Introduction - Solid-state leaps from niche to mainstream

Solid-State Drive (SSD) technology has existed in several forms for more than two decades, and since the mid 1990’s it has found popularity in military and niche applications due to its inherent reliability under harsh conditions and the lack of moving mechanical parts. Today’s solid-state drives have moved from their proprietary interfaces to now emulate standard hard disk drive protocols such as Serial-Attached SCSI (SAS) and Serial ATA (SATA), so can therefore directly replace conventional mechanical hard drives in many applications. Until recently solid-state storage technology remained far too expensive for mainstream enterprise and consumer computing and presented storage capacities that lagged way behind the steady growth of conventional hard drives. Thanks to rapid advances in solid-state technology accompanied by significant annual decreases in raw material costs, the solid-state drive has leapt from its niche origins into mainstream computing to deliver potentially huge storage I/O performance and reliability gains if deployed correctly in suitable application environments.

Considerations for deployment - are all SSDs created equal?

As we move into 2010, mainstream SSD deployment resides in the ‘early adopter’ stage of its technology adoption lifecycle, and like many technologies that are gaining momentum there are trade-offs that need to be considered at this initial stage. Firstly, the cost per gigabyte for SSD will be higher, and in some cases significantly higher, than mechanical drive equivalents, so if improved I/O performance is the driving factor the cost per/IOP will be a useful calculation to make. Secondly there are two main configurations used in SSD manufacture: Single-Level Cell flash memory (SLC) found in the most expensive and performant drives, which as the name suggests uses a single NAND flash cell to store each bit of data. The alternative, Multi-Level Cell flash memory stores 2 or more bits per cell and is found on more cost effective and usually higher capacity SSD devices. When considering which SSD technology is right for an application a useful analogy would be to think of SLC as the high performance and super reliable SAS drive of the solid-state world, while MLC fills the place of the less resilient but higher capacity SATA drive.

SLC vs. MLC - choosing the right grade for the application

If we consider SSD reliability at the most basic level it is quite easy to imagine that the loss of a single cell in SLC will result in less data loss than the loss of a cell carrying two or more bits in MLC. This reliability correlation is not quite so clear cut as there are techniques such as interleaving and wear leveling that can enhance the reliability of MLC, however, in general SLC is considered ‘industrial grade’ technology whereas MLC is more than adequate for commercial grade applications. SSD manufacturers often provide endurance duty cycle measures for SLC in the order of 100k against 10k for MLC. Put into context this would provide a usable life of between 50 -150 years for SLC, far outweighing the lifespan of any underlying hardware; similarly a commercial grade application using MLC could completely write and erase the entire contents of the device once per day for 27 years, again beyond the life expectancy of the hardware. The data workload characteristics of an application are therefore key to choosing the right SSD solution.
Some facts regarding performance

The storage industry is very comfortable with rating hard drive performance in terms of read and write performance benchmarks, so it’s no surprise that the SSD has been subject to the same. Aside from read/write performance a key strength of the SSD is the incredible data access time that it can achieve. A typical consumer hard drive may take on average 10ms to find and retrieve information due to the mechanical rotation of the drive. A SSD retrieves information from a NAND cell similar to the time a server would take to retrieve data from RAM, and this can all be achieved in 0.1ms or less. It is this incredible access time capability which provides SSD with the label of ‘always-on’ technology.

SSDs can achieve significant read and write performance gains over traditional HDDs although measures are dependant on whether the workload characteristics are random or sequential, with the most significant gains being realized with random read operations. The primary factor that affects SSD write performance is the ratio of data ‘write’ to ‘re-write’ operations. A ‘write’ is defined as data being written to a blank NAND cell which is the condition set for all cells after leaving production, a ‘re-write’ is required to place data into cells that already hold data which is a 2-3 pass operation of read/erase/write, and this is much slower than an initial write to a blank cell. Clearly SSD write performance will degrade slightly with use, however SSD manufacturers are incorporating techniques to improve write performance such as write combine buffers to hold written data before committing to disk. Regardless of this imbalance between read and write performance a SLC based RAID set should easily outperform an equivalent number of traditional HDDs in the same configuration. When we compare read performance for random data sets at least 4x the number of HDDs may be required to match the performance of an equivalent SSD configuration. This vast reduction in the number of drives brings significant power savings and much more economical use of rack space.

Power savings and operation in the harshest environments

Without platters to spin or heads to move, a SSD consumes about a third of the power of a typical data center disk drive and requires far less cooling. Combine this with the reduction in the number of high performance drives required to meet a given performance level and the cost savings can be very significant. Unless cooling fans are being used a SSD runs completely silent compared to the spin of a magnetic HDD. A further advantage of the lack of moving parts is the ability to operate in the harshest environmental conditions such as those defined by the military standard MIL-STD-810F. Many SSD devices can operate within -40 °C to +85 °C temperature range, absorb shock conditions to 1,500 g, and withstand random vibration of 16 g at 80,000 feet altitude. This makes SSD an ideal storage solution for military embedded systems and many other applications deployed in harsh environments such as remote telecommunications installations.

SSD Security - erase with no trace of data in seconds

For many industries, in particular military, government and financial sectors, having data fall into unauthorized hands is unacceptable. Traditional hard drives based on magnetic media leave behind traces of confidential data after erasure. Software is available with algorithms that can be applied to overwrite the erased blocks with randomized data, however this is time consuming and may still not meet military specifications which often require the magnetic media to be degaussed or the drive physically destroyed to ensure complete security. Many SSD solutions provide built-in drive level data sanitation tools that can quickly and easily purge all data from the device in a matter of seconds. Options are available to either purge and destroy the cell media or purge and allow the device to remain usable. Further drive level security features include data encryption and protection against data alteration or theft.
3 Key considerations for a migration to SSD

1 - Balancing cost and providing capability for incremental growth

SSD technology has decreased in price such that MLC based drives are now available as an affordable alternative in laptop computers. Although they still command a price/capacity premium over magnetic HDDs many SSD vendors are racing to bring MLC solutions to market which will push pricing down for these consumer grade drives. Enterprise applications will mostly be looking to SLC grade flash to meet performance and endurance requirements, however in the near term SLC pricing will preclude its use as a tier 1 storage solution. To follow the price differential between SLC and MLC we must chart the underlying NAND Flash Contract Price which is a traded commodity and then factor the additional controller technology which is built into SLC devices to deliver true mission-critical performance and reliability. When looking for an external SSD RAID solution it is vital that the solution offers a flexible intermix of SSD, SAS and SATA drives to provide a tiered introduction of SSD technology. Many external SSD solutions on the market only allow SSD drives in a fully populated chassis which reduces flexibility and can significantly increase the investment in SSD above initial requirements.

2 - Do you have the SRM tools to implement a tiered storage pool?

A very effective way to implement SSD technology is to combine its strengths with high performance SAS and high capacity SATA drives in a new storage hierarchy where SSD can take on the label of ‘Tier 0’. With careful capacity planning, storage access for business critical applications can be increased by over 100 times by moving the most frequently accessed data onto SSD. Storage resource management tools (SRM) would need to be purchased and deployed to both identify and size the most frequently accessed data sets, and this should be combined with capacity planning to predict future growth. Automated tiered storage software is also required to ensure this approach remains effective by dynamically moving unused data to the lower storage tiers, thus maintaining the most active content on SSD.

3 - Are you using operating systems that are SSD aware?

From an operating system perspective, SSDs require a different house-keeping approach to traditional HDDs and many of the latest OS editions are shipping with SSD friendly features. Gone is the need for defragmentation as we no longer have mechanical read head latencies to worry about, and unnecessary read/erase/write cycles are detrimental over the longer term. Windows 7 will be able to recognise SSDs through the ATA command set and more efficiently partition the solid state drive so as to minimise unnecessary read/write cycles. The disk defragmentation service will also be disabled when Windows 7 detects installation on a SSD. With OpenSolaris the ZFS filesystem is built upon a virtual storage pool approach which can span many types of storage device. If SSDs are included in a pool, ZFS will transparently utilize these as cache within the pool and act as an automated tiered storage manager by directing frequently used data to the SSDs, and less-frequently used data to slower less expensive HDDs. As SSD technology becomes more prevalent in the market, SSD tuning features will become widespread across all major operating systems to extract the highest performance and durability from solid-state technology.
Applications that can benefit from SSD deployment

The Dot Hill range of networked RAID storage arrays treat SSD as any other drive with both single and dual ported configurations available consisting of both SLC and MLC drive options. Suitable applications which can take immediate benefit from SSD include:

- Federal government, military and defense applications with rugged and/or extended environmental requirements e.g. extended temperature, shock/vibration, dust/particles, SSDs also eliminate the need for hermetically sealed drives for high altitude operation.

- Relational Database and Data Warehousing applications have benefitted enormously from the application of SSDs to provide very rapid access to random short data files such as tables, database indexes, metadata and transaction logs.

- On-Line Transaction Processing and Networked Systems include a broad range of applications that can receive orders of magnitude response time improvements through SSD technology. Here the benefits of performance will be experienced first-hand by users. Providing lower latency can improve the experience of running database queries and processing reports. Applications include reservation systems, trading and banking applications and order processing applications. In many cases a small number of SSDs can replace several racks of traditional HDDs.

- Dot Hill networked RAID solutions supporting SSD/SAS/SATA are ideal storage blocks for any ZFS based storage systems due to the inherent automated storage pool allocation and use of SSD as cache devices by the ZFS filesystem.

- High Speed Data Acquisition – many custom and unique applications requiring high speed acquisition of data for structural/seismic/biological analysis, simulation and modelling applications.

- High Performance Swap Files – SSDs can be used for high speed swap files in multi-tasking systems executing multiple large applications simultaneously, for example Desk Top Publishing.

Useful questions for determining SSD suitability?

- Do you have applications that are deployed beyond commercial environmental conditions that may include: extended operating/storage temperatures, high humidity, high altitude, shock and vibration?

- Is data security of utmost importance, including the ability to quickly erase data without residual trace of information?

- Do you have transactional processing applications that require faster or guaranteed response times in order to meet service level agreements (SLAs), or to avoid online customer churn?

- Are you looking to significantly reduce power, and data center cooling costs?

- Do you wish to reduce data center real-estate to save costs, or achieve more storage performance within a restricted data center floor space?

- Are you looking to implement a versatile tiered storage solution to free up over-worked primary HDDs and dynamically allocate static data to lower cost drives or off-line tape?
Conclusion

SSD technology brings incredible data throughput performance to enterprise storage networking that will revolutionize service delivery, offer new levels of endurance, and deliver security features previously unavailable with magnetic storage media. When combined with automated tiered storage management the investment in SSD technology can be maximized to the full. Users need to understand the characteristics and limitations of SLC and MLC technologies in order to select the best grade of flash drive for their applications. A wide range of SSD aware features will be implemented across operating systems and filesystems that will both enhance SSD performance and promote longevity.

Dot Hill networked RAID storage solutions offer a flexible introduction to SSD technology through unrestricted intermix with high-performance SAS and high-capacity SATA drives at a chassis level. This approach allows users to start small and maximize storage utilization of SSDs by combining drives within a tiered hierarchy which is fully certified for a variety of operating systems and virtualized environments. SSD technology also provides a natural extension to Dot Hill’s established portfolio of NEBS Level 3 and MIL-STD-810F certified solutions for ruggedized environments.