Chapter 3
Storage
Learning Objectives

• Name several general characteristics of storage systems.
• Describe the three most common types of hard drives and what they are used for today.
• Discuss the various types of optical discs available today and how they differ from each other.
• Identify some flash memory storage devices and media and explain how they are used today.
• List at least three other types of storage systems.
• Summarize the storage alternatives for a typical personal computer.
Overview

• This chapter covers:
  – The characteristics common among all storage systems
  – The primary storage for most personal computers—the hard drive
  – How optical discs work and the various types that are available today
  – Flash memory storage systems
  – Network and cloud storage, smart cards, and the storage systems used with large computer systems
  – Storage alternatives for a typical personal computer
Storage System Characteristics

• A storage system consists of a storage medium and a storage device
  – The storage medium is the hardware where data is stored
    • DVD disc, flash memory card, etc.
  – The storage device is the hardware into which the storage medium is inserted
    • DVD drive, flash memory card reader, etc.
    • Can be internal, external, or remote
    • Storage devices are typically identified by letter
  – Some storage media is removable; some is not
Examples of Storage Device Identifiers

The letter C is usually assigned to the first hard drive.

CD/DVD drives are usually assigned letters after the hard drives, such as D for this computer.

Any storage devices attached to the computer via USB ports are typically assigned next, such as E for this USB flash drive.

Other letters, beginning with F for this computer, are used for any other storage devices attached to the computer, such as via this built-in flash memory card reader.

FIGURE 3-1
Storage device identifiers. To keep track of storage devices in an unambiguous way, the computer system assigns letters of the alphabet or names to each of them.
**Volutility and Random vs. Sequential Access**

- **Volutility**
  - Storage media are nonvolatile and, therefore, is used for data to be saved for later use

- **Random vs. sequential access**
  - Random access (direct access) allows data to be retrieved from any location on the storage medium
    - Virtually all storage devices use random access
  - Sequential access means that retrieval of data can occur only in the order in which it was physically stored on the storage medium; for example, a magnetic tape drive
Files, Filenames, and Folders

- A **file** is anything stored on a storage medium, such as a program, document, digital image, or song.
- A **filename** is a name given to a file by the user.
- A **folder** is a named place on a storage medium into which files can be stored.

*FIGURE 3-2*
Organizing data. Folders are used to organize related items on a storage medium.
Logical vs. Physical Representation and Types of Storage Technologies Used

• Logical file representation
  – Individuals view a document stored as one complete unit in a particular folder on a particular drive

• Physical file representation
  – Computers access a particular document stored on a storage medium using its physical location or locations

• Types of storage technology
  – Magnetic (conventional hard drives)
  – Optical (optical discs)
  – Electrons (flash memory media)
Hard Drives

- A **hard drive** stores most programs and data for a personal computer
  - Can be internal or external
  - Available with built-in encryption that limits access to only authorized users
Magnetic Hard Drives

- A **magnetic hard drive** or **hard disk drive (HDD)** contains particles on the metal disks inside the drive that are magnetized to represent the data’s 0s and 1s.
Magnetic Hard Drives (cont’d)

- One or more metal hard disks are permanently sealed inside the drive along with an access mechanism and read/write heads
Hard Disk Organization

- **Tracks** are concentric paths on the disk where data is recorded.
- **Sectors** are small pieces of a track.
- **Clusters** consist of one or more sectors.
  - Smallest addressable area of a disk.
- **Cylinders** are a collection of tracks located in the same location on a set of hard disk surfaces.
Examples of Tracks, Sectors, Clusters, and Cylinders

FIGURE 3-6
Magnetic hard disks are organized into tracks, sectors, clusters, and cylinders.
Magnetic Hard Drive Technologies

• Traditional: Longitudinal magnetic recording aligns magnetic particles on a hard disk horizontally, parallel to the hard disk’s surface

• Newer: Perpendicular magnetic recording (PMR) places bits upright and closer together to increase capacity and reliability

• Newest: Shingled magnetic recording (SMR) squeezes more data onto disks by overlapping the data tracks on them like the shingles on a roof

• Emerging: Heat-assisted magnetic recording (HAMR) uses lasers to temporarily heat the surface of the hard disks when storing data in order to store more data
How It Works

More Storage for Your Tablet

- Tablets often have between 16 GB and 128 GB of storage
- To extend storage, you can transfer content to and from desktops or notebooks
- Easier to use a wireless hard drive and Wi-Fi
  - Download the appropriate app

The 2 TB Seagate Wireless Plus magnetic hard drive.

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Data Recovery Experts

• Recover data from damaged storage devices
• Used when devices are physically damaged or just stop working
• It is important to back up data to prevent data loss

Data recovery. The data on this destroyed computer (left) was recovered by data recovery experts in a clean room (right).
Solid-State Drives (SSDs)

- A **solid-state drive (SSD)** uses flash memory technology to store data
  - Uses less power and has no moving parts
  - Much faster than magnetic hard drives, but more expensive
  - The norm for netbooks, mobile devices, and other portable devices
Solid-State Hybrid Drives (SSHDs)

- A **solid-state hybrid drive (SSHD)** or **hybrid drive** uses a combination of magnetic disks and flash memory chips
  - The data that is most directly associated with performance is stored in the flash memory
  - Nearly as fast as solid-state drives (SSDs)
  - Slightly more expensive than magnetic hard disk drives (HDDs)
Internal and External Hard Drives

• Internal hard drives are permanent storage devices located inside the system unit
  – Removed only if a problem develops
• External hard drives transport large amounts of data from one computer to another, for backup, and for additional storage
  – Full-sized external hard drives are often used for backup
  – Portable external hard drives: smaller and easier to transport
  – Most connect with a USB connection, although some may connect through wired or wireless networking connections
Examples of External Hard Drives

**FULL-SIZED EXTERNAL HARD DRIVES**
This drive is about the size of a 5 by 7-inch picture frame, but thicker, and holds 6 TB.

**PORTABLE HARD DRIVES**
This drive is about the size of a 3 by 5-inch index card, but thicker, and holds 2 TB.

**WIRELESS HARD DRIVES**
This drive connects via Wi-Fi and holds 500 GB.

**FIGURE 3-9**
External hard drives.
Hard Drive Speed and Disk Caching

- **Disk access time** is the total time that it takes for a hard drive to read or write data
  - Consists of seek time, rotational delay, and data movement time
  - SSDs don’t require seek time or rotational delays
- **Disk cache** consists of memory used in conjunction with a magnetic hard drive to improve system performance
  - Typically consists of RAM-based disk cache located inside the hard drive case
  - Can speed up performance and save battery life
Hard Drive Partitioning

• Partitioning divides the physical capacity of a single drive logically into separate areas, called partitions
  – Each partition functions as an independent hard drive
  – Referred to as logical drives
  – Increases efficiency (smaller drives use smaller clusters)

• Partitions are used to create:
  – A recovery partition
  – A new logical drive for data
  – A dual boot system
Hard Drive File Systems and Interface Standards

- File system determines the partition size, cluster size, maximum drive size, and maximum file size
  - FAT, FAT32, and NTFS
- Interface standards determine how a drive connects to the computer
- Common standards
  - Serial ATA (SATA): most common internal hard drive interface standard
  - Serial attached SCSI (SAS)
  - Fibre Channel
  - Internet SCSI (iSCSI)
Quick Quiz (1)

1. Of the following three options, the storage media that would likely hold the most data is a(n) __________.
   a. HDD
   b. USB flash drive
   c. SSD

2. True or False: SSDs are subject to mechanical failures just like magnetic hard drives.

3. The circular rings on a magnetic disk on which data is stored are called __________.

Answers:
1) a; 2) False; 3) tracks
Optical Discs

- **Optical discs** are thin circular plastic discs
  - Are read from and written to using laser beams
  - Are commonly used for software delivery
  - Divided into sectors like magnetic discs but use a single spiral track (groove)
  - Have a relatively large capacity and are durable
  - Used for backup purposes and for storing and transporting music, photos, video, etc.
Representing Data on an Optical Disc

• Pits and lands are used to represent 1s and 0s
• The transition between a pit and a land represents a 1; no transition represents a 0
• Read-only optical disc
  – Surface of disc is molded or stamped to represent data
• Recordable or rewritable disc
  – The reflectivity of the disc is changed using a laser beam to represent the data
  – Different types of optical discs use different types of laser beams
How Recorded Optical Discs Work

**FIGURE 3-11**
How recorded optical discs work.

- **TRACK**: A single track spirals from the center of the disc outward; recorded data is stored on the track.
- **SECTORS**: The track is divided into sectors for data organization.
- **READING DATA**: A low intensity laser beam reads the disc. A transition between a pit and a land is interpreted as a 1; a set period of time between transitions is interpreted as a 0.
- **WRITING DATA**: When data is written to the disc, a laser beam creates pits, represented by dark, nonreflective areas on the disc.
Optical Drives

• Optical discs are read by **optical drives**
  – The optical drive must support the type of optical disc being used
  – Almost always backward-compatible
  – Recording data onto a optical disc is called burning; requires burning software
  – Optical drives can be internal or external
    • External drives typically connect via USB port
    • External drives can be used with netbooks and other devices without an optical drive
Optical Disc Shapes, Sizes, and Capacities

• Standard size is 120-mm (about 4.7 inches)
  – Mini discs are smaller (about 3 inches)
• Theoretically can be made into various shapes, but patent battle has resulted in custom shapes not being available
• Clear background is sometimes used to make a disc look custom shaped
Advantage of Optical Discs

• Major advantage: Large capacity
  – CD discs are normally single layer and hold 700 MB
  – DVD discs hold 4.7 GB (single-layer) or 8.5 GB (dual-layer)
  – BD discs hold 25 GB (single-layer) or 50 GB (dual-layer)
  – BDXL standard uses even more layers to boost capacity up to 128 GB
  – Newest BD discs are Ultra HD Blu-ray discs that hold up to 100 GB and are designed to deliver Ultra HD (4K) movies
  – Discs can also be double-sided
    • Read on one side at a time; must be turned over to access the second side
## Summary of Optical Discs

<table>
<thead>
<tr>
<th>TYPE OF DISC</th>
<th>CAPACITY</th>
<th>USED FOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>700 MB</td>
<td>Audio music delivery; custom CDs containing music, photos, etc.</td>
</tr>
<tr>
<td>DVD</td>
<td>4.7 GB</td>
<td>Movie and software delivery; custom DVDs containing videos, music, photos, etc.</td>
</tr>
<tr>
<td>DVD-DL</td>
<td>8.5 GB</td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>25 GB</td>
<td>Primarily movie delivery</td>
</tr>
<tr>
<td>BD-DL</td>
<td>50 GB</td>
<td></td>
</tr>
<tr>
<td>BDXL (3 layers)</td>
<td>100 GB</td>
<td>Primarily video archiving</td>
</tr>
<tr>
<td>BDXL (4 layers)</td>
<td>128 GB</td>
<td></td>
</tr>
<tr>
<td>Ultra HD (4K) (2 layers)</td>
<td>66 GB</td>
<td>Primarily 4K movie delivery</td>
</tr>
<tr>
<td>Ultra HD (4K) (3 layers)</td>
<td>100 GB</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 3-14**  
Summary of optical discs.
Read-Only Optical Discs: CD-ROM, DVD-ROM, and BD-ROM Discs

- **CD-ROM, DVD-ROM, and BD-ROM discs** can be written to, but not erased and reused
  - Pits are permanent
  - CD-ROM and DVD-ROM discs come prerecorded with software, music, movies, etc.
  - BD-ROM discs come prerecorded with movies
    - Ultra HD Blu-ray discs can be used for 4K movies
  - Additional proprietary read-only discs
    - Gaming systems like Wii, Xbox, PlayStation, etc.

- **CD-R, DVD-R, DVD+R, and BD-R discs** can be written to, but cannot be erased and reused
  - Pits are created in the disc when the disc is recorded
  - Most discs have a recording layer containing organic light-sensitive dye between disc’s plastic and reflective layers
- BD-R discs use inorganic material instead
  - DVD-R DL and DVD+R DL are dual-layer discs
  - BD-R DL discs are dual-layer discs; BD-R XL use 3 or 4 layers
  - Used for backing up files, sending large files to others, and storing multimedia files
Rewritable Optical Discs: CD-RW, DVD-RW, DVD+RW, and BD-RE Discs

- **CD-RW, DVD-RW, DVD+RW, and BD-RE discs** can be written to, erased, and overwritten just like magnetic hard disks
  - Uses phase change technology
    - Heating and cooling process is used to change the reflectivity of the disc
  - The capacities are the same as their read-only and recordable counterparts
  - Appropriate for transferring large files from one computer to another or otherwise temporarily storing data (disc can be reused)
Ultra HD (4K)
• Is the next big step in high-definition (HD) TVs and content
• Four times the resolution of ordinary HD
• Requires four times as much data as regular HD video
• Many Internet connections are not fast enough to support the large amounts of data required for 4K quality
• Available for those individuals who have the speed and bandwidth to support it; also available on Ultra HD discs

An example of a 4K movie.
Quick Quiz (2)

1. The capacity of the standard DVD disc is _____.
   a. 50 GB
   b. 650 MB
   c. 4.7 GB

2. True or False: A DVD-RW disc can be written to and rewritten to.

3. The tiny depressions, dark areas, or otherwise altered spots on an optical disc that are used to represent data are called __________.

Answers:
1) c; 2) True; 3) pits
Flash Memory Storage Systems

- **Flash memory** is a chip-based storage medium that represents data using electrons
  - Used in a variety of storage systems
- **Embedded flash memory** refers to flash memory chips embedded into products
  - Smartphones, tablets, smart watches, and even sunglasses and wristwatches
  - Usually the primary storage for mobile devices such as tablets and smartphones
Examples of Embedded Flash Memory

This tablet contains 64 GB of embedded flash memory.

An embedded flash memory chip.

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Flash Memory Cards and Readers

- A **flash memory card** is a small card containing one or more flash memory chips, a controller chip, and metal contacts to connect the card to the device or reader being used
  - Available in a variety of formats; these formats are not interchangeable
  - Secure Digital (SD) is one of the most widely used types of flash memory media
  - Most common type of storage media for digital cameras, smartphones, and other portable devices
- Many devices today have a built-in flash memory card reader; an external reader via USB port is also used
- Adapters allow the use of smaller flash memory cards in a larger slot of the same type (microSD to SD, etc.)
Examples of Flash Memory Cards, Readers, and Adapters

FIGURE 3-16
Flash memory cards, readers, and adapters.
Flash Memory Cards

• General-purpose flash memory card
  – Appropriate for most applications
• Specialized flash memory cards
  – Professional flash memory cards
  – Gaming flash memory cards
  – Encrypted flash memory cards
• Project Vault is a computer on a flash memory card
USB Flash Drives

- **USB flash drives** (USB drives or flash drives) consist of flash memory media integrated into a self-contained unit that plugs into and is powered by a USB port
  - Designed to be very small and very portable
  - Available in a host of formats
    - Low-profile drives, custom shapes, micro drives, etc.
  - Can be built into a consumer product
  - Additional related hardware becoming available
    - USB duplicator systems
Examples of USB Flash Drives

**CONVENTIONAL DRIVE**

**LOW-PROFILE DRIVE**

**CUSTOM LANYARD DRIVE**

**MICRO DRIVE**

*FIGURE 3-18*

USB flash drives.
Tiny PCs

• The size of a USB flash drive
• Typically connect to a TV via an HDMI port
• May also have built-in storage and a microSD
• Capabilities vary; smart TVs can display and stream Internet content
• The newest tiny PCs are fully functioning “computers-on-a-stick”
Quick Quiz (3)

1. Flash memory cards are available today in capacities up to _____.
   a. 64 GB  
   b. 512 MB  
   c. 1 TB  

2. True or False: Flash memory is the primary storage for mobile devices such as tablets and smartphones.

3. The most common type of flash memory card today is the ___________ card.

Answers:
1) c; 2) True; 3) SD
Other Types of Storage Systems

- Remote storage refers to using a storage device that is not connected directly to the user’s computer.
- **Network storage:** Using a storage device via a local network
  - Works in much the same way as using local storage
  - **Network attached storage (NAS)** devices are high performance storage systems connected individually to a network
  - A **storage area network (SAN)** consist of separate network of hard drives or other storage devices that are attached to the main network
Examples of Network Storage

**LOCAL NETWORKS**
Network devices appear and are accessed in a manner similar to local resources.

**NETWORK ATTACHED STORAGE (NAS) DEVICES**
This NAS device holds up to 12 TB of data on two magnetic hard drives.

*FIGURE 3-19*
Network storage.
Cloud Storage

- **Cloud storage (online storage)** is accessed via the Internet
  - Cloud applications (Flickr, Facebook, Google Docs, etc.)
  - Online storage sites (Box, Dropbox, OneDrive, etc.)
  - Growing in importance because more and more applications are Web-based
  - Increasingly used for backup purposes
  - Files can be synched between PC and cloud storage
  - Many online storage sites offer some free storage
  - Business cloud storage is available; businesses can also create private clouds
Example of Cloud Storage

**FIGURE 3-20**
Cloud storage.

**LOGGING ON**
Users log on to see their personal files stored on the site’s server.

**SYNCING FILES**
Many cloud storage services have a desktop app/sync option, which creates a cloud folder on your device once you download the app—you can just drag items into that folder to upload them to your cloud account.
Smart Cards

- A **smart card** is a credit card-sized piece of plastic that contains some computer circuitry (processor, memory, and storage)
  - Stores a small amount of data (about 64 KB or less)
  - Commonly used to store prepaid amounts of digital cash or personal information
  - Smart card readers are built into or attached to a computer, door lock, vending machine, or other device
  - Some smart cards store biometric data
  - Use of mobile smart cards is an emerging trend
Examples of Uses for Smart Cards

FIGURE 3-21
Uses for smart cards.

Logging onto a computer
Making a store purchase
Accessing a secure facility
Using transit tickets
Storage Systems for Large Computer Systems

• Business storage needs are growing exponentially
  – Digital data produced is expected to double every two years through 2020
• A storage server contains multiple high-speed hard drives
  – Larger than typical NASs
  – Usually contain drawers of hard drives
  – Typically use fast Fibre Channel or iSCSI connections
  – Scalable so that more hard drives can be added as needed
  – Can use magnetic and/or SSD drives
Example of a Large Storage Systems

HARD DRIVES
Are located inside a drive enclosure; this enclosure can hold up to 24 drives of varying capacities—up to 3 TB each.

STORAGE SYSTEM
This system can manage up to 240 hard drives for a total maximum capacity of 432 TB.

FIGURE 3-22
Large storage systems. Large storage systems are usually scalable so additional hard drives can be added as needed.
• **RAID** (*redundant arrays of independent discs*) is a method of storing data on two or more hard drives that work together to record redundant copies
  – Used to protect critical data on large storage systems
  – Helps to increase fault tolerance
  – Different levels of RAID:
    • RAID 0 = disk striping (spread files over two or more hard drives)
    • RAID 1 = disk mirroring (duplicate copy)
    • Other levels use a combination or striping and mirror
Two Primary RAID Techniques

**Striping**
When a file is written to a RAID system using striping, it is split among two or more drives.

**Mirroring**
When a file is written to a RAID system using mirroring, an identical copy of the file is sent to another drive in the system.
Newer RAID Systems

• New storage systems are easier to set up and maintain so dedicated RAID personnel are not needed
  – For example, the Drobo system:
    • Connects to a computer or a network via a USB cable
    • Contains drive bays into which hard drives can be inserted
    • Has capacity and status indicators – drives can be inserted and removed as needed

FIGURE 3-24
A Drobo storage system.
Archival Storage Systems

- Data archiving is the process of identifying and moving data that is no longer actively being used from regular storage systems to a separate long-term archival storage system.

- Options for data archival systems:
  - Large hard drives, such as a helium hard drive (10 TB)
  - Magnetic tape
    - Typically cartridge tapes; can be tape libraries
  - Higher capacity, archival Blu-ray Discs that are becoming available; so are optical jukeboxes
  - Cloud storage
Examples of Data Archiving Options

**FIGURE 3-25**
Helium hard drive.

**FIGURE 3-26**
Magnetic tape. This cartridge holds 2.5 TB of uncompressed data.
Evaluating Your Storage Alternatives

• Product characteristics to consider:
  – Speed, compatibility, storage capacity, convenience, and portability
• Each storage alternative normally involves trade-offs
• Research which devices and media are most appropriate to your personal devices
• All computers need at least one convenient USB port
• Mobile device users
  – Fewer options for storage alternatives
  – Require appropriate wireless connectivity
Quick Quiz (4)

1. An online photo sharing site is an example of __________.
   a. RAID
   b. cloud storage
   c. holographic storage

2. True or False: Smart cards today typically hold at least 1.44 MB of data.

3. A type of sequential storage that is sometimes used today for business data archiving and in some backup systems because of its low cost per terabyte is __________.

Answers:
1) b; 2) False; 3) magnetic tape
Summary

• Storage Systems Characteristics
• Hard drives
• Optical Discs And Drives
• Flash Memory Storage Systems
• Other Types of Storage Systems
• Evaluating Your Storage Alternatives