Module 9

Implementing Local Storage

Module Overview

Storage is one of the key components that you must consider when planning and deploying a Windows Server® 2012 operating system. Most organizations require a great deal of storage because users work regularly with apps that create new files that require storage in a central location. When users keep their files for longer periods of time, storage demands increase. Every time a user logs on to a server, an audit trail is created in an event log; this also uses storage. Even as files are created, copied, and moved, storage is required.

This module introduces you to different storage technologies. It discusses how to implement the storage solutions in Windows Server 2012, and how to use Storage Spaces, a new feature that you can use to combine disks into pools that are then managed automatically.

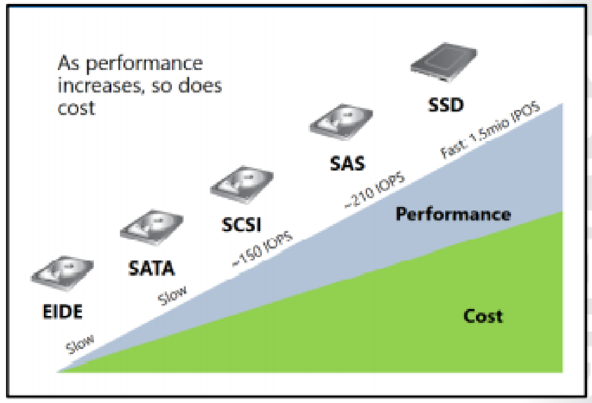
Overview of Storage

When you plan a server deployment, one of the key components that you require is storage. There are various types of storage that you can utilize, such as locally-attached storage, storage that is remotely accessed via Ethernet, or storage connected with optical fiber. You should be aware of each solution's benefits and limitations.

As you prepare to deploy storage for your environment, you need to make some important decisions. This lesson addresses questions to consider, such as:

- Does the storage need to be fast?
- Does the storage need to be highly available?
- How much storage does your deployment actually require?
- How much resilience do you need to add to the initial storage requirement to ensure that your investment remains secure in the future?

Disk Types and Performance



There are various types of disks available that you can use to provide storage to server and client systems. The speed of disks is measured in Input Outputs per second (IOPS).The most common types of disks are:

- *Enhanced Integrated Drive Electronics (EIDE).* EIDE is based on standards that were created in 1986. The Integrated Drive Electronics (IDE) interface supports both the Advanced Technology Attachment 2 (ATA-2) and Advanced Technology Attachment Packet Interface (ATAPI) standards. *Enhanced* refers to the ATA-2 (Fast ATA) standard. Due to the addressing standards of this technology, there is a 128 gigabyte (GB) limitation on storage using EIDE. Also, the speed of an EIDE drive is limited to a maximum of 133 megabytes (MB) per second. EIDE drives are almost never used on servers today.

- *Serial Advanced Technology Attachment (SATA).* Introduced in 2003, SATA is a computer bus interface, or channel, for connecting the motherboard or device adapters to mass storage devices such as hard disk drives and optical drives. SATA was designed to replace EIDE. It is able to use the same low-level commands as EIDE, but SATA host adapters and devices communicate via a high-speed serial cable over two pairs of conductors. It can operate at speeds of 1.5, 3.0, and 6.0 GB per second, depending on the SATA revision (1, 2 or 3 respectively). SATA disks are generally low-cost disks that provide mass storage. Because SATA drives are less expensive than other drive options, but also provide less performance, organizations might choose to deploy SATA drives when they require large amounts of storage but not high performance. SATA disks are also less reliable compared to serial attached SCSI (SAS) disks.

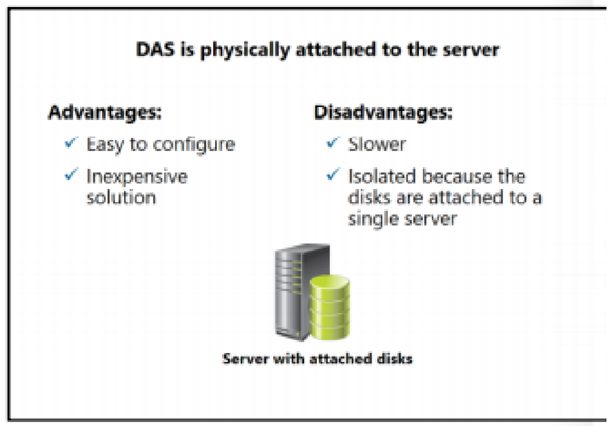
  A variation on the SATA interface is eSATA, which is designed to enable high-speed access to externally-attached SATA drives.

- *Small computer system interface (SCSI).* SCSI is a set of standards for physically connecting and transferring data between computers and peripheral devices. SCSI was originally introduced in 1978 and became a standard in 1986. Similar to EIDE, SCSI was designed to run over parallel cables; however, recently the usage has been expanded to run over other mediums. The 1986 parallel specification of SCSI had initial speed transfers of 5 MB per second. The more recent 2003 implementation, Ultra 640 SCSI, also known as Ultra 5, can transfer data at speeds of 640 MB per second. SCSI disks provide higher performance than SATA disks, but are also more expensive.

- *SAS*. SAS is a further implementation of the SCSI standard. SAS depends on a point-to-point serial protocol that replaces the parallel SCSI bus technology, and uses the standard SCSI command set. SAS offers backward-compatibility with second generation SATA drives. SAS drives are reliable and made for 24 hours a day, seven days a week (24/7) operation in data centers. With up to 15,000 rotations per minute (RPM), these disks are also the fastest traditional hard disks.
- *Solid State Drives (SSDs)*. SSDs are data storage devices that use solid-state memory to store data rather than using the spinning disks and movable read/write heads that are used in other disks. SSDs use microchips to store the data and do not contain any moving parts. SSDs provide fast disk access, use less power, and are less susceptible to failure from being dropped than traditional hard disks (such as SAS drives), but are also much more expensive per GB of storage. SSDs typically use a SATA interface, so you can usually replace hard disk drives with SSDs without any modifications.

What Is Direct Attached Storage?

Almost all servers provide some built-in storage. This type of storage is referred to as *direct attached storage* (DAS). DAS can include disks that are physically located inside the server or connect directly with an external array, or disks that connect to the server with a USB cable or an alternative method. Because DAS storage is physically connected to the server, if the server suffers a power failure, the storage is unavailable. DAS comes in various disk types such as SATA, SAS or SSD, which affect the speed and the performance of the storage, and has both advantages and disadvantages.



Advantages of Using DAS

A typical DAS system is made up of a data storage device that includes a number of hard disk drives that connect directly to a computer through a host bus adapter (HBA). Between the DAS and the computer, there are no network devices such as hubs, switches, or routers. Instead, the storage is connected directly to the server that utilizes it, making DAS the easiest storage system to deploy and maintain.

DAS is also usually the least expensive storage available today, and is widely available in various speeds and sizes to accommodate various installations. In addition to being inexpensive, DAS is very easy to configure. In most instances, you would simply plug in the device, ensure that the running Windows® operating system recognizes it, and then use Disk Management to configure the disks.

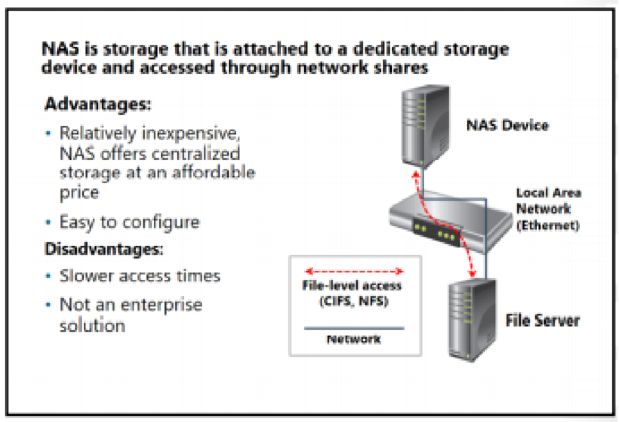
Disadvantages of Using DAS

Storing data locally on DAS makes data centralization more difficult because the data is located on multiple servers. This can make it more complex to back up the data and, for users, more difficult to locate the data they want to find. Furthermore, if any one device that has DAS connected to it suffers a power outage, the storage on that computer becomes unavailable.

DAS also has drawbacks in its access methodologies. Due to the way reads and writes are handled by the server operating system, DAS can be slower than other storage technologies. Another drawback is that DAS shares the processing power and server memory of the server to which it is connected. This means that, on very busy servers, disk access might become slow when the operating system is overloaded.

What Is Network Attached Storage?

Network attached storage (NAS) is storage that is connected to a dedicated storage device and then accessed over the network. NAS is different from DAS in that the storage is not directly attached to each individual server, but rather is accessible across the network to many servers. NAS has two distinct solutions: a low-end appliance (NAS only), and an enterprise-class NAS that integrates with SAN.



Each NAS device has a dedicated operating system that solely controls the access to the data on the device, which reduces the overhead associated with sharing the storage device with other server services. An example of NAS software is Windows Storage Server, a feature of Windows Server 2012.

NAS devices typically provide file-level access to the storage. This means that the data on the storage is accessible only as files, and you must use protocols like Common Internet Files System (CIFS), Server Message Block (SMB), or Network File System (NFS) to access the files.

Advantages of Using NAS

NAS is an ideal choice for organizations that are looking for a simple and cost-effective way to achieve fast data access for multiple clients at the file level. Users of NAS benefit from performance and productivity gains because the processing power of the NAS device is dedicated solely to the distribution of the files.

NAS also fits nicely into the market as a mid-priced solution. It is not expensive, but it suits more needs than DAS in the following ways:

- NAS storage is usually much larger than DAS.
- NAS offers a single location for all critical files, rather than dispersing them on various servers or devices with DAS.
- NAS offers centralized storage at an affordable price.
- NAS units are accessible from any operating system. They often have multi-protocol support and can serve up data via CIFS and NFS simultaneously. For example, Windows and Linux hosts can simultaneously access a NAS unit.

NAS can also be considered a Plug and Play solution that is easy to install, deploy, and manage, with or without IT staff onsite.

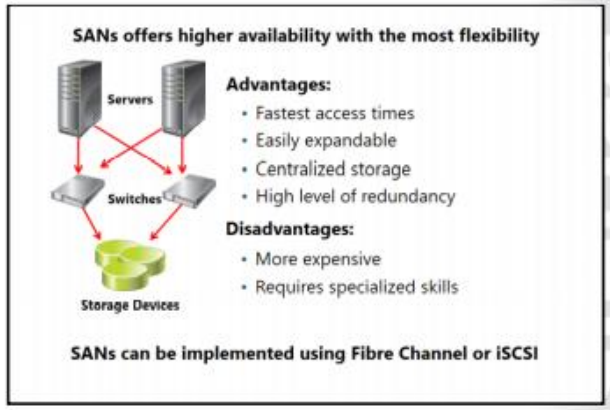
Disadvantages of Using NAS

NAS is slower than SAN technologies. NAS is frequently accessed via Ethernet protocols. Because of this, it relies heavily on the network supporting the NAS solution. For this reason, NAS is commonly used as a file sharing/storage solution and cannot (and should not) be used with data-intensive applications such as Microsoft® Exchange Server and Microsoft SQL Server®.

NAS is affordable for small to mid-size businesses, but provides less performance and may be less reliable than a SAN. For this reason, most large enterprises use SANs rather than NAS.

Additional Reading: For more information about Windows Storage Server 2012 R2, see Windows Server 2012 R2 at http://go.microsoft.com/fwlink/?LinkID=199647.

What Is a SAN?



The third type of storage is a storage area network (SAN). A SAN is a high-speed network that connects computer systems or host servers to high-performance storage subsystems. A SAN usually includes various components such as host bus-adapters (HBAs), special switches to help route traffic, and storage disk arrays with logical unit numbers (LUNs) for storage.

A SAN enables multiple servers to access a pool of storage in which any server can potentially access any storage unit. Because a SAN uses a network, you can use a SAN to connect many different devices and hosts and provide access to any connected device from anywhere.

SANs provide block level access. This means that, rather than accessing the content on the disks as files by using a file access protocol, SANs write blocks of data directly to the disks using protocols such as Fibre Channel over Ethernet (FCOE) or Internet Small Computer System Interface (iSCSI).

Advantages of Using SAN

SAN technologies read and write at block levels, making data access much faster. For example, with most DAS and NAS solutions, if you write a file of 8 GB, the entire file has to be read/written and its checksum calculated. With a SAN, the file is written to the disk based on the block size for which the SAN is set up. This speed is accomplished by using fiber channel and block level writing, instead of having to read/write an entire file by using a checksum.

SANs also provide:

- Centralization of storage into a single pool, which enables storage resources and server resources to grow independently. They also enable storage to be dynamically assigned from the pool when it is required. Storage on a given server can be increased or decreased as needed without complex reconfiguring or re-cabling of devices.
- Common infrastructure for attaching storage, which enables a single common management model for configuration and deployment.
- Storage devices that are inherently shared by multiple systems.
- Data transfer directly from device to device without server intervention.
- A high level of redundancy. Most SANs are deployed with multiple network devices and paths through the network. As well, the storage device contains redundant components such as power supplies and hard disks.

Disadvantages of Using SAN

The main drawback to SAN technology is that due to the complexities in the configuration, SAN often requires management tools and expert skills. It is also considerably more expensive than DAS or NAS—an entry level SAN can often cost as much as a fully-loaded server with a DAS or an NAS device, and that is without any SAN disks or configuration.

To manage a SAN, you often use command-line tools. You must have a firm understanding of the underlying technology, including the LUN setup, the Fibre Channel network, the block sizing, and other factors. In addition, each storage vendor often implements SANs using different tools and features. Because of this, organizations often have dedicated personnel whose only job is to manage the SAN deployment.

What Is RAID?

RAID:

- Combines multiple disks into a single logical unit to provide fault tolerance and performance
- Provides fault tolerance by using:
  - Disk mirroring
  - Parity information
- Can provide performance benefits by spreading disk I/O across multiple disks
- Can be configured using several different levels
- Should not replace server backups

RAID is a technology that you can use to configure storage systems to provide high reliability and (potentially) high performance. RAID implements storage systems by combining multiple disks into a single logical unit called a *RAID array*. Depending on the configuration, a RAID array can withstand the failure of one or more of the physical hard disks contained in the array, and/or provide higher performance than is available by using a single disk.

RAID provides an important component—redundancy—that you can use when planning and deploying Windows Server 2012 servers. In most organizations, it is important that the servers are available all of the time. Most servers provide highly redundant components such as redundant power supplies and redundant network adapters. The goal of this redundancy is to ensure that the server remains available even when a single component on the server fails. By implementing RAID, you can provide the same level of redundancy for the storage system.

How RAID Works

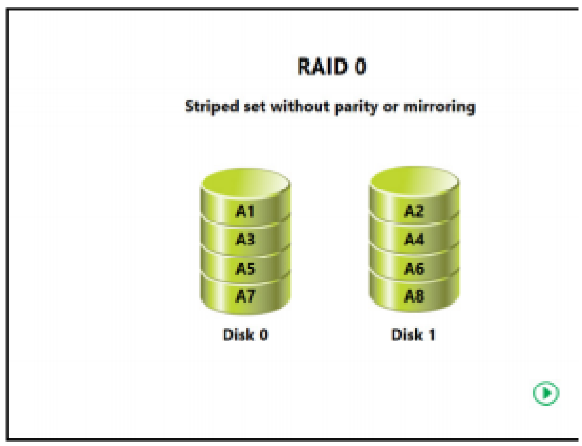
RAID enables fault tolerance by using additional disks to ensure that the disk subsystem can continue to function even if one or more disks in the subsystem fail. RAID uses two options for enabling fault tolerance:

- Disk mirroring. With disk mirroring, all of the information that is written to one disk is also written to another disk. If one of the disks fails, the other disk is still available.
- Parity information. Parity information is used in the event of a disk failure to calculate the information that was stored on a disk. If you use this option, the server or RAID controller calculates the parity information for each block of data that is written to the disks, and then stores this information on another disk or across multiple disks. If one of the disks in the RAID array fails, the server can use the data that is still available on the functional disks along with the parity information to recreate the data that was stored on the failed disk.

RAID subsystems can also provide potentially better performance than single disks by distributing disk reads and writes across multiple disks. For example, when implementing disk striping, the server can read information from all hard disks in the stripe set. When combined with multiple disk controllers, this can provide significant improvements in disk performance.

RAID Levels

When implementing RAID, you need to decide what level of RAID to implement. The following table lists the features for each different RAID level.



Level	Description	Performance	Space utilization	Redundancy	Comments
RAID 0	Striped set without parity or mirroring Data is written sequentially to each disk	High read and write performance	All space on the disks is available	A single disk failure results in the loss of all data	Use only in situations where you require high performance and can tolerate data loss
RAID 1	Mirrored set without parity or striping Data is written to both disks simultaneously	Good performance	Can only use the amount of space that is available on the smallest disk	Can tolerate a single disk failure	Frequently used for system and boot volumes with hardware RAID
RAID 2	Data is written in bits to each disk with parity written to separate disk or disks	Extremely high performance	Uses one or more disks for parity	Can tolerate a single disk failure	Requires that all disks be synchronized Not currently used
RAID 3	Data is written in bytes to each disk with parity written to separate disk or disks	Very high performance	Uses one disk for parity	Can tolerate a single disk failure	Requires that all disks be synchronized Rarely used
RAID 4	Data is written in blocks to each disk with parity written to a dedicated disk	Good read performance, poor write performance	Uses one disk for parity	Can tolerate a single disk failure	Rarely used
RAID 5	Striped set with distributed parity Data is written in blocks to each disk with parity spread across all disks	Good read performance, poor write performance	Uses the equivalent of one disk for parity	Can tolerate a single disk failure	Commonly used for data storage where performance is not critical, but maximizing disk usage is important

Level	Description	Performance	Space utilization	Redundancy	Comments
RAID 0+1	Striped sets in a mirrored set A set of drives is striped, and then the strip set is mirrored	Very good read and write performance	Only half the disk space is available due to mirroring	Can tolerate the failure of two or more disks as long as all failed disks are in the same striped set	Not commonly used
RAID 1+0 (or 10)	Mirrored set in a stripe set Several drives are mirrored to a second set of drives, and then one drive from each mirror is striped	Very good read and write performance	Only half the disk space is available due to mirroring	Can tolerate the failure of two or more disks as long as both disks in a mirror do not fail	Frequently used in scenarios where performance and redundancy are critical, and the cost of the required additional disks is acceptable

Selecting a Disk Type

When selecting a type of disk for use in Windows Server 2012, you can choose between basic disks and dynamic disks.

Basic disks are:

- Disks initialized for basic storage
- The default storage for Windows operating system

Dynamic disks can:

- Be modified without restarting Windows
- Provide several options for configuring volumes

Disk volume requirements include:

- A system volume for hardware-specific files that are required to start the server
- A boot volume for the Windows operating system files

Basic Disk

Basic storage uses normal partition tables that are used by all versions of the Windows operating system. A disk that is initialized for basic storage is called a *basic disk*. A basic disk contains basic partitions, such as primary partitions and extended partitions. You can subdivide extended partitions into logical drives.

By default, when you initialize a disk in the Windows operating system, the disk is configured as a basic disk. You can easily convert basic disks to dynamic disks without any loss of data; however, when converting a dynamic disk to basic disk, all data on the disk is lost.

There is no performance gain by converting basic disks to dynamic disks, and some applications cannot address data that is stored on dynamic disks. For these reasons, most administrators do not convert basic disks to dynamic disks unless they need to use some of the additional volume configuration options that are available with dynamic disks.

Dynamic Disk

Dynamic storage was introduced in the Microsoft Windows 2000 Server operating system. With dynamic storage, you can perform disk and volume management without the need to restart computers running Windows operating systems. A disk that is initialized for dynamic storage is called a *dynamic disk*. A dynamic disk contains dynamic volumes.

When you configure dynamic disks, you create volumes rather than partitions. A *volume* is a storage unit that is made from free space on one or more disks. You can format the volume with a file system, and can assign it a drive letter or configure it with a mount point.

The following is a list of the dynamic volumes that are available:

- *Simple volumes.* A simple volume uses free space from a single disk. It can be a single region on a disk, or consist of multiple, concatenated regions. A simple volume can be extended within the same disk or extended to additional disks. If a simple volume is extended across multiple disks, it becomes a spanned volume.
- *Spanned volumes.* A spanned volume is created from free disk space from multiple disks that is linked together. You can extend a spanned volume onto a maximum of 32 disks. A spanned volume cannot be mirrored, and is not fault-tolerant; therefore, if you lose one disk, you will lose the entire spanned volume.
- *Striped volumes.* A striped volume has data that is spread across two or more physical disks. The data on this type of volume is allocated alternately and evenly to each of the physical disks. A striped volume cannot be mirrored or extended, and is not fault-tolerant. This means that the loss of one disk causes the immediate loss of all the data. Striping is also known as *RAID-0.*
- *Mirrored volumes.* A mirrored volume is a fault-tolerant volume that has all data duplicated onto two physical disks. All of the data on one volume is copied to another disk to provide data redundancy. If one of the disks fails, the data can still be accessed from the remaining disk. A mirrored volume cannot be extended. Mirroring is also known as *RAID-1*.
- *RAID-5 volumes.* A RAID-5 volume is a fault-tolerant volume that has data striped across a minimum of three or more disks. Parity is also striped across the disk array. If a physical disk fails, the portion of the RAID-5 volume that was on that failed disk can be re-created from the remaining data and the parity. A RAID-5 volume cannot be mirrored or extended.

Selecting a File System

When you configure your disks in Windows Server 2012, you can choose between file allocation table (FAT), the NTFS file system, and Resilient File System (ReFS) file systems.

When selecting a file system, consider the differences between FAT, NTFS, and ReFS

FAT provides:
- Basic file system
- Partition size limitations
- FAT32 to enable larger disks
- exFAT developed for flash drives

NTFS provides:
- Metadata
- Auditing and journaling
- Security (ACLs and encryption)

ReFS provides:
- Backward compatibility support for NTFS
- Enhanced data verification and error correction
- Support for larger files, directories, volumes, and so on

FAT

The FAT file system is the most simplistic of the file systems that Windows operating systems support. The FAT file system is characterized by a table that resides at the very top of the volume. To protect the volume, two copies of the FAT file system are maintained in case one becomes damaged. In addition, the file allocation tables and the root directory must be stored in a fixed location so that the system's boot files can be correctly located.

NTFS

NTFS is the standard file system for all Windows operating systems beginning with Windows NT® Server 3.1. Unlike FAT, there are no special objects on the disk, and there is no dependence on the underlying hardware, such as 512-byte sectors. In addition, in NTFS there are no special locations on the disk, such as the tables.

NTFS is an improvement over FAT in several ways, such as better support for metadata, and the use of advanced data structures to improve performance, reliability, and disk space utilization. NTFS also has additional extensions such as security access control lists (ACLs), which you can use for auditing, file system journaling, and encryption.

Resilient File System (ReFS)

ReFS was introduced with Windows Server 2012 to enhance the capabilities of NTFS. ReFS was developed to improve upon NTFS by offering larger maximum sizes for individual files, directories, disk volumes, and other items. Additionally, ReFS offers greater resiliency, meaning better data verification, error correction, and scalability.

You should use ReFS with very large volumes and very large file shares to overcome the NTFS limitation of error checking and correction. Because ReFS was not available prior to Windows Server 2012 (the only choice was NTFS), it makes sense to use ReFS with Windows Server 2012 instead of NTFS to achieve better error checking, better reliability, and less corruption. ReFS cannot be used for the boot volume.

What Is ReFS?

ReFS is a new feature in Windows Server 2012. ReFS is based on the NTFS file system, and provides the following advantages:

- Metadata integrity with checksums
- Expanded protection against data corruption
- Maximizes reliability, especially during a loss of power (while NTFS has been known to experience corruption in similar circumstances)
- Large volume, file, and directory sizes
- Storage pooling and virtualization, which makes creating and managing file systems easier
- Redundancy for fault tolerance
- Disk scrubbing for protection against latent disk errors
- Resiliency to corruptions with recovery for maximum volume availability
- Shared storage pools across machines for additional failure tolerance and load balancing

ReFS is a new file system that is built in to Windows Server 2012. Advantages include:

- Metadata integrity with checksums
- Integrity streams with user data integrity
- Allocation on write transactional model
- Large volume, file, and directory sizes (2^78 bytes with 16-KB cluster size)
- Storage pooling and virtualization
- Data striping for performance and redundancy
- Disk scrubbing for protection against latent disk errors
- Resiliency to corruptions with recovery
- Shared storage pools across machines

What Are Mount Points and Links?

With NTFS and ReFS file systems, you can create mount points and links to refer to files, directories, and volumes.

Mount Points

Mount points are used in Windows operating systems to make a portion of a disk or the entire disk useable by the operating system. Most commonly, mount points are associated with drive-letter mappings so that the operating system can gain access to the disk through the drive letter.

A mount point is a reference to a location on a disk that enables Windows operating system access to disk resources

Use volume mount points:

- To mount volumes or disks as folders instead of using drive letters
- When you do not have drive letters available for creating new volumes
- To add disk space without changing the folder structure

A link file contains a reference to another file or directory

Link options:

- Symbolic file link (or, soft link)
- Symbolic directory link (or, directory junctions)

Links

A *link* is a special type of file that contains a reference to another file or directory in the form of an absolute or relative path. Windows supports the following two types of links:

- A symbolic file link (also known as a *soft link*)
- A symbolic directory link (also known as a *directory junction*)

A link that is stored on a server share could refer back to a directory on a client that is not actually accessible from the server where the link is stored. Because the link processing is done from the client, the link would work correctly to access the client, even though the server cannot access the client.

Module 9

Lab: Implementing Local Storage

Exercise 1: Installing and Configuring a New Disk

▶ Task 1: Initialize a new disk

1. Sign in to **LON-SVR1** with the username **Adatum\Administrator** and the password **Pa$$w0rd**.
2. In Server Manager, click the **Tools** menu, and then click **Computer Management**.
3. In the Computer Management console, under the Storage node, click **Disk Management**.
4. In the Disks pane, right-click **Disk2**, and then click **Online**.
5. Right-click **Disk2**, and then click **Initialize Disk.**
6. In the **Initialize Disk** dialog box, select the **Disk 2** check box, click **GPT (GUID Partition Table)**, and then click **OK**.

▶ Task 2: Create and format two simple volumes on the disk

1. In the Computer Management console, in Disk Management, right-click the black marked box right of Disk 2, and then click **New Simple Volume**.
2. In the New Simple Volume Wizard, on **Welcome to the New Simple Volume Wizard** page, click **Next**.
3. On the **Specify Volume Size** page, in the **Simple volume size MB** field, type **4000**, and then click **Next**.
4. On **Assign Drive Letter or Path** page, ensure that the **Assign the following drive letter** check box is selected, and that **F** is selected in from the drop-down menu, and then click **Next**.
5. On the **Format Partition** page, from the **File system** drop-down menu, click **NTFS**, in the **Volume label** text box, type **Volume1**, and then click **Next**.
6. On **Completing the New Simple Volume Wizard** page, click **Finish**.
7. In the Disk Management window, right-click the black box right of Disk 2, and then click **New Simple Volume**.
8. In the New Simple Volume Wizard, on **Welcome to the New Simple Volume Wizard** page, click **Next**.
9. On the **Specify Volume Size** page, in the **Simple volume size in MB** field, type **5000**, and then click **Next**.
10. On the **Assign Drive Letter or Path** page, ensure that the **Assign the following drive letter** check box is selected, verify that **G** is listed as the drive letter, and then click **Next**.
11. On the **Format Partition** page, from the **File system** drop-down menu, click **ReFS**, in the **Volume label** text box, type **Volume2**, and then click **Next**.
12. On the **Completing the New Simple Volume Wizard** page, click **Finish**.

▶ Task 3: Verify the drive letter in a File Explorer window

1. On the taskbar, open a File Explorer window, expand **This PC**, and then click **Volume1 (F:)**.
2. In File Explorer, click **Volume2 (G:)**, right-click **Volume2 (G:)**, point to **New**, and then click **Folder**.
3. In the **New folder** field, type **Folder1**, and then press Enter.

Results: After you complete this lab, you should have initialized a new disk, created two simple volumes, and then formatted them. You should also have verified that the drive letters you assigned are available in File Explorer.

Exercise 2: Resizing Volumes

▶ Task 1: Shrink Volume1

1. On LON-SVR1, switch to the Computer Management console.
2. In the Computer Management console, in Disk Management, in the middle-pane, right-click **Volume1 (F:)**, and then click **Shrink Volume**.
3. In the Shrink F: window, in the **Enter the amount of space to shrink in MB** field, type **1000**, and then click **Shrink**.

▶ Task 2: Extend Volume2

1. On LON-SVR1, in Disk Management, in the middle-pane, right-click **Volume2 (G:)**, and then click **Extend Volume**.
2. In Extend Volume Wizard, on the **Welcome to the Extended Volume Wizard** page, click **Next**.
3. On the **Select Disks** page, in the **Select the amount of space in MB** field, type **1000**, and then click **Next**.
4. On the **Completing the Extended Volume Wizard** page, click **Finish**.
5. In a File Explorer window, click **Volume2 (G:)**, and verify that **Folder1** is available on the volume.

Results: After this lab, you should have made one volume smaller, and extended another.

Exercise 3: Configuring a Redundant Storage Space

▶ Task 1: Create a storage pool from five disks that are attached to the server

1. On LON-SVR1, on the taskbar, click the **Server Manager** icon.
2. In Server Manager, in the left pane, click **File and Storage Services**, and then in the Servers pane, click **Storage Pools**.
3. In the STORAGE POOLS pane, click **TASKS**, and then in the **TASKS** drop-down menu, click **New Storage Pool**.
4. In the New Storage Pool Wizard window, on the **Before you begin** page, click **Next**.
5. On the **Specify a storage pool name and subsystem** page, in the **Name** box, type **StoragePool1**, and then click **Next**.

6. On the **Select physical disks for the storage pool** page, click the following physical disks, and then click **Next**:
   - **PhysicalDisk3**
   - **PhysicalDisk4**
   - **PhysicalDisk5**
   - **PhysicalDisk6**
   - **PhysicalDisk7**
7. On the **Confirm selections** page, click **Create**.
8. On the **View results** page, wait until the task completes, and then click **Close**.

▶ Task 2: Create a three-way mirrored virtual disk

1. On LON-SVR1, in Server Manager, in the Storage Spaces pane, click **StoragePool1**.
2. In the VIRTUAL DISKS pane, click **TASKS**, and then from the **TASKS** drop-down menu, click **New Virtual Disk**.
3. In the New Virtual Disk Wizard window, on the **Before you begin** page, click **Next**.
4. On the **Select the storage pool** page, click **StoragePool1**, and then click **Next**.
5. On the **Specify the virtual disk name** page, in the **Name** box, type **Mirrored Disk**, and then click **Next**.
6. On the **Select the storage layout** page, in the **Layout** list, click **Mirror**, and then click **Next**.
7. On the **Configure the resiliency settings** page, click **Three-way mirror**, and then click **Next**.
8. On the **Specify the provisioning type** page, click **Thin**, and then click **Next**.
9. On the **Specify the size of the virtual disk** page, in the **Specify Size** box, type **10**, and then click **Next**.

10. On the **Confirm selections** page, click **Create**.
11. On the **View results** page, wait until the task completes.
12. Ensure that the **Create a volume when this wizard closes** check box is selected, and then click **Close**.
13. In the New Volume Wizard window, on the **Before you begin** page, click **Next**.
14. On the **Select the server and disk** page, in the Disk pane, click the **Mirrored Disk** virtual disk, and then click **Next**.
15. On the **Specify the size of the volume** page, click **Next** to confirm the default selection.
16. On the **Assign to a drive letter or folder** page, in the **Drive letter** drop-down menu, ensure that **H** is selected, and then click **Next**.
17. On the **Select file system settings** page, in the **File system** drop-down menu, click **ReFS**, in the **Volume label** box, type **Mirrored Volume**, and then click **Next**.
18. On the **Confirm selections** page, click **Create**.
19. On the **Completion** page, wait until the creation completes, and then click **Close**.

▶ Task 3: Copy a file to the volume, and verify that it is visible in File Explorer

1. Click to the Start screen, type **command prompt**, and then press Enter.
2. In the Command Prompt window, at the command prompt, type the following command, and then press Enter:

```
Copy C:\windows\system32\write.exe H:\
```

3. Close the Command Prompt window.
4. On the taskbar, click the **File Explorer** icon.
5. In the File Explorer window, click **Mirrored Volume (H:)**.
6. Verify that write.exe displays in the file list.
7. Close File Explorer.

▶ Task 4: Remove a physical drive

1. On Host machine, in Hyper-V Manager®, in the Virtual Machines pane, right-click **0410C-LON-SVR1**, and then click **Settings**.
2. In Settings for 20410C-LON-SVR1, in the Hardware pane, click Hard Drive that begins with **20410C-LON-SVR1-Disk5**.
3. In the Hard Drive pane, click **Remove**, and then click **OK**. Click **Continue**.

▶ Task 5: Verify that the write.exe file is still accessible

1. Switch to LON-SVR1.
2. On the taskbar, click the **File Explorer** icon.
3. In the File Explorer window, click **Mirrored Volume (H:)**.
4. In the file list pane, verify that **write.exe** is still available.
5. Close File Explorer.
6. In Server Manager, in the STORAGE POOLS pane, on the menu bar, click the **Refresh "Storage Pools"** button.

   Notice the warning that displays next to Mirrored Disk.
7. In the VIRTUAL DISK pane, right-click **Mirrored Disk**, and then click **Properties**.
8. In the **Mirrored Disk Properties** dialog box, in the left pane, click **Health**.

   Notice that the Health Status indicates a Warning. The Operational Status should indicate Incomplete, Unknown or Degraded.
9. Click **OK** to close the **Mirrored Disk Properties** dialog box.

▶ Task 6: Add a new disk to the storage pool and remove a broken disk

1. Switch to **LON-SVR1**.
2. In Server Manager, in the STORAGE POOLS pane, on the menu bar, click the **Refresh "Storage Pools"** button.
3. In the STORAGE POOLS pane, right-click **StoragePool1**, and then click **Add Physical Disk**.
4. In the Add Physical Disk window, click **PhysicalDisk8 (LON-SVR1)**, and then click **OK**.
5. Click **Windows Powershell** on the Task Bar.

6. Type **Get-PhysicalDisk**, and press Enter.
7. Note the FriendlyName for the disk that shows an OperationalStatus of Lost Communication.
8. Type **$Disk = Get-PhysicalDisk –FriendlyName *diskname*** and press ENTER. Replace *diskname* with the name of the disk you noted in Step 7.
9. Type **Remove-PhysicalDisk –PhysicalDisks $disk -StoragePoolFriendlyName StoragePool1** and press Enter.
10. Type **Y**, and then press Enter.
11. If you get a warning that the disk cannot be removed, wait five minutes and then run the last command again. It can take some time for the mirrored disk to be resynchronized after a disk has been removed and another disk added. If you still cannot remove the disk after five minutes, restart LON-SVR1, sign in as **Adatum\Administrator** using the password **Pa$$w0rd**, and repeat steps 5-10.
12. In Server Manager, in the STORAGE POOLS pane, on the menu bar, click the **Refresh "Storage Pools"** button to see the warnings disappear.

Results: After completing this lab, you should have created a storage pool and added five disks to it. Then you should have created a three-way mirrored, thinly provisioned virtual disk from the storage pool. You should have also copied a file to the new volume and verified that it is accessible. Next, after removing a physical drive, you should have verified that the virtual disk was still available and could be accessed. Finally, you should have added another physical disk to the storage pool.

▶ Prepare for the next module

After you finish the lab, revert the virtual machines back to their initial state. To do this, complete the following steps.

1. On the host computer, start **Hyper-V Manager**.
2. In the **Virtual Machines** list, right-click **20410C-LON-DC1**, and then click **Revert**.
3. In the **Revert Virtual Machine** dialog box, click **Revert**.
4. Repeat steps 2 and 3 for **20410C-LON-SVR1**.