

Guide to Operating Systems, 6th Edition

Module 7: Using and Configuring Storage Devices

Learning Objectives

By the end of this module, you should be able to:

- Describe computer storage
- Configure local storage
- Work with different types of volumes and virtual disks
- Describe cloud storage
- Describe tape drive technologies
- Work with storage management tools



An Overview of Computer Storage

- Files and documents are stored on digital media
- People want instant access to whatever they store
 - Cloud storage services are more popular than ever

What is Storage? (1 of 2)

- Storage is any digital medium that data can be written to and later retrieved
- Long-term storage (non-volatile storage) includes:
 - USB memory sticks (flash drives)
 - Secure Digital (SD) and Compact Flash (CF) cards
 - CDs and DVDs
 - Magnetic tape
 - Solid-state drives
 - Hard disk drives

What is Storage? (2 of 2)

- **Solid-state drives (SSDs)** are very popular for applications requiring greater speed, smaller size, and lower power requirements
 - An SSD uses flash memory and high-speed interfaces
 - SSDs have no moving parts and require less power less things to break + less heat
 - ~~They do not yet have the capacity of HDDs~~
- The benefits of SSDs might outweigh the cost disadvantage in applications that require very fast access to files has a life; has a certain # of reads/writes; if you have a situation where you need SSDs, you want ones that specialize in writes

server will let you know when it dies/unusable

Reasons for Storage

- Most uses of computer storage include:
 - Operating system files
 - User applications
 - User documents
 - Virtual memory
 - Log files
 - Virtual machines
 - Database storage

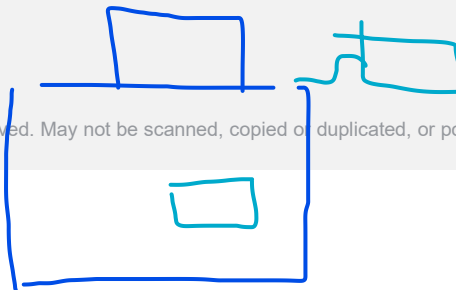
Storage Access Methods (1 of 6)

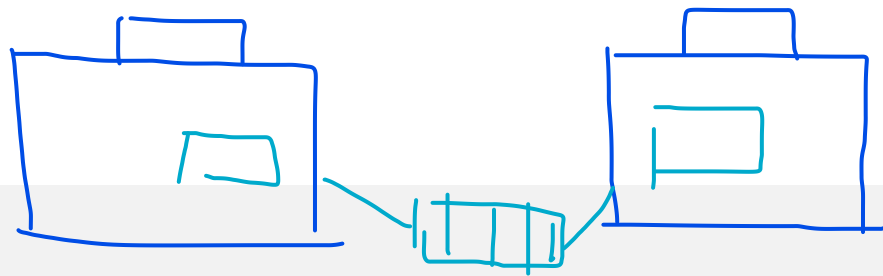
- There are four categories of storage access methods:
 - Local storage
 - Direct-attached storage (DAS)
 - Network-attached storage (NAS)
 - Storage area network (SAN)

Storage Access Methods (2 of 6)

inside the computer case, anything directly attached to the computer?

- **Local storage** is storage media with a direct, exclusive connection to the computer's system board through a disk controller
 - It is almost always inside the computer's case
 - The term *local storage* usually refers to HDDs or SSDs instead of CD/DVDs
 - It provides rapid and exclusive access
- A disadvantage of local storage: only you can access it
 - Only the system where it's installed has direct access to the storage medium





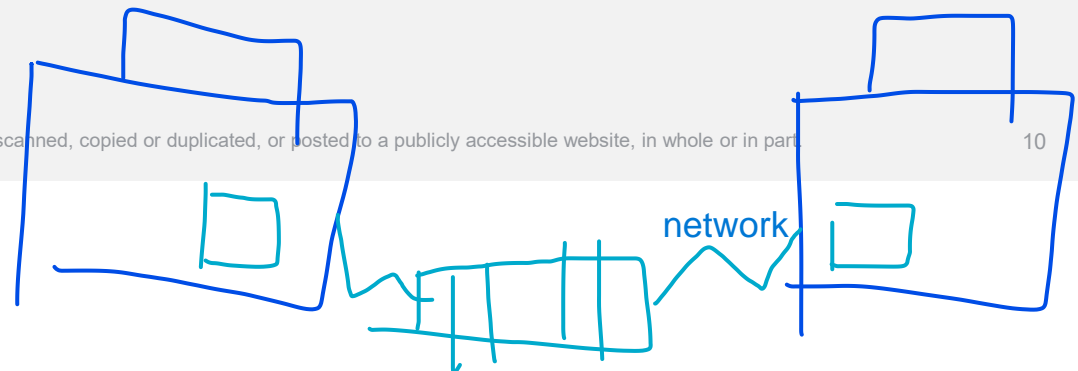
Storage Access Methods (3 of 6)

ex. USB drive, where two computers can access it at the same time, usually 2 machines to cluster them

- **Direct-attached storage (DAS)** is similar to local storage but can also refer to one or more HDDs in an enclosure with its own power supply
- A DAS device with its own enclosure and power supply can usually be configured as a disk array
 - Such as a RAID configuration
- Some DAS systems have multiple interfaces so that more than one computer can access the storage medium simultaneously

Storage Access Methods (4 of 6)

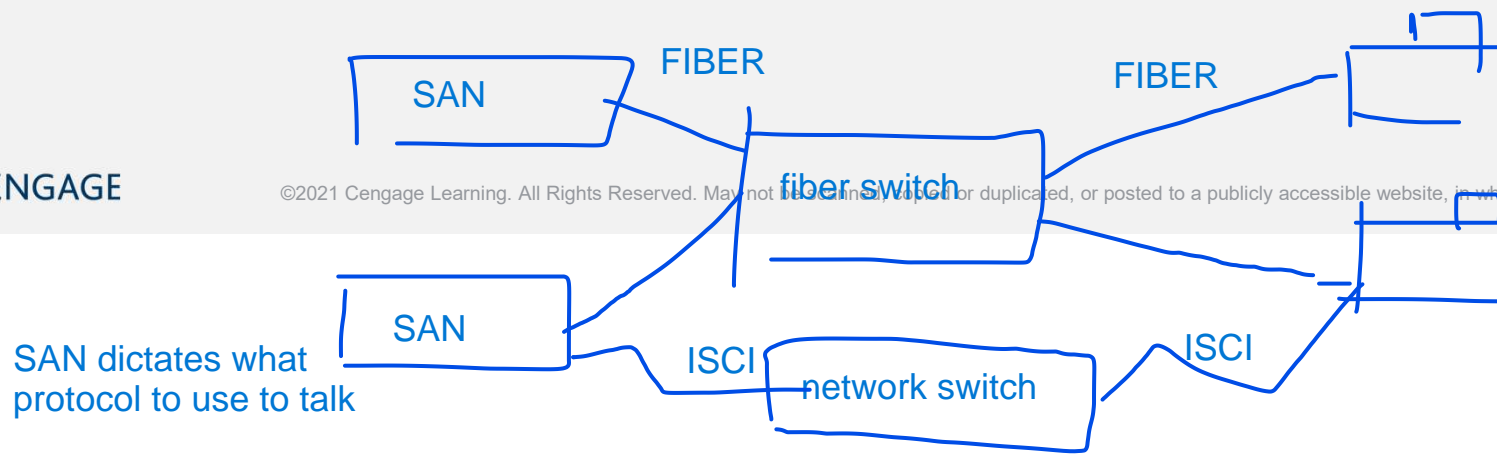
- **Network-attached storage (NAS)** has an enclosure, power supply, slots for multiple HDDs, a network interface, and a built-in OS tailored for managing shared storage
 - NAS is sometimes referred to as a **storage appliance**
- NAS is typically dedicated to file sharing
 - what "language" that we speak over the network to talk to storage (they can talk in each other's language?)
- NAS shares files through standard **network protocols** such as:
 - Server Message Block (SMB), Network File System (NFS), and File Transfer Protocol (FTP)
 - Internet for file transfer
 - Unix



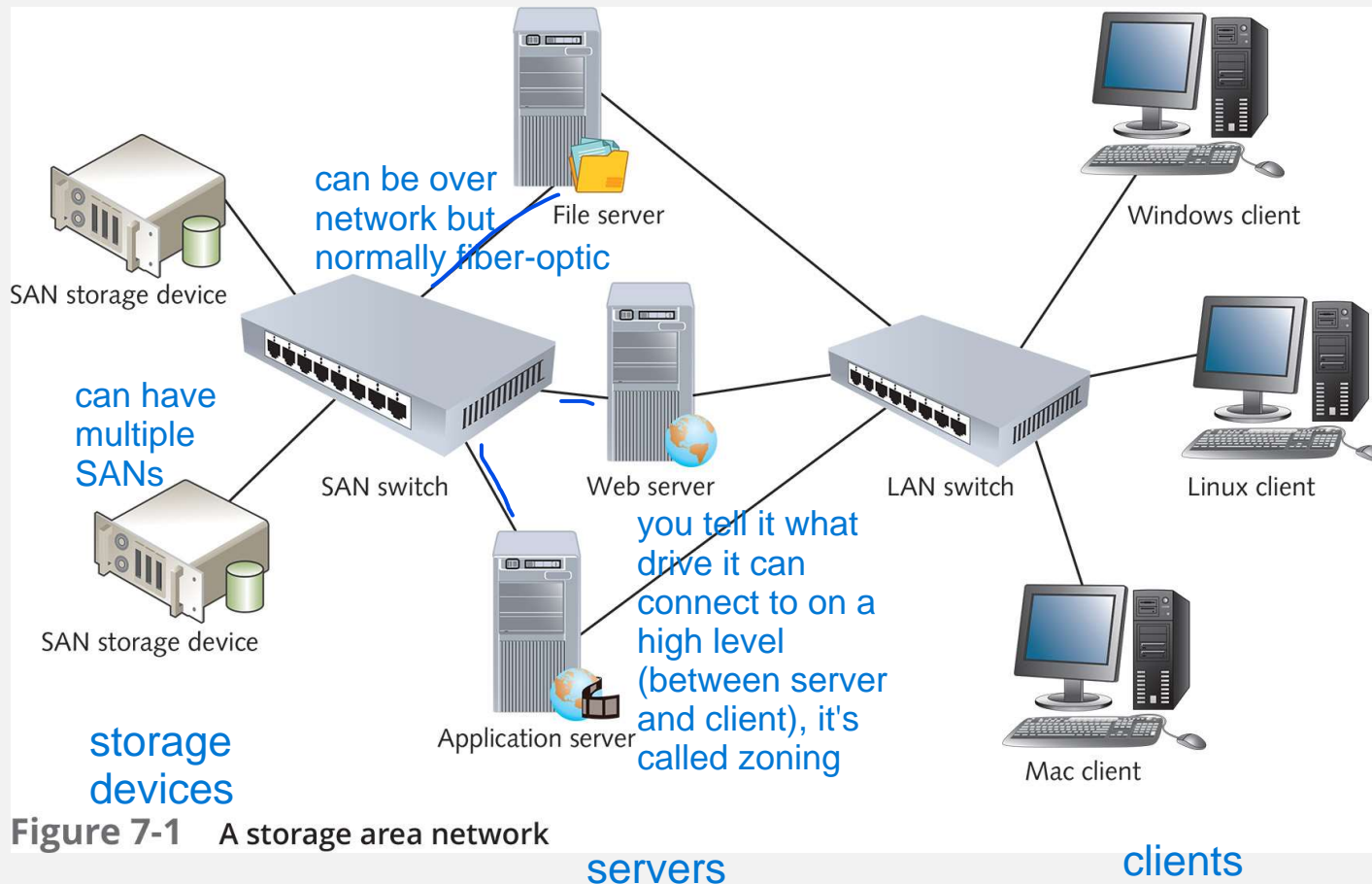
Storage Access Methods (5 of 6)

most large organizations use this

- A **storage area network (SAN)** uses high-speed networking technologies to give servers fast access to large amounts of shared disk storage
 - The most common network technologies used in SANs are Fibre Channel and iSCSI
 - SANs use the concept of a **logical unit number (LUN)** to identify a unit of storage
- anytime you want a new capacity on a server
- A LUN is a **logical reference** point to a unit of storage that could refer to an entire array of disks, a single disk, or just part of a disk



Storage Access Methods (6 of 6)



Configuring Local Storage (1 of 2)

- Configuration of local disks can be divided into two categories:
 - Physical disk properties, which include disk capacity, physical speed, and the interface for attaching a disk to the system
 - Logical disk properties include its format and the partitions or volumes created on it

creating a logical volume that presents itself to the OS

Configuring Local Storage (2 of 2)

- Disk storage terminology:
 - *Disk drive* – a **physical component** with a disk interface connector and a power connector
the slots in the images drawn for DAS and NAS
 - *Volume* – a logical unit of storage that can be formatted with a file system
 - A disk drive can contain one or more volumes
once presented, it can be partitioned and formatted
 - *Partition* – an older term that means the same thing as a “volume” but is used with basic disks
chunk a volume out (using only a part)
 - *Formatting* – prepares a disk with a file system used to organize and store files
formatting so the OS can use it

Disk Capacity and Speed (1 of 2)

- The disk capacity you need depends on how the disk will be used
- Distinct types of data should be kept on separate disks backups, REFS, database disk to perform a different way (transaction logs)
- Disk capacity considerations:
 - On servers or high-performance workstations, the OS installation should be on a separate disk from data and applications OS C drive on one, and D on another disk
 - Virtual memory should be on its own disk, if possible
 - Using RAID as a **fault tolerance option** will combine multiple disks to make a single volume

Disk Capacity and Speed (2 of 2)

- Factors that affect the speed of HDDs:
 - Disk interface technology
 - Rotation speed
 - Servers should have an ^{spinning} HDD with a minimum speed of 7200 rpm (10,000-15,000 preferred) how fast it rotates = how fast to retrieve data?
 - Amount of cache memory installed
 - 32-64 MB cache sizes are common for server-class drives cache is huge to help with performance for SAN
 - cache isn't persistent; if there's a power failure, cache will shut off (performance drops a ton)

real amount of space

a vs i For Storage

DECIMAL SYSTEM		
NAME	FACTOR	VALUE IN BYTES
kilobyte (KB)	10^3	1,000
megabyte (MB)	10^6	1,000,000
gigabyte (GB)	10^9	1,000,000,000
terabyte (TB)	10^{12}	1,000,000,000,000
petabyte (PB)	10^{15}	1,000,000,000,000,000
exabyte (EB)	10^{18}	1,000,000,000,000,000,000
zettabyte (ZB)	10^{21}	1,000,000,000,000,000,000,000
yottabyte (YB)	10^{24}	1,000,000,000,000,000,000,000,000

power of 10

BINARY SYSTEM		
NAME	FACTOR	VALUE IN BYTES
kibibyte (KiB)	2^{10}	1,024
mebibyte (MiB)	2^{20}	1,048,576
gibibyte (GiB)	2^{30}	1,073,741,824
tebibyte (TiB)	2^{40}	1,099,511,627,776
pebibyte (PiB)	2^{50}	1,125,899,906,842,624
exbibyte (EiB)	2^{60}	1,152,921,504,606,846,976
zebibyte (ZiB)	2^{70}	1,180,591,620,717,411,303,424
yobibyte (YiB)	2^{80}	1,208,925,819,614,629,174,706,176

power of 2

substantial size difference (paying for every byte of data is important for cloud space)

Disk Interface Technologies (1 of 5)

cabled into the computer

- The disk interface connects a disk to a computer system

- Usually with some type of cable

faster speeds do better

- The faster the bus, the faster the system can read from and write to the disk

- Most common types of disk interfaces:

- SATA

- SAS

- SCSI

Disk Interface Technologies (2 of 5)

- **Serial ATA drives (SATA)** have replaced parallel ATA (PATA) drives
 - Advantages: faster transfer times and small cable size
- SATA drives are inexpensive, fast, and fairly reliable
- Current standard: 3.2
 - Supports speeds up to 16 Gb/s

Disk Interface Technologies (3 of 5)

- **Small computer system interface (SCSI)** is a parallel bus technology still used on some servers, but it has reached its performance limits
 - The latest variation is Ultra-640, which supports up to 640 MB/s transfer rates
 - storage = bytes B = bytes
 - network = bits b = bits
- **Serial attached SCSI (SAS)** is a newer, serial form of SCSI with transfer rates up to 6 Gb/s and higher
 - SATA drives can be connected to SAS backplanes
 - A **backplane** is a connection system that uses a printed circuit board instead of traditional cables to carry signals more efficient

Disk Interface Technologies (4 of 5)

used in these computers?

- **Non-volatile memory express (NVMe)** is a storage interface and protocol for SSDs
not bound to SCSI protocols
 - It uses the PCIe bus directly
 - Allows data transfer speeds close to the PCIe bus speeds
- NVMe typically can double the performance of SAS and deliver four to six times the performance of SATA SSDs

Disk Interface Technologies (5 of 5)

- Partitioning methods offered by most OSs:
 - **Master Boot Record (MBR)** is the most common method and has been around since DOS
 - Supports volume sizes up to 2 TB
 - **GUID Partitioning Table (GPT)** theoretically supports volume sizes up to 9.5 zettabytes (ZB)
 - Offers improved reliability through partition table replication and cyclic redundancy check (CRC) protection of the partition table

Knowledge Check 1

- Which disk interface technology uses the PCIe bus directly?
 - A) Serial ATA (SATA)
 - B) Non-volatile memory express (NVMe) highest performance
 - C) Small computer system interface (SCSI)
 - D) Serial attached SCSI (SAS)

QUESTION



Knowledge Check 1: Answer

- Which disk interface technology uses the PCIe bus directly?

D1 BASIC WINDOWS
D2
D3 .

- B) Non-volatile memory express (NVMe)

ANSWER



Types of Volumes (1 of 4)

- **Redundant array of independent disks (RAID)** is a disk configuration that uses space on multiple disks to form a single logical volume
- RAID is commonly configured in one of two ways:
 - By the storage controller in hardware more protective?
 - Via the OS storage system in software lots of options today
- Hardware RAID provides better performance by offloading the OS from having to perform the processes involved in RAID

Types of Volumes (2 of 4)

multiple types of RAID

- Common volume types supported by most OSs: no data loss protection for the first 3, so drive fails = lose data
 - *Simple volume* – resides on a single disk, basic or dynamic
 - *Spanned volume* – extends across two or more physical disks
 - *RAID 0 volume* – extends across two or more dynamic disks, but data is written to all disks in the volume equally striped
 - *RAID 1 volume (mirrored volume)* – uses space from two dynamic disks and provides fault tolerance
 - Data written to one disk is duplicated, or mirrored, to the second disk
 - If one disk fails, the other has a copy of the data

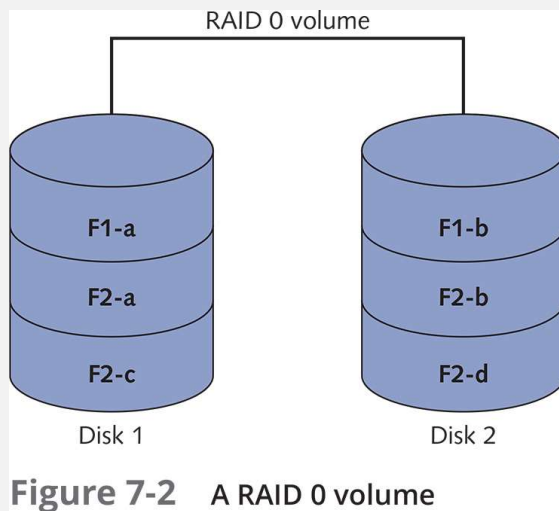


Types of Volumes (3 of 4)

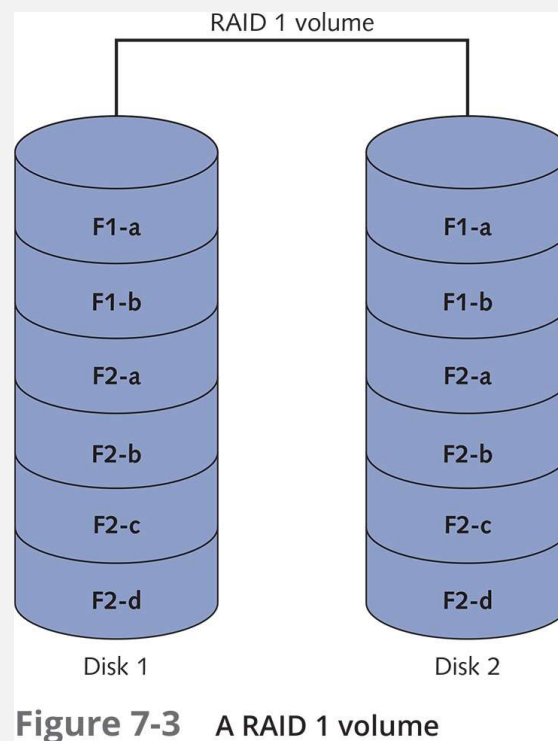
- Common volume types supported by most OSs (continued):
 - *RAID 5 volume* – uses space from three or more dynamic disks and uses disk striping with parity
 - Parity information is used to re-create lost data after a disk failure

know these three (any questions) and NOT raid 10

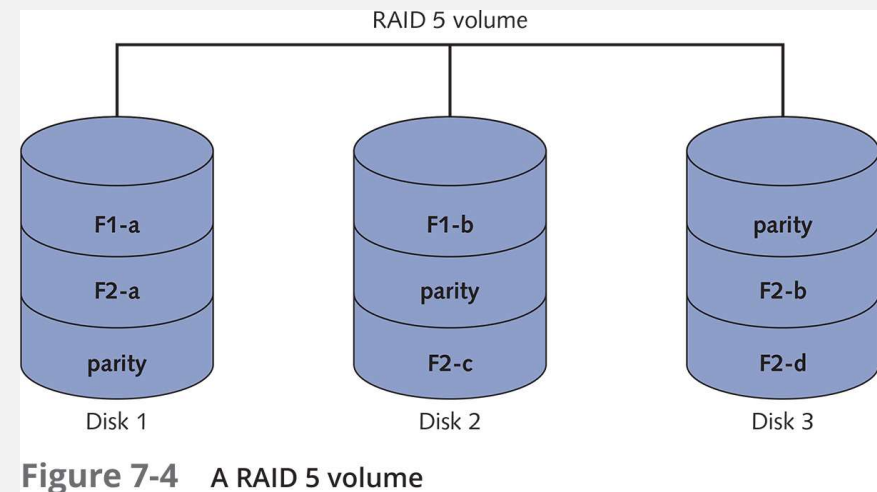
Types of Volumes (4 of 4)



wrote some of the files between the drives (no protection)



perfect copy, altogether

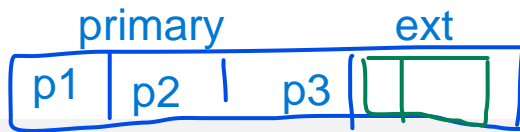


right, right, parity bit (helps recover)
notice how parity is stored on each disk and takes turns, so if we lose one disk, we lose 1/3 of the data or one disk dedicated to parity?

RAID 10 = two raid 5's to mirror every write to each other, so 6 disks that have info (getting data back way quicker when reads are performed, so improves performance)

Windows Volumes and Disk Types (1 of 7)

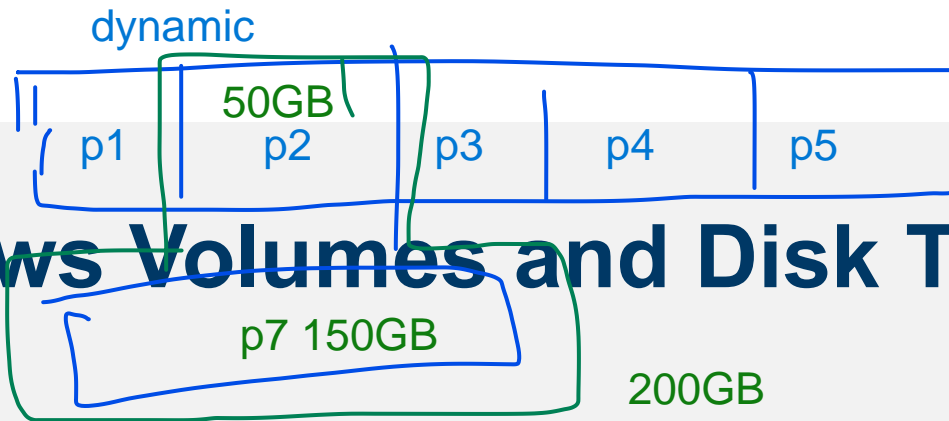
- There are two Microsoft-specific volume definitions:
 - The **boot volume** is the volume where the **Windows folder** is located (also called the *boot partition*)
 - The **system volume** contains files the computer needs to find and load the Windows OS (also called the *system partition*)
 - In Windows 2008 and later versions, it's created automatically during installation if you're installing an OS for the first time on a system
 - It is not assigned a drive letter (can't be viewed in File Explorer)



p4, p5 (treated like any other partition,
but they're part of the extended)

Windows Volumes and Disk Types (2 of 7)

- **Basic disks** can accommodate only basic volumes
 - Volumes on a basic disk are called partitions static dividers
 - Can support a maximum of **four partitions**
 - The first three are primary partitions and the fourth is called an extended partition
 - **Primary partition** – can be assigned a drive letter, be marked active, and contain the Windows system volume
 - **Extended partition** – must be divided into logical drives



lots of flexibility, can add a spanned disk (additionally?)

Windows Volumes and Disk Types (3 of 7)

- **Dynamic disks** are a disk arrangement that can hold up to 128 volumes
 - Volumes can span multiple disks and be configured for RAID
 - A dynamic disk can hold the Windows boot or system partition, but only if converted to dynamic after Windows is already installed on the volume
- To convert a basic disk to dynamic:
 - In Disk Management, right-click the disk and click **Convert to Dynamic Disk**

not locked down to extended partition

can say now that a partition is 50gb, you can bring another disk (another hard drive) to create a volume, and can tell OS to span a partition

Windows Volumes and Disk Types (4 of 7)

VHD can be operated on different brand machines cuz OS doesn't care (virtualized)

- A **virtual hard disk (VHD) file** is the format that virtual machines running in Hyper-V use for their virtual disks
 - VHD files can also be created and mounted with Disk Management and used like physical disks
- A VHD can also be mounted by double-clicking it in File Explorer (or right-click it and click Mount)
- Virtual disks are portable
 - VHD files can be copied to any location for the purposes of backing up data or allowing it to be used by another computer

Windows Volumes and Disk Types (5 of 7)

not go too deep but prolly study anyway

- **Storage Spaces** is a feature introduced in Windows 8 and Windows Server 2012 that provides flexible provisioning of virtual storage
 - Creates volumes from storage pools
- A **storage pool** is a collection of physical disks from which virtual disks and volumes are created and assigned dynamically
- Storage Spaces can allocate storage by using **thin provisioning**
 - Which uses dynamically expanding disks so that you can provision a large volume

thick = give me this right now (fixed -> SAN)
thin = use what i use (get more usable space,
but can run out of space and not realize it)

Windows Volumes and Disk Types (6 of 7)

- Storage Spaces uses the concept of **just a bunch of disks (JBOD)**, in which two or more disks appear as a single disk to the OS
- With JBOD, you can add a physical disk to a storage pool

- Storage Spaces features:

- Disk pooling
- Data deduplication 2 files that are the same everything, stores once
- Flexible storage layouts different sizes and types
- Storage tiering

D1 = 10GB

D2 = 50 GB

D3 = 20 GB

various sizes and stuff

w/ JBOD (Linux does this too) and encapsulates all three in the storage space, which the OS and USER sees = 1 volume of 80GB (and it's dynamic that you can add disks to it)

Windows Volumes and Disk Types (7 of 7)

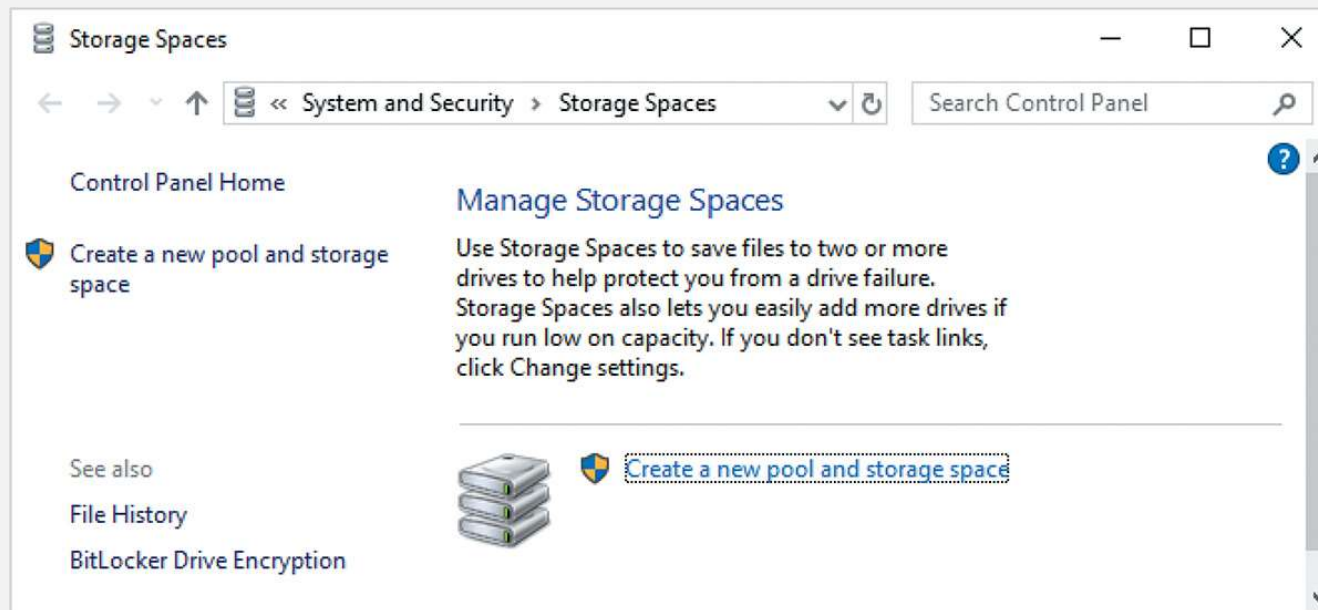


Figure 7-6 Storage Spaces in Windows 10

Volume Types in Linux and macOS (1 of 2)

- Linux and macOS share most terminology for managing storage
- Linux volumes can be created using two methods:
 - Basic partitions – offers same restrictions as basic disks in Windows
 - **Logical volume manager (LVM)** – can create as many partitions as you have space for and use RAID
- LVM uses physical disk partitions called volume groups like p1 and p2?
 - From volume groups, logical volumes are created and assigned space

Volume Types in Linux and macOS (2 of 2)

- You can work with **virtual disks** in Linux:
 - Create a new file of 500 MB using the *fallocate* command
 - Install the ext4 file system
 - Create a folder to mount the virtual disk `/dev`
 - Mount the virtual disk
- You can also use the Disks utility in GNOME to create a disk image from a hard disk or CD/DVD and attach a disk image
- In macOS, use the Disk Utility to create an image from an existing device or folder

Cloud Storage

- With cloud storage, some or all of an organization's data is stored on servers located offsite and maintained by a storage hosting company
 - Customers can manage storage by assigning permissions for user access
- Advantage of cloud storage:
 - Details of managing and backing up storage on local servers are offloaded to a third party
- Dropbox, Microsoft OneDrive, and Google Drive are popular cloud services for individuals and small businesses

can send the data to multiple availability zones (can get to data through another data center)

Tapes and Tape Drives

- **Tape backup systems** are a traditional choice for backing up large amounts of data
- Tapes use magnetic storage and record data in sequential order
 - Disadvantage – in order to find a file near the end of the tape, the tape drive must first go through all of the data recorded prior to that file *serial process*
- Tapes are most popular for long-term storage
 - With the capacity of disk drives growing into terabytes, tape drive technology is continuing to evolve in order to keep up

DAT Drives

- **Digital audio tape (DAT)** drives use a 4-mm tape and the digital data storage (DDS) format
 - DDS-1 has a capacity of 2 GB (4 GB compressed)
 - The current standard is DDS-5, which has a storage capacity of 36 GB (72 GB compressed)
- DDS is backward compatible, which means you can upgrade to a DDS-5 drive and still read DDS-4 tapes
- DAT is still used for audio recordings, but its use for data storage has been mostly replaced by other technologies

DLT and SDLT Drives

- **Digital linear tape (DLT)** drives use half-inch-wide magnetic tapes
 - These tapes record data in tracks, which offers high-speed search capability
 - Used in many automated tape backup systems
- **Super digital linear tape (SDLT)** drives use both magnetic and optical recording methods
 - Laser technology can more accurately write data to the tape and allows for greater density of information
- DLT and SDLT drives have an archival life of up to 30 years

is technology gonna be around to restore it?

AIT and S-AIT Drives

- **Advanced intelligent tape (AIT)** drives use tapes that have an erasable memory chip inside the cartridge that stores information normally written at the beginning of the tape
 - Can fast-forward and pinpoint information **faster** more health?
- Super advanced intelligent tape (S-AIT) has a capacity of 500 GB/1.3 TB (native/compressed)
- Both of these drives can sustain up to 30,000 tape passes and have an archival life of 30 years

LTO Drives

more currently used today

- **Linear tape open (LTO)** drives are most widely accepted in high-end servers (because of high-speed performance)
 - Standards are open to the public and are nonproprietary
- LTO-8 is the newest LTO standard
 - It offers compressed data transfers of up to 900 MB per second and up to 30 TB of compressed capacity

Storage Management Tools

- This section covers some of the OS tools and commands used to manage storage devices

Windows Storage Management Tools (1 of 2)

- Windows Disk Management, a tool for hard drives and removable drives, enables you to:
 - Create, format, and delete partitions
 - Manage partitions
 - Manage removable storage such as DVD/CD-ROM drives and flash drives
 - Convert a basic disk to a dynamic disk
- In Windows 10, you can access this tool by right-clicking Start
- In Windows Server 2012 and later versions, you can use the File and Storage Services tool from Server Manager to manage volumes and Storage Spaces

EFI partition has a small space

flexibility of multiple partitions and spanning

Windows Storage Management Tools (2 of 2)

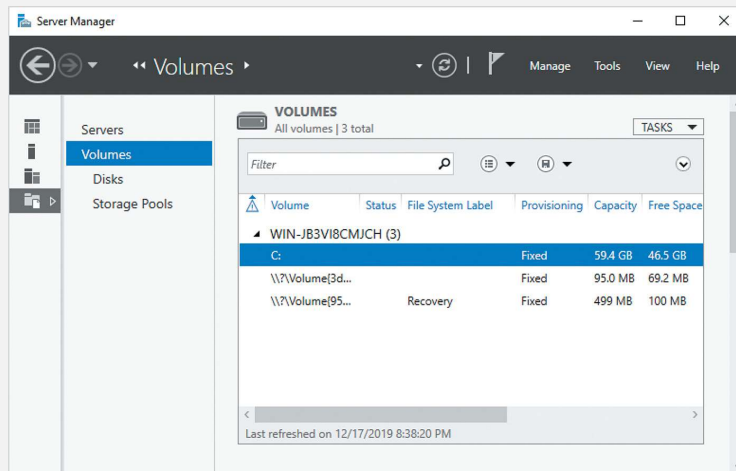


Figure 7-8 File and Storage Services on Windows Server 2019

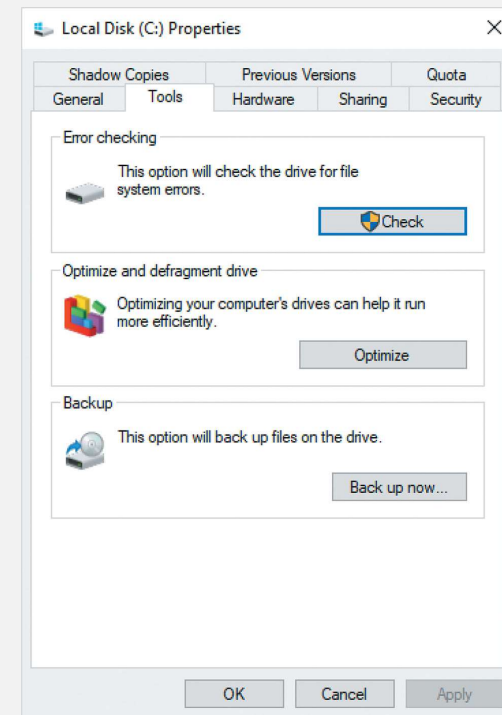


Figure 7-9 The properties of a volume in Windows

Disk Management Tools in Linux (1 of 2)

- Common command-line utilities for managing disks on Linux systems include *fdisk*, *format*, *sfdisk*, and *cdisk*
 - *sfdisk* and *cdisk* enable you to verify partitions, list information about partitions, and repartition a disk
- The command-line utility *mount* mounts a file system so that you can use a disk partition
 - Many users need to manually mount file systems for DVD/CD-ROM or flash drives
- In Linux with the GNOME desktop, there are GUI tools to manage disk storage

Disk Management Tools in Linux (2 of 2)

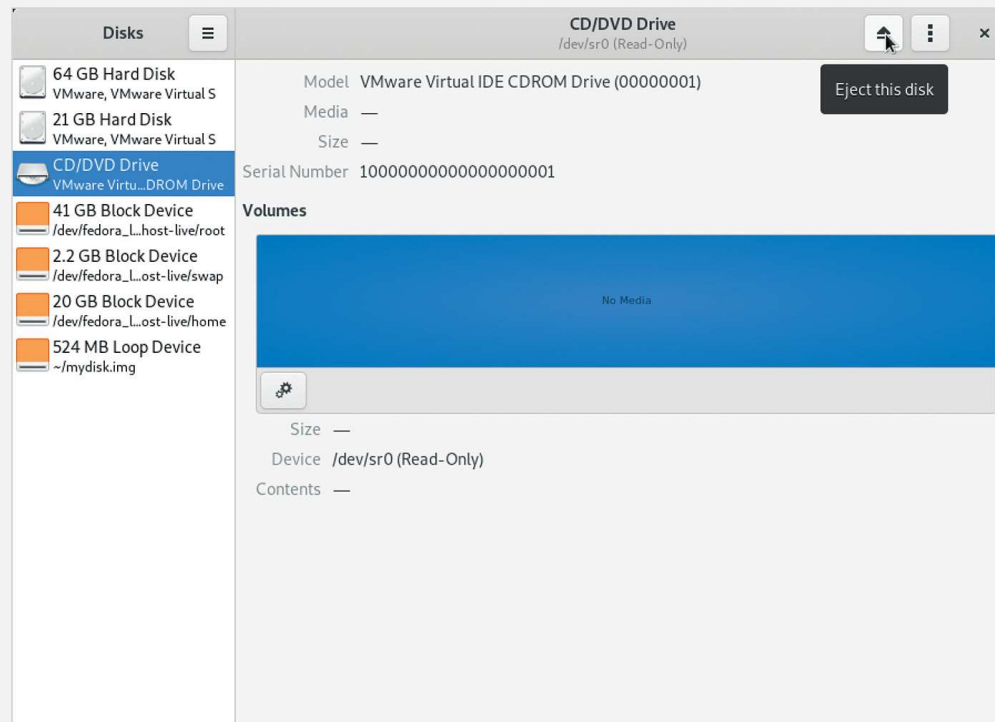


Figure 7-10 The Disks utility in Linux

macOS Disk Utility

- The macOS Disk Utility can partition, format, and manage hard drives
 - It can also manage DVD/CD-ROM drives, removable hard drives, flash drives, and other storage
- For removable media, you can use the Disk Utility to mount and eject media, burn a CD or DVD, and perform other actions
- Because macOS is UNIX-based, you can also open a terminal window and use the *mount* command to manage storage media

Knowledge Check 2

- Which type of RAID volume uses space from two disks, where data written to one disk is duplicated or mirrored to provide fault tolerance?
 - A) RAID 0
 - B) RAID 10
 - C) RAID 1
 - D) RAID 5

QUESTION



Knowledge Check 2: Answer

- Which type of RAID volume uses space from two disks, where data written to one disk is duplicated or mirrored to provide fault tolerance?

- C) RAID 1

ANSWER



Summary (1 of 2)

- Storage is any digital media that data can be written to and later retrieved from
- All computers require at least some storage but servers usually require more than client computers
- The main methods of storage access are local, DAS, NAS, and SAN
- Configuration of local storage can be divided into two broad categories: physical disk properties and logical properties
- Disk types include basic disks and dynamic disks



Summary (2 of 2)

- Storage Spaces provides flexible provisioning of virtualized storage by using storage pools
- Storage Spaces uses the concept of just a bunch of disks (JBOD)
- With cloud storage, some or all of an organization's data is stored on servers located offsite and managed by a storage hosting company
- Tape backup systems are a relatively inexpensive and traditional choice for backing up large amounts of data
- Storage management tools in Windows include Disk Management and File and Storage Services

