Course Outcomes

CO 1: Identify key challenges in managing information and analyze different storage networking technologies and virtualization

CO 2: Explain components and the implementation of NAS

CO 3: Describe CAS architecture and types of archives and forms of virtualization

CO 4: Illustrate the storage infrastructure and management activities

Institution Vision

To produce top-quality engineers who are groomed for attaining excellence in their profession and competitive enough to help in the growth of nation and global society.

Institution Mission

M1: To offer affordable high-quality graduate program in engineering with value education and make the students socially responsible.

M2: To support and enhance the institutional environment to attain research excellence in both faculty and students and to inspire them to push the boundaries of knowledge base.

M3: To identify the common areas of interest amongst the individuals for the effective industry- institute partnership in a sustainable way by systematically working together.

M4: To promote the entrepreneurial attitude and inculcate innovative ideas among the engineering professionals.

Department Vision

To be a center of excellence in Information Science & Engineering education, research and training to meet the growing needs of the industry and society.

Department Mission

M1: To impart theoretical and practical knowledge through the concepts and technologies in Information Science and Engineering

M2: To foster research, collaboration and higher education with premier institutions and industries.

M3: Promote innovation and entrepreneurship to fulfill the needs of the society and industry

Program Educational Objectives

PEO1: Analyse, design and implement solutions to the real-world problems in the field of Information Science and Engineering with multidisciplinary setup

PEO2: Keep abreast with the technology, innovation and pursue higher education with high standards of social and professional ethics

PEO3: Develop professional and entrepreneurship skills to work effectively as an individual and in a team to meet the ever-changing goals of the organization

Program Outcomes

PO1: **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

PO2: **Problem Analysis:** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural science and engineering sciences.

PO3: **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal and environmental considerations.

PO4: **Conduct investigations of complex problems:** Use research based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: **Modern tool usage:** Create, select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations

PO6: **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice

PO7: **Environment sustainability:** Understand the impact of the professional engineering solutions in the societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions

PO11: **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to ones own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: **Lifelong learning:** Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broader context of technological change.

Program Specific Outcome

PSO1: Design, implement and maintain the information systems that fulfill the current needs of the industry and society

PSO2: Apply computational theory, storage and networking concepts to solve the day to day problems of the world

IP SAN and FCoE

iSCSI

- iSCSI is an IP based protocol that establishes and manages connections between host and storage over IP, as shown in Fig below.
- iSCSI encapsulates SCSI commands and data into an IP packet and transports them using TCP/IP.
- iSCSI is widely adopted for connecting servers to storage because it is relatively inexpensive and easy to implement, especially in environments in which an FC SAN does not exist.

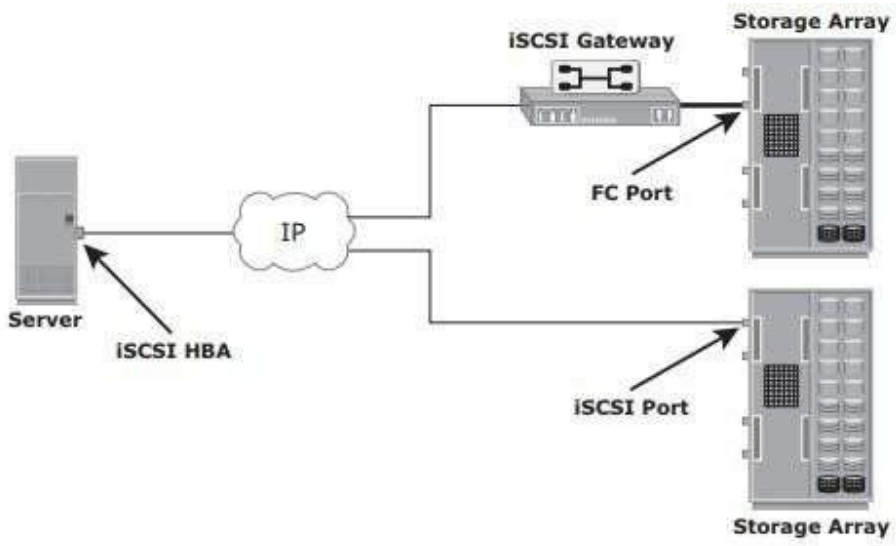


Fig : iSCSI implementation

Components of iSCSI

- An initiator (host), target (storage or iSCSI gateway), and an IP-based network are the key iSCSI components.
- If an iSCSI-capable storage array is deployed, then a host with the iSCSI initiator can directly communicate with the storage array over an IP network.
- However, in an implementation that uses an existing FC array for iSCSI communication, an iSCSI gateway is used.
- These devices perform the translation of IP packets to FC frames and vice versa, thereby bridging the connectivity between the IP and FC environments.

iSCSI Host Connectivity

The three iSCSI host connectivity options are:

- A standard NIC with software iSCSI initiator,
- a TCP offload engine (TOE) NIC with software iSCSI initiator,
- an iSCSI HBA

- The function of the iSCSI initiator is to route the SCSI commands over an IP network.
- A **standard NIC with a software iSCSI** initiator is the simplest and least expensive connectivity option. It is easy to implement because most servers come with at least one, and in many cases two, embedded NICs. It requires only a software initiator for iSCSI functionality. Because NICs provide standard IP function, encapsulation of SCSI into IP packets and decapsulation are carried out by the host CPU. This places additional overhead on the host CPU. If a standard NIC is used in heavy I/O load situations, the host CPU might become a bottleneck. TOE NIC helps reduce this burden.
- A **TOE NIC** offloads TCP management functions from the host and leaves only the iSCSI functionality to the host processor. The host passes the iSCSI information to the TOE card, and the TOE card sends the information to the destination using TCP/IP. Although this solution improves performance, the iSCSI functionality is still handled by a software initiatorthat requires host CPU cycles.
- An **iSCSI HBA** is capable of providing performance benefi ts because it offloads the entire iSCSI and TCP/IP processing from the host processor. The use of an iSCSI HBA is also the simplest way to boot hosts from a SAN environment via iSCSI. If there is no iSCSI HBA, modifi cations must be made to the basic operating system to boot a host from the storage devices because the NIC needs to obtain an IP address before the operating system loads. The functionality of an iSCSI HBA is similar to the functionality of an FC HBA.

iSCSI Topologies

- Two topologies of iSCSI implementations are **native and bridged**.
- Native topology does not have FC components.
- The initiators may be either directly attached to targets or connected through the IP network.

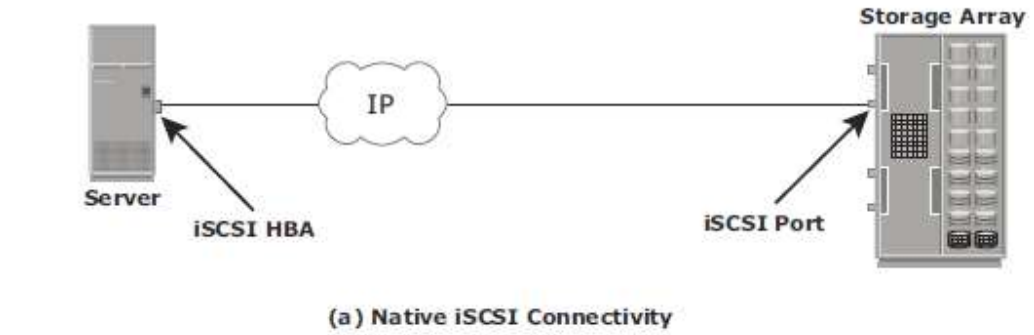
- Bridged topology enables the coexistence of FC with IP by providing iSCSI-to-FC bridging functionality.
- For example, the initiators can exist in an IP environment while the storage remains in an FC environment.

Native iSCSI Connectivity

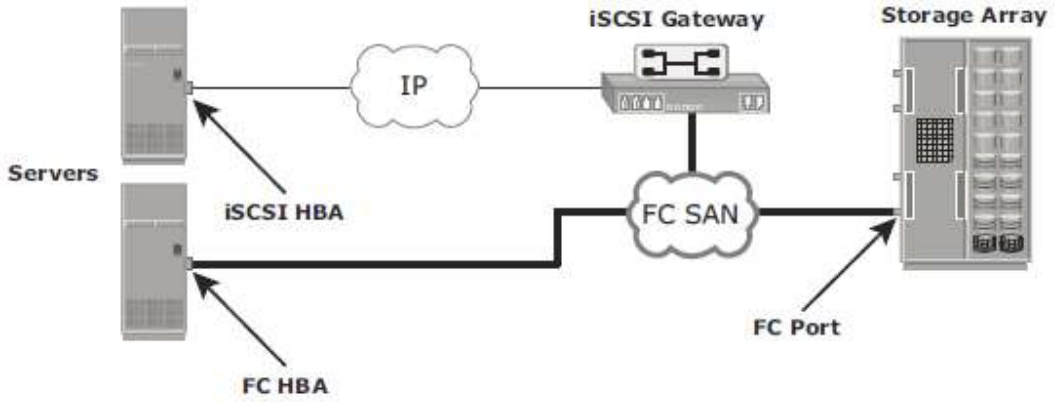
- FC components are not required for iSCSI connectivity if an iSCSI-enabled array is deployed.
- In Fig (a), the array has one or more iSCSI ports configured with an IP address and is connected to a standard Ethernet switch.
- After an initiator is logged on to the network, it can access the available LUNs on the storage array.
- A single array port can service multiple hosts or initiators as long as the array port can handle the amount of storage traffic that the hosts generate.

Bridged iSCSI Connectivity

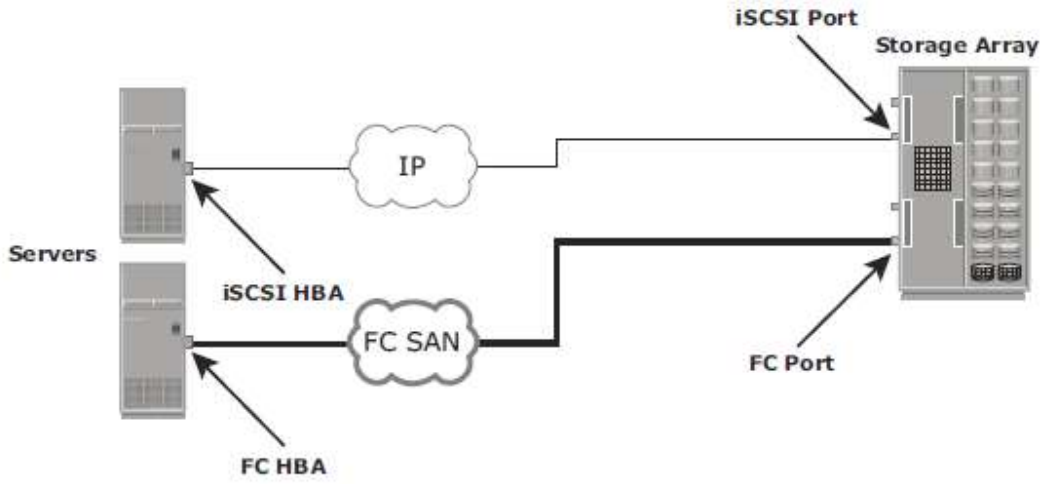
- A bridged iSCSI implementation includes FC components in its configuration.
- Fig (b), illustrates iSCSI host connectivity to an FC storage array. In this case, the array does not have any iSCSI ports. Therefore, an external device, called a gateway or a multiprotocol router, must be used to facilitate the communication between the iSCSI host and FC storage.
- The gateway converts IP packets to FC frames and vice versa.
- The bridge devices contain both FC and Ethernet ports to facilitate the communication between the FC and IP environments.
- In a bridged iSCSI implementation, the iSCSI initiator is configured with the gateway's IP address as its target destination.
- On the other side, the gateway is configured as an FC initiator to the storage array.
- **Combining FC and Native iSCSI Connectivity:** The most common topology is a combination of FC and native iSCSI. Typically, a storage array comes with both FC and iSCSI ports that enable iSCSI and FC connectivity in the same environment, as shown in Fig (c).



(a) Native iSCSI Connectivity



(b) Bridged iSCSI Connectivity



(c) Combining FC and Native iSCSI Connectivity

Fig : iSCSI Topologies

iSCSI Protocol Stack

- Below figure displays a model of the iSCSI protocol layers and depicts the encapsulation order ofthe SCSI commands for their delivery through a physical carrier.

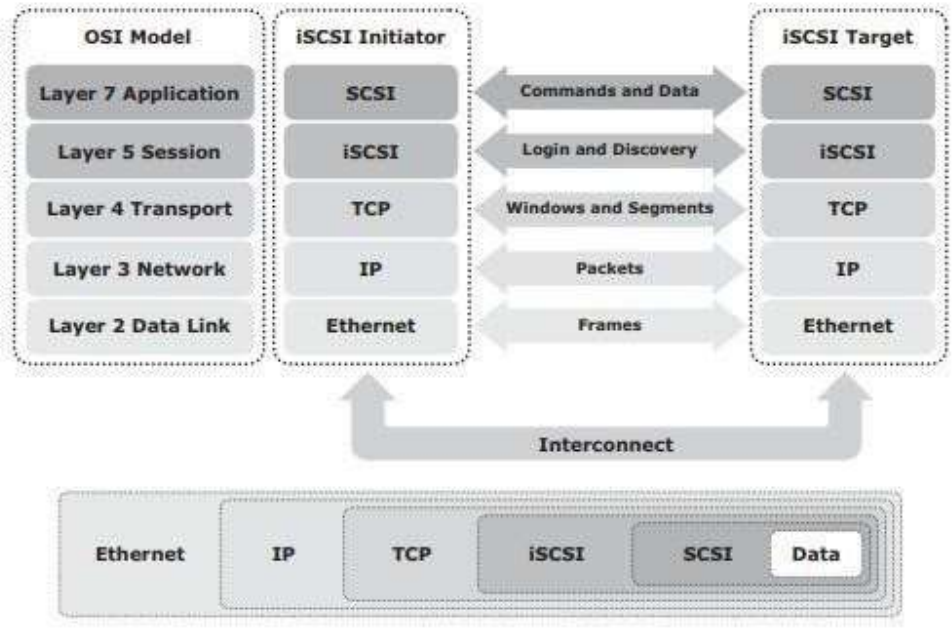


Fig: iSCSI protocol stack

- SCSI is the command protocol that works at the application layer of the Open System Interconnection (OSI) model.
- The initiators and targets use SCSI commands and responses to talk to each other.
- The SCSI command descriptor blocks, data, and status messages are encapsulated intoTCP/IP and transmitted across the network between the initiators and targets.
- iSCSI is the session-layer protocol that initiates a reliable session between devices that recognize SCSI commands and TCP/IP.
- The iSCSI session-layer interface is responsible for handling login, authentication, target discovery, and session management.
- TCP is used with iSCSI at the transport layer to provide reliable transmission.
- TCP controls message flow, windowing, error recovery, and retransmission.
- It relies upon the network layer of the OSI model to provide global addressing andconnectivity.
- The Layer 2 protocols at the data link layer of this model enable node-to-nodecommunication through a physical network.

iSCSI PDU

- A *protocol data unit* (PDU) is the basic "information unit" in the iSCSI environment.
- The iSCSI initiators and targets communicate with each other using iSCSI PDUs. This communication includes establishing iSCSI connections and iSCSI sessions, performing iSCSI discovery, sending SCSI commands and data, and receiving SCSI status.
- All iSCSI PDUs contain one or more header segments followed by zero or more data segments.
- The PDU is then encapsulated into an IP packet to facilitate the transport.
- A PDU includes the components shown in Fig below.
- The IP header provides packet-routing information to move the packet across a network.
- The TCP header contains the information required to guarantee the packet delivery to the target.
- The iSCSI header (basic header segment) describes how to extract SCSI commands and data for the target. iSCSI adds an optional CRC, known as the *digest*, to ensure datagramintegrity. This is in addition to TCP checksum and Ethernet CRC.
- The header and the data digests are optionally used in the PDU to validate integrity and data placement.

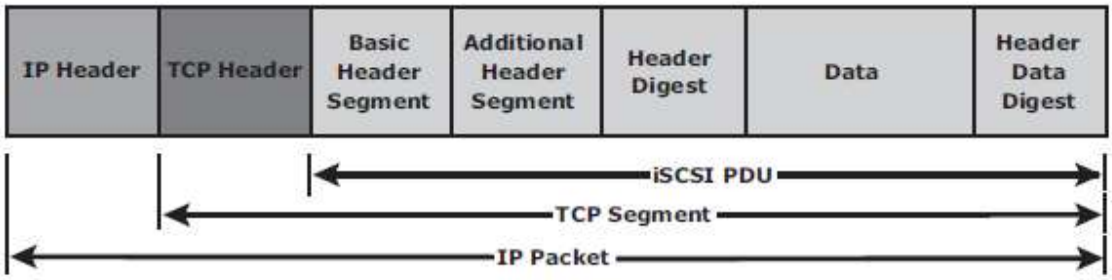


Fig : iSCSI PDU encapsulated in an IP packet

iSCSI Discovery

- An initiator must discover the location of its targets on the network and the names of the targets available to it before it can establish a session.
- This discovery can take place in two ways:
  - **SendTargets discovery**
  - **internet Storage Name Service (iSNS).**

- In *SendTargets discovery*, the initiator is manually configured with the target's network portal to establish a discovery session. The initiator issues the SendTargets command, and the target network portal responds with the names and addresses of the targets available to the host.
- iSNS (Fig below) enables automatic discovery of iSCSI devices on an IP network. The initiators and targets can be configured to automatically register themselves with the iSNS server. Whenever an initiator wants to now the targets that it can access, it can query the iSNS server fora list of available targets.
- The discovery can also take place by using service location protocol (SLP). However, this is less commonly used than SendTargets discovery and iSNS.

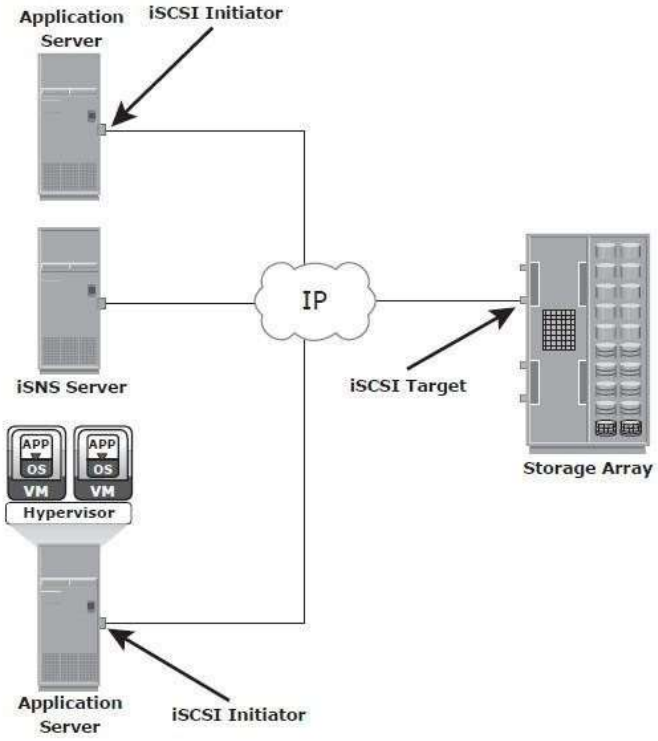


Fig : Discovery using iSNS

iSCSI Names

- A unique worldwide iSCSI identifier, known as an *iSCSI name*, is used to identify the initiators and targets within an iSCSI network to facilitate communication.
- The unique identifier can be a combination of the names of the department, application, or manufacturer, serial number, asset number, or any tag that can be used to recognize and manage the devices.

- Following are two types of iSCSI names commonly used:
  - **iSCSI Qualified Name (IQN):**
  - **Extended Unique Identifier (EUI)**
- **iSCSI Qualified Name (IQN):** An organization must own a registered domain name to generate iSCSI Qualified Names. This domain name does not need to be active or resolve to an address. It just needs to be reserved to prevent other organizations from using the same domain name to generate iSCSI names. A date is included in the name to avoid potential conflicts caused by the transfer of domain names.

An example of an IQN is iqn.2008-02.com.example:*optional_string.* The *optional_string* provides a serial number, an asset number, or any otherdevice identifiers.

- **Extended Unique Identifier (EUI):** An EUI is a globally unique identifier based on the IEEE EUI-64 naming standard. An EUI is composed of the eui prefix followed by a 16-character hexadecimal name, such aseui.0300732A32598D26.
- In either format, the allowed special characters are dots, dashes, and blank spaces.

iSCSI Session

- An iSCSI session is established between an initiator and a target, as shown in Fig.
- A session is identified by a session ID (SSID), which includes part of an initiator ID and a target ID.
- The session can be intended for one of the following:
  - The discovery of the available targets by the initiators and the location of a specific target on a network
  - The normal operation of iSCSI (transferring data between initiators and targets)
- There might be one or more TCP connections within each session. Each TCP connection within the session has a unique connection ID (CID).
- An iSCSI session is established via the iSCSI login process. The login process is started when the initiator establishes a TCP connection with the required target either via the well-known port 3260 or a specified target port.
- During the login phase, the initiator and the target authenticate each other and negotiate on various parameters.
- After the login phase is successfully completed, the iSCSI session enters the full-feature phase for

normal SCSI transactions. In this phase, the initiator may send SCSI commands and data to the various LUNs on the target.

- The final phase of the iSCSI session is the connection termination phase, which is referred to as the logout procedure.
- The initiator is responsible for commencing the logout procedure; however, the target may also prompt termination by sending an iSCSI message, indicating the occurrence of an internal error condition.
- After the logout request is sent from the initiator and accepted by the target, no further request and response can be sent on that connection.

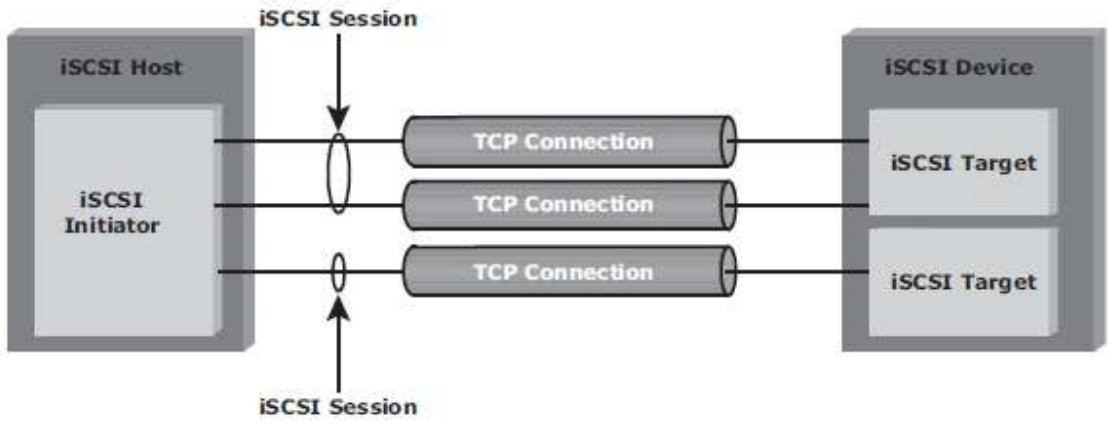


Fig : iSCSI session

Command Sequencing

- The iSCSI communication between the initiators and targets is based on the request-response command sequences.
- A command sequence may generate multiple PDUs.
- A ***command sequence number*** **(CmdSN)** within an iSCSI session is used for numbering all initiator-to-target command PDUs belonging to the session.
- This number ensures that every command is delivered in the same order in which it is transmitted, regardless of the TCP connection that carries the command in the session.
- Command sequencing begins with the first login command, and the CmdSN is incremented by one for each subsequent command.
- The iSCSI target layer is responsible for delivering the commands to the SCSI layer in the order of their CmdSN.
- Similar to command numbering, a ***status sequence number*** **(StatSN)** is used to sequentially

number status responses, as shown in Fig.

- These unique numbers are established at the level of the TCP connection.
- A target sends ***request-to-transfer*** **(R2T)** PDUs to the initiator when it is ready to accept data.
- A *data sequence number* (DataSN) is used to ensure in-order delivery of data within the same command.
- The DataSN and R2TSN are used to sequence data PDUs and R2Ts, respectively.

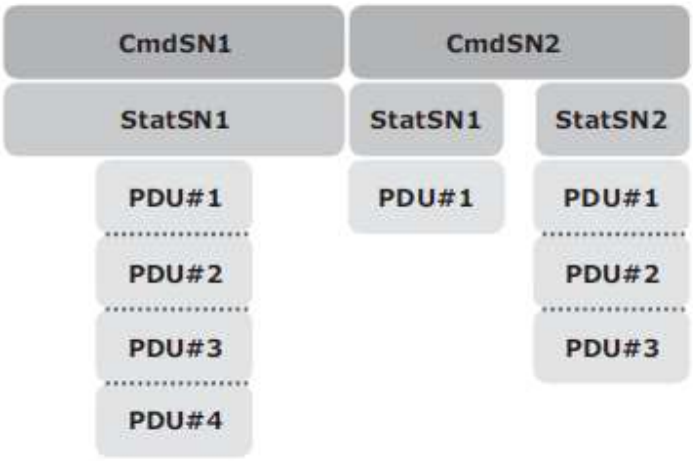


Fig : Command and status sequence number

FCIP (Fibre channel over IP)

- FCIP is a IP-based protocol that is used to connect distributed FC-SAN islands.
- Creates virtual FC links over existing IP network that is used to transport FC data between different FC SANS.
- It encapsulates FC frames into IP packet.
- It provides disaster recovery solution.

FCIP Protocol Stack

- The FCIP protocol stack is shown in Fig below. Applications generate SCSI commands and data, which are processed by various layers of the protocol stack.
- The upper layer protocol SCSI includes the SCSI driver program that executes the read-and- write commands.

- Below the SCSI layer is the Fibre Channel Protocol (FCP) layer, which is simply a Fibre Channel frame whose payload is SCSI.
- The FCP layer rides on top of the Fibre Channel transport layer. This enables the FC frames to run natively within a SAN fabric environment. In addition, the FC frames can be encapsulated into the IP packet and sent to a remote SAN over the IP.

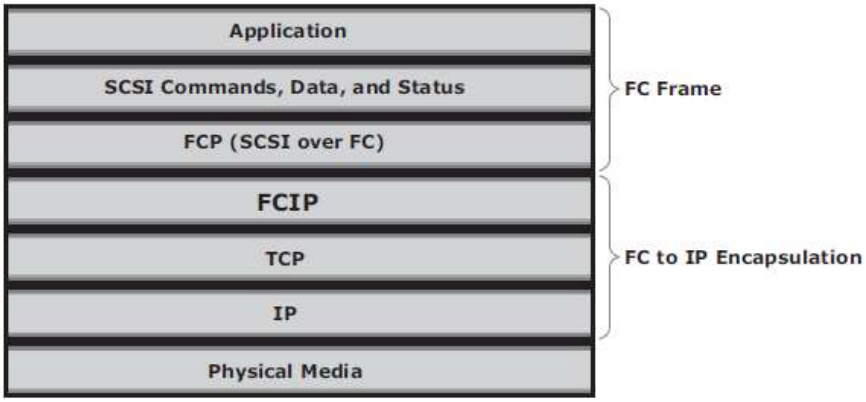


Fig : FCIP protocol stack

- The FCIP layer encapsulates the Fibre Channel frames onto the IP payload and passes them to the TCP layer (see below figure). TCP and IP are used for transporting the encapsulated information across Ethernet, wireless, or other media that support the TCP/IP traffic.
- Encapsulation of FC frame into an IP packet could cause the IP packet to be fragmented when the data link cannot support the maximum transmission unit (MTU) size of an IP packet.
- When an IP packet is fragmented, the required parts of the header must be copied by all fragments.
- When a TCP packet is segmented, normal TCP operations are responsible for receiving and re-sequencing the data prior to passing it on to the FC processing portion of the device.

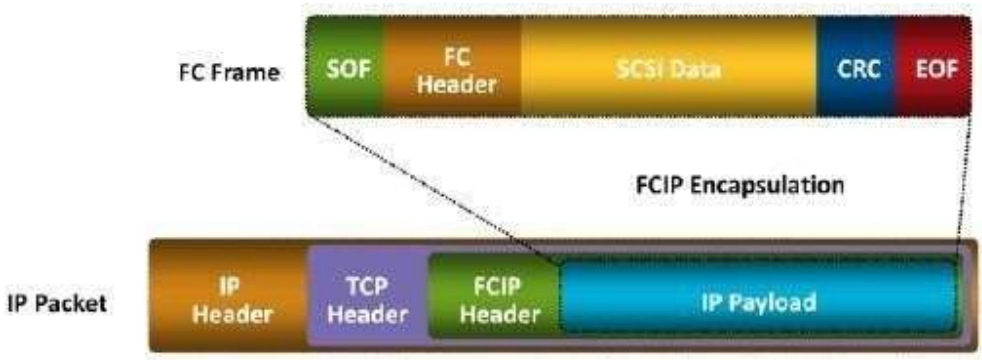


Fig FCIP encapsulation

FCIP Topology

- In an FCIP environment, an FCIP gateway is connected to each fabric via a standard FC connection (Below figure).
- The FCIP gateway at one end of the IP network encapsulates the FC frames into IP packets.
- The gateway at the other end removes the IP wrapper and sends the FC data to the layer 2 fabric.
- The fabric treats these gateways as layer 2 fabric switches.
- An IP address is assigned to the port on the gateway, which is connected to an IP network. After the IP connectivity is established, the nodes in the two independent fabrics can communicate with each other.

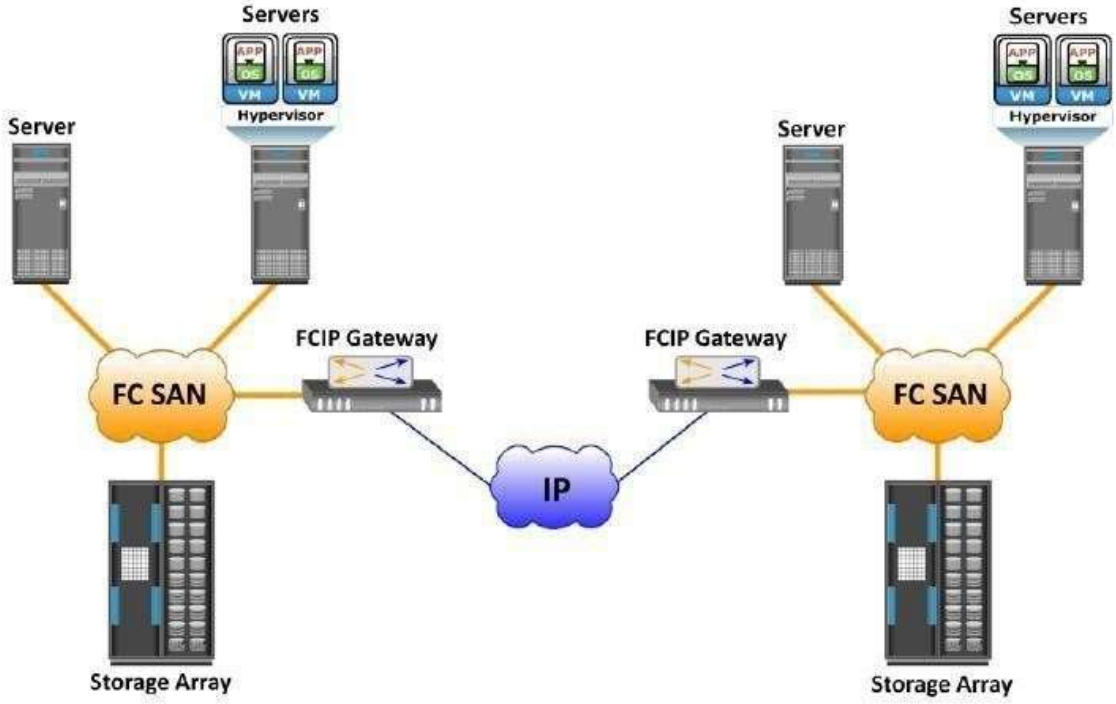


Fig : FCIP topology

NETWORK ATTACHED STORAGE (NAS)

File Sharing Environment

- File sharing enables users to share files with other users
- In file-sharing environment, the creator or owner of a file determines the type of access to be given to other users and controls changes to the file.
- When multiple access a shared file at the same time, a locking scheme is required to maintain data integrity and also make this sharing possible. This is taken care by file-sharing environment.
- Examples of file sharing methods:
    - File Transfer Protocol (FTP)
    - Distributed File System (DFS)
    - Network File System (NFS) and Common Internet File System (CIFS)
    - Peer-to-Peer (P2P)

What is NAS?

- NAS is an IP based dedicated, high-performance file sharing and storage device.
- Enables NAS clients to share files over an IP network.
- Uses network and file-sharing protocols to provide access to the file data.
  Ex: Common Internet File System (CIFS) and Network File System (NFS).
- Enables both UNIX and Microsoft Windows users to share the same data seamlessly.
- NAS device uses its own operating system and integrated hardware and software components to meet specific file-service needs.
- Its operating system is optimized for file I/O which performs better than a general-purpose server.
- A NAS device can serve more clients than general-purpose servers and provide the benefit of server consolidation.

Components of NAS

- NAS device has *two* key components (as shown in below figure): **NAS head** and **storage**.
- In some NAS implementations, the storage could be external to the NAS device and shared with other hosts.
- NAS head includes the following components:

- CPU and memory
- One or more network interface cards (NICs), which provide connectivity to the client network.
- An optimized operating system for managing the NAS functionality. It translates file- level requests into block-storage requests and further converts the data supplied at the block level to file data
- NFS, CIFS, and other protocols for file sharing.
- Industry-standard storage protocols and ports to connect and manage physical disk resources

➢ The NAS environment includes clients accessing a NAS device over an IP network using file-sharing protocols.

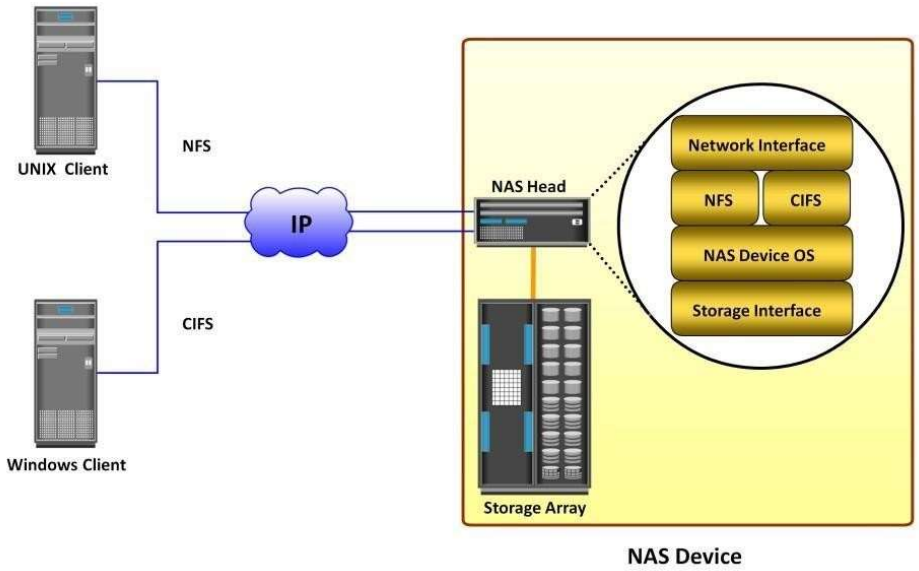


Fig: Components of NAS

NAS I/O Operation

- NAS provides *file-level data access* to its clients. File I/O is a high-level request that specifies the file to be accessed.
- Eg: a client may request a file by specifying its name, location, or other attributes. The NAS operating system keeps track of the location of files on the disk volume and converts client file I/O into block-level I/O to retrieve data.
- The process of handling I/Os in a NAS environment is as follows:
    1. The requestor (client) packages an I/O request into TCP/IP and forwards it through thenetwork stack. The NAS device receives this request from the network.
    2. The NAS device converts the I/O request into an appropriate physical storage request,which is a block-level I/O, and then performs the operation on the physical storage.
    3. When the NAS device receives data from the storage, it processes and repackages thedata into an appropriate file protocol response.
    4. The NAS device packages this response into TCP/IP again and forwards it to the clientthrough the network.
- Below figure illustrates the NAS I/O operation

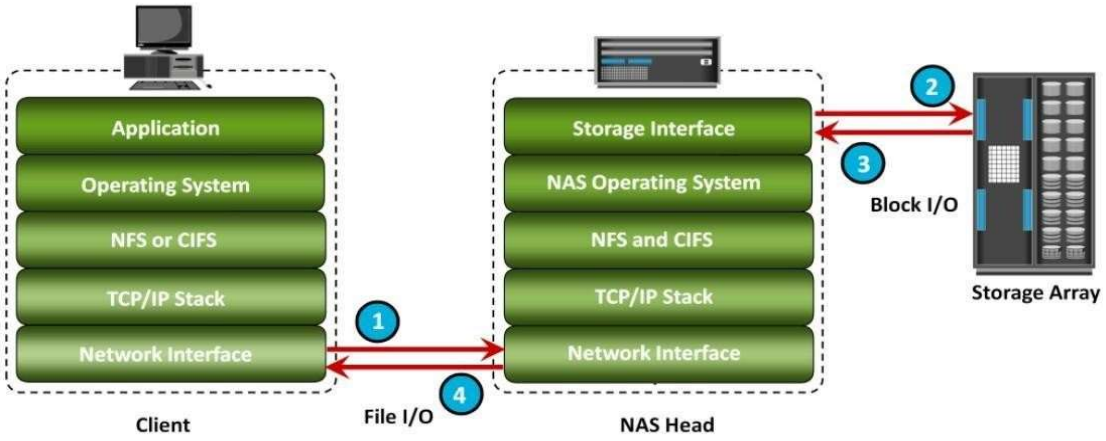


Fig: NAS I/O Operation

NAS Implementations

Three common NAS implementations are unified, gateway, and scale-out. The *unified* NAS consolidates NAS-based and SAN-based data access within a unified storage platform and provides a unified management interface for managing both the environments.

In a *gateway* implementation, the NAS device uses external storage to store and retrieve data, and unlike unified storage, there are separate administrative tasks for the NAS device and storage.

The *scale-out* NAS implementation pools multiple nodes together in a cluster. A node may consist of either the NAS head or storage or both. The cluster performs the NAS operation as a single entity.

Unified NAS

Unified NAS performs file serving and storing of file data, along with providing access to block-level data. It supports both CIFS and NFS protocols for file access and iSCSI and FC protocols for block level access. Due to consolidation of NAS-based and SAN-based access on a single storage platform, unified NAS reduces an organization's infrastructure and management costs.

A unified NAS contains one or more NAS heads and storage in a single system. NAS heads are connected to the storage controllers (SCs), which provide access to the storage. These storage controllers also provide connectivity to iSCSI and FC hosts. The storage may consist of different drive types, such as SAS, ATA, FC, and flash drives, to meet different workload requirements.

Unified NAS Connectivity

Each NAS head in a unified NAS has front-end Ethernet ports, which connect to the IP network. The front-end ports provide connectivity to the clients and service the file I/O requests. Each NAS head has back-end ports, to provide connectivity to the storage controllers.

iSCSI and FC ports on a storage controller enable hosts to access the storage directly or through a storage network at the block level. Figure 7-5 illustrates an example of unified NAS connectivity.

Gateway NAS

A gateway NAS device consists of one or more NAS heads and uses external and independently managed storage. Similar to unified NAS, the storage is shared with other applications that use block-level I/O. Management functions in this type of solution are more complex than those in a unified NAS environment because there are separate administrative tasks for the NAS

head and the storage. A gateway solution can use the FC infrastructure, such as switches and directors for accessing SAN-attached storage arrays or direct attached storage arrays. The gateway NAS is more scalable compared to unified NAS because NAS heads and storage arrays can be independently scaled up when required.

For example, NAS heads can be added to scale up the NAS device performance. When the storage limit is reached, it can scale up, adding capacity on the SAN, independent of NAS heads. Similar to a unified NAS, a gateway NAS also enables high utilization of storage capacity by sharing it with the **SAN environment.**

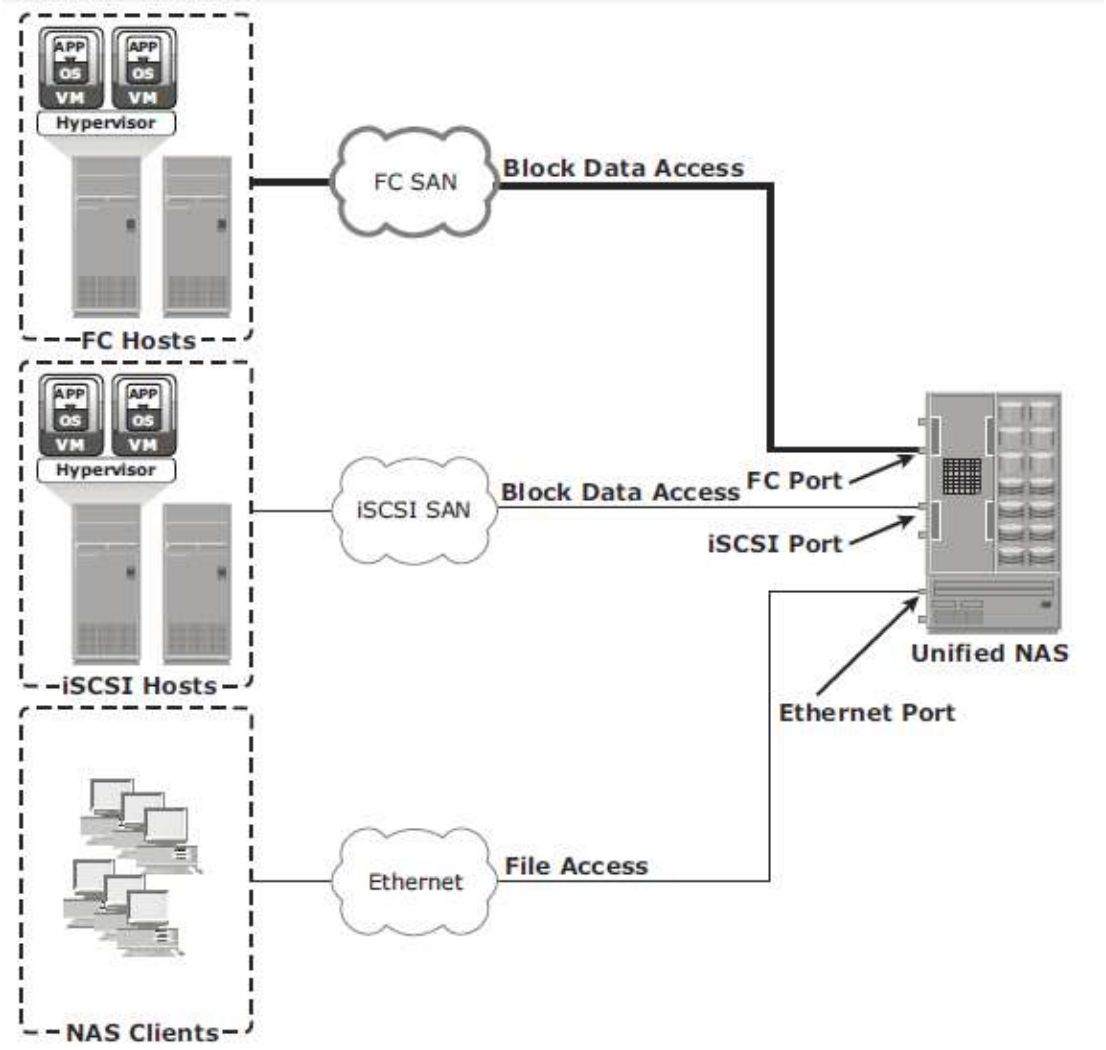


Figure 7-5: Unified NAS connectivity

Gateway NAS Connectivity

In a gateway solution, the front-end connectivity is similar to that in a unified storage solution. Communication between the NAS gateway and the storage system in a gateway solution is achieved through a traditional FC SAN. To deploy a gateway NAS solution, factors, such as multiple paths for data, redundant

fabrics, and load distribution, must be considered. Figure 7-6 illustrates an example of gateway NAS connectivity.

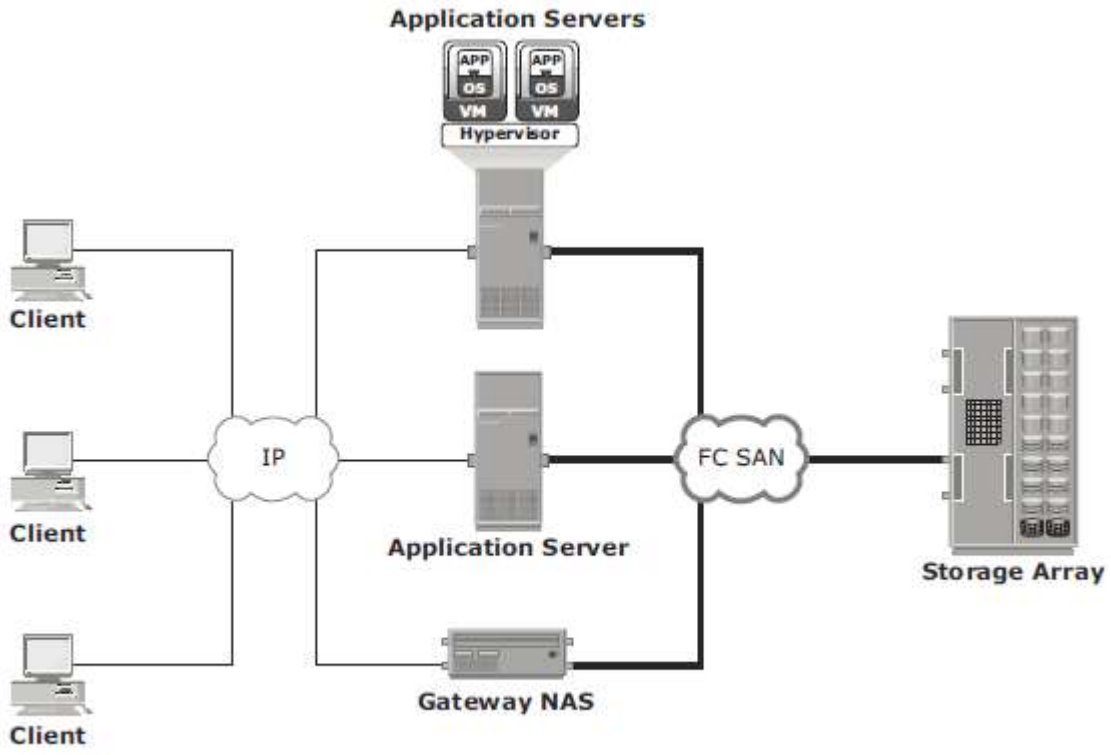


Figure 7-6: Gateway NAS connectivity

Implementation of both unified and gateway solutions requires analysis of the SAN environment. This analysis is required to determine the feasibility of combining the NAS workload with the SAN workload. Analyze the SAN to determine whether the workload is primarily read or write, and if it is random or sequential. Also determine the predominant I/O size in use. Typically, NAS workloads are random with small I/O sizes. Introducing sequential workload with random workloads can be disruptive to the sequential

workload. Therefore, it is recommended to separate the NAS and SAN disks. Also, determine whether the NAS workload performs adequately with the configured cache in the storage system.

Scale-Out NAS

Both unified and gateway NAS implementations provide the capability to scaleup their resources based on data growth and rise in performance requirements. Scaling up these NAS devices involves adding CPUs, memory, and storage to the NAS device. Scalability is limited by the capacity of the NAS device to house

and use additional NAS heads and storage. Scale-out NAS enables grouping multiple nodes together to construct a clustered NAS system. A scale-out NAS provides the capability to scale its resources by simply adding nodes to a clustered NAS architecture. The cluster works as a single NAS device and is managed centrally. Nodes can be added to the cluster, when more performance or more capacity is

needed, without causing any downtime. Scale-out NAS provides the flexibility to use many nodes of moderate performance and availability characteristics to produce a total system that has better aggregate performance and availability. It also provides ease of use, low cost, and theoretically unlimited scalability.

Scale-out NAS creates a single file system that runs on all nodes in the cluster. All information is shared among nodes, so the entire file system is accessible by clients connecting to any node in the cluster. Scale-out NAS stripes data across all nodes in a cluster along with mirror or parity protection. As data is sent from clients to the cluster, the data is divided and allocated to different nodes in parallel. When a client sends a request to read a file, the scale-out NAS retrieves the appropriate blocks from multiple nodes, recombines the blocks into a file, and presents the file to the client. As nodes are added, the file system grows dynamically and data is evenly distributed to every node. Each node added to the cluster increases the aggregate storage, memory, CPU, and network capacity. Hence, cluster performance also increases.

Scale-out NAS is suitable to solve the "Big Data" challenges that enterprises and customers face today. It provides the capability to manage and store large, high-growth data in a single place with the flexibility to meet a broad range of performance requirements.

Scale-Out NAS Connectivity

Scale-out NAS clusters use separate internal and external networks for back-end and front-end connectivity, respectively. An internal network provides connections for intracluster communication, and an external network connection enables clients to access and share file data. Each node in the cluster connects to the internal network. The internal network offers high throughput and low latency and uses high-speed networking technology, such as InfiniBand or Gigabit Ethernet. To enable clients to access a node, the node must be connected to the external Ethernet network. Redundant internal or external networks may be used for high availability. Figure 7-7 illustrates an example of scale-out NAS connectivity

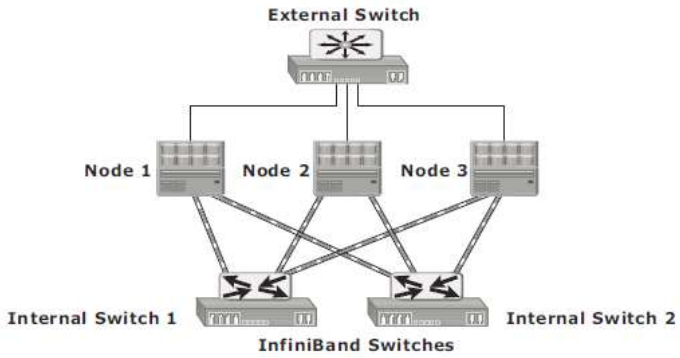


Figure 7-7: Scale-out NAS with dual internal and single external networks

NAS File Sharing Protocols

- NAS devices support multiple file-service protocols to handle file I/O requests
- Two common NAS file sharing protocols are:
    - Common Internet File System (CIFS)
    - Network File System (NFS)
- NAS devices enable users to share file data across different operating environments
- It provides a means for users to migrate transparently from one operating system to another

Network File System (NFS)

- NFS is a **client-server protocol** for file sharing that is commonly used on **UNIX systems**.
- NFS was originally based on the connectionless *User Datagram Protocol (UDP).*
- It uses *Remote Procedure Call (RPC)* as a method of inter-process communication between twocomputers.
- The NFS protocol provides a set of RPCs to access a remote file system for the followingoperations:
    - Searching files and directories
    - Opening, reading, writing to, and closing a file
    - Changing file attributes
    - Modifying file links and directories
- NFS creates a connection between the client and the remote system to transfer data.
- NFSv3 and earlier is a stateless protocol
- It does not maintain any kind of table to store information about open files and associated pointers. Each call provides a full set of arguments - a file handle, a particular position to read or write, and the versions of NFS - to access files on the server .
- Currently, three versions of NFS are in use:
    1. **NFS version 2 (NFSv2):** Uses *UDP* to provide a *stateless* network connection between aclient and a server. Features, such as locking, are handled outside the protocol.
    2. **NFS version 3 (NFSv3):** Uses *UDP or TCP*, and is based on the *stateless protocol*

design. It includes some new features, such as a 64-bit file size, asynchronous writes, andadditional file attributes to reduce refetching.

3. **NFS version 4 (NFSv4):** Uses TCP and is based on a *stateful protocol* design. It offers enhanced security. The latest NFS version 4.1 is the enhancement of NFSv4 and includessome new features, such as session model, parallel NFS (pNFS), and data retention.

Common Internet File System (CIFS)

- CIFS is a *client-server application* protocol
- It enables clients to access files and services on remote computers over **TCP/IP**.
- It is a public, or open, variation of **Server Message Block (SMB)** protocol.
- It provides following features to ensure data integrity:
  - It uses file and record locking to prevent users from overwriting the work of another user on a file or a record.
  - It supports fault tolerance and can automatically restore connections and reopen files that were open prior to an interruption. This feature depends on whether an application is written to take advantage of this.
  - CIFS is a stateful protocol because the CIFS server maintains connection information regarding every connected client. If a network failure or CIFS server failure occurs, the client receives a disconnection notification. User disruption is minimized if the application has the embedded intelligence to restore the connection. However, if the embedded intelligence is missing, the user must take steps to reestablish the CIFS connection.
- Users refer to remote file systems with an easy-to-use file-naming scheme:
- Eg: \\server\share or \\servername.domain.suffix\share

Factors Affecting NAS Performance

NAS uses IP network; therefore, bandwidth and latency issues associated with IP affect NAS performance. Network congestion is one of the most significant sources of latency (Figure 7-8) in a NAS environment. Other factors that affect NAS performance at different levels follow:

1. **Number of hops:** A large number of hops can increase latency because IP processing is required at each hop, adding to the delay caused at the router.

2. **Authentication with a directory service such as Active Directory or NIS:** The authentication service must be available on the network with enough resources to accommodate the authentication load. Otherwise, a large number of authentication requests can increase latency.

3. **Retransmission:** Link errors and buffer overflows can result in retransmission. This causes packets that have not reached the specified destination to be re-sent. Care must be taken to match both speed and duplex settings on the network devices and the NAS heads. Improper configuration might result in errors and retransmission, adding to latency.

4. **Overutilized routers and switches:** The amount of time that an overutilized device in a network takes to respond is always more than the response time of an optimally utilized or underutilized device. Network administrators can view utilization statistics to determine the optimum utilization of switches and routers in a network. Additional devices should be added if the current devices are overutilized.

5. **File system lookup and metadata requests:** NAS clients access files on NAS devices. The processing required to reach the appropriate file or directory can cause delays. Sometimes a delay is caused by deep directory structures and can be resolved by flattening the directory structure. Poor file system layout and an overutilized disk system can also degrade performance.

6. **Over utilized NAS devices:** Clients accessing multiple files can cause high utilization levels on a NAS device, which can be determined by viewing utilization statistics. High memory, CPU, or disk subsystem utilization levels can be caused by a poor file system structure or insufficient resources in a storage subsystem.

7. **Over utilized clients:** The client accessing CIFS or NFS data might also be over utilized. An overutilized client requires a longer time to process the requests and responses. Specifi c performance-monitoring tools are available for various operating systems to help determine the utilization of client resources.

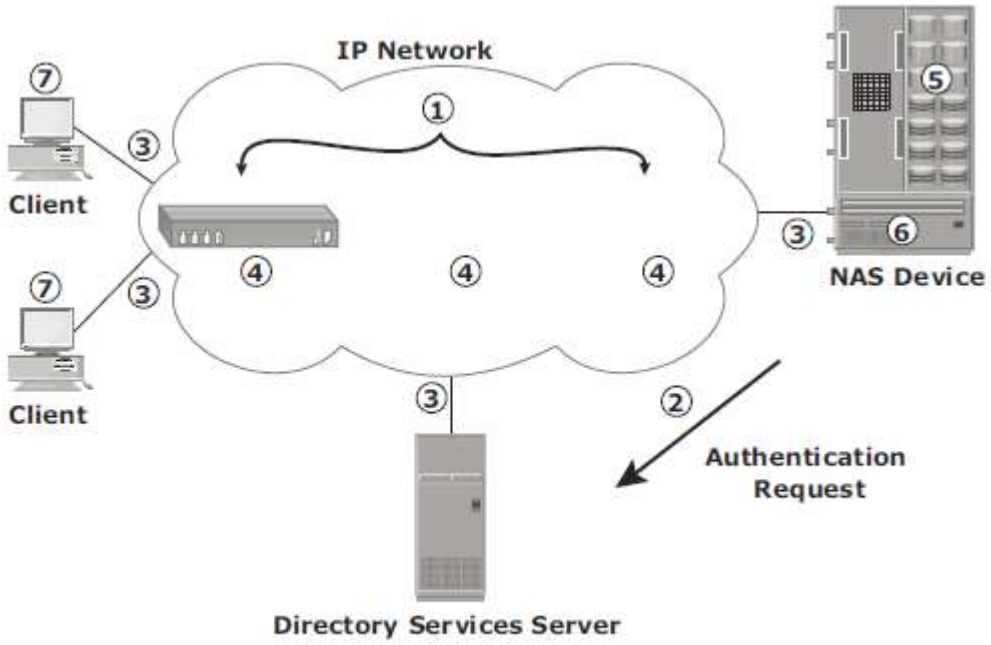


Figure 7-8: Causes of latency

A VLAN is a logical segment of a switched network or logical grouping of end devices connected to different physical networks. An end device could be a client or a NAS device. The segmentation or grouping can be done based on business functions, project teams, or applications. VLAN is a Layer 2 (data link layer) construct and works similar to a physical LAN. A network switch can be logically divided among multiple VLANs, enabling better utilization of the switch and reducing the overall cost of deploying a network infrastructure.

The broadcast traffic on one VLAN is not transmitted outside that VLAN, which substantially reduces the broadcast overhead, makes bandwidth available for applications, and reduces the network's vulnerability to broadcast storms.

VLANs also provide enhanced security by restricting user access, flagging network intrusions, and controlling the size and composition of the broadcast domain. The *MTU* setting determines the size of the largest packet that can be transmitted without data fragmentation. *Path maximum transmission unit discovery* is the process of discovering the maximum size of a packet that can be sent across a network without fragmentation. The default MTU setting for an Ethernet interface card is 1,500 bytes. A feature called *jumbo frames* sends, receives, or transports Ethernet frames with an MTU of more than 1,500 bytes. The most common deployments of jumbo frames have an MTU of 9,000 bytes.

However not all vendors use the same MTU size for jumbo frames. Servers send and receive larger frames more efficiently than smaller ones in heavy network traffic conditions. Jumbo frames ensure increased efficiency because it takes fewer, larger frames to transfer the same amount of data. Larger packets also reduce the amount of raw network bandwidth being consumed for the same amount of payload. Larger frames also help to smooth sudden I/O bursts.

The *TCP window size* is the maximum amount of data that can be sent at any time for a connection. For example, if a pair of hosts is talking over a TCP connection that has a TCP window size of 64 KB, the sender can send only 64 KB of data and must then wait for an acknowledgment from the receiver. If the receiver acknowledges that all the data has been received, then the sender is free to send another 64 KB of data. If the sender receives an acknowledgment from the receiver that only the first 32 KB of data has been received, which can happen only if another 32 KB of data is in transit or was lost, the sender can send only another 32 KB of data because the transmission cannot have more than 64 KB of unacknowledged data outstanding.

In theory, the TCP window size should be set to the product of the available bandwidth of the network and the round-trip time of data sent over the network. For example, if a network has a bandwidth of 100 Mbps and the round-trip time is 5 milliseconds, the TCP window should be as follows:

$$100 \text{ Mb/s} \times .005 \text{ seconds} = 524{,}288 \text{ bits or } 65{,}536 \text{ bytes}$$

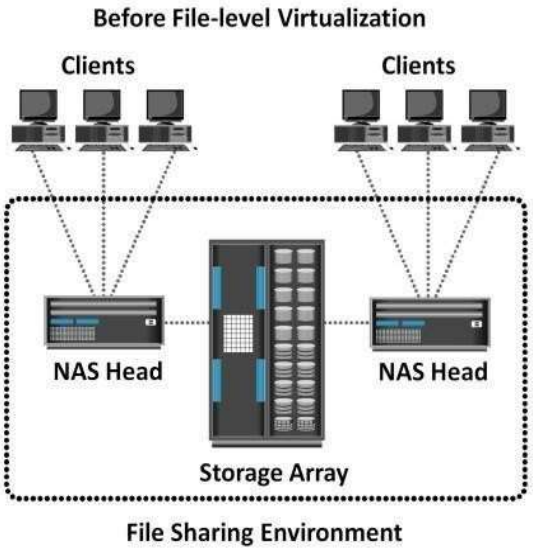
The size of the TCP window field that controls the flow of data is between 2 bytes and 65,535 bytes.

Link aggregation is the process of combining two or more network interfaces into a logical network interface, enabling higher throughput, load sharing or load balancing, transparent path failover, and scalability. Due to link aggregation, multiple active Ethernet connections to the same switch appear as one link. If a connection or a port in the aggregation is lost, then all the network traffic on that link is redistributed across the remaining active connections.

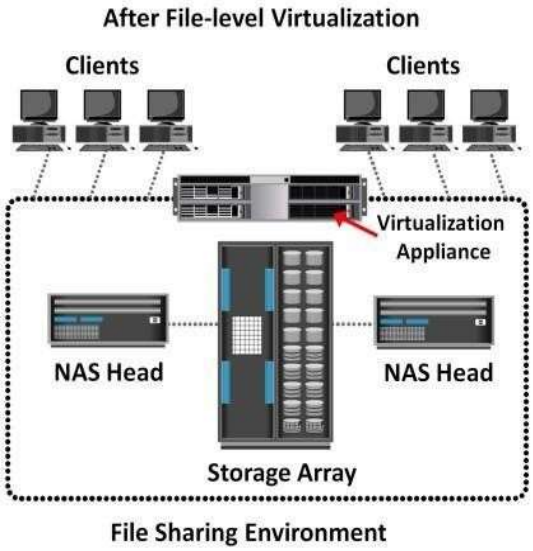
File-level Virtualization

- File-level virtualization, implemented in NAS or the file server environment, provides a simple,non disruptive file-mobility solution.
- It eliminates the dependencies between data accessed at the file level and the location where thefiles are physically stored.
- It creates a logical pool of storage, enabling users to use a logical path, rather than a physicalpath, to access files.
- A global namespace is used to map the logical path of a file to the physical path names. File- level virtualization enables the movement of files across NAS devices, even if the files are being accessed.

Before and After File-level Virtualization



- Dependency between client access and file location
- Underutilized storage resources
- Downtime is caused by data migrations



- Break dependencies between client access and file location
- Storage utilization is optimized
- Non-disruptive migrations

Question Bank

1) Explain with neat diagram, the different topology of iSCSI connectivity.
2) What is iSCSI? Explain iSCSI protocol stack with a neat block diagram
3) What is 'Fibre channel protocol stack'? Explain each of its layers in a diagram showing the functions and protocol.
4) Explain with neat diagram, the components of NAS
5) Discuss the factors that affect NAS performance at different levels.
6) Elaborate different NAS File Sharing ProtocolsExplain FCoE and its components with the help of a neat diagram.
7) Explain the implementation of iSCSI with the help of a neat diagram.
8) Define NAS. Explain the benefits of NAS.
9) Discuss the components of NAS with a neat diagram.
10) Explain NAS implementation in detail.
11) Explain the factors that affect NAS performance.
12) What is NAS? Explain the benefit of NAS.
13) What is iSCSI? Explain iSCSI protocol stack with a neat block diagram
14) List and Explain the benefits of NAS.
15) Explain with neat diagram components of NAS
16) Explain FCIP Topology in detail.
17) With neat diagram, explain iSCSI implementation.
18) Explain with neat diagram iSCSI protocol stack.
19) What is 'Fibre channel protocol stack'.? Explain each of its layers in a diagram showing the functions and protocol.
20) What is significance of IP over the SAN? Explain the same using iSCSI and FCIP as two primary protocols that leverage transport mechanisms.
21) List and Explain the factors that affect NAS performance at different levels?
22) Explain iSCSI Session with diagram.
23) Explain with neat diagram FCIP protocol stack.
24) Explain iSCSI protocol data unit (PDU) encapsulated in an IP packet.
25) Explain with neat diagram iSCSI session, Command sequencing, iSCSI discovery, iSCSI names.
26) What are the factors that affect NAS performance at different levels?
27) What is NAS? Explain the Benefits of NAS. Explain the implementation of NAS.
28) Mention the topology of iSCSI connectivity. Briefly explain them. Mention the diagram of iSCSI protocol stack.
29) Categorize the NAS implementation with brief note on each of them.
30) Write a short note on NAS File sharing protocol.