Solutions to Week 7 Mass Storage

Question 1

Make a comparison of capacity, speed, battery life, form factor, reliability, durability, and price for hard disc drives (HDDs), solid state drives (SSDs), and solid state hybrid drives (SSHDs). What is your conclusion?

Answer:

Laptop Storage Selection Criteria

	Speed	Capacity	Price	Reliability	Form Factor	Durability	Battery Life
HDD	★	★★★	★★★	★★★	★★	★★	★★
SSHD	★★	★★★	★★	★★★	★★	★★	★★
SSD	★★★	★	★	★★★	★★★	★★★	★★★

KEY: ★ = Good ★★ = Better ★★★ = Best

(From http://www.seagate.com/au/en/do-more/how-to-choose-between-hdd-storage-for-your-laptop-master-dm/)

Capacity

HDDs are the workhorses when it comes to sheer capacity and how much data can be stored. SSHD technology also offers maximum capacity points at affordable price points. SSDs are available at various capacity points, but are more expensive above 240GB.

Speed

SSDs provide peak performance for booting and high read/write performance to supporting computing that requires enhanced multitasking capabilities. On the other hand, an SSHD can provide near–SSD performance for booting, launching, and loading data. HDDs usually provide ample performance for the majority of PC platforms available today.

Battery Life

In general, storage has minimal impact on battery life in a laptop computer—less than 10% of overall system power usage. The display and processor are much more significant. When compared, SSD is the most power-efficient, with SSHD and HDD following close behind.

Form Factor

SSD products are not limited by the spinning platters used by HDD and SSHD products, so they have the most flexibility in terms of physical size. For standard laptops and Ultrabooks, SSDs are available in 5mm and 7mm heights. HDDs and SSHDs are available in standard 7mm and 9.5mm designs, and 5mm designs will be available in 2013.

Reliability

Failure rates for the three technologies have very similar ratings. However, SSHD has the potential to demonstrate improved reliability, as the combined use of SSD and HDD in an integrated system can draw on the strengths of each.

Durability

SSDs are viewed as more durable simply because of their solid state design. But practically speaking, other components in a laptop or desktop, such as the display or processor, are more likely to be damaged due to shock, damage or temperature extremes.

Price

At a system level, low-capacity SSDs, such as those in the 32GB to 240GB range, can be affordable. But high-capacity SSDs are very expensive, especially when measured by cost per gigabyte. HDDs provide the lowest cost per gigabyte. SSHDs provide a cost per gigabyte that's just slightly higher than HDDs.

There are a number of factors for possible consideration when choosing between a traditional HDD, SSHD or an SSD. The easiest and most common way to evaluate the differences between these storage devices is to compare cost, performance and total capacity trade-offs. HDDs still offer massive capacity and lowest prices. SSDs are extremely fast, but are more expensive, especially at capacity points above 128GB. SSHDs combine some of the best aspects of both HDD and SSD but may not be the top performers for every criteria.

Question 2

1. What are the differences (i.e. bit per cell, read/write cycles, write speed, endurance, cost and usage) among Single Level Cell (SLC), Enterprise Multi Level Cell (eMLC), Multi Level Cell (MLC), and Triple Level Cell (TLC) flash memory?

   Answer:

   SLC flash is so called for it's single bit that can either be on or off when charged. This type of flash has the advantage of being the most accurate when reading and writing data, and also has the benefit of lasting the longest data read and write cycles. You won't see too many home computers with this type of NAND due to its high cost and low storage capacities.

   eMLC is MLC flash, but optimised for the enterprise sector and has better performance and longevity. It has better performance and endurance over standard MLC. eMLC provides a lower cost alternative to SLC, yet maintains some of the pros of SLC.

   MLC flash as it's name suggests stores multi bits of data on one cell. The big advantage of this is the lower cost of manufacturing versus manufacturing SLC flash. The lower cost in flash production is generally passed onto you as the consumer, and for that reason is very popular among many brands. MLC flash is preferred for consumer SSDs for it's lower costs but the data read/write life is less in comparison to SLC.

Storing 3 bits of data per cell, TLC flash is the cheapest form of flash to manufacture. The biggest disadvantage to this type of flash is that it is only suitable for consumer usage, and would not be able to meet the standards for industrial use.

The summary can be found in the following table:
http://www.mydigitaldiscount.com/everything-you-need-to-know-about-slc-mlc-and-tlc-nand-flash.html

Flash Type	SLC Single Level Cell	eMLC Enterprise Multi-Level Cell	MLC Multi-Level Cell	TLC Triple-Level Cell
Read/Write Cycles	90,000-100,000	20,000-30,000	8,000-10,000	3,000-5,000
Bit Per Cell	1	2	2	3
Write Speed	★★★★★	★★★★☆	★★★☆☆	★★☆☆☆
Endurance	★★★★★	★★★★☆	★★★☆☆	★★☆☆☆
Cost	★★★★★	★★★★☆	★★★☆☆	★★☆☆☆
Usage	Industrial/Enterprise	Industrial/Enterprise	Consumer/Gaming	Consumer

2. What effect can the quality of flash memory have on SSD performance?

   Answer: Higher quality flash memory can have a marked effect on read/write performance, and longevity — compare cheap USB flash disks, to high performance SSDs.

3. What functions are performed by an SSD controller? What effect can the quality of the SSD controller have on performance?

   Answer:

   The controller is an embedded processor that executes firmware-level code and is one of the **most important** factors of SSD performance. In a hybrid SSD, the controller will also manage a small classical hard disk. Popular functions and features decided by the controller include writing, reading, erasing, error checking, encryption, garbage collection, wear levelling, RAISE, and over-provisioning.

   - ECC Engine — Error Checking & Correction are a key part of today's SSD. ECC will correct up to a certain number of bits per block of data. Without ECC, many of the low cost consumer flash cards using very inexpensive memory would not be possible.
   - Wear levelling — the ability to even out the number of write cycles throughout the available NAND
   - Buffer/Cache — Controllers generally have a high speed SRAM/DRAM cache buffer used for buffering the read and/or write data of the SSD. (Since this cache uses

volatile memory, it subjects data to loss if power is unexpectedly lost. It is common to see both internal caches in the controller chip itself as well as external cache chips.)

- Defect Management — Every controller needs a method to deal with bad blocks of memory and new defects. At the point a NAND block becomes unusable, some action on the SSD controller's part must happen. In some cases a spare sector replaces the failed block. In a poor controller design, the SSD fails.
- Encryption — For higher security applications, a hardware encryption and decryption engine is generally built into the silicon of the controller. The encryption engine is typically implemented in hardware to ensure speed for encrypting/decrypting on the fly. The most popular encryption method for SDDs today is AES256.
- Over-provisioning — Some space on the SSD is reserved for the controller and is not available to the user. The controller can use this space for wear levelling, garbage collection, or any other performance optimising features the drive might support.
- Garage collection — Improves write performance by pro-actively eliminating the need for whole block erasures prior to every write operation.

Better SSD controllers have better algorithms for accessing data, wear levelling, making use of its caches — this increases both performance and longevity of the memory being controlled by it.

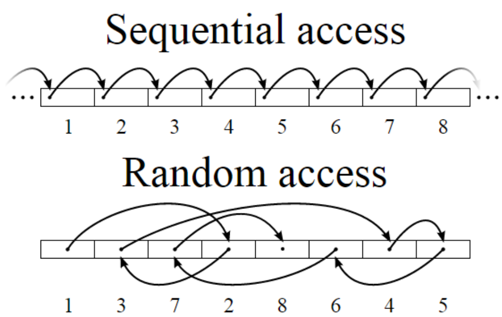
Question 3

Why is the difference between sequential and random access so significant for some kinds of mass storage devices, but not others?

Answer:

Sequential access (large file transfers)

The data is being read sequentially; that is, it is reading one byte after another on the storage device, without having to seek for the next piece of data. For example, magnetic tapes and optical disc drives are suited for sequential access.



Random access (running programs and multitasking)

The data stream being read is all over the recording surface of the storage device, so it has to constantly search for the next piece of data to retrieve, and go ahead and retrieve it. Those that have the issues of head seek time and rotational latency have issues with random access. This is due to the need to align heads, and wait for the platter/disc to rotate to the right spot. Hard disk drivers are suitable for random access.

Those that have no penalty traversing about its media (e.g. solid state disks) have no such issues with accessing data randomly.

Question 4

Hard disks use a technique known as *head parking* to make them more resilient to shock and rough handling when they are switched off. What is head parking? What situations (other than being switched off) might the drive heads be parked?

Answer:

Head parking is a function where the disk head moves off the platter surface. There is usually a special area for the head to move where it is padded and better prepared to survive shock. This lets the hard disk suffer rough handling without the disk heads crashing into the platter surface (known as a "head crash"). The parking function usually activates when power to the disk is switched off.

Modern laptop hard disks have accelerometers, which can detect when it is dropped; this signal tells the hard disk to park itself before the computer hits the ground, even if the computer is switched on and operating. This may not be on the hard disk itself, but the host (e.g. on the laptop it's inside).

Question 5

What kinds of issues and situations prevent a mass storage device from working at its burst rate all the time?

Answer:

Burst speed is related to how fast data travels from your internal or external mass storage device for a short amount of time. The data is buffered and sent in a burst at maximum speed over the bus, so the bus is utilised for only a short period of time. The bus is then released and can be used by other devices.

The sustained transfer rate is the rate at which data can be read (or written) from the medium continuously.

The burst rate will not be maintained:

- Bottlenecks if the bus is shared (either external interface for the RAM , or further upstream)
- Seeking time/return time, etc. if the access pattern is not purely sequential .

Consider a special case of a hard disk drive:

The Hard Disk Controller (HDC) is the interface that enables the computer to read and write information to the hard drive. The burst rate will not be maintained:

- Mainly based on differences in performance/ bottlenecks between internal (media to disk controller) and external (disk controller to chipset) interfaces.
- Caches make the disk faster than normally possible but if the cache algorithms are not running at full efficiency then the burst rate is not sustainable.
- Varying performance of the media, e.g. inner edge of a hard disk platter.

Question 6

Why can't:

1. DVD discs be spun as fast as hard disk platters?

   Answer: DVDs aren't clamped to the drive as securely, so they can't be rotated as quickly without things wobbling and getting out of alignment. If they were run faster they would shatter, ruining the disc and the drive. This does happen sometimes with poor quality media at high speeds (e.g. 52X CD:ROMs).

2. Laptop hard disk platters be spun as fast as desktop hard disk platters?

   Answer: Power consumption is an important aspect of laptop hard drive design; a faster spindle speed increases power consumption. Some laptop HDDs do spin at 7200rpm (same as desktop HDDs), but at a power consumption trade-off.

3. Desktop hard disk platters be spun as fast server hard disk platters?

   Answer: Noise is an important aspect of desktop hard drive design; a faster spindle speed increases noise. The whine of a high-speed server HDD would quickly become intolerable when it's sitting a metre or two away from the user.

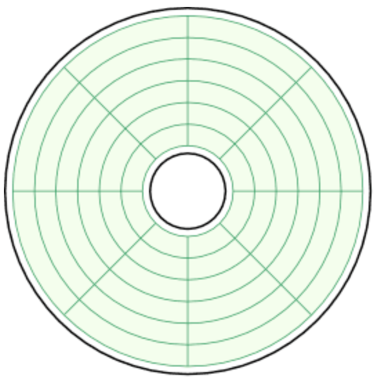
Question 7

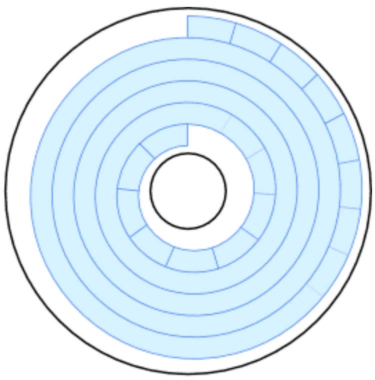
Compare and contrast constant linear velocity (CLA) with constant angular velocity (CAV).

Answer:

Constant Angular Velocity
Placing sectors in concentric rings (tracks) of equal angle sector

Constant Linear Velocity
Placing sectors in an Archimedean spiral with the constant physical length of sectors along the disc


Constant angular velocity disc


Constant linear velocity disc

	Constant Angular Velocity	Constant Linear Velocity
Applications	Faster and newer CD-ROM drives, hard disk drives, floppy disk drives	Conventional CD-ROM drives
Data density	Variable (inner – higher, outer - lower)	Fixed
Rotation speed	Fixed	Variable (inner – faster, outer – slower)
Pros	Simple to design and produce	Increased storage capacity
Cons	Waste of disc space	Latency to switch rotation rate