IBM High IOPS Adapter

User Guide - Windows

for Driver Release 2.2.3

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Introduction

Overview

Congratulations on your purchase of an IBM solid-state storage device. This guide explains how to install, troubleshoot and maintain your IBM High IOPS Adapter.

NOTE Throughout this manual, when you see a reference to an "IBM High IOPS Adapter," you may substitute your device.

"IBM High IOPS Duo Adapter" refers to devices with two memory modules, including the IBM High IOPS SD/MD Class SSD PCIe Adapters.

Designed around a revolutionary silicon-based storage architecture, the IBM High IOPS Adapter is the world's most advanced NAND flash storage device, with performance comparable to DRAM and storage capacity on par with today's hard disks—giving you the power to improve storage performance by orders of magnitude. The IBM High IOPS Adapter allows every computer to exceed the I/O performance of an enterprise SAN.

The IBM High IOPS Adapter is a data accelerator designed specifically to improve the bandwidth for I/O-bound applications. The IBM High IOPS Adapter is a no-compromise solution for the toughest computational challenges faced by data centers today, putting it in a league of its own.

About the ioMemory Virtual Storage Layer (VSL)

In addition to the hardware driver, the IBM High IOPS Adapter also includes the ioMemory Virtual Storage Layer (VSL). This is a hybrid of the RAM virtualization subsystem and the disk I/O subsystem, combining the best of both worlds. It appears like a disk to interface well with block-based applications and software. At the same time, it runs like RAM underneath to maximize performance. This provides the following game-changing benefits:

- Performance: The VSL offers direct and parallel access to multiple CPU cores, enabling near linear performance scaling, consistent performance across different read/write workloads, and low latency with minimal interrupts and context switching.
- Extensibility: The VSL enables flash-optimized software development, making each ioMemory module a flexible building block for building a flash-optimized data center.

Flash: Not Just Another Disk Drive

Whether on a PCIe card or in a drive bay, other SSD providers simply treat flash as another disk drive, putting it behind RAID controllers. This approach has the following limitations:

- Reduced performance and reliability
- Increased latency and complexity
- Limited potential for software development and optimization around the flash storage medium

With the ioMemory VSL, the IBM High IOPS Adapter avoids this limiting approach and provides a wealth of performance and optimization possibilities.

IBM High IOPS Adapters

IBM High IOPS Adapter Options

Feature Code	Option Part Number	Description
0096	46M0877	IBM 160GB High IOPS SS Class SSD PCIe Adapter
0097	46M0878	IBM 320GB High IOPS SD Class SSD PCIe Adapter
1649	46M0898	IBM 320GB High IOPS MS Class SSD PCIe Adapter
5985	81Y4519	640GB High IOPS MLC Duo Adapter for IBM System x
A1NE	81Y4535	320GB High IOPS SLC Adapter for IBM system x
A1ND	81Y4539	640GB High IOPS SLC Duo Adapter for IBM System x
A1NC	81Y4531	640GB High IOPS MLC Adapter for IBM System x
A1NB	81Y4527	1.28TB High IOPS MLC Duo Adapter for IBM System x

Memory Attributes

Feature Code	NAND Type [1]	Total Memory	Memory Modules	Module Capacity	Maximum writes per memory module	Maximum writes per card
0096	SLC	160GB	1	160GB	75PB	75PB
0097	SLC	320GB	2	160GB	75PB	150PB [2]
1649	MLC	320GB	1	320GB	4PB	4PB
5985	MLC	640GB	2	320GB	4PB	8PB [2]
A1NE	SLC	320GB	1	320GB	50PB	50PB
A1ND	SLC	640GB	2	320GB	50PB	100PB [2]
A1NC	MLC	640GB	1	640GB	10PB	10PB
A1NB	MLC	1.28TB	2	640GB	10PB	20PB [2]

1. Single Level Cell (SLC), Multi Level Cell (MLC).

2. Assumes uniform distribution of writes across both memory modules.

Performance Attributes

Feature Code	NAND Type [1]	Read Bandwidth	Write Bandwidth	IOPS [2]	Access Latency
0096	SLC	770 MB/s	750 MB/s	123,000	26 µs
0097	SLC	1.5 GB/s	1.5 GB/s	238,000	26 µs
1649	MLC	735 MB/s	510 MB/s	67,000	29 µs
5985	MLC	1.5 GB/s	1.0 GB/s	138,000	29 µs
A1NE	SLC	770 MB/s	790 MB/s	119,000	26 µs
A1ND	SLC	1.5 GB/s	1.5 GB/s	236,000	26 µs
A1NC	MLC	750 MB/s	550 MB/s	74,000	30 µs
A1NB	MLC	1.5 GB/s	1.1 GB/s	150,000	30 µs

1. Single Level Cell (SLC), Multi Level Cell (MLC).
2. IOPS with 75/25 mixed read/write and 512B packet sizes.

System Requirements

Supported Operating Systems

All operating systems must be 64-bit x86 architecture to support the IBM High IOPS Adapter. Running the latest Service Pack of a release is strongly recommended.

Attention UPGRADE WARNING: Version 2.2.3 and later of the driver software, including ioMemory VSL, are not backward-compatible with any driver version earlier than 2.2.3. When you install version 2.2.3 or later, you cannot revert to any driver version before 2.2.3.

Supported Windows Operating Systems

- Microsoft Windows 2003 Server 64-Bit (with SP2 or higher)
- Microsoft Windows 2008 Server 64-Bit, R1 (with SP2 or higher)
- Microsoft Windows 2008 Server 64-Bit, R2

NOTE IBM High IOPS Adapter devices cannot be used as hibernation devices.

NOTE To determine system and operating support for your High IOPS adapter, please see the latest updates on the IBM ServerProven website.
http://www.ibm.com/systems/info/x86servers/serverproven/compat/us/indexsp.html

Hardware Requirements

IBM High IOPS Adapter Requirements

The IBM High IOPS Adapter requires at least:

- A PCI-Express (PCIe) Gen1 x4 slot.
  The IBM High IOPS Adapter is a half-height, half-length, PCIe 1.1 x4 card and for full performance, it must reside in a PCIe slot where at least 4 lanes are electrically active.
- Adequate system cooling.
  To maximize the longevity and performance of an IBM High IOPS Adapter, we recommend at least 300 Linear Feet per Minute (LFM) of airflow through the system.

  In order to protect against thermal damage, the IBM High IOPS Adapter monitors the temperature of its onboard controller chip (This is reported by the *fio-status* command line utility as "Internal temperature").

  The IBM High IOPS Adapter will start throttling write performance once the controller temperature reaches 78°C. If the controller temperature continues to rise, the IBM High IOPS Adapter will shut down once the controller temperature reaches 85°C.

  NOTE If you experience write-performance throttling due to high temperatures, consult your server's documentation for details on increasing airflow within your system .
- Sufficient system memory (RAM).
  The amount of RAM the VSL requires varies according to the average block size written to the device. Using the average block size table below, you can estimate the amount of system memory needed. You can reduce worst-case memory use by formatting your IBM High IOPS Adapter with a 4K sector size and thereby force the average written block size to be 4K or greater.

  Note however, that for many systems, even those formatted with 512 byte sectors, actual memory utilization typically tracks with I/O operations on 4k or larger chunks of data.

At various block sizes, the following table shows the upper limit of RAM that may be required of your system for every 80 GB of IBM High IOPS Adapter storage space used.

Average Written Block Size (bytes)	RAM Usage (MB) per 80GB of storage space
8192	225
4096 (Most common)	425
2048	825
1024	1600
512	3175

For example, if your system is equipped with a IBM High IOPS Duo Adapter, formatted to use 4,096 byte sectors, your system may require as much as:
(425 MB of RAM / 80 GB) x (640 GB) = **3,400 MB (or around 3.32 GB) of system RAM** for use by the IBM High IOPS Duo Adapter driver.

IBM High IOPS Duo Adapter Requirements

In addition to the IBM High IOPS Duo Adapter cooling and RAM requirements given above, the IBM High IOPS Duo Adapter requires at least:

- A PCIe Gen1 x8 slot or a PCIe Gen2 x4 slot.
- A minimum of a *full-height*, half-length slot with a x8 physical connection. For systems with PCI 1.1, all 8 signaling lanes must be active for full IBM High IOPS Duo Adapter performance. For systems with PCIe 2.0, only 4 signaling lanes must be active for full performance.

Software Installation

NOTE Before installing the ioMemory VSL, make sure you have properly installed the IBM High IOPS Adapter device(s). Refer to the *IBM High IOPS Adapter Hardware User Guide* for full details.

The ioMemory VSL (driver) requires a 64-bit Windows operating system. See *System Requirements* in the introduction to this guide for a full list of supported operating systems.

Attention After you install this version of the ioMemory VSL, you may need to upgrade the firmware to enable operation. See *Upgrading the Firmware* later in the *Maintenance* section for more information

Attention UPGRADE WARNING: Version 2.2.3 and later of the driver software, including ioMemory VSL, are not backward-compatible with any driver version earlier than 2.2.3. When you install version 2.2.3 or later, you cannot revert to any driver version before 2.2.3.

New Installation

To install the IBM High IOPS Adapter software on a new system:

1. Complete all the installation steps given in the *IBM High IOPS Adapter Hardware User Guide*.
2. Log into your computer with an account that has Administrative rights.
3. Download the Windows IBM High IOPS Adapter installation program from *http://www.ibm.com/systems/support* and save it to your desktop or another convenient directory.
4. Run the IBM High IOPS Adapter installation program. The installation program presents a custom setup tree-view with options for installation.
5. Select a type of install from the drop-down menu, or select the checkbox for each component you want to enable. If you change your mind later, you can use the Repair option in Programs and Features, or Add or Remove Programs in the Control Panel.
   NOTE Mouse over a component in the tree view to see its description.
6. Click Next.
7. To select a different folder for the installation, browse to the folder and click **OK**. The default folder is `C:\Program Files\IBM High IOPS`.
   NOTE The uninstaller file is placed in the root of the IBM High IOPS folder (default install folder).
8. Follow the onscreen prompts to complete the install.
   NOTE You may be prompted to stop and start the Microsoft SNMP service at some point during the drivers and software installation.

You also need to install the 64-bit Java Runtime Environment (JRE) if it is not already installed (see *Installing the JRE* later in this section).

The Setup program:

- Creates a folder for the IBM High IOPS Adapter software components (the default path is `C:\Program Files\IBM High IOPS`).
- Installs and loads the ioMemory VSL. (This may require a restart.)
- Installs the IBM High IOPS Management Application administrator console (if selected).
- Creates an IBM High IOPS Management Application desktop icon (if IBM High IOPS Management Application was installed).
- Installs support for SNMP (if installed, and if Microsoft SNMP is installed and the SNMP service is running).

When the install program creates the ioMemory VSL folder on the drive, it also creates these sub-folders:

- `<driver version>\Driver` —for manual installations using Device Manager
- Firmware —contains the latest firmware
- Management —contains the IBM High IOPS Adapter management and configuration software
- SNMP —contains the SNMP components
- Utils —contains the IBM High IOPS Adapter command-line utilities

Installing the JRE

The 64-bit Java Runtime Environment (JRE) is required for the driver. To install the JRE,

1. Download the latest Java Runtime Environment from *http://www.java.com*.
2. Follow the instructions on *http://www.java.com* and in the JRE installer to complete the JRE installation.

NOTE If the JRE installation fails for some reason, contact IBM Support at *http://www.ibm.com/systems/support*

Existing IBM High IOPS Adapter Installation

Attention UPGRADE WARNING: Version 2.2 and later of the driver software, including ioMemory VSL, are not backward-compatible with any driver version earlier than 2.2. When you install version 2.2 or later, you cannot revert to any driver version before 2.2.

NOTE The IBM Setup (installation) program does not remove previous versions of the software. If a previous version is removed after the newest version is installed, the ioMemory VSL will no longer load after a restart. In that case, you need to a) run the Repair option in the Setup program, from **Programs and Features** (or **Add or Remove Programs**) in the **Control Panel**, and b) restart the computer.

To install the latest IBM High IOPS Adapter Windows software on an existing installation:

1. Complete the steps in the *Hardware Installation User Guide* if you also installed a new IBM High IOPS Adapter to the existing installation.
2. Review the *Release Notes and Errata* document for additional steps that may be needed to complete the installation.
3. Log in as Administrator or have Administrator rights.
4. Uninstall the existing IBM driver, utilities, etc., using **Programs** or **Add or Remove Programs** (depending on your version of Windows) in the **Control Panel**.
5. Restart the computer.
6. Download the IBM High IOPS Adapter Windows Setup Program from *http://www.ibm.com/systems/support* to your desktop or a convenient directory.
7. Run the Setup program. The installation program presents a custom setup tree-view with options for installation.
8. Select a type of install from the drop-down menu, or select the checkbox for each component you want to enable. If you change your mind later, you can use the Repair option in Programs and Features, or Add or Remove Programs in the Control Panel.

   NOTE Mouse over a component in the tree view to see its description.

9. Click Next.
10. To select a different folder for the installation, browse to the folder and click **OK**. The default folder is `C:\Program Files\IBM High IOPS`

    The uninstaller file is placed in the root of the IBM High IOPS folder (default install folder).

11. Follow the onscreen prompts to complete the install.
12. Choose **Reboot Now** on the finish screen of the installer.

Once the system reboots, check for an outdated firmware, as described below.

Outdated Firmware Check

To check for outdated or old firmware:

1. Launch IBM High IOPS Management Application and look for any devices that have a warning symbol.
2. Click on any devices with a warning symbol to ensure that the alert is from outdated firmware.
3. Select all devices requiring firmware update and use IBM High IOPS Management Application to update the firmware. Refer to the IBM High IOPS Management Application User Guide for details.

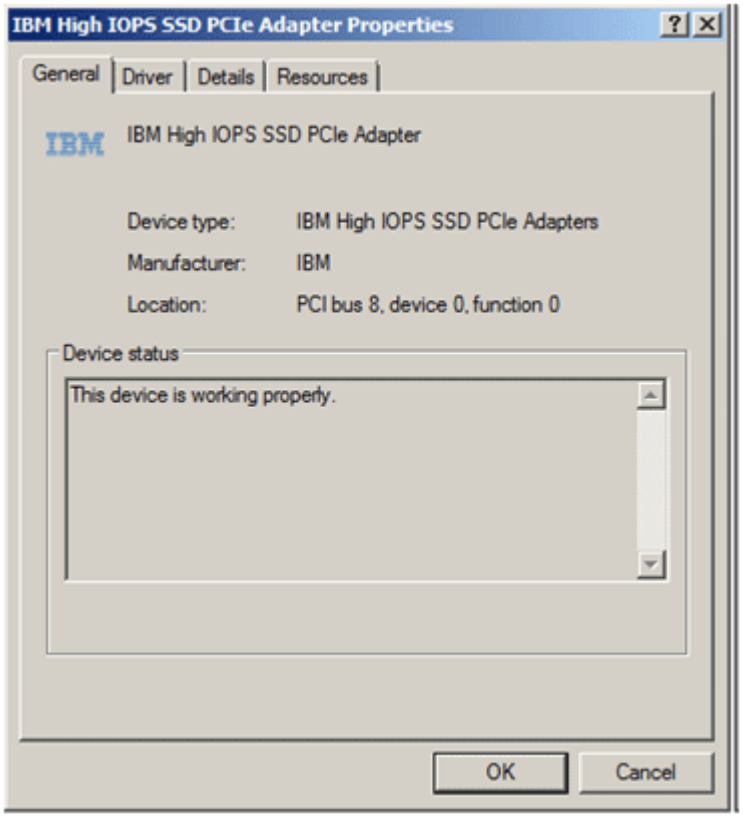
To check for old but not outdated firmware:

1. Find the name of the latest firmware version as noted included in the Release Notes.
2. Use IBM High IOPS Management Application to check each IBM High IOPS Adapter's firmware version against the latest.
3. Refer to the IBM High IOPS Management Application User Guide for instructions on how to update the firmware.

IBM High IOPS Adapter Naming

The IBM High IOPS Adapter receives a name and number as part of the install process for identification. The syntax is `fctx` where *x* is the number of the PCIe bus where you installed the IBM High IOPS Adapter. Use IBM High IOPS Management Application to view this bus number, or follow these steps:

1. Choose **Start** > **Control Panel** > **System** > **Hardware** > **Device Manager**.
2. Select **Fusion-io Devices**. (Select System Devices for pre-1.2.2 drivers.)
3. Click on your IBM High IOPS Adapter in the list. The Properties dialog box appears.



The Location field shows the PCIe bus number for your device (`fct13` in this case).

NOTE The system manufacturer assigns bus numbers, which can range from 0 on up. These numbers may or may not reflect the physical location of the bus. (For example, the second slot from the edge of the motherboard may be Bus 2, but it could also be Bus 16 or another arbitrary number. Checking Device Manager is one way to confirm the specific bus number for your installation. You can also use IBM High IOPS Management Application to view this number as well.)

Adding a File System

With the IBM High IOPS Adapter and ioMemory VSL installed, you can now use the Windows Disk Management utility to make your device available to applications. Typically, Windows detects the new device, initializes it, and displays it in Disk Management. You can then add partitions, format a volume, or create a RAID configuration on your IBM High IOPS Adapter using the standard Windows procedures (see the *Windows Disk Management Utility* documentation for more details).

If Windows does not initialize the device, you can do so manually. To initialize an IBM High IOPS Adapter,

1. Select **Start** > **Control Panel**.
2. Click **Administrative Tools**.
3. Click **Computer Management**.

4. Click **Disk Management** in the Storage section of the console tree.
5. Locate and right-click the IBM High IOPS Adapter in the list of storage devices on the right. (If the IBM High IOPS Adapter does not appear in the list, choose **Rescan Disks** from the Action menu. You may also need to restart your computer to display the IBM High IOPS Adapter in the list.)
6. Click **Initialize Disk**.

You can now use the Disk Management Utility to add a file system to your IBM High IOPS Adapter.

Creating a RAID Configuration

You can use your IBM High IOPS Adapter as part of a RAID configuration. To do so, you must format your IBM High IOPS Adapter as a dynamic volume. In turn, you can then use this dynamic volume to create multi-disk RAID configurations (spanned, striped, mirrored, or RAID 5).

For specific steps to perform a RAID configuration, see the Windows Disk Management Utility documentation for details.

NOTE If you are using RAID1/Mirroring and one device fails, be sure to run a *fio-format* on the replacement device (not the remaining good device) before rebuilding the RAID.

Using the IBM High IOPS Adapter as Swap

To safely use the IBM High IOPS Adapter as swap space, you need to use the `fio-config` utility to pass a special pre-allocation parameter.

For example:

```
fio-config -p FIO_PREALLOCATE_MEMORY 1072,4997,6710,10345
```

- Where 1072,4997,6710,10345 are serial numbers obtained from *fio-status*.

A 4K sector size format is required for swap—this reduces the driver memory footprint to reasonable levels.

NOTE Be sure to provide the serial numbers for the ioMemory Modules, not the adapter.

NOTE `FIO_PREALLOCATE_MEMORY` is necessary to have the drive usable as swap space. This will ensure the drive is crash-free during operation.

Attention You must have 400MB of free RAM per 80GB of IBM High IOPS Adapter capacity (formatted to 4KB block size) to enable the IBM High IOPS Adapter with pre-allocation enabled for use as swap. Attaching an IBM High IOPS Adapter, with pre-allocation enabled, without sufficient RAM may result in the loss of user processes and system instability.

NOTE The `FIO_PREALLOCATE_MEMORY` parameter is recognized by the ioMemory VSL at load time, but the requested memory is not actually allocated until the specified device is attached.

Understanding TRIM Support

With driver version 2.2.3, TRIM (also known as Discard) is enabled by default on many operating systems.

TRIM addresses an issue unique to solid-state storage. When a user deletes a file, the device does not recognize that it can reclaim the space. Instead the device assumes the data is valid.

TRIM is a feature on newer operating systems. It informs the device of logical sectors that no longer contain valid user data. This allows the wear-leveling software to reclaim that space (as reserve) to handle future write operations.

For a complete description of TRIM support on Windows, see the *TRIM Support* appendix.

Windows does not support TRIM with a RAID 5 configuration.

TRIM on Windows 7 and Windows Server 2008 R2

Windows7 and Windows Server 2008 R2 have built-in TRIM support. With these operating systems, ioMemory Devices work with Windows TRIM commands by default.

TRIM on Windows XP, Windows Server 2003, and Windows Server 2008 R1

Windows TRIM is not built into Windows XP, Windows Server 2003, or Windows Server 2008 R1. However, the Fusion-io TRIM service is installed with the Windows ioMemory VSL and it provides the necessary TRIM operations.

The Fusion-io TRIM service is enabled by default, unless it detects an operating system that supports TRIM natively (such as Windows Server 2008 R2). You can disable the Fusion-io TRIM service by using the `fio-trim-config` utility. See the *fio-trim-config* for more details.

Maintenance

The IBM High IOPS Adapter includes both software utilities for maintaining the device as well as external LED indicators to display its status. You can also install SNMP as a monitoring option.

IBM High IOPS Adapter LED Indicators

The IBM High IOPS Adapter includes three LEDs showing drive activity or error conditions.

Green	Yellow	Amber	Indicates	Notes
O	O	O	Power off	
O	O	●	Power on (Driver not loaded and card not attached)	Load driver and attach card
●	O	O	Power on (Driver loaded but card not attached)	Attach card
●	(Flashing) ●	O	Writing (Rate indicates volume of writes)	Can appear in combination with the Read LED
(Flashing) ●	O	O	Reading (Rate indicates volume of reads)	Can appear in combination with the Write LED
●	●	●	Location beacon	Also appears during a firmware update

Optional External Hard Drive LED

You can also use your computer's existing external HDD access light to indicate a combination of both the reads and writes executing on your IBM High IOPS Adapter. This provides a quick activity check for your device. (See the *Hardware Installation User Guide* for instructions on how to connect this LED to the IBM High IOPS Adapter pinout.)

SNMP Support

The IBM High IOPS Adapter Windows Setup program provides the option to install support for SNMP. If you choose this option, the Setup program installs the components and modifies the Registry for this support. You must also have the Microsoft Windows SNMP Service installed and running on the computer to receive reports.

Once you run the IBM High IOPS Adapter Windows Setup program, it will stop and start the Windows SNMP Service to recognize the IBM High IOPS Adapter's agent.

If you did not choose to install the SNMP support at Setup, and want to do so later, rerun the Setup program. Choose to install only the SNMP support from the list of items. Once the Setup program completes the install, it will stop and restart the Windows SNMP Service.

For details on using SNMP Test Mode, see *Appendix G- SNMP Test Mode and MIB Support*.

IBM High IOPS Management Application

Your IBM High IOPS Adapter software includes the ioManager. This application performs the most common operations you need to do with the IBM High IOPS Adapter. In addition, it provides a detailed information screen on each of your installed devices.

The IBM High IOPS Management Application can perform:

- Firmware upgrades
- Low-level formatting
- Attach and detach actions
- Device status and performance information

IBM High IOPS Management Application is installed with the default ioMemory VSL install process. Details on how to install and use IBM High IOPS Management Application appear in the *IBM High IOPS Management Application User Guide*.

Command-line Utilities

The Windows Setup package also includes several command-line utilities for managing your IBM High IOPS Adapter:

- `fio-attach`
- `fio-beacon`
- `fio-bugreport`
- `fio-config`
- `fio-detach`
- `fio-format`
- `fio-pci-check`
- `fio-status`
- `fio-trim-config`
- `fio-update-iodrive`

Each of these is described in detail in *Appendix D- Command-line Utilities*.

Uninstalling the ioMemory VSL

To uninstall the ioMemory VSL,

1. Go to **Start** > **Control Panel**.
2. Click **Administrative Tools**.
3. Click **Computer Management**.
4. Click **Device Manager** in the console tree at the left.
5. Expand the IBM Devices item.
6. Right-click the desired IBM High IOPS Adapter.
7. Click **Uninstall**.

Windows uninstalls the ioMemory VSL.

NOTE On Windows Server 2008 R2, Device Manager has an option to "Delete the driver software for this device." This option makes the uninstall much cleaner.

Upgrading the Windows Driver- Non-RAID Configuration

Attention Be sure to read the Release Notes and Errata document that comes with each new release as well as these installation instructions to ensure no loss of data when performing upgrades.

To upgrade the Windows driver in a non-RAID configuration:

1. Follow the steps in Uninstalling the ioMemory VSL earlier.
2. Download the latest driver from *http://www.ibm.com/systems/support*.
3. Either unzip or run the Windows package to copy the files to a convenient directory.
4. Go to **Start** > **Control Panel**.
5. Click **Administrative Tools**.
6. Click **Computer Management**.
7. Click **Device Manager** in the console tree at the left.
8. Expand the IBM Devices item. (Select **System Devices** with pre-1.2.2 drivers.)
9. Right-click the desired device.
10. Click **Update ioMemory VSL Software**. If needed, refer to *Appendix B- Manual Installation* for details on the remaining steps to install the updated ioMemory VSL.

Windows now detects your device with the upgraded ioMemory VSL.

Upgrading the Windows Driver with a RAID Configuration

Attention Be sure to read the Release Notes and Errata document that comes with each new release as well as these installation instructions to ensure no loss of data when performing upgrades.

To upgrade the IBM High IOPS Adapter Windows driver with a RAID configuration in place:

1. Shut down any applications that are accessing the IBM High IOPS Adapters.
2. Open the IBM High IOPS Adapter Utilities folder. (The default location for release 2.2.3 is `C:\Program Files\IBM High IOPS\Utils`.)
3. Double-click the `AutoAttachDisable.reg` file to add a key to the Windows registry. Your IBM High IOPS Adapter now will not automatically attach the next time you restart the computer.
4. Uninstall the IBM High IOPS software in **Windows Add/Remove Programs**.
5. Restart the computer.
6. Download the latest ioMemory VSL driver package from *http://www.ibm.com/systems/support*.

7. Unzip and install the ioMemory VSL driver package. While finishing installation, click the "No" button to select a manual restart.
8. Open the IBM High IOPS Adapter Utilities folder. (The default location for release 2.1 is `C:\Program Files\IBM High IOPS\Utils`.)
9. Double-click the `AutoAttachEnable.reg` file to reset the key in the Windows registry. Your IBM High IOPS Adapter now will automatically attach the next time you restart the computer.
10. Update the firmware of the IBM High IOPS Adapters. Follow the steps in Upgrading the Firmware, which is the next section.

NOTE Restart the computer after the firmware upgrade is complete. The Check Utility will run at next boot.

Windows now detects your IBM High IOPS Adapters in the RAID configuration with the upgraded driver.

Upgrading the Firmware

Attention You should upgrade the firmware only if the *System Event Log* reports out-of-date firmware, or if instructed to do so by IBM Customer Support or the Release Notes and Errata document.

Viewing the Firmware Version

The firmware version can be found in the Windows Event Log. It is reported by IBM High IOPS Management Application and the `fio-status` command-line utility. For more details, see the IBM High IOPS Management Application *User Guide* or `fio-status` in *Appendix D- Command-line Utilities*.

NOTE Only versions 1.2.4 and higher can be upgraded to version 2.2.3. If your version is older than 1.2.4, it must be upgraded to 1.2.4 before advancing to a newer version.

Performing the Upgrade

Attention You should back up the data on the IBM High IOPS Adapter prior to any upgrade as a precaution.

To perform the upgrade, use either IBM High IOPS Management Application(see the IBM High IOPS Management Application *User Guide* or the `fio-update-iodrive` command-line utility.

Defragmentation

The IBM High IOPS Adapter does not need to be defragmented. Some versions of Windows, however, run defragmentation as a scheduled task automatically. If necessary, you should turn off automatic defragmentation.

Unmanaged Shutdown Issues

Unmanaged shutdown due to power loss or other circumstances can force the IBM High IOPS Adapter to perform a consistency check during restart. This may take several minutes or more to complete and is shown by a progress percentage during Windows startup.

You can cancel this consistency check by pressing Esc during the first 15 seconds after the "Fusion-io Consistency Check" message appears at the prompt. If you choose to cancel the check, however, the IBM High IOPS Adapter(s) will remain unavailable to users until the check is done. (You can perform this check later on using ioManager's Attach function).

Although data written to the IBM High IOPS Adapter will not be lost due to unmanaged shutdowns, important data structures may not have been properly committed to the drive. This consistency check repairs these data structures.

Disabling Auto-Attach

The ioMemory VSL defaults to automatically attach (auto-attach) all installed IBM High IOPS Adapters to the operating system. (If the IBM High IOPS Adapter does not attach, it will not be available to applications or users.) You can disable auto-attach to assist in troubleshooting or diagnostics.

To disable auto-attach:

1. Open the IBM High IOPS Adapter Utilities folder. (The default location is `C:\Program Files\IBM High IOPS\Utils`).
2. Double-click the autoattachdisable.reg file.
3. If necessary, confirm that you want to modify the registry.

This creates a new DWORD parameter registry key called `AutoAttach` in:

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\fiodrive\Parameters
```

Your IBM High IOPS Adapter now will not automatically attach the next time you restart the computer.

When you finish troubleshooting the ioMemory VSL issue, use the IBM High IOPS Management Application to attach the IBM High IOPS Adapter(s) and make them available to Windows.

Enabling Auto-Attach

To re-enable auto-attach after disabling it with the `autoattachenable.reg` file:

1. Open the IBM High IOPS Adapter Utilities folder. (The default location is `C:\Program Files\IBM High IOPS\Utils`).
2. Double-click the `autoattachenable.reg` file.
3. If necessary, confirm that you want to modify the registry.

This resets the AutoAttach parameter in the Registry. The next time you restart your Windows system, your IBM High IOPS Adapter will automatically attach.

Appendix A- Troubleshooting Event Log Messages

The Windows System Event Log displays the following messages concerning the IBM High IOPS Adapter: Informational, Warnings, and Errors.

NOTE Each IBM High IOPS Adapter is numbered from 0 upwards. These numbers reflect the PCIe bus number where you installed the device. Use the `fio-status` utility or IBM High IOPS management Application to view this number for your device.

To open the Windows Event Viewer,

1. Click **Start**.
2. Right-click **Computer** and choose **Manage** from the drop-down list.
3. Expand **System Tools**.
4. Expand **Event Viewer**.
5. Expand **Windows Logs**.
6. Select **System**.

The following are common Event Log error messages, along with suggested solutions:

Message	Suggested Solution
Error: ioDrive(x) firmware is too old. The firmware must be updated.	Use the firmware upgrade instructions in the *Maintenance* section to update the firmware.
Error: ioDrive initialization failed with error code `0xerrorcode` (where `errorcode` is a number that may vary)	1. Reinstall the Windows ioMemory VSL. 2. Remove and reseat the device. 3. Remove and insert the IBM High IOPS Adapter in a different PCIe slot
Error: ioDrive was not attached. Use the `fio-attach` utility to rebuild the drive.	This error may appear after an unmanaged shutdown. You can use either the fio-attach command-line utility or IBM High IOPS management Application to re-attach the IBM High IOPS Adapter. This attach process may take up to ten minutes as the utility performs a consistency check on the drive(s).

Warning: ioDrive was not loaded because auto-attach is disabled.	The IBM High IOPS Adapter must attach to the Windows operating system to be available to users and applications. (This attach normally occurs at boot time.) As part of this attach process, the ioMemory VSL checks to see if there is an AutoAttach parameter in the Windows registry. If you create this Registry parameter to disable auto-attach, the attach operation does not complete. To attach an unattached IBM High IOPS Adapter, 1. Run IBM High IOPS management Application. 2. Select your unattached IBM High IOPS Adapter from the Device Tree. 3. Click Attach. 4. Confirm the Attach operation. Your IBM High IOPS Adapter now attaches to the Windows operating system. To re-enable Auto-Attach at boot time, refer to *Enabling Auto-Attach* in the Maintenance section.

Appendix B- Manual Installation

The Windows Setup program should install your needed ioMemory VSL and software. However, if the ioMemory VSL does not install, you can perform a manual install (or upgrade) using the steps below for Windows Server 2003 or Windows Server 2008.

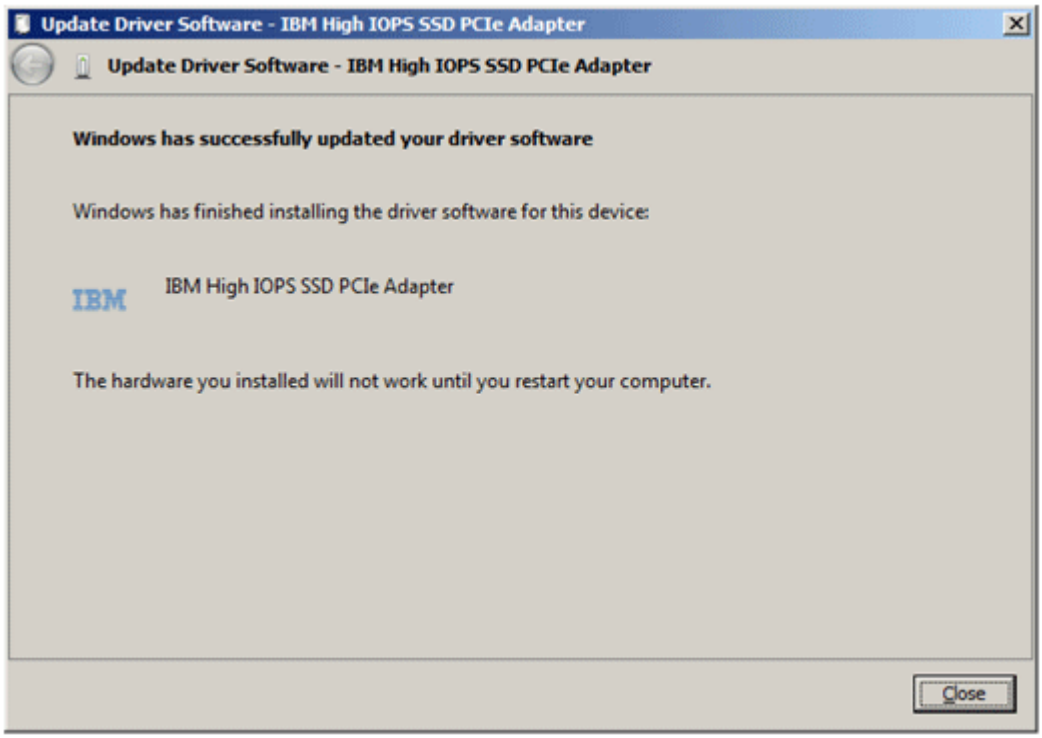
Manual Installation on Windows Server 2003

The Windows Driver Wizard automatically detects the new IBM High IOPS Adapter and start to locate its ioMemory VSL after you restart the system. First, Windows asks you to locate the software driver:

1. If you have not done so, download and run the IBM High IOPS Adapter Windows Setup program from *http://www.ibm.com/systems/support*.
2. Return to the *Update Driver* dialog.
3. Click **Browse my computer for driver software**. The Setup program asks you for a path to search.
4. Click **Browse** next to the path field. Windows displays a file dialog.

5. Select the folder with the ioMemory VSL (the default is `C:\Program Files\IBM High IOPS\2.2.3\drivers`).
6. Click **OK**.

Windows finds the correct driver and installs the device software. When the ioMemory VSL install completes, Windows displays this message:



Now you can view the ioMemory VSL in device manager.

If you need to update your firmware, review the Outdated Firmware Check and Upgrading the IBM High IOPS Adapter Firmware sections of this guide.

Manual Install on Windows Server 2008

The Windows Driver Wizard automatically detects the new IBM High IOPS Adapter and starts to locate its driver after you restart the system. First, Windows ask you to locate the software driver.

1. Click **Browse** next to the path field. Windows displays a file dialog.
2. Select the folder with the IBM High IOPS Adapter driver (the default is `C:\Program Files\IBM High IOPS\2.2.3\drivers`).
3. Click **OK**.

4. Click **Next**.

   Windows finds the correct driver and installs the device software. When the driver installation completes,

5. Restart the computer.
6. Proceed to the *Outdated Firmware Check* section to continue.

Appendix C- Command-line Utilities

The Windows Setup package installs various utilities into the `C:\Program Files\IBM High IOPS\2.2.3\Utils` folder, described in the table below.

Utility	Purpose
`fio-attach`	Makes an IBM High IOPS Adapter available to the OS
`fio-beacon`	Lights the IBM High IOPS Adapter's external LEDs
`fio-bugreport`	Prepares a detailed report for use in troubleshooting problems
`fio-detach`	Temporarily removes an IBM High IOPS Adapter from OS access
`fio-format`	Used to perform a low-level format of an IBM High IOPS Adapter
`fio-pci-check`	Checks for errors on the PCI bus tree, specifically for IBM High IOPS Adapters
`fio-status`	Displays information about the device
`fio-trim-config`	Enables or disables the Trim feature
`fio-update-iodrive`	Updates the IBM High IOPS Adapter's firmware

NOTE **Administrator Rights**: The command-line utilities require administrator rights in order to run under Windows (right-click the **Command Prompt** menu item and select **Run as administrator**.)

NOTE To run these utilities from a command line, you must either change directories to the directory that contains them (by default, `C:\Program Files\IBM High IOPS\<driver-version>\Utils`) or add that directory to your system path. See the documentation for your version of Windows for information about adding a directory to the system path.

NOTE There are `-h` (Help) and `-v` (Version) options for all of the utilities. Also, `-h` and `-v` cause the utility to exit after displaying the information.

fio-attach

Description

Attaches the IBM High IOPS Adapter and makes it available to Windows. You can then partition the IBM High IOPS Adapter, or set it up as part of a RAID array, using the Windows Disk Management utility. This command displays a progress bar and percentage as it completes the attach process.

NOTE In most cases, the ioMemory VSL automatically attaches the device on load and does a scan. You only need to run fio-attach if you ran fio-detach or if you set the IBM High IOPS Adapter's auto_attach parameter to

0.

NOTE If multiple IBM High IOPS Adapter devices are installed in a computer, they will attach in a parallel fashion. If the ioMemory VSL is in minimal mode, auto-attach is disabled.

Syntax

```
fio-attach <device> [-q, -h, -v]
```

where `<device>` is the name given by the ioMemory VSL to your device. This name is `/dev/fctx`, where *x* indicates the PCIe bus number where you installed the IBM High IOPS Adapter. (For example, the name `/dev/fct4` refers to the IBM High IOPS Adapter installed in PCIe Bus 4 in your Windows system. Use ioManager or `fio-status` to view this bus number.)

You can specify multiple IBM High IOPS Adapters. For example, `/dev/fct /dev/fct2` indicates the IBM High IOPS Adapters installed in PCIe Buses 1 and 2 in your Windows system.

Option	Description
`-q`	Quiet: disables the display of the progress bar and percentage.

fio-beacon

Description

Lights the IBM High IOPS Adapter's three LEDs to locate the device. You should first detach the IBM High IOPS Adapter and then run `fio-beacon`.

NOTE This utility always turns the LEDs on, unless you specifically use the `-0` option.

Syntax

```
fio-beacon <device> [-0, -1, -p, -h, -v]
```

where `<device>` is the name given by the ioMemory VSL to your device. This name is `/dev/fctx`, where *x* indicates the device number.

Options	Description
`-0`	Off: Turns off the three LEDs
`-1`	On (default): Lights the three LEDs
`-p`	Prints the PCI bus ID of the device at <device> to standard output. Usage and error information may be written to standard output rather than to standard error.

fio-bugreport

Description

Prepares a detailed report of the device for use in troubleshooting problems.

Syntax

```
fio-bugreport
```

Notes

This utility captures the current state of the device. When a performance or stability problem occurs with the device, run the `fio-bugreport` utility, contact *http://www.ibm.com/systems/support*, and provide the utility output for assistance in troubleshooting.

`fio-bugreport` runs several information-gathering utilities and combines the resulting data into a text file. The results are saved in the `utils` directory (default installation path is `C:\Program Files\IBM High IOPS\2.2.3\Utils\`) in a `.cab` file that indicates the date and time the utility was run.

You are then prompted to send an e-mail describing the problem to support@fusionio.com with the bug report file attached.

NOTE Disregard the message about contacting Fusion-io Support; instead, contact *http://www.ibm.com/systems/support*.

Sample Output

```
C:\Users\username>"\Program Files\IBM High
IOPS\2.2.3\Utils\fio-bugreport.exe"
Generating bug report. Please wait, this may take a while...
-----------------------------------------
Gathering all Windows Event Logs...DONE
Gathering Fusion-io Windows Event Logs...DONE
Gathering System Information...DONE
Running fio utilities...DONE
Compressing to CAB file...DONE
Bug report has successfully been created:
fio-bugreport-20100222_192621.cab.
Please e-mail this file to support@fusionio.com
```

For example, the filename for a bug report file named `fiobugreport-20090921.192621.cab` indicates the following:

- Date (20090921)
- Time (192621, or 19:26:21)

fio-detach

Description

Detaches the IBM High IOPS Adapter and removes the corresponding `fctx` IBM High IOPS Adapter block device from the OS. The `fio-detach` utility waits until the device completes all read/write activity before executing the detach operation. By default, the command also displays a progress bar and percentage as it completes the detach.

Attention Before using this utility, ensure that the device you want to detach is not currently mounted and in use.

Syntax

```
fio-detach <device> [-f, -i, -q, -h, -v]
```

where `<device>` is the name given by the ioMemory VSL to your device. This name is `/dev/fctx`, where *x* indicates the device number. (The number reflects the PCIe bus for the IBM High IOPS Adapter.) For example, the name `/dev/fct4` refers to the IBM High IOPS Adapter installed in PCIe Bus 4 in your system. (Use `fio-status` to view this number.)

You can specify multiple IBM High IOPS Adapters. For example, `/dev/fct1 /dev/fct2` indicates the IBM High IOPS Adapters installed in PCIe Buses 1 and 2 in your Windows system.

Options	Description
`-f`	Force: Causes an immediate detach (does not save metadata). Attention Although the `-f` (force) option causes the IBM High IOPS Adapter to detach, even in a RAID setup, it is strongly recommended to take the drives/volume offline using the Windows Disk Management plug-in, then perform the detach. Forcing the detach may result in loss of data.
`-i`	Immediate: Causes a forced immediate detach (does not save metadata). This will fail if the device is in use by the OS.
`-q`	Quiet: Disables the display of the progress bar and percentage.

Notes

With version 2.0 and later of the driver, attempting to detach an IBM High IOPS Adapter may fail with an error indicating that the device is busy. This typically may occur if the IBM High IOPS Adapter is part of a software RAID (0,1,5) volume. Windows refuses the request to detach the drive associated with the IBM High IOPS Adapter because it is part of a RAID volume and may cause the volume to fail. This does not occur with simple volumes (such as a single IBM High IOPS Adapter). To detach in this case, take the volume offline using the Disk Management MMC plug-in application.

fio-format

Description

NOTE The IBM High IOPS Adapter ships pre-formatted, so `fio-format` is generally not required except to change the logical size or block size of the device, or to erase user data on the drive.

Performs a low-level format of the board. By default, `fio-format` displays a progress-percentage indicator as it runs.

Attention Use this utility with care, as it deletes all user information on the board.

NOTE Using a larger block (sector) size, such as 4096 bytes, can significantly reduce worst-case IBM High IOPS Adapter host memory consumption; however, some applications are not compatible with non-512-byte sector sizes.

NOTE If you do not include the `-s` or `-o` options, the drive size defaults to the advertised capacity. If used, the `-s` and `-o` options must include the size or percentage indicators.

Syntax

```
fio-format <device> [-b <size>, -f, -o <size B|K|M|G|T|%>, -q, -s
<device-size>, -y, -h, -v]
```

where `<device>` is the name given by the ioMemory VSL to your device. This name is `/dev/fctx`, where *x* indicates the PCIe bus number where you installed the IBM High IOPS Adapter. (For example, the name `/dev/fct4` refers to the IBM High IOPS Adapter installed in PCIe Bus 4 in your Windows system. Use ioManager or `fio-status` to view this bus number.)

Options	Description
`-b <size B|K>`	Set the block (sector) size, in bytes or KiBytes (base 2). The default is 512 bytes. For example: `-b 512B` or `-b 4K` (`B` in `512B` is optional).
`-f`	Force the format size, bypassing normal checks and warnings. This option may be needed in rare situations when `fio-format` does not proceed properly. (The "Are you sure?" prompt still appears unless you use the `-y` option.) This option can only be used with the `-o` option.
`-q`	Quiet mode: Disable the display of the progress-percentage indicator.

`-s <size B|K|M|G|T|%>`	Set the device capacity as a specific size (in TB, GB, or MB) or as a percentage of the advertised capacity: • `T` Number of terabytes (TB) to format • `G` Number of gigabytes (GB) to format • `M` Number of megabytes (MB) to format • `%` Percentage, such as 70% (the percent sign must be included)
`-o <size B|K|M|G|T|%>`	Over-format the device size (to greater than the advertised capacity), where the maximum size equals the maximum physical capacity. If a percentage is used, it corresponds to the maximum physical capacity of the device. (Size is required for the `-o` option; see the `-s` option above for size indicator descriptions.) Attention Before you use this option, please discuss your use case with IBM support by contacting *http://www.ibm.com/systems/support*.
`-y`	Auto-answer "yes" to all queries from the application (bypass prompts).

fio-pci-check

Description

Checks for errors on the PCI bus tree, specifically for IBM High IOPS Adapters. This utility displays the current status of each IBM High IOPS Adapter. It also prints the standard PCI Express error information and resets the state.

NOTE It is perfectly normal to see a few errors (perhaps as many as five) when fio-pci-check is initially run. Subsequent runs should reveal only one or two errors during several hours of operation.

Attention The ioMemory VSL *must* be loaded to run this utility. Some PCI errors cannot be reset in Windows.

Syntax

```
fio-pci-check [-d <value>, -f, -i, -r, -v, -y, -h]
```

Options	Description
`-d <value>`	1 = Disable the link; 0 = bring the link up
`-f`	Scan every device in the system.
`-r`	Force the link to retrain.
`-v`	Verbose: Print extra data about the hardware.
`-y`	"Yes" is forced when the user is asked to continue.

fio-status

Description

Provides detailed information about the installed devices. This utility operates on either `fctx` or `fiox` devices. The utility depends on running as root and having the ioMemory VSL loaded. If no ioMemory VSL is loaded, a smaller set of status information is returned.

`fio-status` provides alerts for certain error modes, such as a minimal-mode, read-only mode, and write-reduced mode, describing what is causing the condition.

Syntax

```
fio-status <device> [-a, -c, -d, -fk, -h, -v]
```

where `<device>` is the name given by the ioMemory VSL to your device. This name is `/dev/fctx`, where *x* indicates the device number. (The number reflects the PCIe bus for the IBM High IOPS Adapter.) For example, the name `/dev/fct4` refers to the IBM High IOPS Adapter installed in PCIe Bus 4 in your system. (fio-status displays this number.)

If `<dev>` is not specified, `fio-status` displays information for all cards in the system. If the ioMemory VSL is not loaded, this parameter is ignored.

Options	Description
`-c`	Count: Report only the number of IBM High IOPS Adapters installed.
`-d`	Show basic information set plus the total amount of data read and written (lifetime data volumes). This option is not necessary when the -a option is used.
`-fk`	Format key: Force alternate <"key=value"> format output, which may be easier for scripts and parsing programs to read.
`-a`	Print all available information for each device.

Basic Information: If no options are used, `fio-status` reports the following basic information:

- Number and type of cards installed in the system
- Driver version
  Adapter information:
- Adapter type
- Product number
- PCI power limit threshold (if available)

- Connected ioMemory modules
  Block device information:
- Attach status
- Product name
- Product number
- Serial number
- Firmware version
- Size of the device, out of total capacity
- Internal temperature (average and maximum, since ioMemory VSL load) in degrees Centigrade
- Health status: healthy, nearing wearout, write-reduced or read-only
- Reserve capacity (percentage)
- Warning capacity threshold (percentage)

Data Volume Information: If the -d option is used, the following data volume information is reported *in addition* to the basic information:

- Physical bytes written
- Physical bytes read

All Information: If the `-a` option is used, all information is printed, which includes the following information *in addition* to basic and data volume information:

Adapter information:

- Manufacturer number
- Date of manufacture
- Power loss protection status
- PCIe bus voltage (avg, min, max)
- PCIe bus current (avg, max)
- PCIe power limit threshold (watts)
- PCIe slot available power (watts)
- PCIe negotiated link information (lanes and throughput)

Block device information:

- Part number

- Manufacturer's code
- Manufacturing date
- PCIe slot number
- Vendor and sub-vendor information
- Size of the device, out of total capacity
- Format status and sector information (if device is attached)
- FPGA ID and Low-level format GUID
- PCIe slot available power
- PCIe negotiated link information
- Card temperature, in degrees Centigrade
- Internal voltage, avg. and max.
- Auxiliary voltage:, avg. and max.
- Percentage of good blocks, data and metadata
- Lifetime data volume statistics

Error Mode Information: If the ioMemory VSL is in minimal mode, read-only mode, or write-reduced mode when `fio-status` is run, the following differences occur in the output:

- Attach status is "Status unknown: Driver is in MINIMAL MODE:"
- The reason for the minimal mode state is displayed (such as "Firmware is out of date. Update firmware.")
- "Geometry and capacity information not available." is displayed.
- No media health information is displayed.

fio-trim-config

Description

Enables or disables the Trim feature (Windows service), which reclaims available space from the file system. It is generally recommended that Trim be enabled for best performance. Trim is enabled by default. Running this utility with no options displays the current Trim status.

NOTE This utility affects all IBM High IOPS Adapter devices in the system. You cannot enable or disable Trim for only selected devices. Settings take place immediately, there is no need to reboot the system or the device.

Syntax

```
fio-trim-config [-d, -e, -v, -h]
```

Options	Description
`-d`	Disable Trim on this computer.
`-e`	(Default) Enable Trim on this computer.

fio-update-iodrive

Attention You should upgrade the firmware only if the *System Event Log* reports out-of-date firmware, or if instructed to do so by IBM Customer Support or the Release Notes and Errata document.

Description

Updates the IBM High IOPS Adapter's firmware. This utility scans the PCIe bus for all IBM High IOPS Adapters and updates them. A progress bar and percentage are shown for each drive as the update completes.

To update one or more specific drives:

- If the ioMemory VSL is loaded, use the `-d` option with the device number.

Attention It is extremely important that the power not be turned off during a firmware upgrade, as this could cause device failure. If a UPS is not already in place, consider adding one to the system prior to performing a firmware upgrade.

Attention Note that when running multiple upgrades in sequence (such as going from 1.2.1 to 1.2.4 to 2.2.3), it is critical to load the driver after each firmware upgrade step. Otherwise the on-drive format will not be changed, and there will be data loss.

Attention The default action (without using the `-d` or `-s` option) is to upgrade all IBM High IOPS Adapter devices with the firmware contained in the `<iodrive_version.fff>` file. Confirm that all devices need the upgrade prior to running the update. If in doubt, use the `-p` (Pretend) option to view the possible results of the update.

Attention You must detach all IBM High IOPS Adapter devices before updating the firmware.

Attention UPGRADE WARNING: Version 2.2.3 and later of the driver software, including ioMemory VSL, are not backward-compatible with any driver version earlier than 2.2.3. When you install version 2.2.3 or later, you cannot revert to any driver version before 2.2.3.

NOTE If you receive an error message when updating the firmware that instructs you to update the midprom information, contact Customer Support.

Syntax

```
fio-update-iodrive <iodrive_version.fff> [-d, -f, -l, -p, -q, -s, -h, -v]
```

where `<iodrive_version.fff>` is the path and firmware archive file provided by IBM. The default path is `C:\Program Files\IBM High IOPS\2.2.3\Firmware`. This parameter is required.

Options	Description

`-d`	Updates the specified devices (by `fctx`, where *x* is the number of the device shown in `fio-status`). If this option is not specified, all devices are updated. Attention Use the `-d` or `-s` options with care, as updating the wrong IBM High IOPS Adapter could damage your device.
`-f`	Force upgrade (used primarily to downgrade to an earlier firmware version). If the ioMemory VSL is not loaded, this option also requires the `-d` option. Attention Use the -f option with care, as it could damage your card.
`-l`	List the firmware available in the archive.
`-p`	Pretend: Shows what updates would be done. However, the actual firmware is not modified.
`-q`	Runs the update process without displaying the progress bar or percentage.
`-s`	Updates the devices in the specified slots using '*' as a wildcard for devices. The slots are identified in the following PCIe format: `[[[[<domain>]:]<bus>]:][<slot>][.[<func>]]`

All three external LED indicators light up during the update process.

Appendix D- Trim Support

Introduction

Trim is used to address a unique property of solid-state drives. The problem stems from the fact that when a user deletes a file, the drive that contains the file does not recognize that it can reclaim that space. Instead, the drive assumes the data is valid until the system informs the drive it can overwrite that data. This is fine for a normal hard drive, because you can continually write to the same sector of the drive without significant degradation. A solid-state drive, on the other hand, writes to different flash memory areas when the same logical sector is written to.

Because of the way flash memory handles writes, having a full SSD can cause significant reduction in write throughput. Currently available storage stacks and file systems were not designed with this caveat in mind. The SSD software must assume that all sectors contain valid data, and therefore always treat the drive as full. In reality, a file system does not normally contain a full drive's worth of data.

Trim is an enhancement to existing file systems that informs the SSD software of logical sectors that do not contain valid user data. Trim retrieves this information from a file system when a file has been deleted, and it informs the drive that it can reclaim the space held by that file. This allows the wear-leveling software to reclaim that space as reserve to handle future write operations.

In order for Trim to do this, it continually runs in the background and monitors the file system(s) being used on IBM High IOPS Adapter. The process is meant to be "lazy" so as not to noticeably impact the performance of the computer.

Platforms

The Trim feature is available on devices for Windows operating systems starting with Windows Server 2003.

NOTE Trim capabilities have been built into Windows Server 2008 R2 operating systems. IBM High IOPS Adapter support Windows Trim, which means that IBM High IOPS Adapter Trim is unnecessary under Windows Server 2008 R2, and it will not run when this operating systems is present. No system changes are needed. The Trim service will automatically shut off if it detects a Windows Server 2008 R2 operating system.

Using Trim

Trim runs quietly in the background as a Windows Service a few minutes after the computer is booted, so as not to slow down the boot process. However, you can fine-tune Trim by using the configurable settings described below.

Starting and Stopping Trim

To globally start or stop the Trim service through IBM High IOPS Management Application,

1. In the upper-left corner of the console screen, click the button to toggle the state of the service (either running or stopped).

To start or stop the Trim service through the Windows Services Manager,

1. Search for "Fusion-io Trim Service".
2. Click "Start service" or "Stop service".

Note that stopping the service only stops it for that session. Restarting the computer causes Trim to run again.

Enabling Trim

To enable the trim service,

1. Open a registry editor.
2. Navigate to

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\fiodrive\Parameters
```

3. Add the `TrimEnabled` value as a `DWORD` (see the description below).Stop the Trim service (by either of the two previously mentioned methods) and restart it; or, restart the computer.

> The *`fio-trim-config`* utility will set the `TrimEnabled` flag for you and does not require a reboot of your system or a manual restart of the service for the changes to take effect. This utility is the preferred method of enabling and disabling Trim as it prevents the user from having to edit the registry themselves which has the potential to produce undesired consequences.

`TrimEnabled`

This registry value controls whether Trim will run, regardless of the user starting and stopping Trim through either of the two previously mentioned methods. If this value is present and set to 1, then Trim will run as normal (unless you have stopped the service using the previously mentioned methods). If this value is set to 0 before attempting to start the Trim service, the service will not run until the value is changed to 1 (or removed from the registry) and the service manually restarted. If this value is not present, Trim assumes it should run unless you stop it. Note that this value persists across sessions, so if you restart the computer and set this value to 0, Trim will not run when the computer starts again.

Controlling Trim Aggressiveness

You can control how aggressive the Trim service is. The default settings for Trim minimize impact on computer performance while allowing the device(s) to perform at their best. However, if a drive is being used with a write-intensive application, then you may want Trim to be more aggressive. To do this, you'll need to add a few registry entries.

1. Open a registry editor.
2. Navigate to

   ```
   HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\fiodrive\Parameters
   ```

3. Add the `TrimTimeDelayInSeconds` value as a `DWORD` (see the description below).
4. Add the `BitmapRetrievalDelayInMilliseconds` value as a `DWORD` (see the description below).
5. Stop the Trim service (by either of the two previously mentioned methods) and restart it; or, restart the computer.

`TrimTimeDelayInSeconds`

This registry value controls how quickly Trim will start running again after it has finished processing all the volumes on a system. For example, if this is set to 600 (10 minutes in seconds), then Trim will process all the volumes on a system, sleep for 10 minutes, and then process the volumes again and continue this cycle. This value can be any number between zero and 4,294,967,295. If this value is not set or present in the registry, then Trim assumes a default of 900 seconds (or 15 minutes).

`BitmapRetrievalDelayInMilliseconds`

This value most affects how much impact Trim will have on the CPU. It currently defaults to 25 milliseconds but can be any number between zero (most aggressive) and 4,294,967,295 (pretty much useless).

Configurations

Trim can be used with the following configurations and features:

- RAID volumes (mirrored, spanned, or striped). Note: RAID 5 (striped with parity) is not currently supported.
- Simple volumes (no RAID)
- Any combination of the above RAID levels across multiple devices, so long as there is at least one IBM High IOPS Adapter in the RAID set.
- Multiple partitions on the same IBM High IOPS Adapter
- NTFS and FAT32 file systems

- Volumes with mount points (no <drive letter> is defined)
- Compressed volumes
- Different cluster sizes, packet sizes, and sector sizes
- Extended and shrunk volumes

Appendix E- Monitoring the Health of Devices

This section describes how the health of IBM High IOPS Adapter devices can be measured and monitored in order to safeguard data and prolong device lifetime.

NAND Flash and Component Failure

An IBM High IOPS Adapter product is a highly fault-tolerant storage subsystem that provides many levels of protection against component failure and the loss nature of solid-state storage. As in all storage subsystems, component failures may occur.

By properly selecting NAND flash media for the hosted application and proactively monitoring device age and health, you can ensure reliable performance over the intended product life.

Health Metrics

The ioMemory VSL manages block retirement using pre-determined retirement thresholds. The ioManager and the `fio-status` utilities show a health indicator that starts at 100 and counts down to 0. As certain thresholds are crossed, various actions are taken.

At the 10% healthy threshold, a one-time warning is issued. See the 'monitoring' section below for methods for capturing this alarm event.

At 0%, the device is considered unhealthy. It enters *write-reduced* mode, which somewhat prolongs its lifespan so data can be safely migrated off. In this state the IBM High IOPS Adapter behaves normally, except for the reduced write performance.

After the 0% threshold, the device enters *read-only* mode – any attempt to write to the IBM High IOPS Adapter causes an error. Some filesystems may require special mount options in order to mount a read-only block device in addition to specifying that the mount should be read-only.

Read-only mode should be considered a final opportunity to migrate data off the device, as device failure is more likely with continued use.

The IBM High IOPS Adapter may enter failure mode. In this case, the device is offline and inaccessible. This can be caused by an internal catastrophic failure, improper firmware upgrade procedures, or device wearout.

NOTE For service or warranty-related questions, contact the company you purchased the device from.

NOTE For IBM High IOPS Duo Adapters, these modes are maintained independently for each half of the Duo

and not for the Duo as a whole.

Health Monitoring Techniques

`fio-status`: Output from the `fio-status` utility shows the health percentage and device state. These items are referenced as "`Media status`" in the sample output below.

```
Found 1 ioDrive in this system
Fusion-io driver version: 2.2.3 build 66

Adapter: ioDrive
        IBM 160GB High IOPS SS Class PCIe Adapter, Product Number:46M0884
SN:15833
...
Media status: Healthy; Reserves: 100.00%, warn at 10.00%; Data: 99.12%
Lifetime data volumes:
   Physical bytes written: 6,423,563,326,064
   Physical bytes read   : 5,509,006,756,312
```

IBM High IOPS Management Application: In the Device Report tab, look for the Reserve Space percentage in the right column. The higher the percentage, the healthier the drive is likely to be.

SNMP/SMI-S: On Windows or Linux, see the corresponding appendix for details on how to configure SNMP or SMI-S health indicators.

The following Health Status messages are produced by the `fio-status` utility:

- Healthy
- Low metadata
- Read-only
- Reduced-write
- Unknown

Software RAID and Health Monitoring

Software RAID stacks are typically designed to detect and mitigate the failure modes of traditional storage media. The IBM High IOPS Adapter attempts to fail as gracefully as possible, and these new failure mechanisms are compatible with existing software RAID stacks. An IBM High IOPS Adapter in a RAID group will fail to receive data at a sufficient rate if a) the drive is in a write-reduced state, and b) it is participating in a write-heavy workload. In this case, the drive will be evicted from the RAID group. A drive in read-only mode will be evicted when write I/Os are returned from the device as failed. Catastrophic failures are detected and handled just as though they are on traditional storage devices.

Appendix F- Using Windows Page Files with the IBM High IOPS Adapter

Introduction

This appendix describes how to effectively use paging (swap) files on IBM High IOPS Adapter devices with Windows.

Using a page file with a traditional disk drive places practical limits on the usable size of the page file and virtual memory, due to the poor performance of disk drives in relation to RAM. Placing the OS paging file on one or more IBM High IOPS Adapters allows much larger page files and usable virtual memory. This is due to the much faster response times and bandwidth on IBM High IOPS Adapters versus hard disks. IBM High IOPS Adapter software prior to 2.2.0 did not support paging files.

Configuring Paging Support

The 2.2.0 ioMemory VSL and later versions can be configured to support paging files on one or more IBM High IOPS Adapters. This requires that each IBM High IOPS Adapter used with a paging file pre-allocates the worst-case amount of memory it may need in any possible I/O scenario. This is done on a per-adapter (ioDIMM) instance.

Because of the extra host RAM memory use, paging should be enabled only on IBM High IOPS Adapters that will actually hold a paging file. It is possible to place a single paging file on more than one IBM High IOPS Adapter. In this case Windows will stripe paging I/O across all available paging files, possibly providing additional performance to the Virtual Memory (VM) subsystem.

IBM High IOPS Adapter RAM Consumption

The amount of RAM pre-allocated per IBM High IOPS Adapter depends on the device's total size and the sector (block) size selected when formatting the drive (with `fio-format`). The following table shows the estimated (upper limit) memory consumption for the various device and sector sizes.

Average Written Block Size (bytes)	RAM Usage (MB) per 80GB of storage space
8192	225
4096 (Most common)	425
2048	825
1024	1600

512	3175

Using a larger sector size significantly reduces the amount of host memory consumption needed for paging support. It is recommended that a 4K sector size be used because a) that is generally the natural size of a host memory page, and b) it minimizes overall host memory consumption. In Windows, NTFS will generally use a cluster size of 4K, so formatting to 512 is not useful except for applications that compatible only with 512-byte sector sizes (such as Windows XP and Windows 2003).

The indicated amount is needed per IBM High IOPS Adapter that supports paging. You must carefully plan which IBM High IOPS Adapter(s) will be used to hold a paging file.

Non-paged Memory Pool

Pre-allocated memory for the IBM High IOPS Adapter comes from the Windows kernel non-paged memory pool. This pool dynamically grows as system components consume additional kernel memory. The maximum size of this pool is restricted as follows:

- Server 2003, 2008 R1/R2 - 75% of RAM up to a maximum of 128GB.
- Vista/Windows 7 - 40% of RAM up to a maximum of 128GB.

The amount of in-use, non-paged pool memory should be noted when planning page file usage. This is because the IBM High IOPS Adapter pre-allocates RAM, and that reduces the available physical non-paged memory. The ioMemory VSL will fail to load if the total pre-allocated memory plus the in-use, non-paged memory exceeds the maximum non-paged memory pool.

To determine the total non-paged memory pool use for two IBM High IOPS Adapters, let's use the following example:

- One IBM High IOPS Adapter is 80GB, and the other is 160GB
- Both are formatted with a 4K sector size
- Both will support paging files

The current allocated non-paged pool is obtained from Task Manager and, in this example, has a value of 576 MiB. (Values shown in Task Manager are in MiB (1024x1024 = 1 MiB)). The total RAM on the system is 8196 MiB and the OS is Server 2008 R2.

To calculate the total available non-paged pool, use the following formula:

```
(8196 MiB x 0.75) - 576 - 379 (80 IBM High IOPS Adapter) - 731 (160 IBM High IOPS Adapter)
```

which still leaves 4,718 MiB available for the non-paged pool.

Enabling/Disabling Paging Support

Memory pre-allocation occurs during ioMemory VSL initialization. To enable paging support, you must enable the `FIO_PREALLOCATE_MEMORY` configuration item. This can be done using the `fio-config` command-line utility. This parameter is assigned a string with a list of decimal serial numbers of the IBM High IOPS Adapters that will support a paging file. The ioMemory VSL performs memory pre-allocation for those instances.

Below is an example of using the `fio-config` utility to enable paging and pre-allocation on two IBM High IOPS Adapters with serial numbers 1234 and 17834. Serial number information can be obtained using the `fio-status` utility.

```
fio-config -p FIO_PREALLOCATE_MEMORY "1234,17834"
```

To disable paging support on all drives, use a value of `0` for `FIO_PREALLOCATE_MEMORY`:

```
fio-config -p FIO_PREALLOCATE_MEMORY "0"
```

To query the current value, run this command:

```
fio-config -g FIO_PREALLOCATE_MEMORY
```

An alternate method to manage (enable or disable) paging support is to use IBM High IOPS Management Application.

You must reload the ioMemory VSL for the new pre-allocation setting to take effect. Typically this can be done by restarting the machine or using disable/enable within Device Manager for each IBM High IOPS Adapter instance.

Also, using the Windows System Properties to change paging file configuration requires a system restart before the properties are applied. Therefore, you can change both FIO_PREALLOCATE_MEMORY and the system page file configuration and then apply both with a single restart.

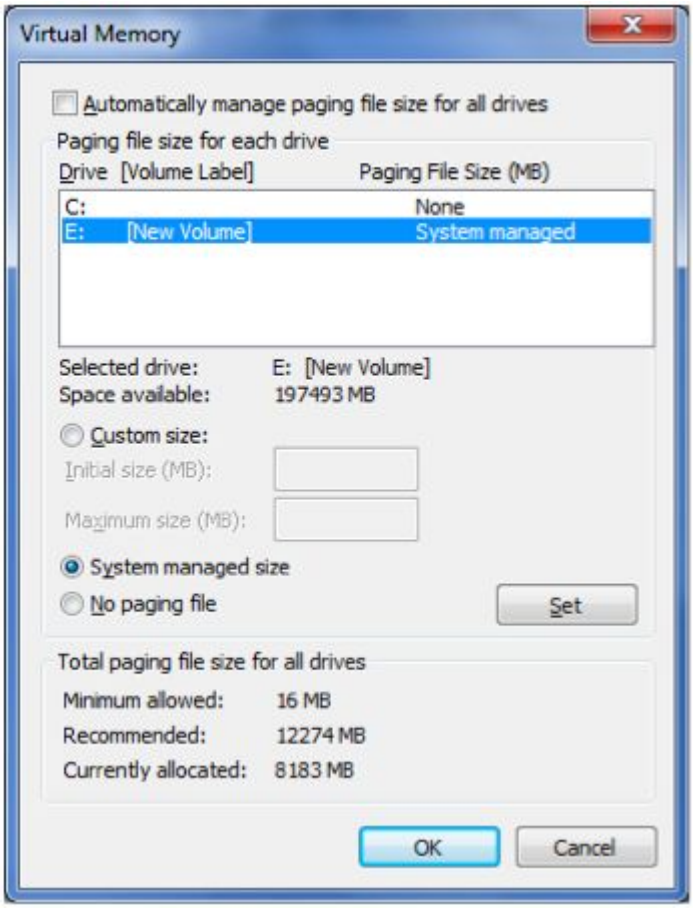
Windows Page File Management

By default, the ioMemory VSL disables support for page files. The previous section described how to enable support for page files on one or more IBM High IOPS Adapters. The following describes how to work with the built-in Windows control panels to configure and set up paging files on IBM High IOPS Adapters.

Setting Up Paging File(s)

To set up page files in Windows,

1. Go to **Control Panel** and double-click System.
2. Click **Advanced system settings** from the Task pane.
3. On the Advanced tab, click **Settings**. The Performance Options dialog opens.
4. On the Advanced tab, click **Change**. The Virtual Memory dialog opens.



Using this dialog, you can configure a page file for each available drive in the system. Selecting the "Automatically manage paging file size for all drives" checkbox causes Windows to create a single page file on the system drive, which is the drive the OS is started from. This checkbox should be cleared when using an IBM High IOPS Adapter with a paging file.

Windows supports up to 16 distinct paging files. To enable a page file on an IBM High IOPS Adapter,

1. Choose the IBM High IOPS Adapter from the device list.
2. Select the **Custom size** radio button.
3. Provide values in the **Initial size** and **Maximum size** fields.
4. Click **Set** to save the setting. Do not omit this step, or your changes will be lost.

5. Click **OK**.
6. When prompted to restart, click **Yes**. This is necessary for the new page file settings to take effect.

To remove a paging file on the drive, follow the steps earlier but select **No paging file**. For performance reasons, typically you will remove all paging files on any system hard disk.

> The Virtual Memory dialog allows page files to be configured on available IBM High IOPS Adapters, even if the IBM High IOPS Adapter has not been configured to support a page file. Even though the dialog allows enabling of the page file, following the required restart you'll notice that no page file was created on the device. Follow the directions earlier in this document to properly enable page file support on one or more IBM High IOPS Adapters.

System Drive Paging File Configuration

By default Windows creates and manages a page file on the system boot drive (typically a hard disk), which is typically where Windows is installed. Keeping a regular page file on the system hard disk is generally not optimal, because the hard disk's I/O performance is many orders of magnitude slower than an IBM High IOPS Adapter. To remedy this, you can eliminate or minimize the size of the system boot drive page file, as explained later. Enabling page files on IBM High IOPS Adapters (but not the system drive) improves Virtual Memory (VM) subsystem performance, as the VM manager stripes I/O across all available page files. Additionally, the IBM High IOPS Adapters act as a very large memory store, which can greatly improve memory usage for large applications.

The Windows kernel uses the system disk page file to store crash dumps. Crash dumps may be small (mini-dumps) or large (full-kernel memory dumps). Typically, running without dump file support or with a small dump file is adequate. There are several possible system drive page file configurations:

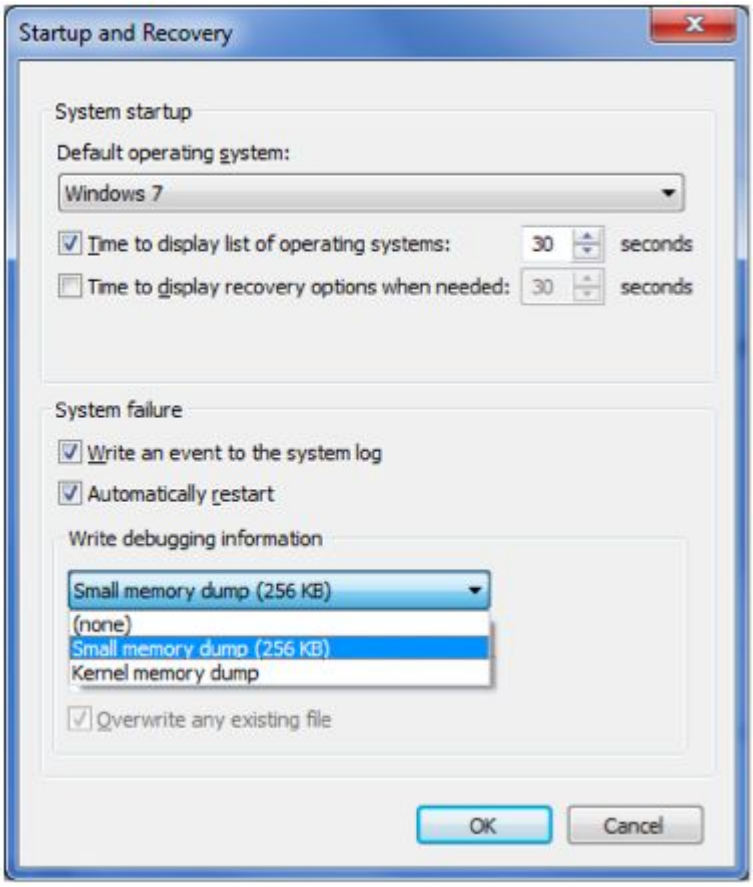
1. Eliminate all page files on any hard disks, including the system boot drive. Although this maximizes paging I/O on IBM High IOPS Adapters, no post-mortem crash dump file will be available if a system crash occurs. However, it may be possible to re-enable a page file on the system drive and then reproduce the crash scenario.
2. Create a minimal-size page file on the system boot drive. The recommended minimum size is 16MB, although Windows may warn that a minimum 400MB page file is needed.
3. Create a page file large enough for a full-kernel memory dump. This typically requires a page file at least the size of installed RAM, with some recommending the size equal to RAM x 1.5.

IBM is actively working on adding support for an IBM High IOPS Adapter being a crash dump target.

To view or change the crash dump configuration,

1. Go to the **System Properties** dialog.
2. Click the Advanced tab.

3. In the Startup and Recovery section, click **Settings**. The Startup and Recovery dialog opens.



In the System Failure section you can change settings to handle the system log, restart, and debugging information.

Guaranteeing Minimum Committable Memory

If you enable "System managed size" or set a "Custom size" in the Virtual Memory dialog, you should do so with care. If the initial size is less than the desired amount of committable virtual memory, this can cause an application to have memory allocation failures if the amount of committed memory exceeds the currently allocated page file size or the initial size value. When committed memory exceeds the current page file size, a request to allocate additional memory will fail. The Windows Virtual Memory manager will slowly increase the size of the paging file up to the available size of its drive or to the "Maximum size" custom setting, whichever is smaller.

If you want to use a large amount of committed virtual memory (more than 1.5 times the amount of RAM) and avoid application memory allocation errors, the initial and maximum committed memory should be explicitly set for the expected application committed memory usage. These values should generally be the same.

How Large Should You Make the Paging File?

The following articles explain in great detail how to size the page file appropriately.

- Main Article Link: *Pushing the Limits of Windows*
- Specific section that documents virtual memory: *Pushing the Limits of Windows: Virtual Memory*

Verifying Page File Operation

To verify that a page file is actively placed on an IBM High IOPS Adapter, you can browse for hidden files at the drive's root. For example, run the following command at a prompt:

```
dir c: /ah
```

In the output listing there should be a file called `pagefile.sys`. If no page file is present, then recheck the page file configuration in the Virtual Memory dialog and verify that page file support has been enabled on the queried IBM High IOPS Adapter.

Performance

Using the IBM High IOPS Adapter as the paging store can improve overall Virtual Memory system performance. Actual benefits will vary widely with an application's virtual memory usage and with hardware platform/performance. To get an idea of the performance difference, a synthetic program was written to allocate a specified amount of virtual memory. The program then accesses each page of the allocated buffer by writing to each page (all 4K). Afterward, each page is then accessed again by reading the first byte of each page.

System memory was artificially reduced to 1GB to force use of the page file. This left 400 MB of free physical memory. The test was run with a 2GB virtual memory buffer.

The program supports random or sequential patterns. It was run using an 80GB IBM High IOPS Adapter as the paging device and then was run on a Hitachi HD7721010SLA360 ATA disk drive. A custom page file was configured with minimum and maximum set to 70000 (70GB).

Device Type	Random Writes (MiB/second)	Random Reads (MiB/second)	Sequential Writes (MiB/second)	Sequential Reads (MiB/second)
Hard Disk	60.37	36.49	334.80	59.67
80GB IBM High IOPS Adapter	236.09	293.29	367.27	242.12

Appendix G- SNMP Test Mode and MIB Support

Introduction

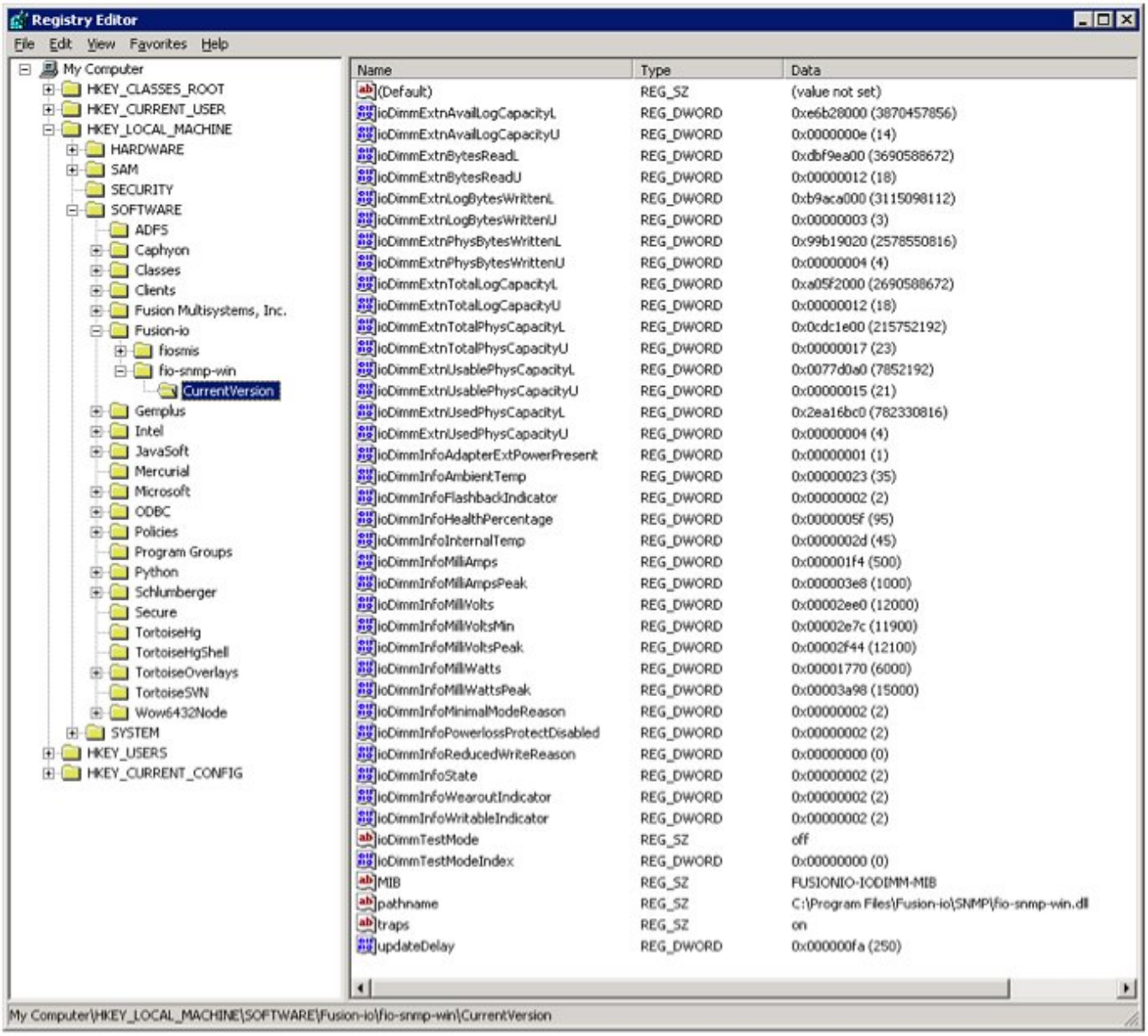
This document explains how you can set up a test mode with your IBM High IOPS Adapter's Windows SNMP agent. This enables you to set test values in a Windows registry and force SNMP traps without having to create the actual conditions on the device.

For example, you can use the SNMP test mode to change the non-writeable indicator and generate a trap, or simulate a change to the physical or logical size of the device, etc.

NOTE To use SNMP Test Mode, you must have installed the SNMP option with your IBM High IOPS Adapter.

Using Test-Mode Registry Values

The picture below shows the registry entries included for SNMP test values.



Each of these entries is described below. Entries marked by an asterisk (*) generate SNMP traps when set to the indicated values, and the `fusionIoDimmMIBCondition` and `fusionIoDimmInfoStatus MIB` variables may be affected because of the changes.

> All entries, except those marked by **, reflect your registry changes immediately. Entries marked by ** require a restart of the Windows SNMP agent for the changes to take effect.

SNMP Test Registry Entry	Description
`ioDimmExtnAvailLogCapacityL`	Lower word of the available logical capacity in bytes

ioDimmExtnAvailLogCapacityU	Upper word of the available logical capacity in bytes
ioDimmExtnBytesReadL	Lower word of the total number of bytes read since the device was formatted
ioDimmExtnBytesReadU	Upper word of the total number of bytes read since the device was formatted
ioDimmExtnLogBytesWrittenL	Lower word of the number of user data bytes written
ioDimmExtnLogBytesWrittenU	Upper word of the number of user data bytes written
ioDimmExtnPhysBytesWrittenL	Lower word of the total physical bytes written
ioDimmExtnPhysBytesWrittenU	Upper word of the total physical bytes written
ioDimmExtnTotalLogCapacityL	Lower word of the total logical capacity in bytes as formatted
ioDimmExtnTotalLogCapacityU	Upper word of the total logical capacity in bytes as formatted
ioDimmExtnTotalPhysCapacityL	Lower word of the total logical capacity in bytes as formatted
ioDimmExtnTotalPhysCapacityU	Upper word of the total logical capacity in bytes as formatted
ioDimmExtnUsablePhysCapacityL	Lower word of the useable physical capacity in bytes. This is space that is holding valid data, or is erased and ready for writing, or is waiting to be reclaimed via garbage collection.
ioDimmExtnUsablePhysCapacityU	Upper word of the useable physical capacity in bytes. This is space that is holding valid data, or is erased and ready for writing, or is waiting to be reclaimed via garbage collection.
*ioDimmInfoCurrentTemp	Current temperature of the device in degrees Celsius. If this value is set above 78 degrees Celsius for ioDimm cards, a trap is generated. If set above 90 degrees for HP Mezzanine cards, a trap is generated.
*ioDimmInfoFlashbackIndicator	1 = flashback redundancy is degraded; 2 = false
*ioDimmInfoNonWritableIndicator	1 = device is no longer writable because it has surpassed the read-only threshold; 2 = false
ioDimmInfoPercentLifeRemaining	Upper word of the total logical capacity in bytes as formatted
*ioDimmInfoState (trap generated if state = 4)	Current state of the attached client device: unknown(0) detached(1) attached(2), minimal(3), error(4), detaching(5), attaching(6), scanning(7), formatting(8), updating(9), attach(10), detach(11), format(12), update(13)

*ioDimmInfoWearoutIndicator	Boolean: True = device has surpassed the wearout threshold
ioDimmTestMode	Set test mode on or off
ioDimmTestModeIndex	Number indicating the selected IBM High IOPS Adapter
mib	Name of the MIB in use
pathname	Path to the driver, set at installation
**traps	Set trap generation on or off
**updateDelay	Number of milliseconds to wait until getting the next value from the ioMemory VSL to generate a trap

SNMP MIB Support

The following SNMP MIB fields are supported in Windows:

fusionIoDimmMibRevMajor	fusionIoDimmInfoReducedWriteReason
fusionIoDimmMibRevMinor	fusionIoDimmInfoMilliVolts
fusionIoDimmMibCondition	fusionIoDimmInfoMilliVoltsPeak
fusionIoDimmInfoIndex	fusionIoDimmInfoMilliVoltsMin
fusionIoDimmInfoStatus	fusionIoDimmInfoMilliWatts
fusionIoDimmInfoName	fusionIoDimmInfoMilliWattsPeak
fusionIoDimmInfoSerialNumber	fusionIoDimmInfoMilliAmps
fusionIoDimmInfoPartNumber	fusionIoDimmInfoMilliAmpsPeak
fusionIoDimmInfoSubVendorPartNumber	fusionIoDimmInfoAdapterType
fusionIoDimmInfoSparePartNumber	fusionIoDimmInfoAdapterPort
fusionIoDimmInfoAssemblyNumber	fusionIoDimmInfoAdapterSerialNumber
fusionIoDimmInfoFirmwareVersion	fusionIoDimmInfoAdapterExtPowerPresent
fusionIoDimmInfoDriverVersion	fusionIoDimmInfoPowerlossProtectDisabled
fusionIoDimmInfoUID	fusionIoDimmInfoInternalTempHigh
fusionIoDimmInfoState	fusionIoDimmInfoAmbientTemp
fusionIoDimmInfoClientDeviceName	fusionIoDimmExtnIndex
fusionIoDimmInfoBeacon	fusionIoDimmExtnTotalPhysCapacityU
fusionIoDimmInfoPCIAddress	fusionIoDimmExtnTotalPhysCapacityL
fusionIoDimmInfoPCIBandwidthCompatibility	fusionIoDimmExtnUsablePhysCapacityU

fusionIoDimmInfoPCIDeviceID	fusionIoDimmExtnUsablePhysCapacityL
fusionIoDimmInfoPCIPowerCompatibility	fusionIoDimmExtnUsedPhysCapacityU
fusionIoDimmInfoPCISubdeviceID	fusionIoDimmExtnUsedPhysCapacityL
fusionIoDimmInfoPCIVendorID	fusionIoDimmExtnTotalLogCapacityU
fusionIoDimmInfoPCISubvendorID	fusionIoDimmExtnTotalLogCapacityL
fusionIoDimmInfoPCISlot	fusionIoDimmExtnAvailLogCapacityU
fusionIoDimmInfoWearoutIndicator	fusionIoDimmExtnAvailLogCapacityL
fusionIoDimmInfoFlashbackIndicator	fusionIoDimmExtnBytesReadU
fusionIoDimmInfoWritableIndicator	fusionIoDimmExtnBytesReadL
fusionIoDimmInfoInternalTemp	fusionIoDimmExtnBytesWrittenU
fusionIoDimmInfoHealthPercentage	fusionIoDimmExtnBytesWrittenL
fusionIoDimmInfoMinimalModeReason	fusionIoDimmExtnFormattedBlockSize

Appendix H- Documentation Permissions

The `AVR bootloader` and the `tree.h` file, which ship in binary form with the driver, contain content that have the following documentation copyright requirements:

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tree.h

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IBM Support

IBM High IOPS Adapter Customer Support is available on the web at the following address:

http://www.ibm.com/systems/support

IBM part number 60Y1445