Chapter 1

1. A hospital uses an application that stores patient X-ray data in the form of large binary objects in an Oracle database. The application is hosted on a UNIX server, and the hospital staff accesses the X-ray records through a Gigabit Ethernet backbone. An EMC CLARiiON storage array provides storage to the UNIX server, which has 6 TB of usable capacity. Explain the core elements of the data center. What are the typical challenges the storage management team may face in meeting the service-level demands of the hospital staff? Describe how the value of this patient data might change over time.

   Solution/Hint:

   Core elements of the data center:
   - Application
   - Database – oracle
   - Server and operating system – UNIX server
   - Network – LAN, SAN
   - Storage array – EMC CLARiiON storage array

   Challenges:
   - Long term preservation
   - High cost

   How patient data might change over time:
   - For first 60 days, the patient data is accessed frequently
   - After that the requirement of the patient data is very less, so it could be moved to CAS.

2. An engineering design department of a large company maintains over 600,000 engineering drawings that its designer's access and reuse in their current projects, modifying or updating them as required. The design team wants instant access to the drawings for its current projects, but is currently constrained by an infrastructure that is not able to scale to meet the response time requirements. The team has classified the drawings as "most frequently accessed," "frequently accessed," "occasionally accessed," and "archive."
   - Suggest and provide the details for a strategy for the design department that optimizes the storage infrastructure by using ILM.
   - Explain how you will use "tiered storage" based on access frequency.
   - Detail the hardware and software components you will need to implement your strategy.
   - Research products and solutions currently available to meet the solution you are proposing.

   Solution/Hint:
   - Classify the data according to access frequency or value and use tiered storage that optimizes the infrastructure cost and performance by using ILM.
   - Storage requirement can be classify as:
     - frequently used data should be placed in high end storage array
     - occasionally accessed should be in low end storage array
     - and archived data in specialized CAS system

- Hardware and software components needed:
  - High end and Mid range storage array
  - Content addressed storage(CAS)
  - FC SAN, LAN
  - Server

  Software:
  - ILM tool

- Research on following products and solutions (www.emc.com)
  - Storage arrays – CLARiiON / Symmetrix
  - CAS – Centera
  - FC SAN – Switches / Directors
  - ILM strategy

3. The marketing department at a mid-size firm is expanding. New hires are being added to the department and they are given network access to the department's files. IT has given marketing a networked drive on the LAN, but it keeps reaching capacity every third week. Current capacity is 500 MB (and growing), with hundreds of files. Users are complaining about LAN response times and capacity. As the IT manager, what could you recommend to improve the situation?
   Solution/Hint:
   - NAS

4. A large company is considering a storage infrastructure—one that is scalable and provides high availability. More importantly, the company also needs performance for its mission-critical applications. Which storage topology would you recommend (SAN, NAS, IP SAN) and why?
   Solution/Hint:
   - SAN is a recommended solution.
   - Because SAN has high scalability and availability (using director or switch).

Chapter 2

1. What are the benefits of using multiple HBAs on a host?
   Solution/Hint:
   - High availability

2. An application specifies a requirement of 200GB to host a database and other files. It also specifies that the storage environment should support 5,000 IOPS during its peak processing cycle. The disks available for configuration provide 66GB of usable capacity, and the manufacturer specifies that they can support a maximum of 140 IOPS. The application is response time sensitive and disk utilization beyond 60 percent will not meet the response time requirements of the application. Compute and explain the theoretical basis for the minimum number of disks that should be configured to meet the requirements of the application.
   Solution/Hint:
   Number of disk required = max (size requirement, IOPS requirements)
   To meet the size requirement = 200 GB/66 GB= 4 disks
   To meet the IOPS requirement= 5000 IOPS/(140×0.6 IOPS)= 60 disks
   = max (4, 60) = 60 disks

3. Which components constitute the disk service time? Which component contributes the largest percentage of the disk service time in a random I/O operation?
   Solution/Hint:
   - seek time, rotational latency and transfer rate
   - seek time

4. Why do formatted disks have less capacity than unformatted disks?
   Solution/Hint:
   - In order to make storage device functional, it need to be formatted. Common types of drive formats are FAT32, NTFS and ext2. In each of the formatting schemes, a portion of the storage space is allocated to configured file system to enable cataloging data on the disk drive.

5. The average I/O size of an application is 64 KB. The following specifications are available from the disk manufacturer: average seek time = 5 ms, 7,200 rpm, transfer rate = 40 MB/s. Determine the maximum IOPS that could be performed with the disk for this application. Taking this case as an example, explain the relationship between disk utilization and IOPS.
   Solution/Hint:

   - The disk service time (R_S) is a key measure of disk performance; and R_S along with disk utilization rate (U) determines the I/O response time for applications.
   - The total disk service time (R_S) is the sum of seek time (E), rotational latency (L), and the internal transfer time (X):

     $$R_S = E+L+X$$

E is determined based on the randomness of the I/O request. L and X are measures provided by disk vendors as technical specifications of the disk.

- Average seek time of 5ms in a random I/O environment, or E=5ms
- Disk rotation speed of 7,200 rpm – from which rotational latency (L) can be determined, which is one half of the time taken for a full rotation or

  L= (0.5/7,200 rpm expressed in ms)
- 40 MB/s internal data transfer rate, from which the internal transfer time (X) is derived based on the block size of the I/O.

  With a block size of 64 KB, X= 64 KB/40 MB

  Consequently R_s = 5 ms + (0.5/7,200) + 64 KB/40 MB

  = 5+4.167+1.6

  = 10.767 ms

  The maximum no. of I/Os serviced per second or IOPS = $1/R_s$

  In other words, for an I/O with a block size of 64 KB and R_s = 10.767 ms, the maximum IOPS will be

  $1/(10.767*10^{-3})$ = 92.876 IOPS

6. Consider a disk I/O system in which an I/O request arrives at the rate of 80 IOPS. The disk service time is 6 ms.

   a. Compute the following: Utilization of I/O controller, Total response time, Average queue size, and Total time spent by a request in a queue.

   b. Compute the preceding parameter if the service time is halved.

   Solution/Hint:

   Arrival rate (a) = 80 IOPS, consequently, the arrival time

   Ra = 1/a = 1/80 = 12.5 ms

   Rs = 6 ms (given)

   1. Utilization (U) = Rs/Ra

      = 6/12.5 = 0.48 or 48%
   2. Response time (R) = Rs/(1-U)

      = 6/(1-0.48) = 11.5 ms
   3. Average queue size = $U^2/(1-U)$

      = $(0.48)^2/(1-0.48)$

      = 0.44
   4. Time spent by a request in a queue = UxR, or the total response time-service time = 0.48x11.5 = 5.52 ms

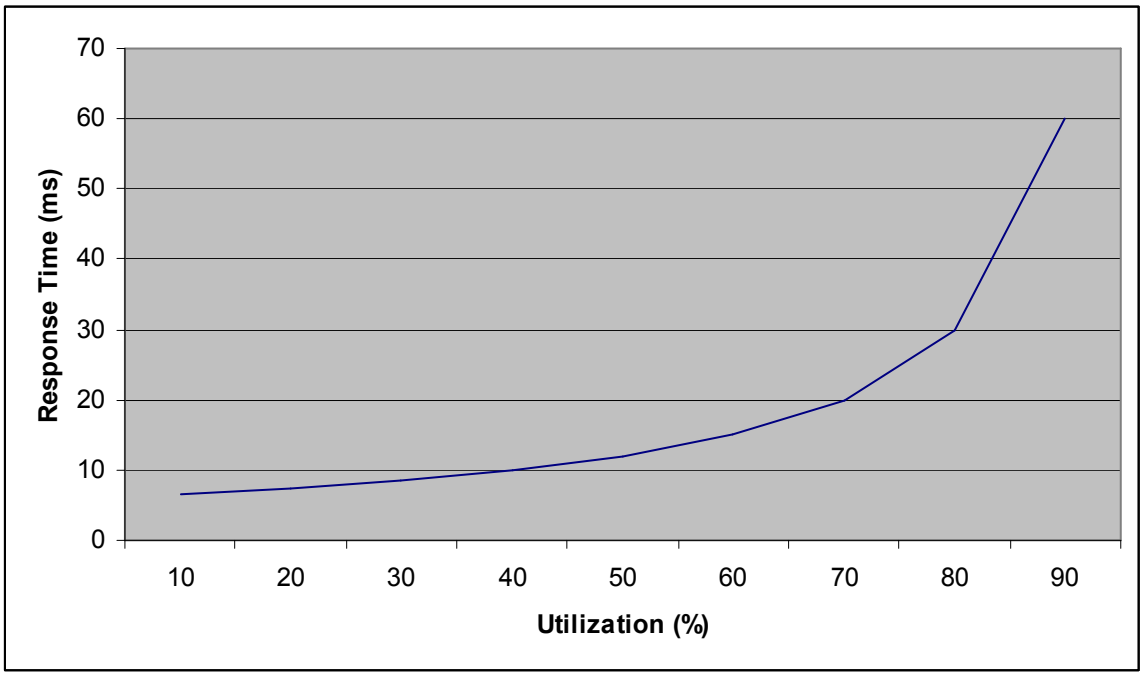
   Now, if controller power is doubled, or the service time is halved; consequently Rs = 3 ms in this scenario.

   1. Utilization (U) = Rs/Ra = 3/12.5 = 0.24 or 24 %
   2. Response time (R) = Rs/(1-U) = 3/(1-0.24) = 3.9 ms
   3. Average queue size = $U^2/(1-U)$ = $(0.24)^2/(1-0.24)$ = 0.08
   4. Time spent by a request in a queue = 0.24x3.9 = 0.936 ms

7. Refer to Question 6 and plot a graph showing the response time and utilization, considering 20 percent, 40 percent, 60 percent, 80 percent, and 100 percent utilization of the I/O controller. Describe the conclusion that could be derived from the graph.

Solution/Hint:

1. Utilization = 20 % = 0.2
   Response time = 7.5 ms
2. Utilization = 40 % = 0.4
   Response time = 10 ms
3. Utilization = 60 % = 0.6
   Response time = 15 ms
4. Utilization = 80 % = 0.8
   Response time = 30 ms
5. utilization = 100 % = 1
   Response time = infinity



Chapter 3

1. Why is RAID 1 not a substitute for a backup?
   Solution/Hint:
   - RAID 1 provides protection against disk failure and not a solution for data recovery due to disaster.

2. Why is RAID 0 not an option for data protection and high availability?
   Solution/Hint:
   - It does not provide any data protection.

3. Explain the process of data recovery in case of a drive failure in RAID 5.
   Solution/Hint:
   - It performs XOR operation between remaining disks and regenerate lost data.

4. What are the benefits of using RAID 3 in a backup application?
   Solution/Hint:
   - Backup application performs large sequential I/Os and RAID 3 gives best result in case of large sequential I/O operation.
5. Discuss the impact of random and sequential I/O in different RAID configurations.
   Solution/Hint:

RAID	Random	Sequential
3	Good for random reads and poor to fair for small random writes.	very good for sequential reads and good for large, sequential writes.
5	Very good for random reads. Fair for random write. Slower due to parity overhead.	Good for sequential reads. Fair to good for sequential writes.
1/0	Very good for random write.	Poor to fair for sequential writes

6. A 10K rpm drive is rated to perform 130 IOPS, and a 15K rpm drive is rated to perform 180 IOPS for an application. The read/write ratio is 3:1. Compute the RAID-adjusted IOPS for the 10K and 15K drives for RAID 1, RAID 5, and RAID 6.
   Solution/Hint: **Question Invalid**

7. An application has 1,000 heavy users at a peak of 2 IOPS each and 2,000 typical users at a peak of 1 IOPS each, with a read/write ratio of 2:1. It is estimated that the application also experiences an overhead of 20 percent for other workloads. Calculate the IOPS requirement for RAID 1, RAID 3, RAID 5, and RAID 6.

   Solution/Hint:

1000 heavy users at a peak of 2 IOPS each = 2000 IOPS
2000 typical users at a peak of 1 IOPS each = 2000 IOPS

Assume maximum concurrency 90%
[(2000 + 2000)*0.9] = 3600 host based IOPS for 3000 users during peak activity period

read / write ratio 2:1

For RAID 1 = 3600*2/3 + (2*1/3*3600) = 4800 IOPS
For RAID 3 = 3600*2/3 + (4*1/3*3600) = 7200 IOPS
For RAID 5 = 3600*2/3 + (4*1/3*3600) = 7200 IOPS
For RAID 6 = 3600*2/3 + (6*1/3*3600) = 9600 IOPS

8. For Question 7, compute the number of drives required to support the application in different RAID environments if 10K rpm drives with a rating of 130 IOPS per drive were used.

Solution/Hint:
Number of drives required to support the application in different RAID environments, if 10k rpm drives with a rating of 130 IOPS per drive

For RAID 1 = 4800/130 = 37 drives
For RAID 3 = 7200/130 = 55 drives
For RAID 5 = 7200/130 = 55 drives
For RAID 6 = 9600/130 = 74 drives

Chapter 4

1. Consider a scenario in which an I/O request from track 1 is followed by an I/O request from track 2 on a sector that is 180 degrees away from the first request. A third request is from a sector on track 3, which is adjacent to the sector on which the first request is made. Discuss the advantages and disadvantages of using the command queuing algorithm in this scenario.

   Solution/Hint:
   - In this scenario, command queuing provide rotational latency optimization where request from track 3 is serviced before request 2 to avoid one rotation timing. Assume if request 3 is from the same track 1 in that case command queuing provides seek time optimization and improves disk performance.

2. Which application benefits the most by bypassing the write cache and Why?

   Solution/Hint:
   - Application with very large size I/O writes.

3. An Oracle database uses a block size of 4 K for its I/O operation. The application that uses this database primarily performs a sequential read operation. Suggest and explain the appropriate values for the following cache parameters: cache page size, cache allocation (read versus write), pre-fetch type, and write aside cache.

   Solution/Hint:

Cache page size	: 4 K
Cache allocation (read versus write)	: more read cache
pre-fetch type	: fixed pre-fetch
Write aside cache	: Large value

Chapter 5

1. DAS provides an economically viable alternative to other storage networking solutions. Justify this statement.

Solution/Hint:

- Setup requires a relatively lower initial investment
- Setup is managed using host-based tools, such as the host OS, which makes storage management tasks easy for small and medium enterprises.
- Requires fewer management tasks, and less hardware and software elements to set up and operate.

2. How is the priority sequence established in a wide SCSI environment?

Solution/Hint:

- In a wide SCSI, the device IDs from 8 to 15 have the highest priority, but the entire sequence of wide SCSI IDs has lower priority than narrow SCSI IDs.
- Therefore, the overall priority sequence for a wide SCSI is 7, 6, 5, 4, 3, 2, 1, 0, 15, 14, 13, 12, 11, 10, 9, and 8.

3. Why is SCSI performance superior to that of IDE/ATA? Explain the reasons from an architectural perspective.

Solution/Hint:

- SCSI offers improved performance and expandability and compatibility options, making it suitable for high-end computers.
- Number of devices supported is 16
- SCSI architecture derives its base from the client-server relationship
- SCSI initiator, or a client, sends a request to a SCSI target, or a server.
- The target performs the tasks requested and sends the output to the initiator
- When a device is initialized, SCSI allows for automatic assignment of device IDs on the bus, which prevents two or more devices using the same SCSI IDs.

4. Research blade server architecture and discuss the limitations of DAS for this architecture.

Solution/Hint: – DAS Limitations

- DAS does not scale well, has a limited number of ports
- A limited bandwidth in DAS restricts the available I/O processing capability.
- The distance limitations associated with DAS
- Inability to share the resources, unused resources cannot be easily re-allocated, resulting in islands of over-utilized and under-utilized storage pools.

5. What would you consider while choosing serial or parallel data transfer in a DAS implementation? Explain your answer and justify your choice.

Solution/Hint:

- Distance and speed are the key factors
- Serial data transfer can overcome the distance limitations
- Parallel data transfer can overcome the seed limitations
- Parallel data transfer is suitable for Internal DAS
- Serial data transfer is suitable for External DAS

6. If three hard disk drives are connected in a daisy chain and communicate over SCSI, explain how the CPU will perform I/O operations with a particular device.

Solution/Hint:

- Each disk will be identified by cn|tn|dn number
- As the three disks are connected in a daisy chain cn and tn number will be the same for all the disks
- SCSI commands/response will be used for the communication

Chapter 6

1. What is zoning? Discuss a scenario,
   (i) where soft zoning is preferred over hard zoning.
   (ii) where hard zoning is preferred over soft zoning.

Solution/Hint:

Zoning is an FC switch function that enables nodes within the fabric to be logically segmented into groups that can communicate with each other. A zone consists of selected devices, such as host bus adapters (HBAs) and storage devices, in the fabric. Devices assigned to one zone can communicate with other devices in the same zone, but not with devices in zones of which they are not members. This zoning practice provides a fast, efficient, and reliable means of controlling the HBA discovery/login process. Without zoning, the HBA will attempt to log in to all ports on the fabric during discovery and during the HBA's response to a state change notification. With zoning, the time and Fibre Channel bandwidth required to process discovery and the state change notification are minimized.

(i) Soft zoning is also called WWN zoning and it is preferred when user need flexibility to physically move attached nodes between switch portsre cable the SAN, that may take place during switch maintenance and repair without reconfiguring the zone information. This is possible because the WWN is static to the node port.

(ii) Hard zoning is also called port zoning, it is convenient when there is a need for hardware replacement as WWN is uniquely associated with a hardware.

2. Describe the process of assigning FC address to a node when logging in to the network for the first time.

Solution/Hint::

To log on to the fabric, a node sends a FLOGI frame with the World Wide Node Name (WWNN) and World Wide Port Name (WWPN) parameters to the login service at the well-known FC address FFFFFE. In turn, the switch accepts the login and returns an Accept (ACC) frame with the assigned FC address for the device. Immediately after the FLOGI, the N_port registers itself with the local name server on the switch, indicating its WWNN, WWPN, and assigned FC address.

3. Seventeen switches, with 16 ports each, are connected in a mesh topology. How many ports are available for host and storage connectivity if you create a high-availability solution?

Solution/Hint:

- Total ports = 17 * 16 = 272
- Number of ISL 136
- Each ISL consumes 2 ports
- 0 number of ports available for hosts

4. Discuss the advantage of FC-SW over FC-AL.

Solution/Hint::

Unlike a loop configuration, a Fibre Channel switched fabric (FC-SW) network provides interconnected devices, dedicated bandwidth, and scalability. The addition or removal of a device in a switched fabric is minimally disruptive; it does not affect the ongoing traffic between other devices (as compared to FC-AL). In FC-SW, nodes do not share a loop; instead, data is transferred through a dedicated path between the nodes. FC uses 24-bit fibre channel addressing scheme for connectivity which can support up to 15 million devices (FC-AL uses 8-bit addressing which can support up to 127 devices on a loop)

5. How flow control works in FC network.

Solution/Hint::

Flow control is used to define and regulate the pace of flow of data frames between sender and receiver during data transmission. FC technology uses two flow-control mechanisms: buffer-to-buffer credit (BB_Credit) and end-to-end credit (EE_Credit).

BB_Credit: The process is as follows

1. At login, the transmitter and the receiver exchange parameters and establish the BB_Credit value.
2. The transmitter's count initializes to the BB_Credit value.
3. If (BB_Credit > 0), transmitter sends a frame, and decrements the count per transmitted frame.
4. An R_RDY (Receiver Ready) is sent from the receiving port to the transmitting port for every available buffer on the receiving side.
5. The transmitter increments the count by 1 for each R_RDY it receives from the receiver. The transmitting port maintains a count of free receiver buffers.
5. Upon a link reset, the BB_Credit value resets to the value negotiated upon login.

EE_Credit

The function of end-to-end credit, known as EE_Credit, is similar to that of BB_Credit.(The EE_Credit mechanism is used for the flow control for class 1 and class 2 traffic only).

6. Why is class 3 service most preferred for FC communication?

Solution/Hint:

- Non-dedicated connection
- BB_credit
- High bandwidth utilization
- Support for multiplexing

Chapter 7

1. List and explain the considerations for capacity design for both CPU and storage in a NAS environment.

Solution/Hint:

- The scalability of capacity can be a constraint in an integrated NAS. However, the gateway NAS can scale for the required connectivity and storage.
- Gateway NAS shares CPU load with SAN workload and may face constraint on CPU utilization. Typically, CPU capacity is not the major bottleneck factor in a NAS system, but other considerations such as memory requirement, number of network ports, file system, IOPS requirements, along with storage capacity requirements are important factor.

2. SAN is configured for backup to a disk environment, and the storage configuration has additional capacity available. Can you have a NAS gateway configuration use this SAN? Discuss the implications of sharing the backup-to-disk SAN environment with NAS.

Solution/Hint:

- As the additional capacity is available gateway NAS can be implemented.
- But during the backup window it will have considerable performance impact on Network and hence NAS.

3. Explain how the performance of NAS can be affected if the TCP window size at the sender and the receiver are not synchronized.

Solution/Hint:

- This will affect the NAS performance as this may lead to re-transmission of data, lower bandwidth utilization, performance degradation of the network, intermittent connectivity, and data link errors.

4. Research the use of baby jumbo frames and how it affects NAS performance.

Solution/Hint:

- Common Ethernet Jumbo frame size is 9000 Bytes
- Baby jumbo frames size is 2.5KB Bytes

5. Research the file sharing features of the NFS protocol.

Hint: Research question (refer to NFS protocol section in the book)

6. A NAS implementation configured jumbo frames on the NAS head, with 9,000 as its MTU. However, the implementers did not see any performance improvement and actually experienced performance degradation. What could be the cause? Research the end-to-end jumbo frame support requirements in a network.

Solution/Hint:

- Jumbo frames are used at the end point (NAS Head) with MTU of 9000
- Check if the intermediate network uses a different MTU size (e.g. 1500).
- This can cause the router to drop packets which then have to re-transmit at the TCP layer.

- Packets are then fragmented and have to reassemble to accommodate the different MTU sizes. This degrades network performance.

7. Acme Corporation is trying to decide between an integrated or a gateway NAS solution. The existing SAN at Acme will provide capacity and scalability. The IT department is considering a NAS solution for the Training department at Acme for training videos. The videos would only be used by the training department for evaluation of instructors. Pick a NAS solution and explain the reasons for your choice.

Solution/Hint:

- Existing SAN; so the choice will be gateway NAS
- Check if SAN has additional capacity available.

Chapter 8

1. How does iSCSI handle the process of authentication? Research the available options.

Solution/Hint::

- CHAP (Challenge handshake authentication protocol)

2. List some of the data storage applications that could benefit from an IP SAN solution.

Solution/Hint:

- Extending reach of existing SAN
- Disaster recovery solutions
- Remote office applications

3. What are the major performance considerations for FCIP?

Solution/Hint:

- Refer section 8.2.2 FCIP Performance and security

4. Research the multipathing software available for an iSCSI environment. Write a technical note on the features and functionality of EMC PowerPath support for iSCSI.

Hint: Research work

5. Research the iSCSI capabilities in a NAS device; provide use case examples.

Hint: Research work

6. A company is considering implementing storage. They do not have a current storage infrastructure to use, but they have a network that gives them good performance. Discuss whether native or bridged iSCSI should be used and explain your recommendation.

Solution/Hint:

- Native iSCSI implementation doesn't involve any FC components while Bridged iSCSI implementation involves FC components
- As the company doesn't have storage infrastructure and the network they have gives them a good performance native iSCSI should be deployed.
- iSCSI enabled Storage is only needed if native iSCSI is to be implemented in this case.

7. The IP bandwidth provided for FCIP connectivity seems to be constrained. Discuss its implications if the SANs that are merged are fairly large, with 500 ports on each side, and the SANs at both ends are constantly reconfigured.

Solution/Hint:

- As bandwidth is insufficient IP network will become the bottleneck
- As the fabrics on both sides are fairly large and are constantly reconfigured any disruption in the IP network will lead to instabilities in unified fabric.
    - These include a segmented fabric, excessive RSCNs, and host timeouts.

- The solution can be to segregate FCIP traffic into a separate virtual fabric, to provide additional stability,

8. Compared to a standard IP frame, what percentage of reduction can be realized in protocol overhead in an iSCSI configured to use jumbo frames with an MTU value of 9,000?

Solution/Hint:

- iSCSI PDU size =1460 bytes (contain payload and additional header segment)
- Jumbo frame size of 9000MTU out of which payload is 8960
- Jumbo Frames allows a significant amount of increased payload to be delivered in each iSCSI PDU.

9. Why should an MTU value of at least 2,500 be configured in a bridged iSCSI environment?

Solution/Hint:

FC supports frame size of 2148 byte

Chapter 9

1. Explain how a CAS solution fits into the ILM strategy.

   Solution/Hint:
   According to ILM strategy value of information changes over its lifecycle, when created value of information is very high and it is frequently accessed and changed, hence placed in a high performance costly storage. With the time its value drops and it becomes fixed content which is rarely accessed, but still holds place in costly storage space. For the cost optimization less accessed data should be moved to archived and leave the costly space for high value data. CAS is a solution for archived data, which not only provide cost benefit but also provide faster access and reliable storage to fixed content.

2. To access data in a SAN, a host uses a physical address known as a logical block address (LBA). A host using a CAS device does not use (or need) a physical address. Why?

   Solution/Hint:
   Unlike file-level and block-level data access that use file names and the physical location of data for storage and retrieval, CAS stores data and its attributes as an object. The stored object is assigned a globally unique address known as a content address which is derived from the actual binary representation of stored data.

3. The IT department of a departmental store uses tape to archive data. Explain 4–5 major points you could provide to persuade the IT department to move to a CAS solution. How would your suggestions impact the IT department?

   Solution/Hint:
   Guaranteed Content Authenticity and Integrity: Data can not be manipulated once stored, meet regulatory and business compliance.
   Single Instance Storage: Simplifies storage resource management, especially when handling large amount of fixed content.
   Faster Data Retrieval: Compared to tape
   Technology independence: As long as the application server is able to map the original content address the data remains accessible.
   Better data protection and disposition: All fixed content is stored in CAS once and is backed up with a protection scheme.

Chapter 10

1. What do VLANs virtualize? Discuss VLAN implementation as a virtualization technology.

Solution/Hint:

VLAN stand for virtual LAN which has same attributes as of physical LAN, but allows hosts to be grouped together even if they are not located on the same network switch. With the use of network reconfiguration software, ports on the layer 2 switch can be logically grouped together, forming a separate, Virtual Local Area Network. VLANs help to simplify network administration. Ports in a VLAN can be limited to only the number needed for a particular network. This allows unused ports to be used in other VLANs. Through software commands, additional ports can be added to an existing VLAN if further expansion is needed. If a machine needs to be moved to a different IP network, the port is reassigned to a different VLAN and there is no need for the physical movement of cables.

3. How can a block-level virtualization implementation be used as a data migration tool? Explain how data migration will be accomplished and discuss the advantages of using this method for storage. Compare this method to traditional migration methods.

Solution/Hint:

Conventionally data migration needs physical remapping of servers to new storage location which resulted in application downtime and physical changes. In a virtualized environment virtual volumes are assigned to the host out of physical pool of storage capacity. Data migration is achieved through these virtual volumes. To move a virtual volume, virtualization software performs a redirection of I/O from one physical location to another. Despite the fact that the I/O is physically redirected to a new location by the virtualization software, the address of the virtual volume presented to the host never changes. This is accomplished through virtual addressing. This allows the process to be transparent and non disruptive to the host. Additionally, since the copying and remapping is done by the virtualization system, no host cycle are required, freeing servers to be dedicated to their proper application centric function.

Chapter 11

1. A network router has a failure rate of 0.02 percent per 1,000 hours. What is the MTBF of that component?

   Solution/Hint:

   MTBF of network router = 1/Failure rate
   = 100*1000/0.02
   = 50, 00,000 hrs

2. The IT department of a bank promises customer access to the bank rate table between 9:00 a.m. and 4:00 p.m. from Monday to Friday. It updates the table every day at 8:00 a.m. with a feed from the mainframe system. The update process takes 35 minutes to complete. On Thursday, due to a database corruption, the rate table could not be updated, and at 9:05 a.m., it was established that the table had errors. A rerun of the update was done, and the table was recreated at 9:45 a.m. Verification was run for 15 minutes, and the rate table became available to the bank branches. What was the availability of the rate table for the week in which this incident took place, assuming there were no other issues?

   Solution/Hint:

   Availability = total uptime/total scheduled time
   Total scheduled time = 7 hrs * 5 = 35 hrs
   Total up time = 34 hrs (as on Thursday rate table was made available at 10:00 am instead of 9:00 am)
   Therefore, availability of the rate table for the week = 34/35

3. "Availability is expressed in terms of 9s." Explain the relevance of the use of 9s for availability, using examples.

   Solution/Hint:

   Uptime per year is based on the exact timeliness requirements of the service, this calculation leads to the number of "9s" representation for availability metrics.
   For example, a service that is said to be "five 9s available" is available for 99.999 percent of the scheduled time in a year (24× 7 × 365).

Uptime (%)	Downtime (%)	Downtime per Year	Downtime per Week
99.999	0.001	5.25 minutes	6 sec

4. Provide examples of planned and unplanned downtime in the context of data center operations.

   Solution/Hint:

   - Examples of planned downtime: installation /integration /maintenance of new hardware, software upgrades or patches, taking backups, application

and data restores, facility operations (renovation and construction), refresh/migration of testing environment to the production data
- Examples of unplanned downtime: failure caused by database corruption, component failure, human errors

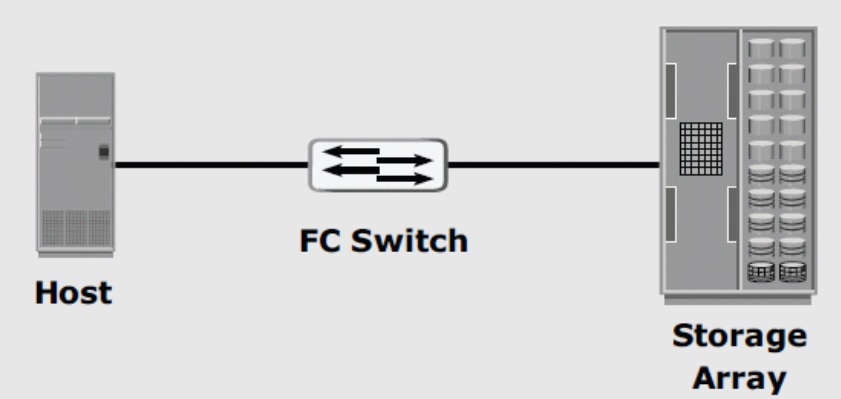
5. How does clustering help to minimize RTO?

Solution/Hint:
- **RTO of 1 hour:** Cluster production servers with controller-based disk mirroring.
- **RTO of a few seconds:** Cluster production servers with bidirectional mirroring, enabling the applications to run at both sites simultaneously.

6. How is the choice of a recovery site strategy (cold and hot) determined in relation to RTO and RPO?

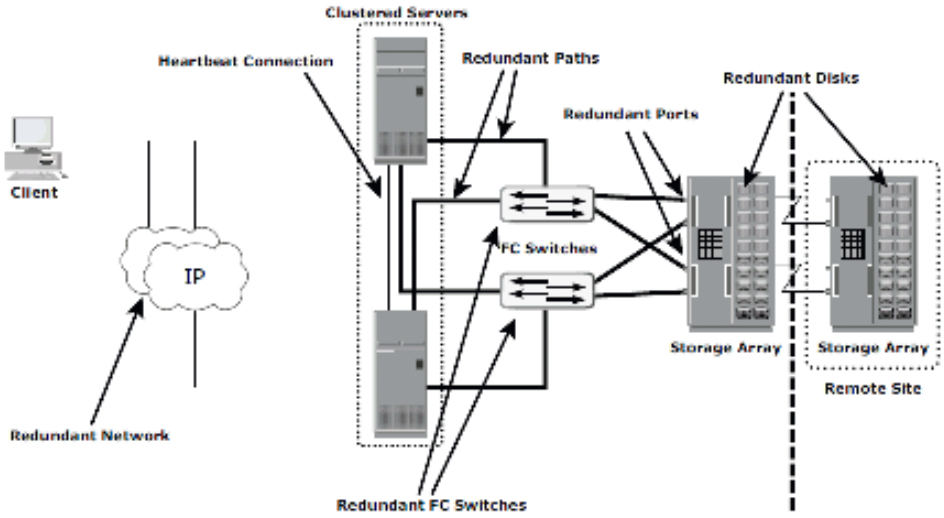
Solution/Hint:
- RTO and RPO – small – hot site
- RTO and RPO – large – cold site

7. Assume the storage configuration design shown in the following figure:



Perform the single point of failure analysis for this configuration and provide an alternate configuration that eliminates all single points of failure.

Solution/Hint:
- Single point of failure: host, switch, storage array, HBA, array port and path
- Alternate configuration as shown below to avoid SPF


Clustered Servers
Heartbeat Connection
Redundant Paths
Redundant Disks
Redundant Ports
Client
FC Switches
IP
Storage Array
Storage Array
Remote Site
Redundant Network
Redundant FC Switches

Chapter 12

1. A manufacturing corporation uses tape as its primary backup storage media throughout the organization:
   - Full backups are performed every Sunday.
   - Incremental backups are performed Monday through Saturday.
   - The environment contains many backup servers, backing up different groups of servers.
   - The e-mail and database applications have to be shut down during the backup process.

   Due to the decentralized backup environment, recover-ability is often compromised. There are too many tapes that need to be mounted to perform a full recover in case of a complete failure. The time needed to recover is too lengthy. The company would like to deploy an easy-to-manage backup environment. They want to reduce the amount of time the e-mail and database applications are unavailable, and reduce the number of tapes required to fully recover a server in case of failure.
   Propose a backup and recovery solution to address the company's needs. Justify how your solution ensures that their requirements will be met.

   Solution/Hint:
   The solution should have the following elements:
   - Centralized backup server
   - Backup agents to avoid the requirement for critical applications to be shutdown during the backup process.
   - Use of a cumulative backup policy instead of incremental backups, reducing the amount of tape required for a full restore.

2. There are limited backup devices in a file sharing NAS environment. Suggest a suitable backup implementation that will minimize the network traffic, avoid any congestion, and at the same time not impact the production operations. Justify your answer.

   Solution/Hint:
   This is achieved by the introduction of NDMP, to promote data transport between NAS and backup devices. Due to its flexibility it is no longer necessary to transport the data through the backup server. Data is sent from the filer directly to the backup device, while metadata is sent to the backup server for tracking purposes. This solution meets the strategic need to centrally manage and control distributed data, while minimizing network traffic. NDMP 3-way is useful when there are limited backup devices in the environment, enabling the NAS device controlling the backup device to share it with other NAS devices, by receiving backup data via NDMP.

3. Discuss the security concerns in backup environment.

Solution/Hint:
Major security concern in backup environment is spoofing backup server, backup client or backup node identity by unauthorized host, to gain access to backup data. Another concern is backup tape being lost, stolen, or misplaced, especially if the tapes contain highly confidential information. Backup-to-tape applications are also vulnerable to security implications if they do not encrypt data while backing up. Lastly backup data shredding should also consider, by performing safe tape data erasure or overwriting if they no longer required.

4. What are the various business/technical considerations for implementing a backup solution, and how do these considerations impact the backup solution/ implementation?

Solution/Hint:
- → RTO and RPO are the primary considerations in selecting and implementing a
- → specific backup strategy.
- → Retention period
- → Backup media type
- → Backup granularity
- → Time for performing backup and available backup window
- → Location and time of the restore operation
- → file characteristics (location, size, and number of files) and data compression

5. What is the purpose of performing operation backup, disaster recovery, and archiving?

Solution/Hint:
Operation backup: To restore data in the event of data loss or logical corruptions
Disaster recovery: For restoring data at an alternate site when the primary site is incapacitated due to a disaster.
Archiving: For long term data retention (regulatory compliance or business requirement)

6. List and explain the considerations in using tape as the backup technology. What are the challenges in this environment?

Solution/Hint:
Advantages:
- Offsite data copy
- Lower initial cost

Challenges:
- Reliability
- Restore performance (mount, load to ready, rewind, dismount times)
- Sequential Access
- HVAC controlled environment
- Shipping / handling challenges

7. Describe the benefits of using "virtual tape library" over "physical tapes."

Features	Tape	Virtual Tape
Offsite Capabilities	Yes	Yes
Reliability	No inherent protection methods	RAID, spare
Performance	Subject to mechanical operations, load times	Faster single stream
Use	Backup only	Backup only

Chapter 13

1. What is the importance of recoverability and consistency in local replication?

Solution/Hint:

- Recoverability enables restoration of data from the replicas to the production volumes in the event of data loss or data corruption.
- Recoverability must provide minimal RPO and RTO for resuming business operations on the production volumes.
- Consistency ensures the restart ability from data. Business operation can not resume from inconsistent data.

2. Describe the uses of a local replica in various business operations.

Solution/Hint:

- Alternate source for backup
- Fast recovery
- Decision support activities such as reporting
- Testing platform
- Data migration

3. What are the considerations for performing backup from a local replica?

Solution/Hint:

- The replica should be consistent PIT copy of the source
- Replica should not be updated when the backup window is open

4. What is the difference between a restore operation and a resynchronization operation with local replicas? Explain with examples.

Solution/Hint:

Restore operation

- Source is synchronized with the target data
- For example, if source contains a database where a logical data corruption occurs, the data can be recovered by attaching the latest PIT replica of the source and making incremental restore operation.

Resynchronization operation

- Target is synchronized with the source data
- For example, after target is detached from the source, both source and target data are updated by the host. After sometime the target needs to be synchronized with the source data. For that, target is again attached to the source and incremental resynchronization is performed.

5. A 300 GB database needs two local replicas for reporting and backup. There are constraints in provisioning full capacity for the replicas. It has been determined that the database has been configured on 15 disks, and the daily rate of change in the database is approximately 25 percent. You need to configure two pointer-

based replicas for the database. Describe how much capacity you would allocate for these replicas and how many save volumes you would configure.

Solution/Hint:

- 75GB of save volumes are required
- 0 space/capacity is allocated, since it is pointer based replica

6. For the same database described in Question 5, discuss the advantages of configuring full-volume mirroring if there are no constraints on capacity.

Solution/Hint:

- In full volume mirroring, the source need not be up/healthy for recovery.

7. An administrator configures six snapshots of a LUN and creates eight clones of the same LUN. The administrator then creates four snapshots for each clone that was created. How many usable replicas are now available?

Solution/Hint:

- Usable replicas = 6 + 8 + 32 = 46

8. Refer to Question 5. Having created the two replicas for backup and reporting purposes, assume you are required to automate the processes of backup and reporting from the replicas by using a script. Develop a script in a pseudo language (you can use the standard Time Finder commands for the operations you need to perform) that will fully automate backup and reporting. Your script should perform all types of validations at each step (e.g., validating whether a synchronization process is complete or a volume mount is successfully done).

Solution/Hint:

Create a flow chart in simple language.

Chapter 14

1. An organization is planning a data center migration. They can only afford a maximum of two hours downtime to complete the migration. Explain how remote replication technology can be used to meet the downtime requirements. Why will the other methods not meet this requirement?

   Solution/Hint:
   - SAN based remote replication technology can be used to avoid the downtime as it provide non-disruptive data migration.
   - Conventional methods need downtime to migrate data from one location to other.

2. Explain the RPO that can be achieved with synchronous, asynchronous, and disk-buffered remote replication.

   Solution/Hint:
   - RPO that can be achieved with synchronous – of the order of Seconds
   - RPO that can be achieved with asynchronous – of the order of Minutes
   - RPO that can be achieved with Disk buffered remote replication – of the order of hours

3. Discuss the effects of a bunker failure in a three-site replication for the following implementation:
   - Multihop—synchronous + disk buffered
   - Multihop—synchronous + asynchronous
   - Multitarget

   Solution/Hint:

   Multihop – synchronous + disk buffered

   Same as synchronous + asynchronous

   Multihop – synchronous + asynchronous

   If there is a disaster at the bunker site or if there is a network link failure between the source and bunker sites, the source site will continue to operate as normal but without any remote replication. This situation is very similar to two-site replication when a failure/disaster occurs at the target site. The updates to the remote site cannot occur due to the failure in the bunker site. Hence, the data at the remote site keeps falling behind; but the advantage here is that if the source fails as well during this time, operations can be resumed at the remote site. RPO at the remote site depends on the time difference between the bunker site failure and source site failure.

   Multitarget

   A failure of the bunker or the remote site is not considered a disaster because normal operations can continue at the source site while remote disaster recovery protection is still available with the site that has not failed. A network link failure to either the bunker site (target 1) or the

remote site (target 2) enables business operations to continue uninterrupted at the source site while remote disaster recovery protection is still available with the site that can be reached.

4. Discuss the effects of a source failure in a three-site replication for the following implementation, and the available recovery options:
   - Multihop—synchronous + disk buffered
   - Multihop—synchronous + asynchronous
   - Multitarget

   Solution/Hint:

   Multihop – synchronous + disk buffered

   Same as synchronous + asynchronous

   Multihop – synchronous + asynchronous

   If there is a disaster at the source, operations are failed over to the bunker site with zero or near-zero data loss. But unlike the synchronous two-site situation, there is still remote protection at the third site. The RPO between the bunker and third site could be on the order of minutes.

   Multitarget

   If a source site disaster occurs, BC operations can be started with the bunker (target 1) or the remote site (target 2). Under normal circumstances, the data at the bunker site is the more recent and up-to-date. Hence, operations are resumed with the bunker site data. In some circumstances, the data on the remote site is more current than the data on the bunker site—for example, if the network links between the source and bunker sites has failed. In this case, the workload would continue at the source site with just the asynchronous replication to the remote site. If the synchronous links are down long enough, then the data at the remote site would be more current than the data at the bunker site. If a source site disaster occurs at this time, the data on the remote site should be used to recover. The network links between the bunker and remote sites are activated in this situation to perform incremental synchronization. The RPO is near zero if the bunker site data is used, and it is in minutes if the remote site data is used.

5. A host generates 8,000 I/Os at peak utilization with an average I/O size of 32 KB. The response time is currently measured at an average of 12 ms during peak utilizations. When synchronous replication is implemented with a Fibre Channel link to a remote site, what is the response time experienced by the host if the network latency is 6 ms per I/O?

   Solution/Hint:

   Actual response time = 12+ (6*4) + (32*1024/8000) = 40.096

   Where 12 ms = current response time

   6 ms per I/O = latency

   32*1024/8000 = data transfer time

Chapter 15

1. Research the following security protocols and explain how they are used:
   Hint: Research work

2. A storage array dials a support center automatically whenever an error is detected. The vendor's representative at the support center can log on to the service processor of the storage array through the Internet to perform diagnostics and repair. Discuss the impact of this feature in a secure storage environment and provide security methods that can be implemented to mitigate any malicious attacks through this gateway.

   Solution/Hint:

   - Modification attacks

     In a modification attack, the unauthorized user attempts to modify information for malicious purposes. A modification attack can target data at rest or data in transit. These attacks pose a threat to data integrity.

   - Denial of Service

     Denial of Service (DoS) attacks denies the use of resources to legitimate users. These attacks generally do not involve access to or modification of information on the computer system. Instead, they pose a threat to data availability. The intentional flooding of a network or website to prevent legitimate access to authorized users is one example of a DoS attack.

   - Eavesdropping

     When someone overhears a conversation, the unauthorized access is called Eavesdropping.

   - Snooping

     This refers to accessing another user's data in an unauthorized way. In general, snooping and eavesdropping are synonymous.

   - Management access

     Management access, whether monitoring, provisioning, or managing storage resources, is associated with every device within the storage network. Most management software supports some form of CLI, system management console or a web-based interface.

     - ✓ Controlling administrative access

       Controlling administrative access to storage aims to safeguard against the threats of an attacker spoofing an administrator's identity or elevating another user's identity and privileges to gain administrative access. Both of these threats affect the integrity of data and devices. To protect against these threats, administrative access regulation and various auditing techniques are used to enforce accountability.

     - ✓ Protecting the management infrastructure

       Protecting the management network infrastructure is also necessary. Controls to protect the management network

infrastructure include encrypting management traffic, enforcing management access controls, and applying IP network security best practices. These best practices include the use of IP routers and Ethernet switches to restrict traffic to certain devices and management protocols.

3. Develop a checklist for auditing the security of a storage environment with SAN, NAS, and iSCSI implementations. Explain how you will perform the audit. Assume that you discover at least five security loopholes during the audit process. List them and provide control mechanisms that should be implemented to eliminate them.

Solution/Hint:

SAN, NAS, iSCSI

- Servers (Production, management, backup, third party, NAS)
  - What data or object was accessed /attempted to access?
  - What action was performed?
  - When was executed?
  - Who authorized and performed the action?
  - NFS/CIFS access (shared files)
- Fabric/ IP network
  - Physical and logical access
- Switches
  - Physical and logical access
  - Zoning
- Storage
  - Which volume was accessed /attempted to access?
  - What action was performed?
  - When was executed?
  - Who authorized and performed the action?
  - LUN masking
  - Provisioning
  - Upgrade/replacement
  - Handling of physical media

Process

- Collect log and correlate
- Analyze access and change control
  - Production and DR site
  - Backup and replication
  - Third party service
- Check alerting mechanism
- Check security controls

    - Physical
    - Administrative
    - Technological
- Identify security gap
- Documentation and recommendation

Five security loopholes
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1. Authentication allows multiple login
2. No firewall
3. No authentication at the switch level
4. No encryption for in-flight data
5. Poor physical security at the data center

Control
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1. Restriction in number of login attempt, two part password
2. Implement firewall to block inappropriate or dangerous traffic
3. Authenticate users/administrators of FC switches using RADIUS (Remote Authentication Dial In User Service), DH-CHAP (Diffie-Hellman Challenge Handshake Authentication Protocol), etc.
4. Encrypting the traffic in transit
5. Increase security manpower and implement biometric security

Chapter 16

1. Download EMC ControlCenter simulator and the accompanying lab guide from http://education.emc.com/ismbook and execute the steps detailed in the lab guide.
   - Lab exercise

2. A performance problem has been reported on a database. Monitoring confirms that at 12:00 a.m., a problem surfaced, and access to the database is severely affected until 3:00 p.m. every day. This time slot is critical for business operations and an investigation has been launched. A reporting process that starts at 12:00 p.m. contends for database resources and constrains the environment. What monitoring and management procedures, tools, and alerts would you establish to ensure accessibility, capacity, performance, and security in this environment?
   Hints:

   Monitoring:
   - Setting up monitoring and reporting for accessibility, capacity, performance and security on production and replication data
   - Monitoring and management tools such as ECC Performance manager need to be deploy to gather all performance statistics data (historical data)
   - Performance analysis – performance constraint is because of the resource

   Management:
   - Requirement: Database need to be replicate for reporting process
     - ✓ Based on requirement and infrastructure chosen replication software need to be deploy
     - ✓ Provision storage capacity for replication
     - ✓ Configure the environment for accessing replicated data (need configuration at host, network and storage)
     - ✓ Configure adequate capacity based on policy on data retention and change
     - ✓ Configure security for replicated data

3. Research SMI-S and write a technical paper on different vendor implementations of storage management solutions that comply with SMI-S.
   Research work