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## Review on evolution of storage devices

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### ABSTRACT

*With the Fast development of the internet, Decrease in the cost of storage and the improvement made to the storage devices with greater capacity resulted in the creation of an environment with a large amount of data. Things like Consistency, Performance, Data Preservation, Manageability, Security etc. have become extremely important for storage devices. We explain in this research paper how storage devices have evolved over the years.*

**Keywords**— External storage, Hard disk, Magnetic tapes, Punch card

### 1. INTRODUCTION

In today's world, we are drowning in data. We have been engulfed with a lot of data in recent years from many data-intensive apps like NASA's Earth Observing System project, the core part of the Earth Science Enterprise, produces petabytes of data per year. A petabyte is approximately equal to the amount of information in one billion graphically formatted books. The online databases of satellite images used by Google Earth [1] are multiple terabytes in size. The sales data warehouse of Wal-Mart's contains over a half petabyte of data. But the Question is how is this huge amount of data stored?

It all began in 1956 when the first data storage device was announced by IBM. After nearly 6 decades the storage devices have improved greatly with The introduction of the device like Hard Disk Drive(HDD), Solid State Drive(SSD) To name a few. Development of these devices have laid the groundwork for the current storage system industry [2].in recent years the storage capacity of HDDs has improved greatly and the demand has also increased ex in 2016 Seagate average shipped capacity increased from 1.32 TB to 1.42 TB, a 7.6% increase. Western Digital average shipped capacity increased from 1.39 TB to 1.44 TB, a 3.6% increase [3]. The jump from HDDs to SSDs was brought a great performance boost with it we were seeing improvement in performance from anywhere between 50% and 100%. though we there was a huge performance alteration between SSD and the HDD the price to Gigabit ratio was very high i.e. though worth the upgrade they are quite expensive [4].

### 2. EXTERNAL STORAGE DEVICES TYPES

- Magnetic storage: Floppy Disk, HDDs
- Optical storage: CD, DVD Blu-Ray
- Flash memory: SSDs, Memory Card, USB flash drive
- Online cloud storage
- Paper storage: OMR, Punch Card

#### 2.1 Magnetic Tapes

A memory device, in computer language, is a data-storage medium that permits for knowledge archiving, collection, and the backup. one magnetic tape is shown below in fig 1. At first, the tapes were wound in wheel-like reels, on the other hand, cassettes and cartridges came on, that offered a lot of protection for the tape within. One aspect of the tape is coated with a magnetic material. Knowledge on the tape is written and skim consecutive. Finding a selected record takes time, as a result of the machine must scan each record ahead of it. Most tapes area unit used for deposit functions, instead of ad-hoc writing/reading. Data is written into 'tracks' on the medium: Some lies the edge of the tape (linear recording), whereas others area unit is written diagonally (helical recording). Older magnetic tapes used eight tracks, whereas a lot of new ones will handle 128 or a lot of tracks [6].



Fig. 1: Magnetic Tape [5]

**2.1.1 History of magnetic tapes:** Much of the world's information continues to be unbroken on tape, together with information for basic science, like high-energy physics and astronomy, human heritage and national archives, major motion footage, banking, insurance, oil exploration, and more. There's even a cadre of individuals (including American state, trained in materials science, engineering, or physics) whose job is to improve tape storage. The tape has been around for an extended period of time whereas, yes, however, the technology hasn't been frozen in time. Quite the contrary just like the magnetic disk and also the semiconductor, mag tape has advanced greatly over the decades. The first business digital-tape storage system, IBM's Model 726 may store approximately 1.1 megabytes on one reel of tape. Today, a contemporary cartridge will hold fifteen terabytes. And one robotic tape library will contain up to 278 petabytes of information. Storing that a lot of information on compact discs would need quite 397 million of them, that if stacked would be a tower over 476 kilometers high. [7]

**2.1.2 Future with Magnetic Tapes:** It's true that tape doesn't provide the quick access speeds of exhausting disks or semiconductor memories. Still, the medium's benefits are several. To start with, tape storage is additional energy efficient: Once all the information has been recorded, a cartridge merely sits quietly in an exceedingly squeeze a robotic library and doesn't consume any power in the least. The tape is additionally passing reliable, with error rates that square measure four to 5 orders of magnitude under those of exhausting drives. And tape is extremely secure, with constitutional, on-the-fly secret writing and extra security provided by the character of the medium itself. After all, if a cartridge isn't mounted in an exceedingly drive, the information can't be accessed or changed. This "air gap" is especially engaging in lightweight of the growth rate of knowledge-stealing through cyber- attacks. The offline nature of tape additionally provides an extra line of defense against buggy software package. As an example, in 2011, a flaw in an exceeding software package update caused Google to accidentally delete the saved email messages in concerning 40,000 Gmail accounts. That loss occurred despite there being many copies of information held on to exhausting drives across multiple data centers. Fortuitously, the information was additionally recorded on tape, and Google may eventually restore all the lost knowledge from that backup. The 2011 Gmail incident was one in every one of the primary disclosures that a cloud-service supplier was mistreatment tape for its operations. In addition, recently Microsoft's Azure Archive Storage uses IBM tape storage instrumentality [8].

## 2.2 Punch Card

A punched card is a piece of stiff paper that is used to contain digital data represented by the presence or absence of holes in predefined positions. This Digital data can be used for data processing applications or used to directly control automated machinery. Punched cards were mostly used in the 20<sup>th</sup> century in the data industry as it was the primary medium for input of both computer programs and data [9].

The basic idea of punching holes came to work in 1725. Which later Charles Babbage, Semyon Korsakov used in informatics for information storage and search. By 1932 there were printing presses for printing punched cards. They were used in legal documentation, decrypted German messages during World War 2. It was one of the most powerful tools for business data processing. In the 1950s the UNITYPER introduced magnetic tape for data entry. During the 1960s, the punched card was gradually replaced as the primary means for data storage by magnetic tape, as better, more capable computers became available. Initially punched cards were also commonly named as IBM card and Hollerith card. In its first documentation IBM used IBM card but later it was changed to punch card or card or cards. The Hollerith punched cards commonly had printing such that the row and column position of a hole could be easily seen. For applications requiring master cards to be separated from following detail cards, the respective cards had a different design like different upper corner diagonal cuts and thus could be easily separated with the help of a sorter. Other cards typically had one upper corner diagonal cut so that cards not oriented correctly, or cards with different corner cuts could be identified [10].

Different binary formats were used for different computer applications. Binary, where each hole represented a single binary digit, every column (or row) is treated as a simple bit field, and each and every combination of holes is permitted. As a prank, in the binary mode, punched cards could be created where each and every possible punch position had a hole. As a result, such "lace cards" lacked structural strength, and would frequently buckle and jam inside the machine [11].

But in the industry, the IBM 80-column punched card format dominated, commonly known as just IBM cards, even though other companies made cards and equipment to process them. The IBM 5081 card format was one of the most common punched card formats, a general purpose layout with no field divisions. Other IBM punched formats are:

- IBM 40-column Port-A-Punch card format
- IBM 96-column punched card format
- Powers/Remington Rand UNIVAC 90-column punched card format
- Powers-Samas punched card formats
- Mark sense card format
- Aperture card format [12]

Though punched cards have not been that widely used for like a generation, but the impact of it was so great that for most of the 20th century they still appear from time to time in popular culture. Like artists using it in the form of public art, books, secret messages during the wars, research purposes in the university studies, movies based on the books and famous novels of then renowned writers.

Punch cards have also played a major role in student body movements, one such example is the Free Speech Movement where punched cards, used for class registration, were first and foremost a symbol of uniformity [13].

### **2.3 Floppy disk**

A floppy disk is a type of disk storage composed of a disk made of thin and flexible magnetic storage medium, which is sealed in a rectangular plastic enclosure lined with a fabric that removes the dust particles. Floppy disk drive (FDD) used to read and write in floppy disks. Floppy disks, were initially sized as 8-inch and later in 5 1/4-inch and 3 1/2-inch sizes, were a widespread form of data storage and exchange from the mid-1970s to the very first years of the 21st century. Floppy disks became very common during the 1980s and 1990s in their use with personal computers to distribute software, transfer data, and create backups and also they come up with up in affordable price to the public [14].

In the mid-1990s, higher-density floppy disks which were mechanically incompatible were introduced, like the Iomega Zip disk. At that time the adoption was limited first by the competition between proprietary formats and second was the need to buy very costly drives for computers where the disks are going to be used. In some cases, failure in the market was aggravated by the release of very high-capacity versions of the drives and the media were not backward-compatible with the original drives, which divides the users as new and old adopters. Consumers were cautious to the danger of making costly investments into an unproven and rapidly changing unpredictable technologies, so none of the technologies became an established standard [15].

By 2002 the new technology revolution came into the market which had led to very less usage of floppy disk since it was not that much efficient than other technology, the companies who manufactured computers that time had even stopped production of computers with inbuilt floppy disks but it was externally available for purchase for people who got work with it at a price of 20\$. The most effective left over the use of floppy then left was that floppy disks were used for emergency boots in different aging systems which lack support for other sources of bootable media and for the BIOS updates since most of the BIOS and other firmware programs can still be executed from any of the bootable floppy disks.

In May 2016, the United States Government Accountability Office released a report that covered the need to upgrade or replace legacy computer systems within federal agencies. According to this document, old IBM Series/1 minicomputers running on 8-inch floppy disks are still used to coordinate "the operational functions of the United States' nuclear forces". The government plans to update some of the technology by the end of the 2017 fiscal year [16].

Windows 10 no longer includes a generic driver for USB floppy drives [17].

Even though the floppy disk is not that useful now but the floppy disk symbol is still used by software on user-interface elements related to saving files, such as the release of Microsoft Office 2016, even though the physical floppy disks are largely obsolete [18].

### **2.4 Hard disk drive**



**Fig. 2: A Magnetic hard drive [19]**

Magnetic hard disc drives given in figure 2 has undergone immense technological enhancements since their introduction as storage devices over forty-five years past, and these enhancements have had a marked influence on how disk drives are applied and what they'll do. Areal density will increase have exceeded the standard semiconductor development flight and have yielded higher-capacity, higher-performance, and smaller-form-factor disk drives, enabling desktop and mobile computers to store multi-gigabytes of knowledge simply. Server systems containing giant numbers of drives have achieved unique dependability, performance, and storage capability. All of those characteristics are achieved at speedily declining disk prices. This paper relates advances in disk drives to corresponding trends in storage systems and comes wherever these trends might lead within the future [20].

**2.4.1 Working of a hard disk drive:** Let's begin to know a number of the parts of a contemporary disk. We begin with a platter, a circular pave on that knowledge is hold on persistently by causation magnetic changes to that. A disk could have one or a lot of platters; every platter has a pair of sides, every of that is termed a surface. These platters are typically made from some laborious material (such as aluminum), and so coated with a skinny magnetic layer that permits the drive to persistently store bits even once the drive is hopped-up off. The platters are all sure along around the spindle, that is connected to a motor that spins the platters around (while the drive is hopped-up on) at a relentless (fixed) rate. The speed of rotation is usually measured in rotations per minute (RPM), and typical fashionable values are within the seven, 200 RPM to 15,000 rev vary. Note that we are going to usually have an interest in the time of one rotation, e.g., a drive that rotates at ten thousand rev means that that one rotation takes regarding six milliseconds (6 ms). Data is encoded on every surface in concentrically circles of sectors; we tend to decision one such concentrically circle a track. One surface contains several thousands and thousands of tracks, tightly packed along, with many tracks fitting into the dimension of a person's hair. To scan and write from the surface, we want a mechanism that enables us to either sense (i.e., read) the magnetic patterns on the disk or to induce an amendment in (i.e., write) them. This method of reading and writing is accomplished by the disk head; there's one such head per surface of the drive. The disk head is connected to one disk arm, which moves across the surface to position the top over the required track [21].

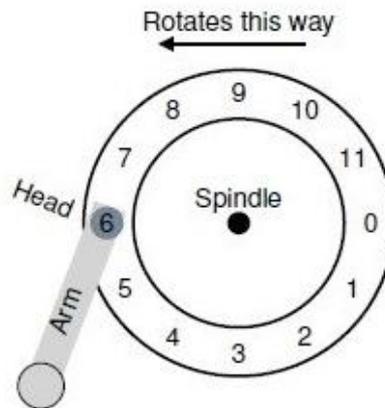


Fig. 3: Single track plus head [22]

**2.4.2 Technological impact of HDD:** Magnetic disk drives have undergone vast technological enhancements since their introduction as storage devices over forty-five years ago, and these enhancements have had a marked influence on however disk drives are applied and what they will do. Region density increases have exceeded the standard semiconductor development mechanical phenomenon and have yielded higher-capacity, higher performance, and smaller-form-factor disk drives, enabling desktop and mobile computers to store multi-gigabytes of information easily. Server systems containing massive numbers of drives have achieved unequalled reliability, performance, and storage capability. All of those characteristics are achieved at quickly declining disk prices.

“Since the first disk drive was introduced in 1956, drives have undergone a rapid evolution, thanks to the application of new magnetic, electronic, and mechanical technologies. These developments have yielded storage devices with very significant capacity and performance increases. Early disk drives were specialized and very expensive, whereas today's drives are nearly commodity items and are universally available. Although the fundamental architecture of disk drives has changed very little in the years since their introduction, the geometric size of drives has been reduced almost to the point of micro-miniaturization, and these smaller sizes have resulted in storage system characteristics that offer new horizons in data retention and availability. The trends characterizing storage systems in which large numbers of drives participate as a single storage unit has followed the evolutionary behavior of their principal component, the hard disk drive (HDD). Storage system characteristics are also influenced somewhat by components other than disk drives, including DRAM (dynamic random-access memory) caches and buffers, cooling systems, frames and cases, and system software.” [23].

**2.4.3 Future of hard disk drives:** The growth of hard disc drive technology is studied, and upcoming storage technology is discovered. Firstly, region density growth and upgrading of performance like information transfer rate and access speed are checked out, equivalent to the development of magnetic materials. Then, state of the art high-density recording technologies is studied. The bit proportion is taken into account in relation to the trends on exactitude method of pole tips, and high output detector evolution. Finally, the future of data storage is inspected, and storage types toward 1 Tb/in<sup>2</sup>/sup 2/ recording are explored [24].

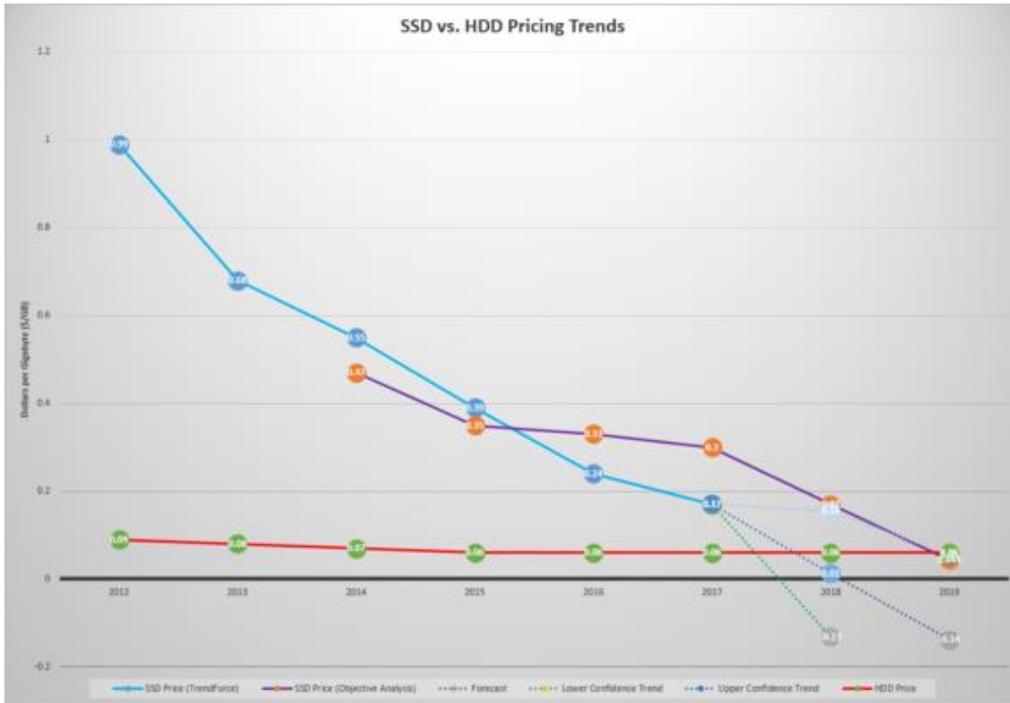
Magnetic hard disk drives have considerably enhanced in dimensions, performance, and price because of several technological modernizations; together with magneto-resistive heads, low noise skinny film disks, PRML channels, and advanced mechanical actuators and motors. By analyzing requirement trends of every new Winchester drive style, a viewpoint of this development is established and style features of future disk drives are predictable [25].

## 2.5 Solid state drive

In the last 15 years, NAND Flash memory has greatly impacted our lives. SD Cards have almost replaced photographic film in the camera and floppy disk have been driven o extinction by USB. Due to a trade-off between Price and performance NAND flash drive have been fighting HDD as SSD [26].

Solid State Drives or SSDs are a storage device that use IC assemblies to store data. There are SSDs that have the same form factor as Traditional hard disk drives r HDDs and also have similar Protocols such as SAS and SATA which help greatly simplifying usage of SSDs in computers. However, SSDs with new form factor such as M.2 and protocols Such as NVME have also been developed these new form factors are much smaller than traditional HDDs and thus are quite useful in computer systems with smaller form factor or laptops as manufacturers can reduce the space required for Storage devices and can give bigger battery instead or in ultra-thin laptops like the Acer Swift 7 where there is no space for a traditional HDDs. Hybrid drives or Solid State Hybrid Drives(SSHDDs) like the Apple’s Fusion drive Combine the feature of both SSD and HDD. In SSHDD there is a large HDD and a small SDD that acts as a cache to improve the performance of the frequently accessed data.

The World’s first SSD was introduced in 1976 by Dataram its capacity was 2mb and cost 9700\$ in 1977. World’s first prototype SSD to use flash memory was introduced in 1988 by a small Alabama based Pc vendor. In 2006 Samsung released one of the first mass-marketed SSDs, a 2.5 inch 32 Gb drive with a PATA interface it cost 699\$ at the time [27]. Fast Forwarding to today SSDs Have Been Becoming Cheaper and are coming in Greater Storage Capacities. But The SSDs don’t come at a cheap price. They are considerably more expensive than HDDs.

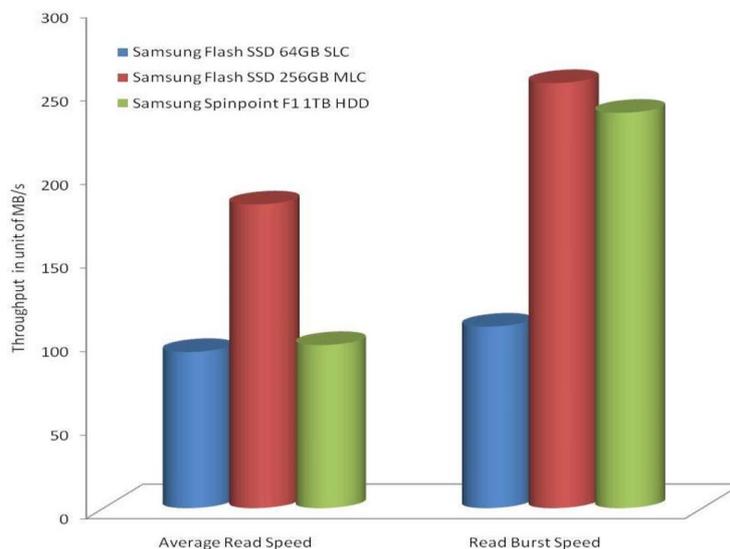


**Fig. 4: SSD vs. HDD Price [28]**

Figure 4 above Shows the Decline in the pricing of SSDs over The years. It Ca be seen in the graph the price of SSDs have been decreasing and as the performance of SSDs is also improving over the years they are an essential Upgrade over the HDDs.

**3. SSDS VS HDDS**

SSDs and HDDs are the most commonly used local storage devices used in laptops, Computers etc. So it has become a very commonly asked question which is a better solution. If you just compare the Performance of the two SSD Outperforms HDDs Which is shown in figure 5 below.



**Fig. 5: SSD vs. HDD Performance [29]**

As seen in figure 5 above the average read time and read burst speed is greatly improved when moving from SSD to HDD. It also affects the boot time of a system.

But SSD Cost a lot more than an HDD which also a great factor for people a 1 TB WD SSD costs 15,722 INR [30] whereas a 1 TB WD HDD costs 3649 INR [31]. This can also be observed in Fig 6. Which is comparing the price of the two over the year? The price difference is huge but the performance bump is also a big one So SSDs are worth the upgrade and as the price of SSDs is decreasing steadily they are becoming more and more accessible to the majority of people.

Still, HDDs are more popular than SSD among the consumer usually because of the low cost but the user who is willing to pay for the extra performance prefer SSDs. SSDs are also on their way of becoming a default storage device system especially in laptops given that they have smaller form factor.

#### **4. STORAGE SYSTEMS COME OF AGE: FROM COMPONENTS TO SYSTEMS**

It was recognized that the disk drive cannot provide a range of storage capabilities. The first device storage was connected to CPU but later changes were made in the external storage system.

##### **4.1. Networked storage**

During the early 1990's drive for low-cost LAN technology became a trend in storage systems. And since the PC was unmanaged and notoriously unreliable, and so to achieve sharing of data, rudimentary low-cost PC-class storage servers became common. The most frequently used software for networking was "Novell Netware". At the same time resurgence in Unix workstation and Unix servers were there. The next step was the emergence of the NAS which typically served standard protocols such as NFS, CIFS, HTTP, and FTP.

##### **4.2 Autonomic storage**

Working in progress, IBM called for a manifesto to action for academia, government to address the problem of ease and cost of management. The basic goal was to improve ownership, reliability, and ease of use of information technologies. For achieving the promise autonomic computing systems need to become more self-configuring, self-healing and self-protecting, and during operation, more self-optimizing.

##### **4.3 Future challenges**

Requirements are accelerating for the storage systems and new paradigms are increasing creating different challenges in the cloud [32-41]. Though data is being rapidly increasing moreover the sources of data generation are also increasing which is one of the big challenges to deal with. Till now data has been widely distributed in databases, textual data, and data on web pages. But now since new sources such as machine-generated data that is data sourced by sensors, surveillance cameras and digital medical imaging it has increased the complexity. Effective data mining can also provide new opportunities in security, customer relationship management, and other application areas.

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