Managing the information that drives the enterprise

SOLID-STATE STORAGE IMPLEMENTATION
Get ahead...or stay ahead...of your competition by maximizing your investment in solid-state storage

ALSO
- TAPPING THE POWER OF SOLID-STATE
- GET THE MOST OUT OF SOLID-STATE STORAGE
- RAID WITH SSD: A PRIMER
- DEPLOYING PCI EXPRESS SSD DEVICES
- IMPACT OF SSDs ON THE NETWORK AND CPU
Tapping the power of solid-state

Solid-state storage's versatility might be as important a consideration as its blazing speed. With a number of implementation choices, your applications will determine your best approach to deploying solid-state storage.

If we were talking cars, we’d probably just be gawking through the showroom window. But for storage pros, those three words can only mean one thing: solid-state storage.

The speed is well documented, and it’s clear that solid-state drives (SSDs) run circles around spinning disks—and they do that running without creating a lot of heat and while taking tiny sips of electric power. Most importantly, however, is the price part. There’s no question that, on a bucks-per-byte basis, SSDs are pure data center bling. But for high-performance applications, they are—ironically—often a cheaper alternative than a stack of short-stroked high-speed hard disk drives.

A selective approach to SSD implementation will help yield the greatest benefit without putting too big a dent in your storage
budget. But even after identifying what apps could use an SSD’s extra horsepower, you’ll need to determine just where to implement the solid-state storage with that application’s infrastructure.

There are plenty of alternatives including SSDs sitting side-by-side with spinning disk in a shared-occupancy array, solid-state-based caching devices, all-SSD arrays or directly attached to a server via its PCIe bus or SAS/SATA interface.

Once you figure out the best place for your solid-state storage, be prepared for how this high-speed storage is likely to affect your storage infrastructure in general. On the positive side, it might be the incentive you’ve needed to seriously consider implementing automated tiering for the storage environment. In many cases, to fully exploit solid-state storage, it’s best to move data in and out of the solid-state as needed, and then to put the data back on a slower and less expensive tier when it no longer requires high performing storage. Auto tiering is a great way to squeeze greater efficiency out of not only SSDs, but all of your storage.

You should be prepared for some effects that aren’t nearly as pleasing. Solid-state may break the storage performance bottleneck, but in the process solid-state may just push that bottleneck into another part of the infrastructure. The unexpected performance could, for instance, cause new incidents of I/O congestion and the overworked bandwidth could mask the performance gains from the SSD.

This guide will help step you through the process of determining the best place to add solid-state storage to your environment. It will also give you a heads-up about some of the ripple effects you’ll need to keep a lookout for and, of course, steps you can take to sort them out. A small amount of solid-state storage can go a long way, so your initial implementation may require a modest commitment but yield impressive results. ■

Rich Castagna is editorial director of the Storage Media Group.
Get the most out of solid-state storage

The benefits of solid-state state storage are clear; it's fast, cool and sips power. But the technology is also changing the fundamental ways we use data center storage. BY DENNIS MARTIN

Solid-state storage has brought a slew of changes to data storage environments and reshuffled the way we approach ongoing storage operations. Solid-state has revived interest in automated tiering, caching applications and data compression, along with providing high-performance persistent storage.

Solid-state storage is not only transforming the storage industry, it’s making waves across the entire computing industry. We’ve seen how flash storage has completely revolutionized the consumer electronics space, replacing spinning disk drives in virtually every category of consumer devices.

This same enthusiasm for flash storage is spreading to the data center. Database administrators, system admins and application owners have become aware of solid-state storage and the benefits it brings. They recognize the performance and power consumption benefits, but still have some concerns about flash endurance supporting enterprise applications. However, the storage industry is addressing flash endurance with newer flash controllers that
can extend the life and performance of lower-cost flash media so it can be used in enterprise applications in place of more expensive enterprise flash media.

**BEST FIT FOR SSD**

Solid-state drives (SSDs) provide a viable, faster alternative to hard disk drives (HDDs). But the first step in determining the correct storage for a job is defining the application’s specific storage performance requirements. Those requirements should determine whether solid-state storage or traditional hard disk storage is the most appropriate and most cost-effective solution.

We'll start with a relatively simple example and then move up to more complex circumstances. One area where SSDs are already creeping into the data center environment is in laptop computers. An SSD in a laptop PC provides very fast boot-ups and overall performance, and will also extend battery life significantly as the internal SSD uses very little electric power. Applications such as word processing, large documents with graphics, spreadsheet macros, database and video will all respond very quickly. Copying files to or from the laptop is also very fast. So the effects of using solid-state storage go beyond just application performance.

The same benefits can also be realized with desktop PCs. Using solid-state storage to boot computers, for example, is a relatively easy and inexpensive way to improve performance. Installing an SSD as the boot drive in a desktop computer can extend the life of an older machine simply because much of the I/O is accelerated.
This can also work for older laptop computers, if you get an SSD with the correct interface.

**SPEEDING UP DATABASE OPERATIONS**

Any application that needs improved performance or lower storage latency is a good candidate for solid-state storage technology. For example, many database operations are actually a sequence of several small requests grouped together as a package, such as table scans and queries, which are executed sequentially where the output of one request becomes the input of the next request and so on. The final answer isn't returned to the application until all the smaller requests comprising the entire transaction have been satisfied. In these cases, the significantly reduced latency (faster turnaround) that solid-state storage delivers can make a huge difference in the overall performance of the application or end-user experience.

The best enterprise hard disk drives have an average seek time latency of approximately 2ms for every request, and not every storage system enables the cache memory on the drives due to data protection concerns. So even if the SSDs in use had the same performance as the hard drives, the SSDs would provide better overall latency because they have no seek time. Imagine running a large batch of complex database transactions where every I/O is subject to the seek time latency of good enterprise hard drives; then imagine that same batch of complex database operations without the seek time latency and with faster storage devices, and you'll see why SSDs are so good for database applications.

**SSD ENABLES TIERING**

Performance gains with solid-state storage technology aren't limited to database applications. This is why we see an increased de-
mand for caching and tiering solutions. Most servers—whether singly or in groups—are kept busy with a variety of application workloads, each having various busy times and slow times. If you have all your data on solid-state storage, you might not need to consider caching and tiering; but if your data center is like the majority of data centers, most of your current application data is kept on some type of spinning hard disk drives.

With tiering for SSDs, the user decides what data to place on the SSD and when to place it there. Tiering can be performed manually or with automated tiering software on the host or in the storage

<table>
<thead>
<tr>
<th>TYPE OF STORAGE DEVICE</th>
<th>$/GB</th>
<th>$/IOPS</th>
<th>IOPS/WATT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-level cell (SLC) SSD</td>
<td>$10 to $40</td>
<td>$0.005 to $0.15</td>
<td>1,000 to 15,000</td>
</tr>
<tr>
<td>Multi-level cell (MLC) SSD</td>
<td>$1 to $3</td>
<td>$0.004 to $0.05</td>
<td>1,000 to 15,000</td>
</tr>
<tr>
<td>Enterprise HDD</td>
<td>$0.50 to $1</td>
<td>$1 to $3</td>
<td>10 to 30</td>
</tr>
<tr>
<td>Desktop HDD</td>
<td>$0.05 to $0.10</td>
<td>$1 to $4</td>
<td>10 to 40</td>
</tr>
</tbody>
</table>

**Bottom line:** SSDs are dollars per gigabyte and pennies per IOPS, while HDDs are pennies per gigabyte and dollars per IOPS.
controller. Tiering is all about moving specific hot data to the SSD tier at the right time and moving it back to the slower disk tiers (again, at the right time). If tiering is performed manually, then the administrator must observe the I/O activity over time and decide when to move certain files or data. You would have to manually track the number of accesses of every file on all your systems and then decide when to move files to and from SSDs based on those accesses. For systems of any size, this would be an impossible task to do manually, so automated tiering software would be required. With automated tiering software, the file and data accesses are tracked automatically and data movement occurs at a scheduled time based on user-defined policies. Tiering only benefits the apps whose data is moved to the faster tier, but the performance boost is immediate and significant. Automated tiering solutions are a good choice if you have several applications you believe need the performance boost but you can’t or don’t want to decide—or you don’t have the time to prove—which apps need the performance boost. If you only had one application that could benefit from tiering, you wouldn’t need automated tiering software. But most data centers have dozens, hundreds or maybe even thousands of applications that could benefit from higher performance.

**SOLID-STATE CACHING**

Another approach is SSD caching. Caching for SSDs is determined by host software or the storage controller, but it places a copy of the data into the SSD cache without moving the data from its
original location that’s known to users and applications. Caching is relatively simple to manage because nearly all the decisions are made by the caching software or controller. Caching benefits any application whose data is considered “hot” within the scope of data accessible to the cache, but the performance improvement is a bit more gradual, increasing as more data is placed into the cache. This gradual performance improvement is called “warm-up” or “ramp-up,” and it can occur over minutes or hours, depending on the implementation and number of I/O operations occurring. Caching can be read-only or for both reads and writes, depending on the implementation. Caching with SSDs follows many of the same caching algorithms used for memory caching or even caches inside of processors. Some SSD caching solutions will not only cache the obvious hot data, but may pre-fetch adjacent data the caching software believes might become hot based on the I/O patterns observed. Most caching solutions let the admin decide which files or volumes are eligible for the cache performance boost, so you can exclude certain data from clogging the cache. If you believe that most or all of your applications would benefit from a performance boost, you should consider SSD caching.

With tiering and caching, SSDs can be added to the configurations to allow more capacity for the performance boost. For either of these solutions, you’ll have to figure out how much SSD capacity is need to make a difference. Many environments seem to need as little as 3% or as much as 10% of the total disk storage capacity in SSD technology to get a significant performance boost.
DATA COMPRESSION WITH SSD

Compression is another topic gaining a fresh look because of solid-state storage technology. Because SSD technology is generally more expensive than hard-drive technology, when looking only at price per gigabyte, one way to increase the benefit of SSD technology is to compress the data before placing it on the SSDs, thereby consuming smaller amounts of a more precious resource. These days, with processors gaining in performance, it may make more sense to spend some extra CPU cycles compressing data to place it on significantly faster storage devices, therefore increasing overall performance. This can make sense whether the compression occurs in the host or in the storage system. When compression is enabled on some storage systems, the data is compressed immediately upon entering the storage system, so that any cache, SSD or disk device only sees the compressed data, so less capacity is consumed at every stage.

Another solution, mentioned above, is to have all-flash storage arrays. This will become more common as the big storage vendors take up the trend begun by some startup companies last year. We can fully expect to see flash arrays from the big storage vendors announced this year. It’s also very likely that in the near future, all-flash arrays will have the same advanced features that current hard drive-only systems have today, including things like thin provisioning, data deduplication and more. ■

Dennis Martin has been working in the IT industry since 1980, and is the founder and president of Demartek, a computer industry analyst organization and testing lab.
RAID with SSD: A primer

Discover the pros and cons of using RAID with SSDs, the basics of SSD RAID and the relevance of using RAID to improve data availability and increase the performance of HDD systems.

BY MARK PETERS

TWO YEARS AGO, a business without a fax was unthinkable. Today, life without email defies the imagination and nobody faxes anymore. So, is it so crazy to wonder about storage – especially solid-state storage – without RAID?

RAID seems to be a storage fixture, but it was only formally defined in 1987. The major objectives of RAID were always to address the lack of hard-disk-drive (HDD) reliability by improving data availability and to drive up the performance of HDD systems.

While RAID is still a de facto storage standard, there is still a question of whether it is an optimum approach – even for HDD systems – because almost all levels of RAID require an overhead to provide the protection.

For solid-state storage, there are even more questions about RAID’s relevance. This tip will explore the basics of using SSD and RAID together and offer key advice for RAID, SSD and your storage environment.
RAID WITH SSD: THE BASICS
Solid-state storage gives users loads of performance, so RAID’s performance enhancements are moot. That puts the focus on data availability and protection. Many flash chips have basic RAID built-in to increase redundancy and longevity; the question is whether more system RAID on top of that helps.

Whether your solid-state storage is used as a tier or as a cache is a key consideration: Many vendors’ implementations require confirmation from a lower tier of spinning disks before confirming the write. And most cache – aside from read-only – is unlikely to offer immediate data protection.

This affects performance and adds to the cost – so check with your prospective vendors about how they address this.

HOW RAID WORKS WITH SSD
If SSDs merely replace some HDDs in a system, then the same RAID can be applied. You’ll invariably need the same RAID to be applied within and across RAID groups to allow tiering and movement flexibility. For most high-end systems, RAID 5 or RAID 10 are likely sufficient, but for added security, RAID 6 (double parity) is probably preferable. Of course, the raw reliability of solid-state is also relevant: Many solid-state vendors are now claiming “x” years for a given number of full daily writes that are often considerably better than equivalent figures for HDDs.

If SSDs merely replace some HDDs in a system, then the same RAID can be applied. You'll need the same RAID applied within and across RAID groups for tiering and movement flexibility.
WHY YOU MIGHT USE RAID WITH SSD

There are many reasons why you might use RAID with SSDs. A PCIe solid-state storage card in a server is a popular approach to boost application and storage performance; however, it’s effectively a DAS model, which translates to a single point of failure. To help protect against losing data, a simple RAID 1 (using a mirrored flash card) model might be an appropriate, albeit expensive, approach. Otherwise, such cards are often implemented as read-only cache so the protection is performed more economically at the HDD level. This all comes back to knowing what you want to achieve regarding the balance of performance and data availability/protection.

SPECIALIZED SOLID-STATE RAID HARDWARE/SOFTWARE

New and updated RAID controllers are emerging that allow storage systems to use more of the massive performance boost that solid-state storage can provide, as a few SSDs can quickly overrun the capabilities of traditional controllers. The main focus of these new controllers is simply to allow more SSD performance to flow to the server and applications rather than a revamping of RAID. However, it’s important to note that, with the new breed of purpose-built all-flash and hybrid flash/HDD arrays, some vendors are implementing a special version of RAID that’s optimized for their particular SSD implementations.
ECONOMICS AND MIXING HDDS AND SSDS IN RAID ARRAYS

Having established that RAID is – by definition – all about redundancy, the simple truth is that some amount of copied data and/or parity data has to be stored somewhere. The extent and placement of that “extra” data depends ultimately on economics. If money was no object, you’d have multiple copies on multiple solid-state devices. Realistically, that’s not economically feasible, so a hybrid approach makes more sense for using RAID with SSD. Prospective users of solid-state storage should give careful consideration to the options offered by various vendors. A hybrid or mixed approach can make sense in the array (although it requires careful pool management) but it doesn’t make sense in a RAID group because the performance and reliability characteristics are so different that you’d lose the solid-state advantage in the process. Some of the emerging vendors have sophisticated firmware to fully use the solid-state while placing the redundancy data on lower cost media, which can save in the range of 10% to 50% on overall costs (compared to traditional RAID on flash alone) for well-protected, highly available data.

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Deploying PCI Express SSD devices

With a PCI Express (PCIe) solid-state drive (SSD), the storage network can be eliminated entirely in certain situations. Learn about the considerations and challenges of PCIe SSD and if it's right for your environment. By Stephen Foskett

Solid-state storage based on NAND flash memory chips has drawn much attention from traditional enterprise data storage vendors, along with less familiar names and newcomers. The message from storage vendors has been to deploy solid-state storage alongside disks in their arrays, relying on specialized software to handle the migration of data to and from this high-performance tier. But newcomers and system vendors offer an alternative approach: Solid-state storage deployed as a PCI Express card within the server itself. The PCIe approach eliminates the storage network entirely in certain situations. This tech tip focuses on the reality of the PCIe SSD market and where these devices should be deployed in today’s systems.

Contrasting PCIe SSD and networked storage

Enterprise storage has slowly evolved from internal disks to direct-
attached storage (DAS) RAID to networked arrays (SAN and NAS). Each step has maintained backward-compatibility with what went before, allowing applications to be deployed on SAN or NAS without major changes from DAS.

The technologies employed for block storage—Fibre Channel (FC) and iSCSI—rely on the SCSI protocol and drivers just like internal disk drives do, but with different results. Modern storage systems might use Ethernet adapters and switches, and can communicate with devices that are distant in terms of geography. Most storage systems are also virtualized, disguising their complex arrangement of caches and mobility. All of this effort goes to balance flexibility and performance, but it places an upper limit on storage performance.

PCI-based storage is entirely different. Rather than masquerading flash or DRAM memory as a SCSI-connected hard disk drive, PCI Express SSD products often use specialized drivers to communicate using direct memory access (DMA) over the PCI bus. This is game-changing in terms of I/O latency, enabling random read and write performance that’s orders of magnitude faster than the quickest storage array. Although throughput is also improved thanks to the bandwidth of the PCI Express bus and memory, the expense of solid-state chips limits the amount of capacity that can be deployed.

WHERE TO DEPLOY PCIE SSD TODAY

Enterprise systems architects face a wide variety of challenges, with each application or component placing unique demands on
data storage subsystems. Some require massive storage capacity while others must constantly move vast amounts of data. Neither of these is appropriate for PCIe SSD at this point because of the high per-gigabyte cost of SSD and the limited connectivity of the PCI Express bus.

Instead, architects should consider deploying PCI Express SSD in servers that demand extremely low storage latency or applications generating massive amounts of random read and write operations. The expense and difficulty of integrating these devices requires a careful examination of the various servers that make up critical applications. Consider investing in an application performance monitoring (APM) software suite to characterize application bottlenecks and identify the optimum locations for these cards.

It’s too simple to say that databases are appropriate for PCIe SSDs because the performance profile of database-driven applications varies greatly. This is one product that requires a deeper knowledge of applications, so a sit-down with database and application managers is in order. Consider non-traditional applications as well: PCIe SSDs have found success in web applications and creative workstations, not just database servers.

**PCI EXPRESS SSD IMPLEMENTATION CHALLENGES, CONSIDERATIONS**

As PCI Express devices, these SSDs require an empty slot inside the server as well as an outage window for installation and maintenance. This can be problematic for mission-critical applications, but most will have some opportunity for installation.

Blade server users face special challenges when it comes to PCIe SSDs. Dedicated mezzanine SSDs exist for Hewlett-Packard (HP) Co.’s c-Class blade chassis, but it’s more difficult to install them in other blade servers. Many vendors sell PCI Express expansion chassis, and Xsigo Systems Inc.’s I/O Director and other prod-
ucts enable these to be shared. But these options affect the performance of a PCIe SSD to an extent.

These devices are also expensive, though perhaps not when compared to a high-performance enterprise storage infrastructure. Because they’re PCI Express devices and require special operating system-specific drivers, a PCIe SSD can’t be easily shared with other servers. Such a card will be of great benefit to the server it’s installed in and those that rely on its I/O processing abilities. But this investment can’t be spread among a group of servers, and any excess capacity will go unused.

THE FUTURE OF PCIe SSD
PCIe SSD is an entirely new category of storage device, delivering unprecedented random I/O performance right inside critical servers. The entry of EMC into the market with VFCache and rapid growth of sales at companies like Fusion-io, LSI Corp., Texas Memory Systems and others indicates that there are many buyers looking for this kind of performance.

These devices should be deployed as point solutions to specific performance demands. Use application performance monitoring software to determine if you have an I/O bottleneck and consult with database and application managers to decide whether a PCIe SSD is appropriate for their needs. As you can see, both the devices themselves and their use case are entirely new for enterprise storage managers.

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The impact of SSD technology on the network and CPU

Find out how SSD technology affects the performance balance among CPU, memory, networks and storage, as well as why SSDs and 10-gigabit networking can be a good match. BY DENNIS MARTIN

You’ve probably seen television advertisements for medications where the announcer eventually says “possible side effects include...” and then describes a long list of potential adverse conditions that may occur when taking it. It might be useful to do the same thing when describing the benefits of solid-state drives (SSDs). The good news is that some side effects associated with SSD technology may actually benefit you.

SSDs have the ability to move bottlenecks away from storage and expose new bottlenecks in systems, sometimes in unexpected places. Based on the tests we’ve been running in our lab over the past couple of years, I would like to focus on two areas of IT infrastructure that can be affected when SSDs are deployed: the network and the CPU.
SSD TECHNOLOGY AND THE NETWORK
Depending on the application, solid-state drive technology can have a noticeable effect on the network. Because SSDs provide significantly improved performance when compared to spinning disk drives, more I/Os can be completed in less time. This means enterprise applications that use the network can generate increased network load when SSDs are deployed. In some cases, this increased network load isn’t a problem; it simply drives up network utilization from what may be low levels to moderate levels. In other cases, application performance may grow enough to require an additional network adapter for the purpose of network interface card (NIC) teaming to provide enough bandwidth for peak loads and possibly even sustained loads.

In one of our tests, we deliberately increased the traffic load to very high levels with a PCI-Express (PCIe) SSD card, but were perplexed by the relatively slow performance of the storage. Upon further analysis, we realized that even though we were using four 1 GbE NICs teamed together on the application server, the network was the bottleneck and was preventing us from achieving full performance of the PCIe SSD. So we reconfigured the test to use our 10 Gb network with 10 gigabit adapters in the clients and application server. It was only then that we were able to get full performance out of the PCIe SSD.

We’re at an interesting inflection point in our industry: We’re seeing increased adoption of 10 Gb networking at the same time we’re seeing increased adoption of SSDs. My personal observation is that SSDs and 10 Gb networking are made for each other.
SSD TECHNOLOGY AND CPU UTILIZATION

When a single operating system in a physical, non-virtualized server environment is running on a relatively modern server platform, we find CPU utilization is generally pretty low—often well under 20%—which we characterize as underutilized. In virtualized environments, CPU utilization generally climbs to something much higher and may not be considered underutilized, depending on the number of guest machines and applications running.

In our tests with SSDs where we have driven applications to higher performance levels, we noticed that because of the higher performance and lower latency of SSDs, the CPU utilization goes up in many cases. In some of our tests we’ve seen CPU utilization of approximately 10% with spinning disks in a physical server environment grow to 50% CPU utilization with SSDs in the same physical server. Of course, we’re getting considerably more work done, so this is a good thing. However, the answer to the question of how many virtual machines (VMs) can run on a physical server needs to account for significantly improved storage performance when SSDs are deployed.

SUMMARY: SSDS CAN MOVE BOTTLENECKS

SSD technology has the capability to move bottlenecks. The performance balance among CPU, memory, network and storage is certainly changed when SSDs are deployed. And as SSDs become more widely adopted, server, network and storage administrators need to adjust their workload calculations in each of their respective areas. We invite you to see how bottlenecks moved in our test results in the Demartek SSD zone.

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