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Introduction

As more organizations seek to harness the power of information, the demand for data intensive and transactional workloads such as data warehousing, real-time analytics, and virtualized environments is expanding. Solid-state storage technology delivers the performance, energy efficiency, and high-density ideal for these workloads. To optimize solid-state media performance, HP ProLiant Gen8 servers include an embedded, 6 Gb/s SAS controller with 6X the performance of previous controller generations.

HP Smart Array Controllers provide powerful I/O solutions to meet demanding storage requirements. They allow you to add drives to expand capacity and support high performance through increased drive count and RAID technology. They provide excellent data availability plus advanced data loss protection and storage management. HP Smart Array Controllers are particularly important for entry-level to enterprise-class servers that require performance and scalability through external SAS port to a storage subsystem.

This paper gives you an overview of the latest H-Series host bus adapter and both the P-Series and B-Series storage controllers. It addresses performance, data loss protection, and storage management factors. It also includes tips for optimizing Solid State Drive (SSD) performance with HP Smart Array Controllers.

H-Series Host Bus Adapter

The HP H222 Host Bus Adapter (HBA) has a 1x4 external port and 1x4 internal port that provide flexibility and speed ideal for internal and external connectivity to tape drives, HDDs, and external JBODs. The H222 HBA supports 6 Gb SAS HDDs, SATA HDDs, and SAS tape drives. The H222 HBA can also provide high performance for SSDs that do not require data protection. This SAS HBA is ideal for driving cost-effective and reliable scalability in today's data centers.

New technology in the H Series H222 controller supports eight external 6 Gb/s SAS ports (two 4x external connectors). Other typical uses include shared external storage and multi-LUN tape libraries or external tape. When used with SSDs, an HBA controller can provide higher total IOPS and lower latency, but each drive must be managed independently with no redundancy for data protection.

HP Smart Array P-Series Controllers

We embed HP Smart Array P-Series Controllers on the system board or offer them as low-profile cards (Table 1). Embedded controllers in HP ProLiant Gen8 servers can support up to twice as many internal storage devices or twice as many external devices as previous controller generations. The option of using embedded or add-on Smart Array Controllers gives you flexibility in meeting your storage needs and conserving slot real estate.

The new Smart Array P-Series Controllers (except for the P220i) support the latest PCI-e 3.0 host interface and 6 Gb/s SAS storage interface.

<table>
<thead>
<tr>
<th>Controller</th>
<th>Type</th>
<th>Ports (external/internal)</th>
<th>Host interface support</th>
</tr>
</thead>
<tbody>
<tr>
<td>P220i</td>
<td>Embedded (blade)</td>
<td>0/1</td>
<td>PCI-e 2.0</td>
</tr>
<tr>
<td>P222</td>
<td>Low profile card</td>
<td>1/1</td>
<td>PCI-e 3.0</td>
</tr>
<tr>
<td>P420</td>
<td>Low profile card</td>
<td>0/2</td>
<td>PCI-e 3.0</td>
</tr>
<tr>
<td>P420i</td>
<td>Embedded (rack)</td>
<td>0/2</td>
<td>PCI-e 3.0</td>
</tr>
<tr>
<td>P421</td>
<td>Low profile card</td>
<td>2/0</td>
<td>PCI-e 3.0</td>
</tr>
<tr>
<td>P822</td>
<td>Full-height, ½ length stand-up board</td>
<td>4/2</td>
<td>PCI-e 3.0</td>
</tr>
</tbody>
</table>

Benchmark testing shows that HP P-Series Controllers give about a three-fold increase in IOPS and a two-fold increase in RAID 5 read performance over previous generations.

Smart Array P-Series Controllers for ProLiant Gen8 servers include controller technology enhancements that enable the following functionality:

- Predictive spare activation to reduce drive rebuild time. Before a drive fails, it enters a predicted failure state, and the drive controller starts to copy the data to a spare drive.
• RAID parity initialization
• Intelligent provisioning to deploy and configure storage
• Proactive warning from new drive carriers to administrators if removing a drive will cause data loss
• Active Health System Support for 24/7 mission control for automated monitoring, diagnostics, and alerting. Active Health System monitors and securely logs more than 1600 system parameters and 100% of configuration changes.
• HP Service Pack for ProLiant, comprehensive systems software and firmware offered as a solution on all HP ProLiant SL/ML/DL 300, 500, 700, and 900 series servers and HP blade servers supported with Insight Foundation suite for ProLiant version 8.70
• Software management via Array Configuration Utility (ACU), System Management Homepage (SMH), HP Systems Insight Manager (HP SIM), and Option ROM Configuration for Arrays (ORCA)
• PCI-e 3.0 offering 2x bandwidth support

Technology enhancements also include optional features enabled by Smart Array Advanced Pack (SAAP) 2.0 support with a license key from HP. SAAP 2.0 adds the following capabilities to existing SAAP 1.0 features:
• Advanced Data Mirroring (ADM), a new data loss protection technology. ADM is 1000 times more effective in preventing data loss than traditional RAID 1. It increases uptime and improves read performance through three-drive mirroring to ensure continuous data availability.
• Ability to move or delete individual logical drives
• Online splitting of RAID 1×0 mirrors

### Table 2. Characteristics of HP Gen8 Smart Array P-Series Controllers

<table>
<thead>
<tr>
<th>HP Smart Array P220i (blades)</th>
<th>HP Smart Array P222</th>
<th>HP Smart Array P420/P420i</th>
<th>HP Smart Array P421</th>
<th>HP Smart Array P822</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory bus speed and width</td>
<td>DDR3-1333 MHz 40 bit 512 MB</td>
<td>DDR3-1333 MHz 40 bit 512 MB</td>
<td>DDR3-1333 MHz 40 bit 512 MB; DDR3-1333 MHz 72 bit 1 or 2 GB</td>
<td>DDR3-1333 MHz 72 bit 1 or 2 GB</td>
</tr>
<tr>
<td>Maximum drives</td>
<td>Up to 4</td>
<td>Up to 4 internal; 200 drives external</td>
<td>Up to 27 internal</td>
<td>Up to 200</td>
</tr>
<tr>
<td>RAID Support</td>
<td>0 and 1 for blades</td>
<td>0, 1, 1+0, 5 and 50</td>
<td>0, 1, 1+0, 5 and 50</td>
<td>0, 1, 1+0, 5, 6, 50, 60 and 1 ADM</td>
</tr>
</tbody>
</table>

### HP Smart Array B-Series Controllers

The embedded HP B-Series Smart Array controllers (listed in Table 3) support either SAS or SATA interconnects. Smart Array firmware supports HP software RAID with hardware assist that takes advantage of idle CPU clock cycles to increase overall performance.

### Table 3. Characteristics of HP Gen8 Smart Array P-Series Controllers

<table>
<thead>
<tr>
<th>Controller</th>
<th>Drive support</th>
<th>Ports (internal)</th>
<th>Host interface support</th>
</tr>
</thead>
<tbody>
<tr>
<td>B120i</td>
<td>6 SATA (or more)</td>
<td>6</td>
<td>PCI-e 2.0</td>
</tr>
<tr>
<td>B320i</td>
<td>8 SATA or SAS (or more)</td>
<td>2</td>
<td>PCI-e 3.0</td>
</tr>
</tbody>
</table>

B-Series controllers use software RAID that supports the Array Configuration Utility (ACU), ACU-CLI (command line interface), SNMP agents, and Web-Based Enterprise Management (WBEM) providers. For a list of the complete feature set and support information for the B320i and B120i Software RAID, download the user guide at hp.com/products/quickspecs/14343_div/14343_div.html.
Each Dynamic Smart Array includes RAID 5 support with cache upgrade and hot-plug drive support. An optional 512 MB flash-back write cache (FBWC) module is available for these controllers.

New technology in the B-Series controllers supports drive migration to P-Series controllers and use of system memory as read cache.

**Smart Array performance factors**

Multiple, interdependent factors contribute to HP Smart Array performance: a multi-core, multi-processing engine; advanced caching capabilities; and hardware tuning, including customized connection settings.

**Smart Array process engine**

The Smart Array multi-core, multi-processing engine manages the RAID system. The processing engine transforms high-level read or write requests from an application into the individual instructions required for the RAID array. P-Series Smart Array Controllers for ProLiant Gen8 servers use an embedded RAID-on-Chip processor.

**Cache module performance**

To increase performance and improve reliability we implement a caching system on our Smart Array controllers. Cache is memory that acts as a buffer for HDD or SSD I/O. Our latest generation of controllers has FBWC modules instead of battery-backed write cache (BBWC) modules. FBWC retains data longer and eliminates dependence upon batteries that drain power over time. When a controller detects a power loss, any data in cache automatically writes to the controller’s NAND flash memory for retrieval when power returns.

Cache can operate on both reads and writes to disk. The advanced read-ahead and write-back caching capabilities significantly improve I/O performance on Smart Array Controller cache modules.

FBWC is available in 512 MB, 1 GB, or 2 GB modules. The greater your cache size, the more data it can buffer. Increased cache size provides better performance as measured in both iOPS and throughput.

**Read-ahead caching**

HP Smart Array Controllers use an adaptive read-ahead algorithm to anticipate data needs and reduce wait time. The algorithm detects sequential-read activity on single or multiple I/O threads and predicts when sequential-read requests will follow. The algorithm then reads ahead from the drives. When the read request occurs, the controller retrieves the data from high-speed cache memory in microseconds rather than from the drive in milliseconds. This adaptive read-ahead scheme provides excellent performance for sequential, small-block read requests.

When the read-ahead algorithm on HP Smart Array Controllers detects non-sequential read activity, however, it disables read-ahead caching so it will not slow random read requests. This eliminates issues with fixed read-ahead caching schemes, which increase sequential read performance but degrade random read performance.

**Write-back caching**

An HP Smart Array Controller uses a write-back caching method so that host applications can continue without waiting for write operations to complete to the drives. A controller without a write-back cache returns completion status to the OS only after it writes the data to the drives. A controller with write-back caching can post write data to high-speed cache memory and immediately return the status of “complete” to the OS. That write cache operation completes in microseconds rather than in milliseconds. The controller then writes data from the write cache to disk at an optimal time for the controller.

Once the controller locates write data in the cache, subsequent reads to the same disk location come from the cache. Subsequent writes to the same disk location replace the data held in cache. This is called a “read cache hit.” It improves bandwidth and latency for applications that frequently write and read the same area of the drives.

**Hardware tuning**

RAID controllers perform poorly when they lack signal integrity and an optimized PCI-e bus. We customize controller link settings to maximize signal margins and reduce error rates.

The industry standard Unrecoverable Bit Error (UBE) rate is specified at 1-bit error in 1012 for enterprise-class disk drives in Fiber Channel and SAS environments. Signal integrity requirements for HP Smart Array Controllers are more stringent than that. On every Smart Array Controller, we tune transmitter and receiver connection settings with every connected device, and even with the PCI-e bus.
RAID implementation with HP Smart Array P-Series Controllers

Smart Array controllers use an integrated RAID-on-Chip (ROC) that includes the RAID processor, a memory controller, host interface, and I/O interfaces to connect to either HDD or SSD storage. This allows off-loading RAID execution from the host system.

The ROC implementation provides the following:

- Protection at boot—There is no negative impact on data availability if the boot drive has medium errors or fails completely.
- RAID application independent of the host—There are no data integrity issues if the system crashes.
- Enhanced protection in case of power loss—ROC implementations typically track in-progress writes in non-volatile hardware.
- RAID task offloaded from the host—This is best suited for complex RAID 5 or RAID 6 scenarios, which usually offer best cost-performance ratio.
- Dedicated GUI and software to build and maintain the RAID—These make it easy to set up and maintain the RAID array.
- Support for advanced RAID features—Typical examples include disk hot plug, array-level migration, and online capacity expansion.
- On-controller caching—This accelerates access times by using cache memory and enables using write-back caching if memory is protected by a battery.

RAID implementation with HP Smart Array B-Series controllers

B-Series controllers use software RAID that runs on the CPU of your host system. The software RAID code uses the CPU’s calculating power. The code shares the computing power with the operating system and all the associated applications.

HP implements software RAID with hardware assist that enables RAID functionality when the system is switched on. This provides redundancy during boot to reduce the impact of any storage media errors that could lead to data corruption or an inoperable system. This solution provides BIOS setup software that is available at system boot. This makes setup easy and lets you maintain the RAID array without installing or booting an OS from hard disk or CD.Host ROM. Hardware-assisted software RAID usually comes with a variety of drivers for the most popular operating systems.

Software RAID with hardware-assist requires a dedicated GUI and software to build and maintain the RAID. The cost of this solution is moderate. You need only an HBA (plug-in card) or an additional flash memory for the BIOS down on the motherboard. If the controller supports RAID 5, it may include a hardware XOR accelerator.

Tips for optimizing SSD performance with HP Smart Array Controllers

You can optimize SSD performance by using cache modules, activating accelerator settings, or disabling the accelerator for read-intensive applications. Consider the following factors about the Smart Array Controller cache with SSD storage:

- The Smart Array Controller cache is referred to as the Array Accelerator. Use the HP Array Controller Utility (ACU) to enable or disable the Array Accelerator and to set the percentage of cache dedicated to host reads and writes.
- Whether you plan to enable or disable the Array Accelerator, we highly recommend using the 1 GB or 2 GB cache module. These modules provide a performance advantage over the 512 MB module because they have a physically wider access path to the memory. A portion of the SDRAM memory on the cache module is used for running array instruction code. The wider memory access path allows the array instruction code to execute faster.
- Never run SSDs in Zero Memory RAID (ZMR) configuration (meaning with no module at all). Without the cache module, there is no SDRAM, so the array instruction code must run from Flash memory.
- The Array Accelerator enabled or disabled setting can be different for each array logical drive. With both HDDs and SSDs on the same Smart Array Controller, the SSDs will always be configured as a different logical drive, which accommodates different settings. If both SSD and HDD logical drives exist on the same controller, set the Array Accelerator to “enabled” for HDDs.
- When testing SSDs, most synthetic benchmark results will show better random workload performance with the Array Accelerator disabled. You should always check for best performance using both settings while running your actual application. Real application workloads exhibit more access locality. Because they are more complex, real workloads will behave significantly differently than workloads in most synthetic benchmarks.
When testing SSD performance with the Array Accelerator enabled, start with an Array Accelerator ratio of 0% Read/100% Write (which is not the default). If the Array Accelerator is to provide any performance advantage with SSDs, this is optimal setting.

In most situations of random workloads, the Array Accelerator ratio 0% Read/100% Write setting will help the host write performance but will penalize host read performance. On host reads, the controller must still check the cache for recent writes that have not been flushed to the media. This required cache check adds latency to every host read, thus lowering read performance.

The worst Array Accelerator ratio setting to consider is 100% Read/0% Write, even if you know your application is read intensive. This setting is not the same as disabling the Array Accelerator because although the Write cache ratio is 0%, the cache is not turned off.

The various settings for the Array Accelerator Ratio may not display in the ACU if there are no logical drives with the Array Accelerator enabled, or if the cache module battery pack is not connected. The controller Array Accelerator Ratio setting has no meaning if there are no logical drives that have the Array Accelerator enabled.

**Conclusion**

Advancements in controller technology allow you to choose from a broad spectrum of storage controller solutions, each with unique performance and reliability characteristics. When considering which controller technology to choose for your storage needs, consider all components that contribute to the solution.

Controller technology determines system performance, capacity limits, manageability, and data loss protection. For all but smaller, lower performance systems, choosing an appropriate Smart Array Controller adds state-of-the-art data loss protection and storage management options to your Gen8 system.
Resources, contacts, or additional links

Server drive technology
hp.com/bc/docs/support/SupportManual/c01071496/c01071496.pdf

HP Smart Array Controllers Basic of RAID performance factors

Smart Array Advanced Pack
hp.com/products/servers/proliantstorage/arraycontrollers/smartarray-advanced/index.html

RAID 1+0: breaking mirrors and rebuilding drives

RAID 1+0: breaking mirrors and rebuilding drives