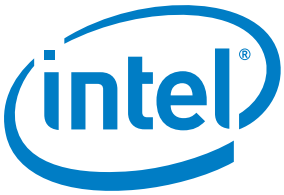


# Intel® Cache Acceleration Software (Intel® CAS) Version 2.0 for Windows*

## Administrator's Guide

***December 2012***

Order Number: 328330-001

# Contents

## Tables

# Revision History

| Date | Revision | Description |
|---|---|---|
| December 2012 | 001 | Initial release of document. |

# 1 About This Guide

This guide offers the quickest way to install and begin using Intel® Cache Acceleration Software (Intel® CAS). This guide assumes users have a basic knowledge of storage and application management, as well as knowledge of the Microsoft* Windows* Server environment.

## 1.1 Intel® Cache Acceleration Software Overview

Intel® CAS accelerates Microsoft* Windows* Server applications by caching active (*hot*) data to a local flash device inside servers and virtual machines. Intel® CAS implements caching at the server level, utilizing local high-performance flash media as the cache drive media inside the application server as close as possible to the CPU, thus reducing storage latency as much as possible.

The Intel® Cache Acceleration Software installs into the Windows* operating system itself, using the OS for protocol and driver support. The nature of the integration provides a cache solution that is transparent to users, VMs and applications, and your existing storage infrastructure. No storage migration effort or application changes are required.

Intel® CAS employs a file-based caching architecture that provides for advanced policy management, allowing you to define what data specifically is accelerated through the cache system (see Section 4.2 for details).

Intel® CAS supports 64-bit Windows* Server operating systems running natively or virtually under VMware* or Hyper-V (see Section 2.1 for details).

## 1.2 Reference Documents

The following resources and tools are suggested for assisting with Intel® CAS testing and operations and/or learning more about caching and application I/O performance management.

**Table 1. Reference Documents**

| Document | Location |
|---|---|
| Monitoring specific system activity using Performance Monitor | http://technet.microsoft.com/en-us/library/cc771692%28WS.10%29.aspx#BKMK_Scen2 |
| Iometer I/O test tool | http://www.iometer.org/ |
| TPC-C transactional database performance test for SQL | http://www.tpc.org/tpcc/ |

### 1.2.1 Documentation Conventions

The following conventions are used in this manual:

- `Courier font` - code examples, command line entries, filenames, directory paths, and executables
- **Bold text** - graphical user interface (GUI) entries and buttons

# 2 Product Specifications and System Requirements

## 2.1 Supported Platforms

Intel® CAS supports the platforms listed below for 64-bit processors.

**Table 2. Supported Platforms**

| Platform | Notes |
|---|---|
| Windows* Server 2008 R2 | |
| VMware* ESXi | Installed into Windows* Server 2008 R2 running as the Guest |
| Windows* Hyper-V | Installed into Windows* Server 2008 R2 running as the Guest |
| Citrix* XenServer | Installed into Windows* Server 2008 R2 running as the Guest |
| KVM* | Installed into Windows* Server 2008 R2 running as the Guest |

## 2.2 System Requirements

The table below lists system requirements for Intel® CAS.

**Table 3. System Requirements**

| | |
|---|---|
| Memory | 4GB of memory minimum; 8GB or greater recommended |
| CPU Overhead | Intel CAS only consumes approximately 2% of CPU resources. It is recommended that the CPU is not at maximum capacity. |
| Flash/SSD | Windows* supported Flash device (SAS, SATA, PCIe, Fiber Channel) 60GB or larger recommended.<br>Validated and supported on the Intel® SSD Data Center Family. |
| Storage | Primary storage device including SAN, local disk, RAID, iSCSI, or Fiber Channel, etc. |
| Application Support | .NET Framework version 3.5 is required.<br>Any I/O intensive applications, including databases, Microsoft* Exchange and SharePoint, transactional web servers, etc. |

# 3 Installation Guide

This installation guide describes how to invoke the automated installer and describes the default settings. One of the main features of Intel® CAS is its simplicity; it does not have many options that are necessary to be tuned.

## 3.1 Configuring the Flash Device

Prior to installing Intel® CAS, you must have a Flash media device configured as an NTFS drive on the application server, VM host, or shared storage device. The Flash device can be any SSD drive (SATA or SAS) or any PCIe Flash Card supported by Windows* Server 2008 R2.

### 3.1.1 Windows* Server 2008 R2

Physically install the Flash device on the server, and format the device as an NTFS drive. Proceed to Section 3.2 later in this section.

### 3.1.2 Windows* Hyper-V with Windows* Guest

Intel® CAS is installed into Windows* Server 2008 R2 running as the guest.

Start by physically installing the Flash device on the Windows* Server 2008 R2 host or shared storage resource, and formatting the device as an NTFS drive and then create a VHD on the Flash drive and attach it to the guest as described below.

1. Launch the **Hyper-V Manager** and select the Guest VM to be accelerated.
2. Click on **New** in the **Actions Menu** and then choose **Hard Disk…**
3. Step through the wizard.
4. Provide an appropriate name for the newly created VHD file. For Location, select the physical flash drive.
5. Select the guest VM and then choose **Settings** from the **Actions Menu**
6. Select IDE Controller – Hard Drive
7. Click **Add**
8. In the **Virtual hard disk (.vhd)** file text field, select the location of the VHD file created earlier, and click **Apply**
9. Select the guest VM and then choose **Start** from the **Actions Menu**
10. Login to the guest VM and launch **Computer Management** and select **Disk Management**
11. Right-click the newly created hard drive and select **Format**.
    Assign a driver letter, for example, **S:**

Proceed to Section 3.2 later in this section.

***Note:*** To install into multiple guest instances of Windows* Server 2008 R2, you must create separate VHDs on the Flash drive for each guest and attach them individually to each guest. Multiple guests can not share the same VHD as the cache drive.

### 3.1.3 VMware* ESX, ESXi with Windows* Guest

Intel® CAS is installed into Windows* Server 2008 R2 running as the guest.

Start by physically installing the Flash device on the ESX host or shared storage resource, and then add the drive to VMware* using the vSphere Client as described below.

***Note:*** In order to support vMotion while maintaining a "hot" cache, it is necessary to install the Flash device on a shared storage resource that is accessible by all the VMware* host machines.

1. Start the **Add Hardware** wizard.
2. Select **Hard Disk**, and click **Next**
3. Select **Create a New Virtual Disk**, and click **Next**
4. Enter the disk capacity, and select the location as **Specify a Datastore**
5. Browse for the datastore location, and click **Next**
6. Specify the virtual device node.
7. It is recommended you set the **virtual disk mode options** to **Independent**, followed by **Persistent**, and click **Next**
8. Click **Finish**
9. Launch the VM and initialize the disk using Windows* Disk Management tools as an NTFS formatted drive.

Proceed to Section 3.2 below.

***Note:*** To install into multiple guest instances of Windows* Server 2008 R2, you must create separate VHDs on the Flash drive for each guest and attach them individually to each guest. Multiple guests can not share the same VHD as the cache drive.

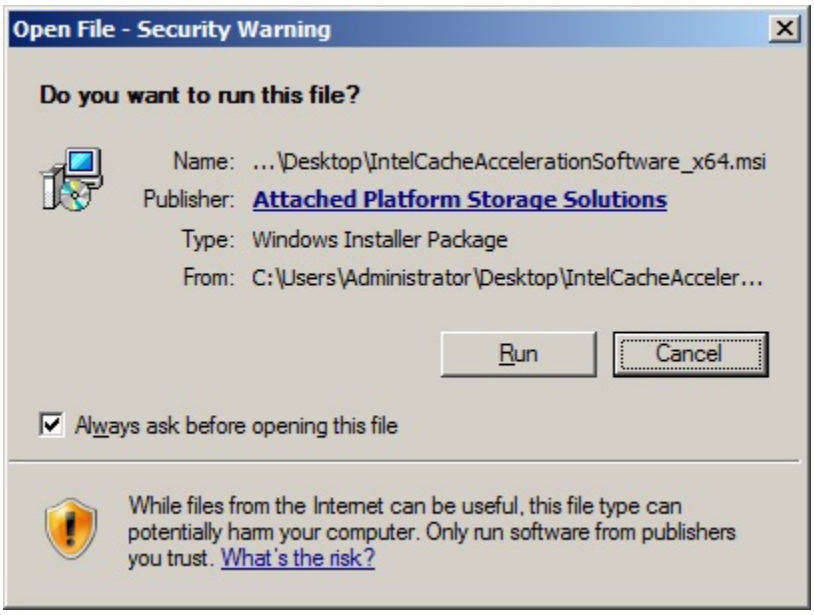
## 3.2 Installation Instructions

***Note:*** You must be logged in as an Administrator to install the software.

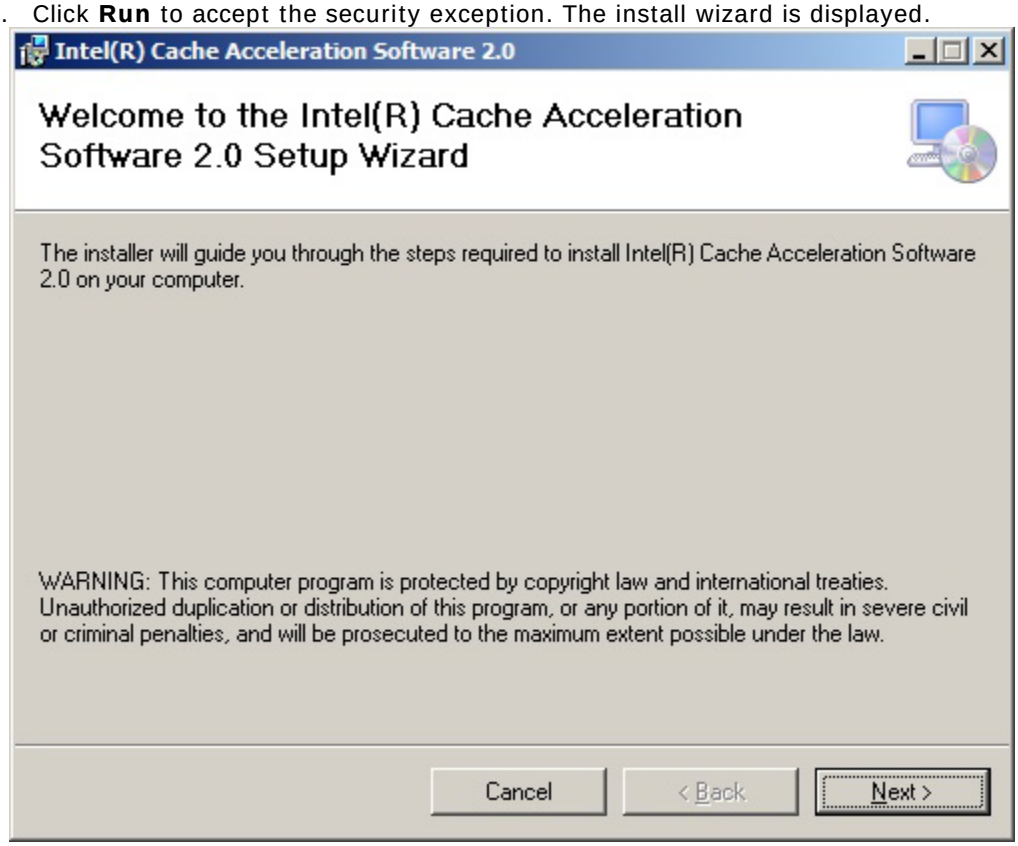
***Note:*** If an earlier version of the software is already installed, you must manually uninstall it before continuing. See Section 3.3 for details on uninstalling.

1. Download or copy the Intel® CAS Installer onto the target Microsoft* Server 2008 R2 server or VM guest.

2. Double-click `IntelCacheAccelerationSoftware_x64.msi` to start the install. A security warning is displayed before launching the install Wizard.




3. Click **Run** to accept the security exception. The install wizard is displayed.

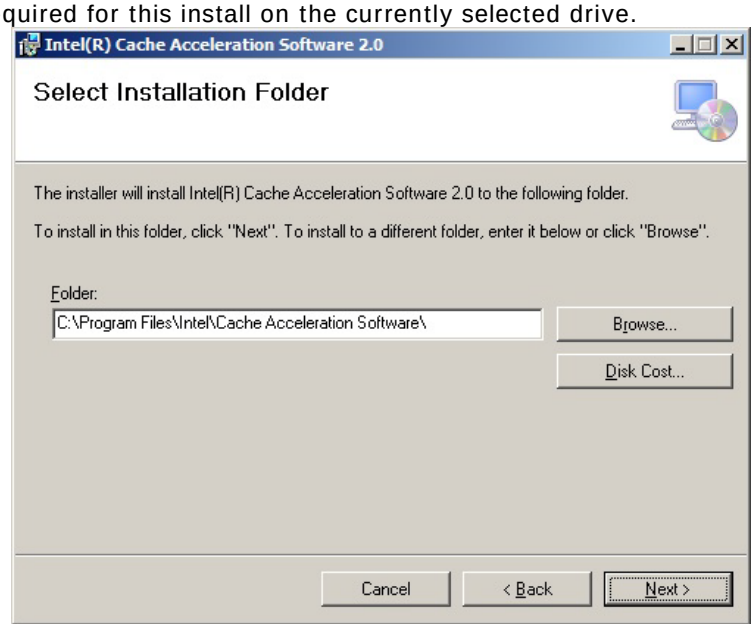


Click **Next** to proceed to the License Agreement. Clicking **Cancel** at any time cancels the install.

4. In order to proceed with the install, you must read and mark that you agree to the License agreement.

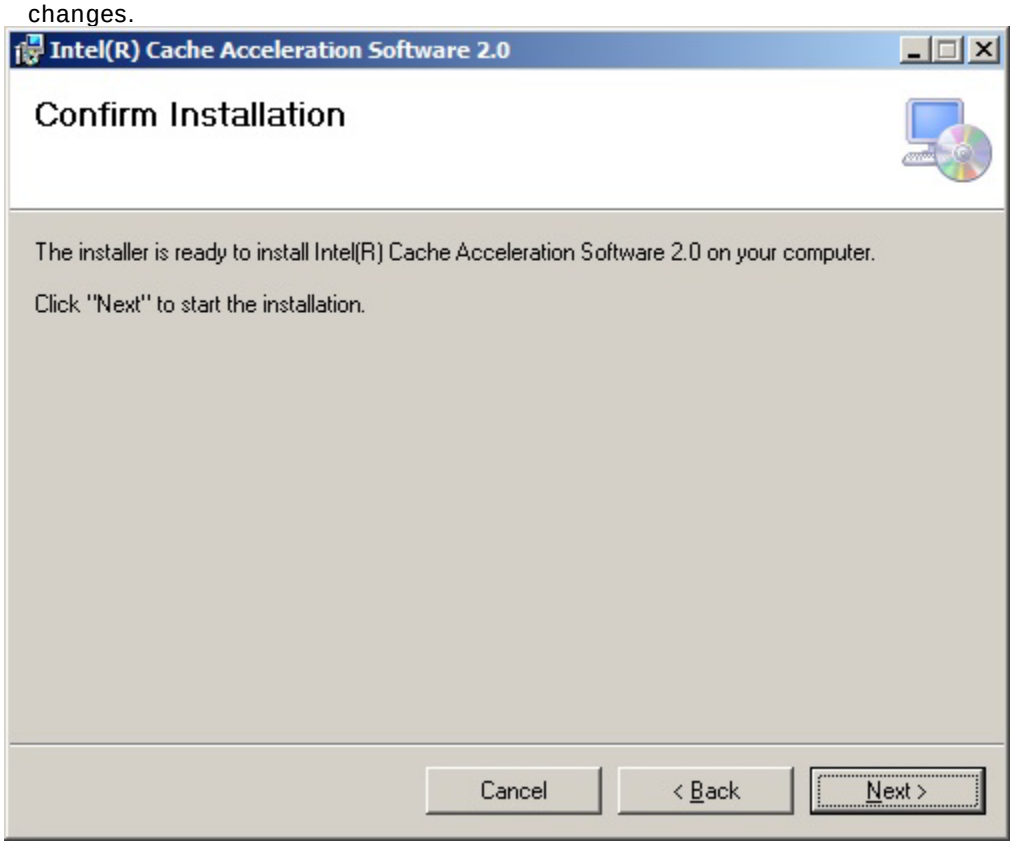

Click **I Agree** followed by **Next** to continue.

5. It is recommended you accept the default installation folder in Program Files. To change the location, select **Browse...** to pick another folder location.
The **Disk Cost...** option provides information on your available disk space and the space required for this install on the currently selected drive.



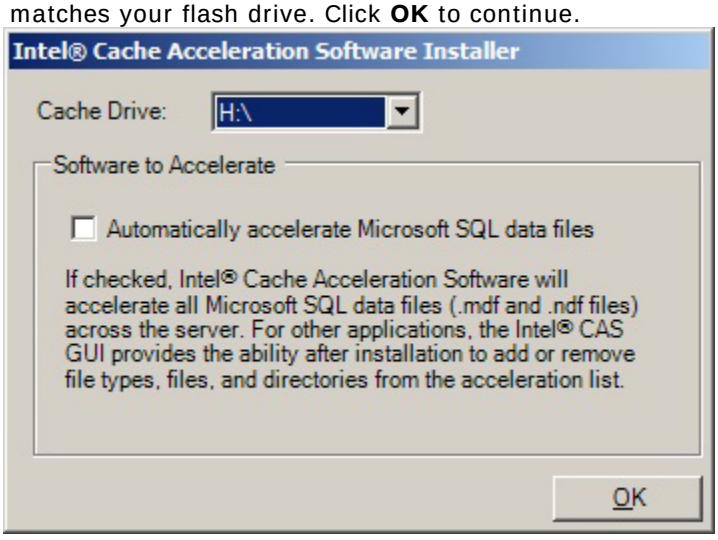
Click **Next** to proceed to the Confirm Installation window.

6. Click **Next** to proceed, **Cancel** to quit the install, and **Back** to make any required changes.

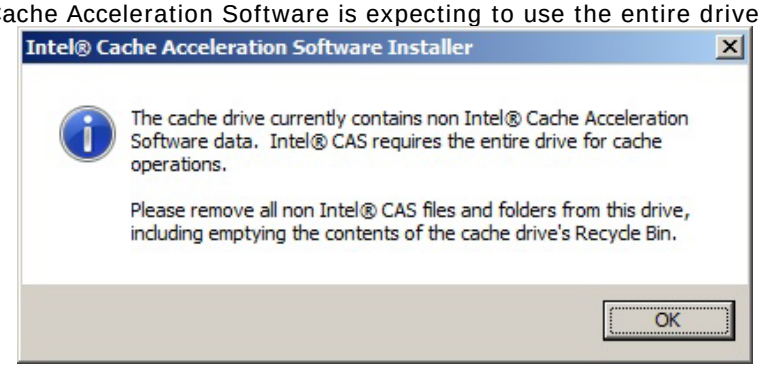



7. During installation, a progress dialog is displayed.

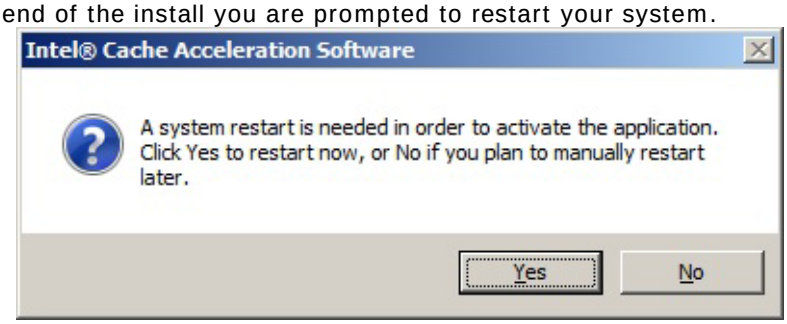
   You are prompted to select the drive to be used as a cache drive. Select the drive letter that matches your flash drive. Click **OK** to continue.



8. If Intel® Cache Acceleration Software detects any files on the cache drive, even hidden or system files, the following dialog box is displayed to warn you that Intel® Cache Acceleration Software is expecting to use the entire drive.

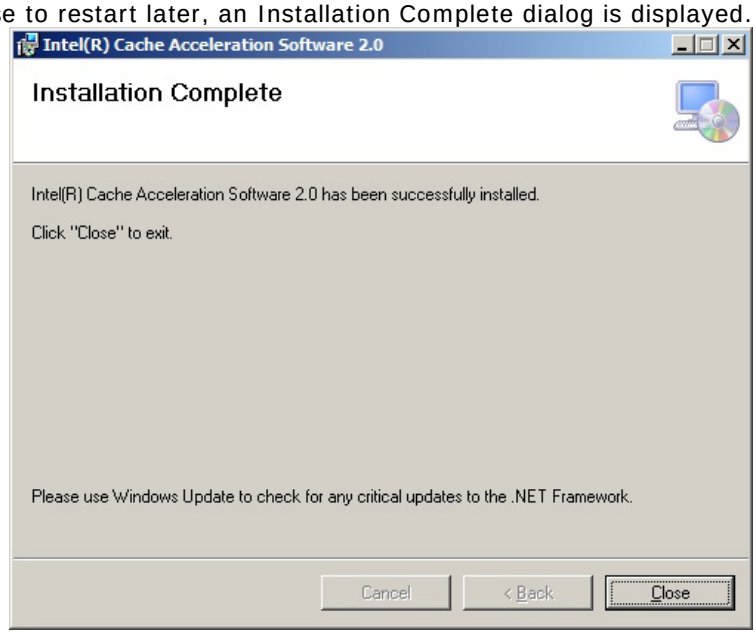



9. At the end of the install you are prompted to restart your system.



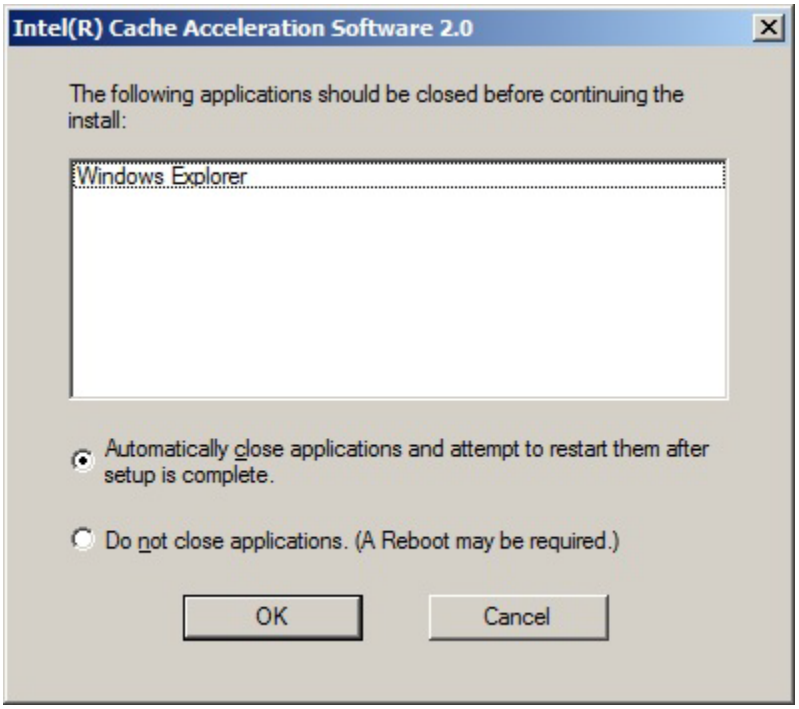

10. The server must be restarted in order for Intel® CAS to update system drivers. It is recommended that you close all open application and select **Yes** to restart now. You can, however, choose **No** and reboot the system at a later date and time. Please note that Intel® CAS does not start until after reboot.

If you choose to restart later, an Installation Complete dialog is displayed.

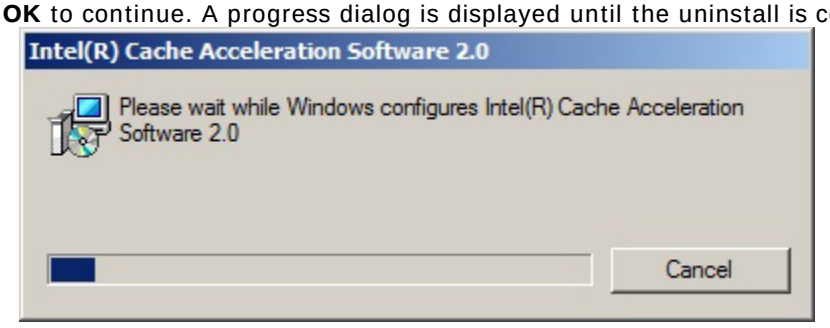


## 3.3 Uninstalling the Software

1. From the **Start Menu**, click on **Control Panel** and under the **Programs** section select **Uninstall a Program**. A list of installed software is displayed. Select **Intel® Cache Acceleration Software** from the list and then choose **Uninstall** from the menu bar. A confirmation message is displayed.
2. Click **Yes** to uninstall Intel® CAS. The Windows* Installer appears, making preparations to uninstall the software from your system.
3. If the following screen appears, it means that Intel® CAS or the installed Intel® CAS Service is still running, and Windows* needs your permission to close them before the uninstall can continue.




4. Click **OK** to continue. A progress dialog is displayed until the uninstall is complete.




5. If you chose not to close the applications, you need to reboot your system in order to complete the uninstallation procedure. Otherwise, it is recommended, but not required, to reboot your system after uninstall.

# 4 Configuring Intel® Cache Acceleration Software

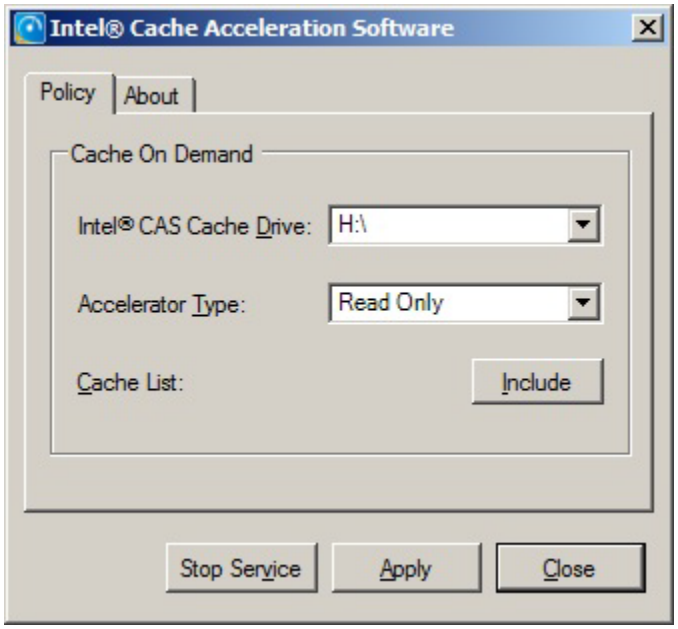
***Note:*** You must be logged in as an Administrator to make any configuration changes.

After installation, the Intel® CAS icon (below) is shown in the Start Menu and the Desktop.

Intel® CAS is configured using a GUI.

To bring up the GUI, double-click the Intel® CAS Service icon in the system tray.

The following screen is displayed.



## 4.1 Starting or Stopping the Intel® Cache Acceleration Software Service

If the Intel® CAS Service is not running (there is no Intel® CAS icon in the system tray) you can start it using a Start Menu item or by double-clicking the installed desktop icon.

***Note:*** If the Intel® CAS icon is present in the system tray, the Start Menu or Desktop icon items do **not** launch the GUI. This will be fixed in a future release.

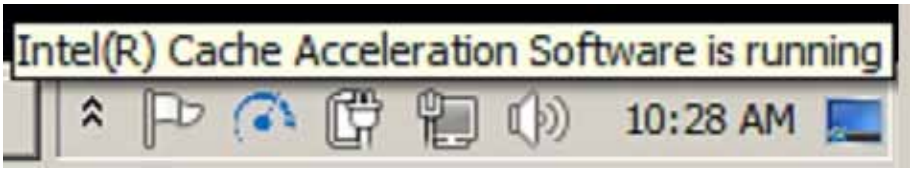
You can also start the Intel® CAS Service by launching **Computer Management**:

1. Select **Services and Applications**
2. Click on **Services**
3. Select **Intel® Cache Acceleration Software** from the list of services.
4. Click **Start**

To stop the Intel® CAS Service, double-click the Intel® CAS Service Icon in the system tray to bring up the GUI. On the main screen, click the **Stop Service** button. The button title changes to **Start Service**, and can be used to re-start the Intel® CAS Service.

***Note:*** If the Intel® CAS icon is not present, you can stop the service by launching **Computer Management**. Select **Services and Applications** and click on **Services**. Select **Intel® Cache Acceleration Software** from the list of services and click **Stop**.

The Intel® CAS Service icon in the system tray is blue when the service is running and the icon is red when the service is stopped.





You can also see the status in the log file which is located by default in:

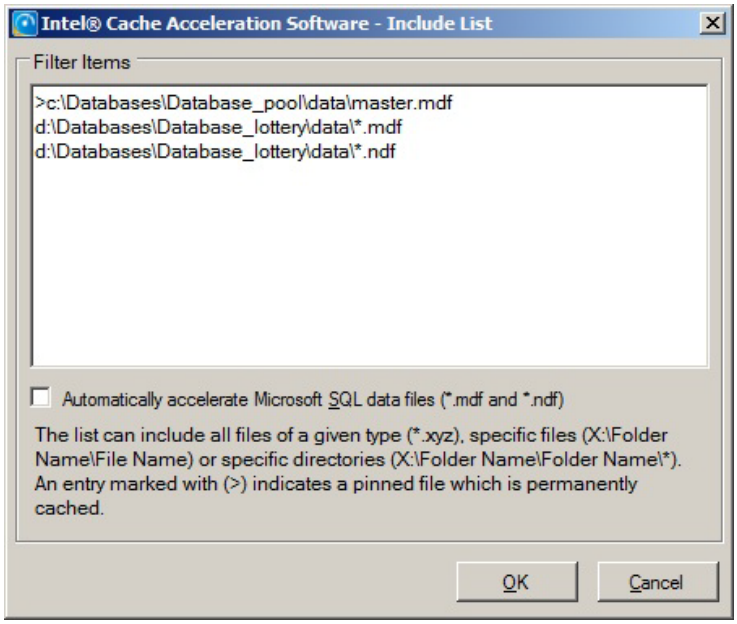
```
C:\ProgramData\Intel\Cache Acceleration Software\logs\IntelCAS.log
```

## 4.2 Managing the Cache Include List

To accelerate server applications or focus the cache on a particular SQL Server database, you must manually set the associated data files in the Intel® CAS include list.

***Note:*** For files that are locked and in use (such as Microsoft SQL Server database files), it is recommended that you stop the application before adding those files to the cache.

1. To add or remove files from the include list, open the GUI and click the **Include** button from the main screen.




2. Click **OK** to close the Include list dialog.
3. Click **Apply** in the main GUI window.
4. You must restart the service for the changes to take effect.

Cached files are defined by type of file (such as `*.pdf`), filename, partial filename (such as `*Intel*`), or directory path (such as `D:\Directory\*`). Files that are permanently included in the cache (pinned files) are denoted by a **>** in the include list.

**The following structure is used for the include list:**

- Global application file type match is in the form `*.xyz`
- File paths in the form `X:\Folder Name\File Name`
- Folder paths are in the form `X:\Folder Name\Folder Name\*`
- Always cached files (pinned files) begin with a **>** symbol

**Please note the following restrictions and specifics:**

- Drive name requires the \ character (path should be `C:\*.xyz` not `C:*.xyz`)
- `*.*` in a valid path is automatically changed to *
- Intel® CAS does not check for the existence of files or folders in the include list
- You cannot include files or folders on the cache drive itself
- The following items are always excluded:
  - `C:\Windows`
  - Intel® CAS program files directory and log directory
  - Cache drive itself

## 4.3 Pinning Files in the Cache

Intel® CAS supports pinning files into the cache. These files are cached immediately and are never evicted, unless they are subsequently unpinned.

**Pinning or un-pinning using the GUI**

1. Open the GUI and click the **Include** button from the main screen.
2. In the Filter Items box, enter the **>** symbol, followed by the filename with complete path, and click **Enter**. Repeat for all the files you wish to pin to the cache. To un-pin, select the file you wish to un-pin, and click **Delete**.
3. Click **OK** to close the Include list dialog.
4. Click **Apply** in the main GUI window.
5. You must restart the service for the changes to take effect.

**Pinning using the mouse**

1. Open **Windows Explorer** and browse to the file(s) you wish to pin.
2. Select the right-mouse property menu option **Intel® Cache Acceleration Software**, followed by sub-menu item **Add to Intel® Cache Acceleration Software Include List**.
3. Once you have finished pinning files, click **Apply** in the GUI window.
4. You must restart the service for the changes to take effect.

## 4.4 Setting the Cache Drive or Accelerator Type

Intel® Cache Acceleration Software Version 2.0 only supports **Read Only** as the **Accelerator Type**. Read Only acceleration means that only read operations are accelerated by the cache, but both read and write operations populate the cache (Read with Write-Through caching). Future versions will include write acceleration (Read with Write-Back caching).

To change the drive used for the cache files, open the GUI, and from the main screen:

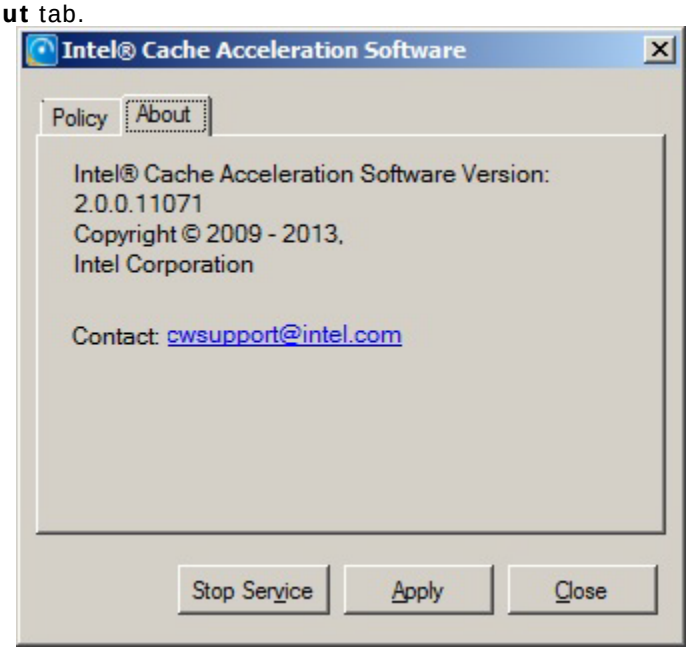
1. If Intel® CAS is running, select **Stop Service**.
2. Select the drive letter for the new cache drive in the cache drive pulldown and click **Apply**.

***Note:*** The selected drive must be formatted as an NTFS drive and must be empty. The cache starts from scratch; cache data is not copied from the previous drive.

3. Select **Start Service**.

## 4.5 Viewing the Build Number

To view the build number for your installed version of Intel® CAS, open the GUI, and select the **About** tab.




## 4.6 Multi-Level Caching

Intel® CAS can work with either a one-level or two-level cache (multi-level caching). When using a two-level cache, Intel® CAS integrates with the Windows* file cache in DRAM memory. However, there is an operating system restriction on the Windows* DRAM cache processing speed. Therefore, choosing a one-level or two-level cache depends on the application, CPU speed, and/or the flash device type and throughput. For example, for Microsoft SQL Server acceleration on a high-performance server with PCIe Flash, a one-level cache provides the best performance. Conversely, for a non-database application and an SSD-based Flash device, a two-level cache provides the best performance.

The default is a two-level cache. If the performance of the caching system is not as expected, change to a one-level cache to see if results improve.

### 4.6.1 Setting up a one-level cache

Perform the following:

1. Stop the service.
2. Open `IntelCASService.exe.config` in the install directory using a text editor.
3. Find the line:

```
<add key="LfsDrive" value="Cache_Drive_Letter:\" />
```

   below that, add the line:

```
<add key="UseUnBufferedCacheMode" value="True" />
```

4. Save the `IntelCASService.exe.config` file.
5. Re-start Intel® CAS.

### 4.6.2 Setting up a two-level cache

Perform the following:

1. Stop the service.
2. Open `IntelCASService.exe.config` in the install directory using a text editor.
3. Find the line:

   ```
   <add key="LfsDrive" value="Cache_Drive_Letter:\" />
   ```

   below that, delete the line:

   ```
   <add key="UseUnBufferedCacheMode" value="True" />
   ```

4. Save the `IntelCASService.exe.config` file.
5. Re-start Intel® CAS.

# 5 Monitoring Intel® Cache Acceleration Software

The performance and operation statistics of Intel® CAS are managed using Windows* Performance Monitor (perfmon), which is included by default with Windows* Server 2008 R2.

Intel® CAS records the following statistics (counters) for Performance Monitor.

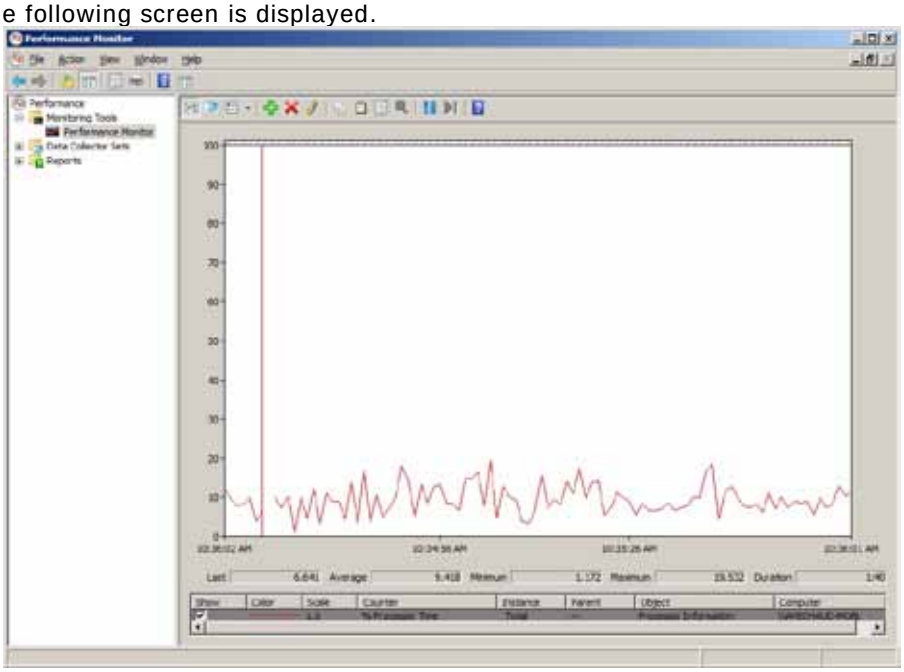
| | |
|---|---|
| **Total Cache (MB)** | Number of MB present in the cache |
| **Write Cache (MB)** | Number of MB that are dirty in the cache |
| **Writes** | Number of write operations |
| **Writes/sec** | Number of write operations per second |
| **Reads** | Number of read operations |
| **Reads/sec** | Number of read operations per second |
| **Read Hits %** | Percentage of cache hits |
| **Read Hits/sec** | Number of read hits per second |
| **Read Hits + Read Misses** | Base for % of cache hits |
| **Read Misses %** | Percentage of cache misses |
| **Read Misses/sec** | Number of reads missed per second |
| **Read Misses + Read Hits** | Base for % of cache misses |
| **Lazy Written (MB)** | Number of MB cleaned from the cache |
| **Lazy Written (MB/s)** | Number of MB/s cleaned from the cache |
| **Cache Freed (MB)** | Number of MB freed in the cache |
| **Cache Freed (MB/s)** | Number of MB/s freed in the cache |

## 5.1 Starting Performance Monitor

To start Performance Monitor:

1. Click **Start**, click in the **Start Search** box, type **perfmon**, and press **ENTER**.

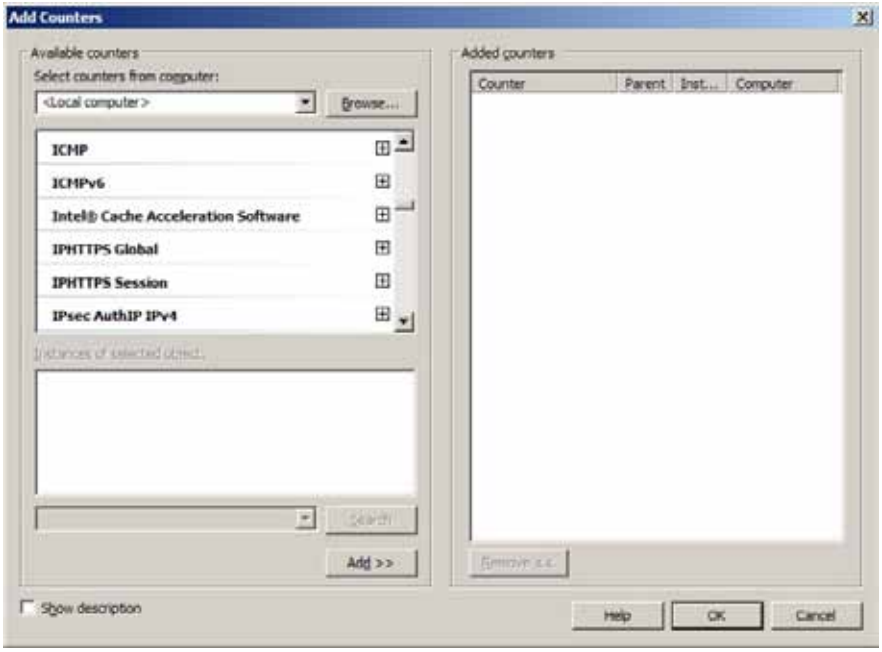
2. In the navigation tree, expand **Monitoring Tools**, and then click **Performance Monitor**.
   The following screen is displayed.



## 5.2 Adding Statistics

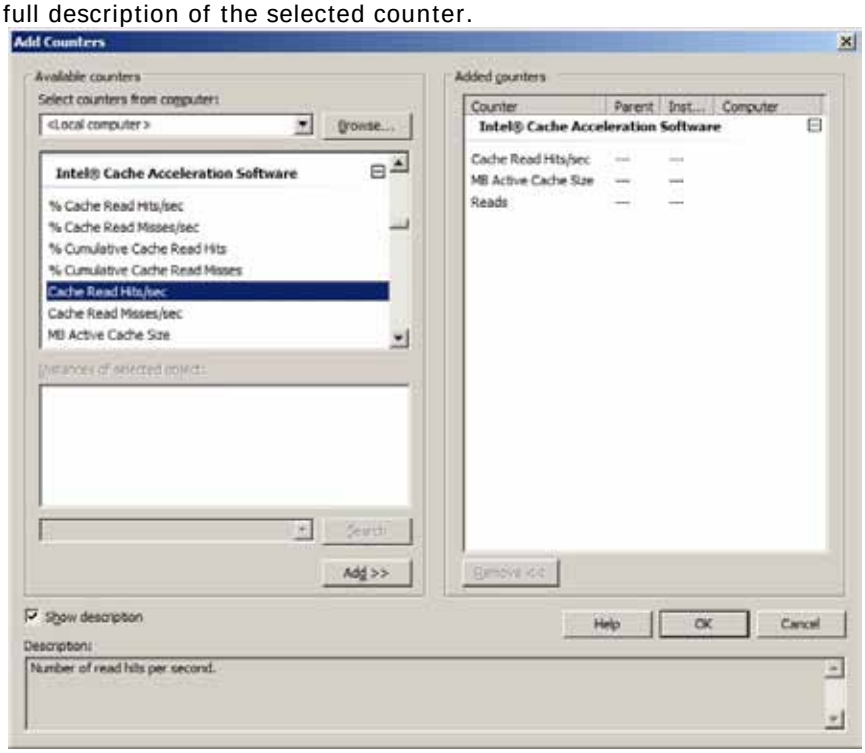
To add Intel® CAS statistics:

1. Select the green **+** icon on the toolbar or type **CTRL-N**, which brings up the **Add Counters** screen.

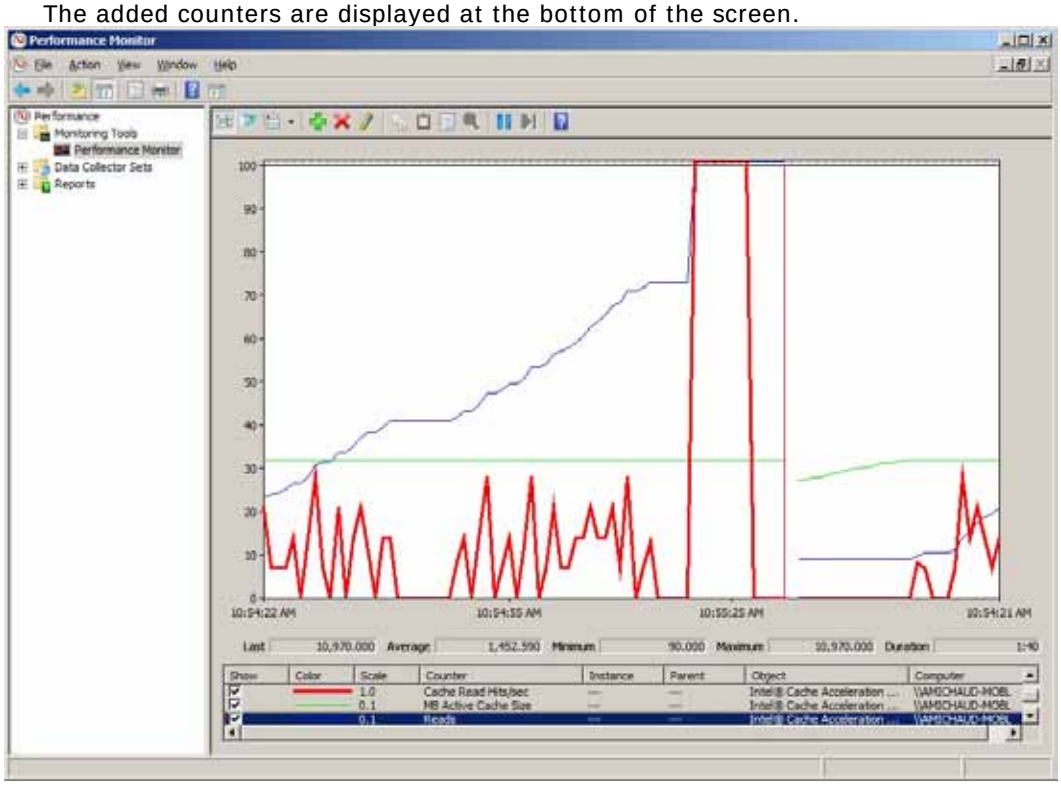


2. Scroll to Intel® Cache Acceleration Software and double-click it or select the down arrow to display the list of available counters.

   Selecting the **Show Description** checkbox on the bottom left of the page displays the full description of the selected counter.



3. Select the desired counters and click **Add >>** to move them to the **Added Counters** box, then click **OK** to return to the main screen.
   The added counters are displayed at the bottom of the screen.




4. Click the **Show** checkbox to include (or hide) the counters in the graphical display.
5. Intel® CAS counters are updated every 10 seconds and are reset only at the time of the installation.

***Note:*** If an error `Setting up performance counters failed` is displayed, you must rebuild the configuration registry key by running `lodctr /R` from a Windows* command prompt. This is a known issue with Windows* performance counters.

# 6 Frequently Asked Questions

### How do I contact support?

Contact support by phone at 800-538-3373 or at the following URL: http://www.intel.com/support/ssdc/cache/cas/

### Nothing happens when I click on Intel® Cache Acceleration Software on the Start Menu or desktop icon?

There is a known issue with the shortcut links where they only launch Intel® CAS if it is not already running. If the Intel® CAS icon is present in the system tray, the Start Menu or Desktop icon items does **not** launch the GUI. This will be fixed in a future release.

To bring up the GUI, double-click the icon in the system tray.

### How do I tell what applications need more I/O?

Disk usage statistics are recorded in Windows* Performance Monitor (`perfmon`), which is included by default with Windows* Server 2008 R2. Two counters that can be monitored to determine overall disk I/O activity are:

- PhysicalDisk: % Disk Time (percentage of time that the disk is busy with I/O)
- PhysicalDisk: Avg. Disk Queue Length (how many system requests are waiting for disk access)

Individual applications may have specific counters to determine the amount of I/O generated by the application. For example, in Microsoft* SQL Server:

- SQL Server:Buffer Manager:Page reads/sec
- SQL Server:Buffer Manager:Page writes/sec

Refer to Section 5 in this document for more information on using Windows* Performance Monitor.

### How do I test performance?

In addition to Windows* Performance Monitor (see above), there are several third-party tools which can help you test I/O performance on your applications and system, including Iometer (http://www.iometer.org/) for overall I/O performance, and the TPC-C transactional database performance test for SQL (http://www.tpc.org/tpcc/).

### Performance is slower than I expect, what can I do?

Intel® CAS can run as a one or two level caching system. It is possible that your application or hardware require you to run in a particular configuration. You should try switching between one and two level caches to see if that solves your performance issue. See Section 4.6 for details.

### Where are the cached files located?

Cached files are located in the folder `<drive>:\IntelCAS\` on your cache drive.

### How do I delete all the cache files?

You can clear the cache by stopping the service, deleting all the data under `<drive>:\IntelCAS\` on your cache drive, and then re-starting the service.

### Does Intel® Cache Acceleration Software support write-back caching?

No. The current release of Intel® CAS supports 'read with write-through' caching only. In this mode, both read and write operations build the cache data, but only read operations are accelerated (writes are written into the cache and to backend storage concurrently). Data integrity is never a concern with write-through.

A future release will support write-back caching, in which writes are written first to the cache and sync'd to backend storage when I/O is available. That release will also allow you to specify what applications or data is set to write-through versus write-back modes.

### How do I change the cache drive used by the service?

Launch **Intel® Cache Acceleration Software**. In the **Policy** tab, drop down the **Cache Drive** combo-box and select the drive you want to use. Click **Apply**.

### How do I add to or change the list of files to be accelerated?

Launch **Intel® Cache Acceleration Software**. In the **Policy** tab, click the **Include** button. Type the names of the specific files you want to accelerate or all files of a given type (`*.xyz`) or specific directories (`X:\Folder Name\Folder Name\*`). Click **Apply**.

### How can I tell if all the operations are being performed without errors?

The Intel® CAS service logs all important operations in a log file called `IntelCAS.log`. This file resides in the folder on the drive where the software is installed. Any errors or exceptions thrown by the software are logged in this file.

By default, the logs folder is located at:
`C:\ProgramData\Intel\Cache Acceleration Software\logs\`

### Where is the log file located?

By default, the logs folder is located at:
`C:\ProgramData\Intel\Cache Acceleration Software\logs\`

### How can I report debug messages in the log file?

Browse to the folder where Intel® Cache Acceleration Software is installed. By default, this is: `C:\Program Files\Intel\Cache Acceleration Software\`

Open `IntelCASDebug.log` in Notepad (or another text editor) and find the line: `Element <rules> <logger Name="*" minlevel="Info" writeTo="file" />`

Change `Info` to `Debug`.

***Note:*** This should be done for support and diagnostic purposes only, because logging debug messages slows down performance considerably.

### After launching the software, the icon is not in the taskbar, where is it?

If Intel® CAS is already running, the software resides in the system tray. Double-click the icon in the system tray to bring up the **Configuration** screen.

### The log file returns an exception, what do I do?

If the exception `Setting up performance counters failed` is displayed, you must rebuild the configuration registry key by running `lodctr /R` from a Windows* command prompt. Information regarding Performance Monitor Counters is stored in the registry and this exception implies that the configuration registry key is invalid. This is a known issue with Windows* performance counters.

# Appendix A Glossary

| 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. |
| **CCN (Content Centric Networking)** | An alternative approach to networking that allows for data storage to be disseminated across the network infrastructure. |
| **DAS (Direct-Attached Storage)** | A storage system directly attached to a server or workstation, without a storage network in between, mainly used to differentiate non-networked storage from SAN and NAS. |
| **De-duplication** | A way to compress storage data size by eliminating redundant copies of data and replacing them with pointers to the reference copy. |
| **Dirty data** | When data is modified within cache but not modified in main memory, the data in the cache is called dirty data. |
| **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. |
| **Hyper-V*** | Microsoft's Virtual Machine (VM) platform, supported on Windows* Server 2008 and Windows* Server 2008 R2. |
| **Hypervisor*** | A hardware virtualization technique that allow 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. |
| **I/O Blender** | A special case of the I/O Bottleneck seen in VM environments, where the varying levels of I/O demands from all the virtual applications are merged through the virtual layer onto a single physical server, creating a constantly high blended I/O level. |
| **I/O Bottleneck** | A term used to describe application slowdown due to the inability of storage I/O to keep up with application demand. |

| Term | Definition |
|---|---|
| **IOPS** | Abbreviation for Input/output Operations Per Second. |
| **L1 (L2, L3, …) Cache** | Represents the cache Level in a multi-level cache hierarchy. Generally operates by checking the smallest and fastest Level 1 (L1) cache first, then proceeds to the next levels. |
| **Latency (also Lag, Response Time)** | As it relates to storage, the measure of time delay from a requested I/O operation to its response. |
| **Lazy Write** | See Write-Back. |
| **LUN (Logical Unit Number)** | A number used to identify a device accessed by storage protocols which supports read/write operations (usually a logical disk). The term is often also used to refer to the disk itself. |
| **NAND Flash** | The type of memory primarily used in Flash cards and SSD drives, which is connected in a way that resembles a NAND (Negated AND) style circuit gate. |
| **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. |
| **Over-Provisioning** | As it relates to primary storage, the allocation of additional physical disks to provide higher IOPS/performance via load balancing. |
| **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. |
| **Sparse File** | A type of file that utilizes file system space more efficiently by only storing the necessary blocks of a file, with the unneeded pieces represented by empty space. |
| **SSD (Solid-State Disk)** | A device used for data storage that utilizes memory chips instead of a revolving disk. |
| **Storage Virtualization** | An abstraction layer between users (servers and applications) and storage hardware that allows a common set of features to be applied to storage devices of different brands or types. |
| **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. |
| **TPC-C** | TPC (Transaction Processing Performance Council) Benchmark C is an industry standard OLTP (On-Line Transaction Processing) benchmark for comparing database performance. |

| Term | Definition |
|---|---|
| **VM Density** | The measure of the number of virtual machines that can be supported per physical server. The greater the VM density, the less infrastructure required to support a given number of virtual applications, and therefore, less cost per application. |
| **Write-Around** | A write caching policy where data is written only to primary storage, bypassing the cache, as well as evicting any old versions of that data from cache. |
| **Write-Back** | A write caching policy where data is written first to the cache and then mirrored to primary storage when I/O is available. The process of mirroring to primary storage is known as a Lazy Write. |
| **Write-Through** | A write caching policy where every write to the cache causes a synchronous write to primary storage. |