider several factors when configuring Intel CAS QEMU in a virtual environment with many virtual machines (VMs), as some configurations are not allowed due to how QEMU operates. The following configuration guidelines should be utilized:

Configurations must adhere to the following limitations:

1. There must be a one-to-one relationship between a core device/partition and a cache device/partition.
2. A particular core device/partition, cache device/partition, or Intel CAS device may only be assigned to a single VM.

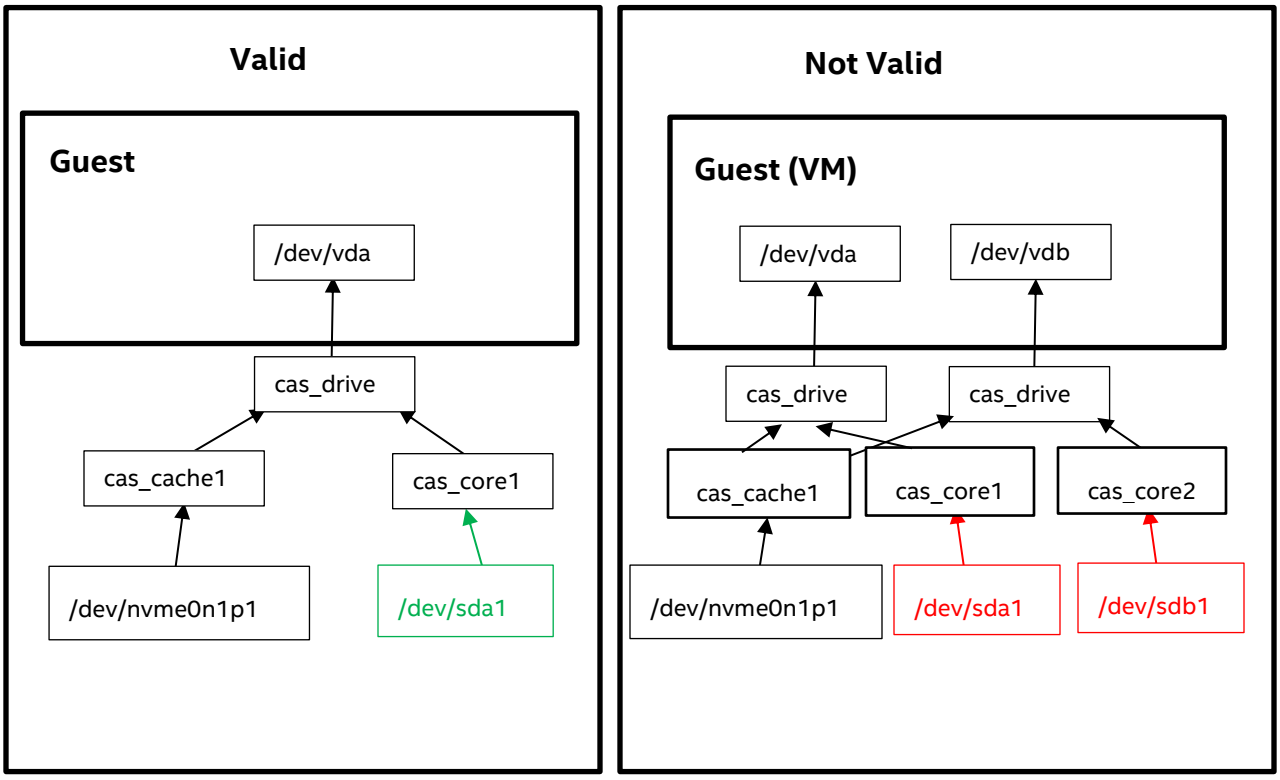
Therefore, the following configurations are NOT valid:

1. Two or more core devices/partitions (HDDs) using the same cache device/partition (SSD).
2. The same core device/partition cannot be assigned to two different caches.
3. The same core device/partition cannot be used across multiple VMs (guest OSs).
4. The same cache device/partition cannot be used across multiple VMs (guest OSs).
5. The same Intel CAS device (cache-core pairing) cannot be used across multiple VMs.

Examples:

1. One cache partition can only be used by one core device regardless of number of VMs (guest OSs).

Figure 3: Example of proper pairing of one cache drive/partition with one core/partition



2. To cache multiple core devices/partitions (HDDs) to the same caching SSD, you must create a separate cache partition on the SSD for each core device.

As an example in the following table, if you have four core devices/partitions and one SSD, you will create four partitions on the SSD, one for each core device/partition that you'll be caching.

Table 13: Example Pairing of Guest (VM) Cache and Core Devices

VM	Cache Device	Core Device
vm1	cache1	core1
vm1	cache2	core2
vm1	cache3	core3
vm1	cache4	core4

NOTE: If caching a single core device/partition to a single cache device, you do not need to create a partition on the SSD and Intel CAS will utilize the full capacity of the SSD for caching.

3. Each VM (guest OS) has a dedicated Intel CAS device (cas_drive) as depicted in the earlier figure. This Intel CAS device is presented to the VM (guest OS) as a virtio-blk drive (e.g. /dev/vda), and is the pairing of the core and cache devices designated in the QEMU startup command. In other words, the same HDD partition (and its associated Intel CAS device) cannot be shared amongst multiple VMs. Each VM will require its own unique HDD partitions and caching instance.

   NOTE: If a given core or cache device/partition is already in use by a cache volume, Intel CAS will return an error if you try to start Intel CAS QEMU caching on that device/partition.

13.6 Administration of Intel® CAS QEMU*

Intel CAS QEMU uses QMP command set to provide cache statistics or to allow changing of the caching mode. In order to use QMP commands you need to first connect via a telnet session to the appropriate channel on the host. Once a telnet session is established the QMP commands can be executed.

There are two caching modes available in Intel CAS QEMU, write-through (WT) and pass-through (PT). The PT mode will stop caching I/O as described earlier in this document. To change from WT to PT mode, for example, follow the procedure below:

1. Start QMP with QMP channel. The example below starts QMP on TCP/IP port 4444.

   ```
   # qemu-system-x86_64 -chardev
   socket,id=qmp,port=4444,host=localhost,server,nowait-
   mon,chardev=qmp,mode=control,pretty=on
   ```

2. Telnet to the QMP port.

   ```
   # telnet localhost 4444
   ```

3. Next you must initialize the QMP session. To initialize the session execute the following command:

   ```
   { "execute": "qmp_capabilities" }
   ```

4. Execute the QMP command to change Intel CAS mode to PT for cache instance 1.

```
{"execute": "intelcas-set-cache-mode", "arguments": { "cache-id": 1, "cache-
mode": "pt" } }
```

   Expected output:

```
{"return": { }}
```

5. To Display caching statistics through QMP follow the example below. Also note that Intel CAS provides cache statistics and does not expose user data as part of the statistics or the QEMU logs.

```
{"execute": "intelcas-query-stats", "arguments": {"cache-id": 1}}
```

   Expected output:


```
{"return": {"Eviction-policy": "lru","Cache-line-size": {"Value":
409,"Unit": "B"},"Dirty-for": {"Value": 0,"Unit": "Seconds"}, "Error":
{"Cache": {"Write": {"Value": 0,"Percentage": 0 }, "Total": { "Value": 0,
"Percentage": 0},"Read": {"Value": 0, "Percentage": 0} },"Total":
{"Value": 0,"Percentage": 0},"Core": {"Write": {"Value": 0,"Percentage":
0}, "Total": {"Value": 0, "Percentage": 0},"Read": {"Value":
0,"Percentage": 0}},"Unit": "Requests"},"Usage": {"Occupancy": {"Value":
259,"Percentage": 0},"Free": {"Value": 5242365,"Percentage":
100},"Clean": {"Value": 259, "Percentage": 100},"Unit": "4KiB
blocks","Dirty": {"Value": 0,"Percentage": 0}},"Core-device": "core-
virtio", "Cleaning-policy": "alru","Metadata-mode": "normal","Cache-
device": "cache-virtio","Block": {"Exp-dev": {"Write": {"Value":
0,"Percentage": 0},"Total": {"Value": 799,"Percentage": 100}, "Read": {
"Value": 799,"Percentage": 100}},"Cache": {"Write": {"Value":
260,"Percentage": 32},"Total": {"Value": 799,"Percentage": 100},"Read":
{"Value": 539,"Percentage": 68}},"Core": {"Write": {"Value":
0,"Percentage": 0},"Total": {"Value": 260,"Percentage": 100},"Read":
{"Value": 260,"Percentage": 100}},"Unit": "4KiB blocks"},"Cache-id":
1,"Metadata-memory-footprint": {"Value": 318483488,"Unit": "B"},"Status":
"Running","Request": {"Write": {"Total": {"Value": 0,"Percentage":
0},"Hits": {"Value": 0,"Percentage": 0},"Full-miss": {"Value":
0,"Percentage": 0},"Partial-miss": {"Value": 0,"Percentage": 0}},"Total":
{"Value": 151,"Percentage": 100},"Unit": "Requests","Pass-through":
{"Write": {"Value": 0,"Percentage": 0},"Serviced": {"Value": 151,
"Percentage": 100},"Read": {"Value": 0,"Percentage": 0}},"Read":
{"Total": {"Value": 151,"Percentage": 100},"Hits": {"Value":
107,"Percentage": 70},"Full-miss": {"Value": 44,"Percentage":
30},"Partial-miss": {"Value": 0,"Percentage": 0}}},"Write-policy":
"pt","Size": {"Value": 21473787904,"Unit": "B"}}}
```


6. To reset statistics execute the following command:

```
{"execute": "intelcas-reset-stats-counters", "arguments": {"cache-id": 1 } }
```

   Expected output:

```
{"return": { }}
```

For further information on QEMU or QMP, refer to the appropriate documentation:

http://download.qemu-project.org/qemu-doc.html

http://wiki.qemu-project.org/Documentation/QMP

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14 Intel® CAS on Ceph*

This section describes some of the most commonly used tasks for utilizing Intel CAS in a Ceph* environment. Note that this is an example and your environment, including software version and hardware configuration, may require a different approach. Please contact Intel Support for further details and assistance.

14.1 Installing Intel® CAS in a Ceph* Cluster

Intel CAS can be used to improve the performance of Ceph storage by deploying it on the Ceph storage nodes (OSD nodes). To utilize Intel CAS, you must first deactivate the Ceph OSDs, install and configure Intel CAS, then reactivate the Intel CAS-enabled OSD devices.

This procedure must be performed on **all** storage (OSD) nodes in the Ceph cluster. The example in this document was performed on Jewel version of Ceph. This is an example only and you may need to modify it for your specific environment and devices.

14.1.1 Stopping OSDs on Each Ceph* Storage Node

Prior to stopping all the OSDs, configure the cluster so Ceph does not rebalance in order to install Intel CAS with minimal impact to the cluster.

```
# ceph osd set noout
# ceph osd set norebalance
# systemctl stop ceph-osd@*
```

14.1.2 Unmounting OSD Drives on Each Ceph* Storage Node

In this example, each Ceph storage node has 24 HDDs and two Intel NVMe SSDs. Ceph was configured so that the journals for 12 of the hard drives (HDDs) were on NVMe1 (nvme0n1) and the journals for the second set of 12 HDD drives were on NVMe2 (nvme1n1). For example, the journals for /dev/sda1, /dev/sdb1, ..., /dev/sdl1 were placed on nvme0n1, and the journals for /dev/sdm1, /dev/sdn1, .../dev/sdx1 were on nvme1n1.

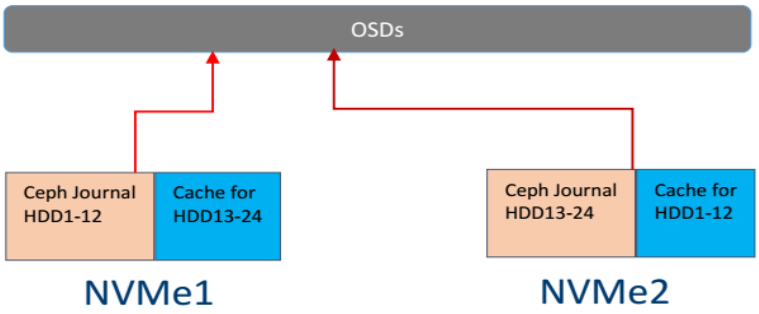
When we add Intel CAS, we will also spread the caching among the two Intel NVMe SSDs, placing the cache partitions for the first set of 12 HDDs on the second NVMe2 (nvme1n1), and the second set of HDDs on the first NVMe1 (nvme0n1), reverse of the journal placements.

We call this method interleaving journals and cache, providing potentially further performance improvements. However this is not mandatory and your environment may be different.

```
# umount /dev/sda1 /dev/sdb1 /dev/sdc1 /dev/sdd1 /dev/sde1 /dev/sdf1 /dev/sdg1
/dev/sdh1 /dev/sdi1 /dev/sdj1 /dev/sdk1 /dev/sdl1 /dev/sdm1 /dev/sdn1 /dev/sdo1
/dev/sdp1 /dev/sdq1 /dev/sdr1 /dev/sds1 /dev/sdt1 /dev/sdu1 /dev/sdv1 /dev/sdw1
/dev/sdx1
```

The following figure shows an example interleave configuration.

Figure 4: Interleave Configuration Example



14.1.3 Installing Intel CAS on Each Ceph Storage Node

This example shows a generic version of Intel CAS (-xxxx.xxxx), where xxxx.xxxx is the appropriate version number.

```
# ./installer-Intel-CAS-xxxx.xxxx
```

14.1.4 Replacing a bad Hard Disk Drive (HDD)

If a HDD no longer enumerates within the OS or cluster, the HDD or core device is in an inactive state. If a reboot affecting that HDD occurs, the cache associated with the inactive core is in an incomplete state. This will be visible in the casadm -L command output. To replace this drive with a different HDD, the user should perform the following operations:

1. Remove bad device from cache instance: casadm -R -i X -j Y -n
2. Remove bad HDD physically from the system and replace with new
3. Add the new drive as a core in place of the old one: casadm -A -i X -j Y -d /dev/disk/by-id/NEW_DEV_ID
4. Update intelcas.conf file - replace old drive WWN ID with new WWN ID

14.1.5 Start Caching and Pairing all HDDs with SSD (NVMe) Drives

Note: This assumes that Intel CAS has already been installed and NVMe/SSD are partitioned properly.

The following commands will start Intel CAS in WT (write-through which is the default caching mode) using caching partition p13 and p14 on nvme0n1 and p13 and p14 on nvme1n1, respectively. A total of four caching instances are created.

The following commands start all the cache instances:

```
# casadm -S -i 1 -c wt -d /dev/nvme0n1p13
# casadm -S -i 2 -c wt -d /dev/nvme0n1p14
# casadm -S -i 3 -c wt -d /dev/nvme1n1p13
# casadm -S -i 4 -c wt -d /dev/nvme1n1p14
```

The following commands will pair the HDDs and the SSDs by assigning them to the caching partitions:

```
# casadm -A -i 3 -d /dev/sda1
# casadm -A -i 3 -d /dev/sdb1
# casadm -A -i 3 -d /dev/sdc1
# casadm -A -i 3 -d /dev/sdd1
# casadm -A -i 3 -d /dev/sde1
```

```
# casadm -A -i 3 -d /dev/sdf1
#
# casadm -A -i 4 -d /dev/sdg1
# casadm -A -i 4 -d /dev/sdh1
# casadm -A -i 4 -d /dev/sdi1
# casadm -A -i 4 -d /dev/sdj1
# casadm -A -i 4 -d /dev/sdk1
# casadm -A -i 4 -d /dev/sdl1
#
# casadm -A -i 1 -d /dev/sdm1
# casadm -A -i 1 -d /dev/sdn1
# casadm -A -i 1 -d /dev/sdo1
# casadm -A -i 1 -d /dev/sdp1
# casadm -A -i 1 -d /dev/sdq1
# casadm -A -i 1 -d /dev/sdr1
#
# casadm -A -i 2 -d /dev/sds1
# casadm -A -i 2 -d /dev/sdt1
# casadm -A -i 2 -d /dev/sdu1
# casadm -A -i 2 -d /dev/sdv1
# casadm -A -i 2 -d /dev/sdw1
# casadm -A -i 2 -d /dev/sdx1
```

Verify that caching is configured properly:

```
# casadm -L
```

14.1.6 Manual Mount and Activation of OSDs on Ceph Storage Nodes

The preferred methods for installing Ceph are automation tools such as Ansible (Red Hat and derivatives) or Salt (SUSE). If the administrator needs to test manual mounting/activation of OSD drives, the commands below may be of assistance and are for reference only with older Ceph versions. Newer versions of Ceph, e.g., Luminous and later, no longer use the ceph-deploy command.

After Intel CAS has been activated and caching configured on the Ceph storage nodes, new Intel CAS devices, such as intelcas-x-x, will represent the new devices used by Ceph. These Intel CAS-enabled devices must be mounted and activated so Ceph storage nodes can utilized them.

In the example below we are executing our commands on a storage node called ceph-node1. The Intel CAS devices, such as intelcas1-1, are being used in place of the HDD devices. In addition the Ceph journals have also been configured as separate partitions on the SSDs (NVMe).

```
# ceph-deploy osd activate ceph-node1:intelcas1-1:nvme1n1p1
# ceph-deploy osd activate ceph-node1:intelcas1-2:nvme1n1p2
# ceph-deploy osd activate ceph-node1:intelcas1-3:nvme1n1p3
# ceph-deploy osd activate ceph-node1:intelcas1-4:nvme1n1p4
# ceph-deploy osd activate ceph-node1:intelcas1-5:nvme1n1p5
# ceph-deploy osd activate ceph-node1:intelcas1-6:nvme1n1p6
#
# ceph-deploy osd activate ceph-node1:intelcas2-1:nvme1n1p7
# ceph-deploy osd activate ceph-node1:intelcas2-2:nvme1n1p8
# ceph-deploy osd activate ceph-node1:intelcas2-3:nvme1n1p9
# ceph-deploy osd activate ceph-node1:intelcas2-4:nvme1n1p10
# ceph-deploy osd activate ceph-node1:intelcas2-5:nvme1n1p11
# ceph-deploy osd activate ceph-node1:intelcas2-6:nvme1n1p12
#
# ceph-deploy osd activate ceph-node1:intelcas3-1:nvme0n1p1
# ceph-deploy osd activate ceph-node1:intelcas3-2:nvme0n1p2
# ceph-deploy osd activate ceph-node1:intelcas3-3:nvme0n1p3
# ceph-deploy osd activate ceph-node1:intelcas3-4:nvme0n1p4
```

```
# ceph-deploy osd activate ceph-node1:intelcas3-5:nvme0n1p5
# ceph-deploy osd activate ceph-node1:intelcas3-6:nvme0n1p6
#
# ceph-deploy osd activate ceph-node1:intelcas4-1:nvme0n1p7
# ceph-deploy osd activate ceph-node1:intelcas4-2:nvme0n1p8
# ceph-deploy osd activate ceph-node1:intelcas4-3:nvme0n1p9
# ceph-deploy osd activate ceph-node1:intelcas4-4:nvme0n1p10
# ceph-deploy osd activate ceph-node1:intelcas4-5:nvme0n1p11
# ceph-deploy osd activate ceph-node1:intelcas4-6:nvme0n1p12
```

14.1.7 Verifying Ceph OSDs and cluster health

After activating the newly CAS-enabled OSD devices, reset the cluster parameters you changed earlier and verify the health of the Ceph cluster:

```
# ceph osd unset noout
# ceph osd unset norebalance
# ceph -s
# ceph osd tree
```

14.2 Intel® CAS Startup and Shutdown in Ceph*

Prior to Intel CAS 3.5, Ceph services started up before caching, and the startup and shutdown process had to be modified for restart/reboot of Ceph storage nodes to properly work. In Intel CAS 3.5, we improved integration with Ceph to provide a more robust solution. To take advantage of this new method, you must configure Intel CAS on each Ceph storage node (OSD Node).

Ensure that the /etc/intelcas/intelcas.conf file includes the path to the core (HDD) devices and not to a partition on the device. Otherwise, Ceph OSD devices will not properly start. In other words, the correct procedure is to pair the complete core drive with the caching instance.

We recommend using the unique /dev/disk/by-id/wwn (World Wide Name) path to the core (HDD) devices to ensure that the appropriate raw disk drive is used, and that the cluster will not undergo any disk name or disk order changes following startup or reboot. The /dev/disk/by-id path is also recommended for the cache device(s). NVMe drives do not show a WWN in this path, so Model/Serial Number is normally used.

In order to have intelcas devices start correctly following a reboot, the user may perform one of the following:

1. Manually pair the cache and core devices using casadm -S and casadm -A commands. Pairing is the action performed to specify that the HDD (or other core device) is added to the cache for performance acceleration. See Section 9.1.
2. Configure the cache(s) and cores pairing in the intelcas.conf file.

The following example shows correct syntax of the intelcas.conf file for cache and core devices.

Example of the /etc/intelcas/intelcas.conf file:

```
# Caches configuration section
[caches]
# Cache ID  Cache device       Load    Cache mode    Extra fields (optional)
1 /dev/disk/by-id/nvme-INTEL_SSDPEDMD... no WT ioclass_file=ioclass_config.csv
#
# Core devices configuration
[cores]
# Cache ID      Core device                          Extra fields (optional)
1               /dev/disk/by-id/wwn-0x50014ee0aebd2b4b
1               /dev/disk/by-id/wwn-0x50014ee65b4d9f35
1               /dev/disk/by-id/wwn-0x50014ee605f96091
```

Note: Contact Intel support if you require further details on startup/shutdown procedures for previous releases of Intel CAS in a Ceph environment.

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15 Intel® CAS on SUSE*

The Intel CAS software is available through the SUSE* Solid Driver Program. This version is the open source version of Intel CAS and may not include all the latest features available in the Enterprise version of CAS. This section describes information regarding the Intel CAS RPM packages and functionalities that may differ from the Enterprise version.

15.1 Installing Intel® CAS on SUSE*

To install Intel CAS RPM package from the SUSE Solid Driver you can utilize SUSE management tools such as YAST to install CAS add-on using the SUSE repo listed below:

https://drivers.suse.com/intel/Intel-CAS/sle-12-sp2-x86_64/1.0/install

Please review the install-readme.html file in the repo for detailed installation instructions:

https://drivers.suse.com/intel/Intel-CAS/sle-12-sp2-x86_64/1.0/install-readme.html

The Intel CAS RPM package consists of an RPM installation file with a naming convention of 'Intel-CAS-kmp-default-<kernel_version>-<release-version>.x86_64.rpm', Intel CAS Release Notes, and this Administration Guide, which will be installed in /usr/share/doc/packages/Intel-CAS-kmp-default. Documentation is also available online in doc subdirectory:

https://drivers.suse.com/intel/Intel-CAS/sle-12-sp2-x86_64/1.0/doc/

Please note that the installation process follows the already established SUSE SLES installation procedures and tools as outlined in the install-readme.html file and differs from the Intel CAS Enterprise installer described in this document.

15.2 Post Installation and Updates

15.2.1 Upgrading Intel CAS with Existing SLES & SP Versions:

If you are upgrading Intel CAS within the same SLES operating system and service pack such as SLES12-SP2, then you can perform the upgrade by utilizing the SUSE Yast or CLI (zypper) and the upgrade repo.

In order to uninstall or upgrade the CAS RPM, the following preconditions must be met. Otherwise, an rpm upgrade or uninstall error message will be returned.

1. There are no caches running, no cores in detached cores, etc. (casadm -L lists no devices)
2. There is no dirty data on devices specified in the intelcas.conf file

Procedure for upgrading CAS using zypper:

```
# intelcas stop --flush
# zypper up 'Intel-CAS*'
# intelcas init
```

(this command is required only if there are caches specified in intelcas.conf. Without this, caches might not start after reboot due to a mismatch in device metadata.)

CAS package can be removed using Yast interface or manually, using zypper:

```
# intelcas stop --flush
# zypper remove 'Intel-CAS*'
```

15.2.2 Upgrading Intel CAS and Upgrading SLES & SP Versions:

Upgrading SLES Operating System or Service Packs (such as upgrading from SLES12 SP2 to SP3) are normally considered major upgrades and require careful planning.

To upgrade Intel CAS between different SUSE Operating Systems or Service Packs requires stopping all caching and Intel CAS services, then removing CAS packages prior to the SLES upgrade. In addition if Intel CAS is in WB mode please ensure you flush all caches first before performing any other tasks.

Once the SLES operating system and/or Service Pack upgrades are successfully completed, the appropriate version of Intel CAS can then be installed. Please verify the correct version of Intel CAS for your new operating environment prior to the install.

If the Intel CAS services and devices are in use, then you must first stop them prior to removing the Intel CAS packages. The SUSE package manager will remove Intel CAS packages leaving /etc/intelcas/intelcas.conf.rpmsave file after the RPM uninstall, preserving the configurations. If a new version of Intel CAS is installed, the administrator can utilize this file to rebuild the previous CAS configuration. Please note that this applies only to an uninstallation where the user had modified their CAS configuration file. During a normal package upgrade all existing Intel CAS configuration files are preserved by default.

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16 Terminology

Table 14: Terms and Definitions

Term	Definition
cache	The transparent storage of data so that future requests for that data can be served faster.
cache hit	When requested data is contained in (and returned from) the cache.
cache miss	When requested data is not in the cache, and therefore must be retrieved from its primary storage location.
core device	The device to be cached.
dirty data	This refers to data that is modified within the cache but not modified in main memory.
guest	An operating system running on a Virtual Machine (VM) environment.
host	The operating system running (hosting) the Virtual Machine (VM) environment, on which guest Operating Systems can be installed.
hypervisor	A hardware virtualization technique that allows multiple operating systems, termed guests, to run concurrently on a host computer.
I/O	Abbreviation for input/output as it relates to the flow of data.
lazy write	The process of mirroring to primary storage. See also *write-back*.
NAS	Network-attached storage. File-level data storage (such as fixed disk and magnetic tape drives) that are directly linked to a storage area network or other network.
pass-through	A caching mode in which the cache will be bypassed for all operations.
primary storage	As it relates to caching, the storage system or location (DAS, SAN, NAS, etc.) where the data is stored.
SAN	Storage Area Network. Framework used to attach remote computer storage devices to servers. Storage devices appear as if they were attached locally to the operating system.
SSD	Solid State Drive. A device used for data storage that uses memory chips instead of a revolving disk.
tiered storage	A data storage technique that moves data between two or more kinds of storage, which are differentiated by four primary attributes: price, performance, capacity, and function.
write-around	A caching mode in which some write operations are not cached. Writes to blocks that do not exist in cache are written directly to the core device, bypassing the cache. If a write operation is issued to a block that is already in cache (because of a previous read operation), then writes are sent to both the core device the cache device. Write-Around cache improves performance of workloads where write operations are done rarely and no further read accesses to that data are performed, so there is no benefit in caching it.
write-back	A caching mode in which data is written first to the cache and then mirrored to primary storage when I/O bandwidth is available. The process of mirroring to primary storage is known as a *lazy write*.
write-through	A caching mode in which every write to the cache causes a synchronous write to primary storage.

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A. Frequently Asked Questions

This appendix provides contact information and answers to frequently asked questions.

How do I contact technical support?

Contact technical support by phone at 800-404-2284 or at the following URL: http://www.intel.com/support/go/cas.

Why does Intel CAS for Linux use some DRAM space?

Intel CAS for Linux uses a small amount of system memory for metadata, which tells us which data is in the SSD, which is in the HDD. The amount of memory needed is proportional to the size of the cache space. This is true for any caching software solution. However with Intel CAS this memory footprint can be decreased using the variable cache line parameter (--cache-line-size) which may be useful and more cost effective in high density servers with many large HDDs.

Does Intel CAS for Linux work with non-Intel® SSDs?

Yes, however we validate only on Intel SSDs. In addition Intel CAS utilizes the features of Intel SSD to provide improved performance and functionality that may not be available with third party products. Intel CAS is also favorably priced when purchased with Intel SSDs.

How do I test performance?

In addition to the statistics provided (see Monitoring Intel® CAS for details), third-party tools are available that can help you test I/O performance on your applications and system, including:

- FIO (*http://freecode.com/projects/fio*)
- dt (*http://www.scsifaq.org/RMiller_Tools/dt.html*) for disk access simulations

Is it possible to experience slower than HDD performance when using caching?

Yes, it is possible. For example, if the cache is in write-back mode and the entire cache is full of dirty data and a read occurs which requires new blocks to be loaded into the cache, performance will be degraded even if the read is sequential. The cache must first evict dirty blocks, which requires random writes to the HDD, then read the new data from the HDD and finally, write it to the cache. Whereas, without caching it would have simply resulted in a single read from the HDD. To avoid situations such as these, Intel CAS opportunistically flushes dirty data from the cache during idle IO times.

Where are the cached files located?

Intel CAS for Linux does not store files on disk; it uses a pattern of blocks on the SSD as its cache. As such, there is no way to look at the files it has cached.

How do I delete all the Intel CAS for Linux installation files?

Stop the Intel CAS software as described in Stopping Cache Instances on page 22, then uninstall the software as described in Section 3.6 Uninstalling the Software.

Does Intel CAS for Linux support write-back caching?

Yes. Intel CAS for Linux v2.6 and newer supports write-back caching. See Manual Configuration for Write-back Mode on page 18 for details.

Must I stop caching before adding a new pair of cache/core devices?

No, you can create new cache instances while other instances are running.

Can I assign more than one core device to a single cache?

Yes. With Intel CAS for Linux v2.5 and newer, many core devices (up to 32 have been validated) may be associated with a single cache drive or instance. You can add them using the `casadm -A` command.

Can I add more than one cache to a single core device?

No, if you want to map multiple cache devices to a single core device, the cache devices must appear as a single block device through the use of a system such as RAID-0.

Why do tools occasionally report data corruption with Intel CAS?

Some applications, especially micro benchmarks like *dt* and *FIO*, may use a device to perform direct or raw accesses. Some of these applications may also allow you to configure values like a device's alignment and block size restrictions explicitly, for instance via user parameters (rather than simply requesting these values from the device). In order for these programs to work, the block size and alignment for the cache device must match the block size and alignment selected in the tool.

Do I need to partition the cache device?

No. If you do not specify a partition, Intel CAS uses the entire device as the cache device.

Can I use a partition on a SSD as a cache device?

Yes, however, using the entire SSD device as the cache is highly recommended for best performance.

Do I need to format the partition or the device configured as the cache device?

No, the cache device has no format requirement. If any formatting is used, it is transparent to the caching software.

What is the logical and physical block size for Intel CAS cache volumes (for exported objects)?

The logical block size for Intel CAS cache volumes is inherited from the core device, while the physical block size will be represented as the larger of the physical block sizes of the cache or core devices.

Note: It is not possible to add a core device to a cache instance when the logical block size of the cache device is greater than that of the core device (eg. when the SSD has 4KiB logical block size and the HDD has 512B logical block size).

What happens if my SSD or HDD becomes unresponsive or disconnected?

In the event of a cache or core device becoming unresponsive, Intel CAS will fail all IO to all exported devices for the related cache (eg. /dev/intelcas1-1, /dev/intelcas1-2, etc.). To resume IO to the exported devices for the given cache, the user must restart the affected cache (in this example, cache ID 1).

When my device becomes disconnected, will I receive any notification from Intel® Cache Acceleration Software?

No. The OS does not send notification to Intel CAS of the disconnection of the device, so the software will not know of this event until IO to the device is attempted. The device will still be listed in the `--list-caches` and `--stats` output, and no warning will be logged, until IO to the device is attempted. Check `/var/log/messages` and `dmesg` for standard Linux device IO errors.

Where is the log file located?

All events are logged in the standard Intel CAS system logs. Use the *dmesg* command or inspect the */var/log/messages* file.

To log all messages during testing or kernel debugging, use the command `echo 8 > /proc/sys/kernel/printk`.

Typical log sample of successful cache initialization:

```
[Intel(R) CAS] Cache line size: 64 KiB
[Intel(R) CAS] Metadata capacity: 25 MiB
[Intel(R) CAS] Parameters (policies) accepted:: 0 1 1 4
[Intel(R) CAS] Pre-existing metadata, Clean shutdown
[Intel(R) CAS] Done saving cache state!
[Intel(R) CAS] Cache 1 successfully added
[Intel(R) CAS] IO Scheduler of intelcas1-1 is cfq
[Intel(R) CAS] Core "/dev/sdc" successfully added
```

Typical log sample of successful cache removal:

```
[Intel(R) CAS] Removing Cache 1
[Intel(R) CAS] Trying to remove 1 cached device(s)
[Intel(R) CAS] Removed device intelcas1-1.
[Intel(R) CAS] Done saving cache state!
[Intel(R) CAS] Cache 1 successfully removed
```

Why does flushing the cache drive in Write Back mode take so long?

Flushing time has many factors, including but not limited to, cache device capacity, storage performance, and overall system utilization. Flushing time can vary greatly depending on these factors. You can check the status of the cache device being flushed by using the -L option in casadm.

```
# casadm -L
```

The following command can be used as well to verify activity and loading of the IO devices.

```
# iostat -xmt 1
```

Should nr_request be modified for further tuning?

The *nr_requests* controls how many requests may be allocated in the block layer for read or write requests. It represents the IO queue size. Each request queue has a limit on the total number of request descriptors that can be allocated for each read and write I/O. By default, the number is 128, meaning 128 reads and 128 writes can be queued at a time before putting a process to sleep.

Large values of *nr_request* may increase throughput for workloads writing many small files. For larger I/O operations, you may decrease the *nr_request* value. To get better read performance, you can set the *nr_request* value to 1024 for example, but increasing the value too high might introduce latency and degrade write performance. For latency sensitive applications, the converse is also true.

Configuring *nr_requests* to a larger value may improve performance for some customers who are caching multi-HDD RAID onto one SSD. However, this may not be useful with environments, such as Ceph, where each HDD is being cached to one SSD or a partition on an SSD. Your application and its I/O patterns may vary and require a detailed tuning exercise.

To change the *nr_requests* value, use the following procedure:

```
# cat /sys/block/sda/queue/nr_requests
128
# echo 256 > /sys/block/sda/queue/nr_requests
```

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B. Generic ssh-keygen Code Snippet

This appendix provides an *ssh-keygen* code snippet that allows you to pair two machines, with “no-password login” enabled.

Generate keys with the *ssh-keygen* command:

```
# ssh-keygen
```

Note: We recommend providing an optional passphrase when prompted. Do not leave the passphrase empty.

This will generate a private/public key pair in the *~/.ssh* directory. In order to copy the public key to a client machine, type the following in the Intel CAS shell:

```
# ssh-copy-id -i ~/.ssh/id_rsa.pub <admin>@<host_ip>
```

To confirm that this secure pairing has worked properly, use the following command to *ssh* to the remote system:

```
# ssh <admin>@<host_ip>
```

You must do this not only to make sure *ssh* setup has worked, but also to accept the RSA key fingerprint. (Otherwise the automatic script will fail.)

Note: Additional command information on this topic is beyond the scope of this guide, but you can consult the *man* pages or any of the freely available *ssh* and *ssh-keygen* examples on various Intel CAS how-to websites for further details.

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C. Installation File Tree

This appendix provides a list of paths and file names for files that get installed by the intelcas installer.

Installed to all OSes:

/sbin/casadm
/sbin/intelcas
/etc/intelcas/*
/lib/intelcas/*
/usr/share/man/man8/casadm.8.gz
/usr/share/man/man8/intelcas.8.gz
/lib/modules/`uname -r`/extra/intelcas.ko (Note: this path may differ if DKMS is enabled)
/lib/modules/`uname -r`/extra/inteldisk.ko (Note: this path may differ if DKMS is enabled)
/lib/udev/rules/60-persistent-storage-intelcas-load.rules

Additional files installed if DKMS is enabled:

/usr/src/intelcas-<CAS_version>/*

Additional file installed to SystemD based OSes (e.g. RHEL 7.0):

/usr/lib/systemd/system/intelcas-shutdown.service

Additional file installed to SysV based OSes (e.g. RHEL 6.8):

/etc/init.d/intelcas-shutdown

The following files are installed on SUSE Operating Systems available through the SUSE Solid Driver Program RPM packages starting with SLES12-SP2:

/etc/intelcas/intelcas
/etc/intelcas/intelcas.conf
/etc/intelcas/ioclass-config.csv
/lib/intelcas/icas.py
/lib/intelcas/icas.pyc
/lib/intelcas/icas.pyo
/lib/intelcas/intelcas
/lib/intelcas/intelcas-loader
/lib/intelcas/intelcas-mount-utility
/sbin/casadm
/sbin/intelcas
/usr/lib/systemd/system/intelcas-shutdown.service
/usr/lib/udev/rules.d/60-persistent-storage-intelcas-load.rules
/usr/lib/udev/rules.d/60-persistent-storage-intelcas.rules/usr/sbin/rcintelcas
/usr/sbin/rcintelcas-shutdown
/usr/share/doc/packages/Intel-CAS/Intel_Cache_Acceleration_Software_for_Linux_*_AdminGuide.pdf
/usr/share/doc/packages/Intel-CAS/Intel_Cache_Acceleration_Software_for_Linux_*_RelNotes.pdf
/usr/share/man/man5/intelcas.conf.5.gz
/usr/share/man/man8/casadm.8.gz

/usr/share/man/man8/intelcas.8.gz
/lib/modules/`uname -r` /updates/intelcas/intelcas.ko
/lib/modules/`uname -r` /updates/inteldisk/inteldisk.ko