IA 1 Answers

1. What is a data centre? Explain the key characteristics of a data centre with a neat diagram.

Data Center

A data centre is a facility that provides shared access to applications and data using a complex network, compute, and storage infrastructure. Industry standards exist to assist in designing, constructing and maintaining data centre facilities and infrastructures to ensure the data is both highly secure and highly available. Because they house an organization's most critical and proprietary assets, data centres are vital to the continuity of daily operations.

Key characteristics of data centre elements are:

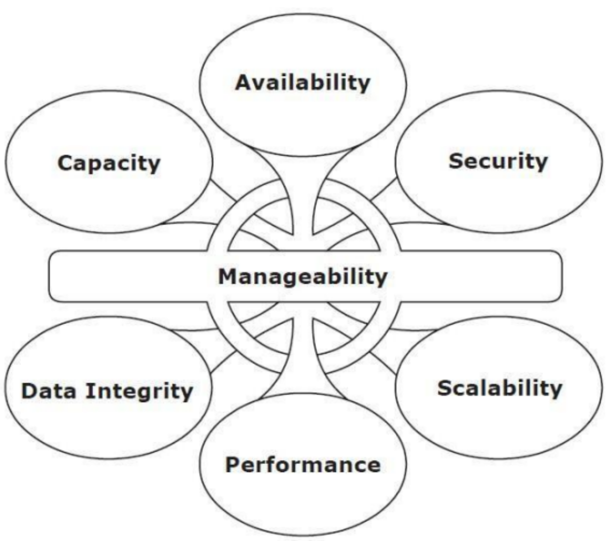


Fig 1.6: Key characteristics of data center elements

1. **Availability:** All data centre elements should be designed to ensure accessibility. The inability of users to access data can have a significant negative impact on a

business.

2. **Security:** Policies, procedures, and proper integration of the data centre core elements that will prevent unauthorized access to information must be established.
3. **Scalability:** Data centre operations should be able to allocate additional processing capabilities (Eg: servers, new applications, and additional databases) or storage on demand, without interrupting business operations. The storage solution should be able to grow with the business.
4. **Performance:** All the core elements of the data centre should be able to provide optimal performance and service with all processing requests at high speed. The infrastructure should be able to support performance requirements.
5. **Data integrity:** Data integrity refers to mechanisms such as error correction codes or parity bits that ensure that data is written to disk exactly as it was received. Any variation in data during its retrieval implies corruption, which may affect the operations of the organization.
6. **Capacity:** Data centre operations require adequate resources to store and process large amounts of data efficiently. When capacity requirements increase, the data centre must be able to provide additional capacity without interrupting availability or performance.
7. **Manageability:** A data centre should perform all operations and activities in the most efficient manner. Manageability can be achieved through automation and the reduction of human (manual) intervention in common tasks.

2. Explain the Architecture and evolution of storage technology with a neat diagram.

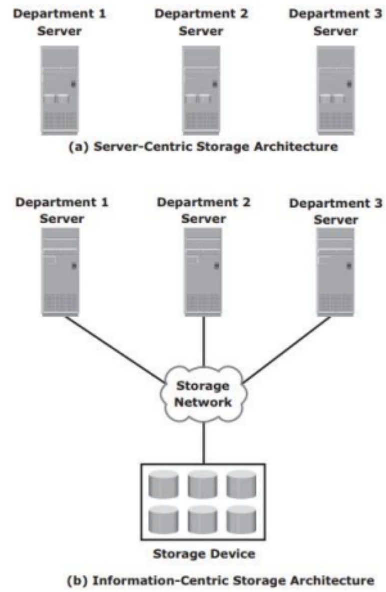


Fig 1.4: Evolution of storage architecture

- Historically, organizations had centralized computers (mainframe) and information storage devices (tape reels and disk packs) in their data centre.
- The evolution of open systems and the affordability and ease of deployment that they offer made it possible for business units to have their own servers and storage.
- In earlier implementations of open systems, the storage was typically internal to the server. This approach is referred to as **server-centric storage architecture**.
- In this server-centric storage architecture, each server has a limited number of storage devices, and any administrative tasks, such as maintenance of the server or increasing storage capacity, might result in the unavailability of information.
- The rapid increase in the number of departmental servers in an enterprise resulted in unprotected, unmanaged, fragmented islands of information and increased capital and operating expenses.
- To overcome these challenges, storage evolved from **server-centric** to **information-centric** architecture.
- In information-centric architecture, storage devices are managed centrally and independent of servers.
- These centrally-managed storage devices are shared with multiple servers.

- When a new server is deployed in the environment, storage is assigned from the same shared storage devices to that server.
- The capacity of shared storage can be increased dynamically by adding more storage devices without impacting information availability.
- In this architecture, information management is easier and cost-effective.
- Storage technology and architecture continue to evolve, which enables organizations to consolidate, protect, optimize, and leverage their data to achieve the highest return on information assets.

The new technology evolution includes:

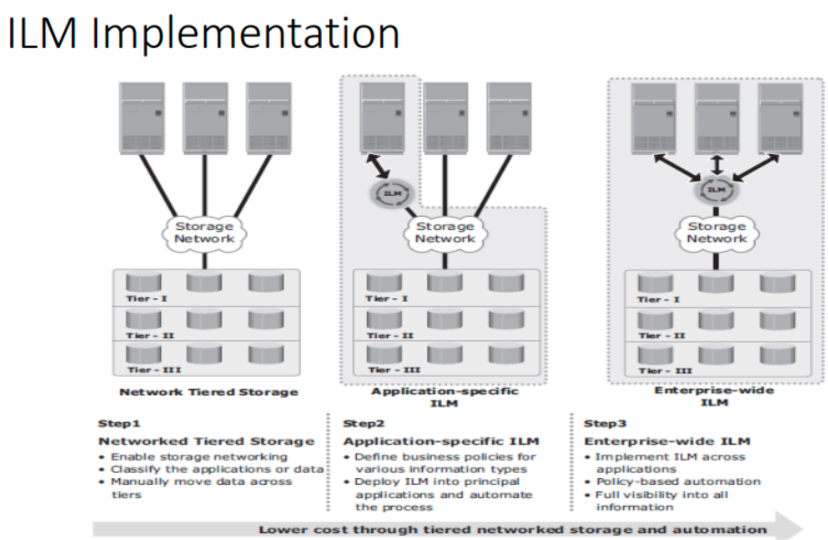
- **Redundant Array of Independent Disks (RAID):** This technology was developed to address the cost, performance, and availability requirements of data.
- **Direct-attached storage (DAS):** This type of storage connects directly to a server (host) or a group of servers in a cluster.
- **Storage area network (SAN):** This is a dedicated, high-performance Fibre Channel (FC) network to facilitate block-level communication between servers and storage.
- **Network-attached storage (NAS):** This is dedicated storage for file serving applications.
- **Internet Protocol SAN (IP-SAN):** One of the latest evolution in storage architecture, IP-SAN provides block-level communication across a local or wide area network (LAN or WAN).

3. What are the core elements of a Data Center?

- **Application:** An application is a computer program that provides the logic for computing operations. Eg: order processing system.
- **Database:** A database management system (DBMS) provides a structured way to store data in logically organized tables that are interrelated. A DBMS optimizes the storage and retrieval of data.

- **Host or compute:** A computing platform (hardware, firmware, and software) that runs applications and databases.
- **Network:** A data path that facilitates communication among various networked devices.
- **Storage array:** A device that stores data persistently for subsequent use.

4. Describe ILM (Information LifeCycle Management) implementation in detail. Mention its benefits.



- **Classifying** data and applications on the basis of business rules and policies to enable differentiated treatment of information.
- **Implementing** policies by using information management tools, starting from the creation of data and ending with its disposal.
- **Managing** the environment by using integrated tools to reduce operational complexity.
- **Organizing** storage resources in tiers to align the resources with data classes, and storing information in the right type of infrastructure based on the information's current value.

ILM Benefits

- Improved utilization by using tiered storage platforms and increased visibility of all enterprise information.
- Simplified management by integrating process steps and interfaces with individual tools and by increasing automation.
- A wider range of options for backup, and recovery to balance the need for business continuity.
- Maintaining compliance by knowing what data needs to be protected for what length of time.
- Content Management
- Federal Compliance
- Faster Access to Information
- Reduced Data Storage Cost

5. What is RAID? Explain Software and Hardware RAID implementation.

RAID (redundant array of independent disks) is a way of storing the same data in different places on multiple hard disks or solid-state drives (SSDs) to protect data in the case of a drive failure. This technology was developed to address the cost, performance, and availability requirements of data.

Hardware RAID

- In hardware RAID implementations, a specialized hardware controller is implemented either on the host or on the array.
- Controller card RAID is a host-based hardware RAID implementation in which a specialized RAID controller is installed in the host, and disk drives are connected to it.
- Manufacturers also integrate RAID controllers on motherboards.

- A host-based RAID controller is not an efficient solution in a data centre environment with a large number of hosts.
- The external RAID controller is an array-based hardware RAID.
- It acts as an interface between the host and disks.
- It presents storage as volumes to the host, and the host manages these volumes as physical drives.

Software RAID

- Software RAID uses host-based software to provide RAID functions.
- It is implemented at the operating-system level and does not use a dedicated hardware controller to manage the RAID array.
- Advantages when compared to Hardware RAID:
    - Cost efficiency
    - Simplicity benefits
- Limitations:
    - **Performance:** Software RAID affects overall system performance. This is due to additional CPU cycles required to perform RAID calculations.
    - **Supported features:** Software RAID does not support all RAID levels.
    - **Operating system compatibility:** Software RAID is tied to the host operating system; hence, upgrades to software RAID or to the operating system should be validated for compatibility. This leads to inflexibility in the data-processing environment.

6. Explain the three RAID techniques: a) Mirroring b) Striping c) Parity

Striping

- A RAID set is a group of disks. Within each disk in a RAID set, a predefined number of contiguously addressable disk blocks are defined as strips.
- The set of aligned strips that spans across all the disks within the RAID set is called a stripe.
- Strip size (also called stripe depth) describes the number of blocks in a strip and is the maximum amount of data that can be written to or read from a single disk in the set.
- Striping is a technique to spread data across multiple drives (more than one) to use the drives in parallel.

Mirroring

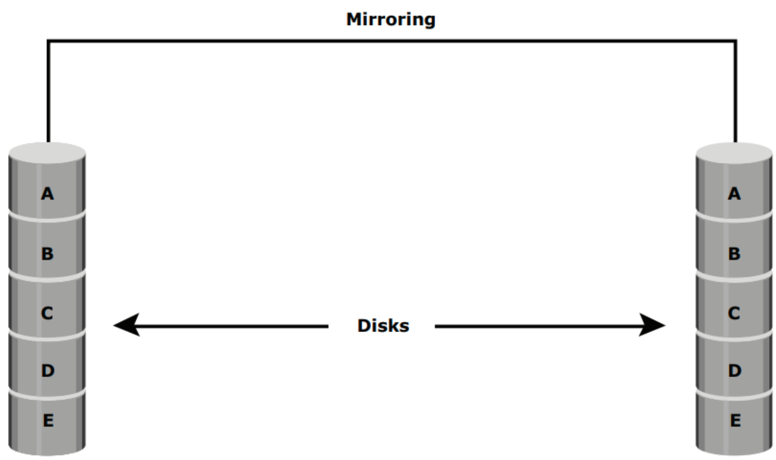


Figure 3-3: Mirrored disks in an array

- Mirroring is a technique whereby the same data is stored on two different disk drives, yielding two copies of the data.
- If one disk drive failure occurs, the data is intact on the surviving disk drive and the controller continues to service the host’s data requests from the surviving disk of a mirrored pair.
- When the failed disk is replaced with a new disk, the controller copies the data from the surviving disk of the mirrored pair.

Parity

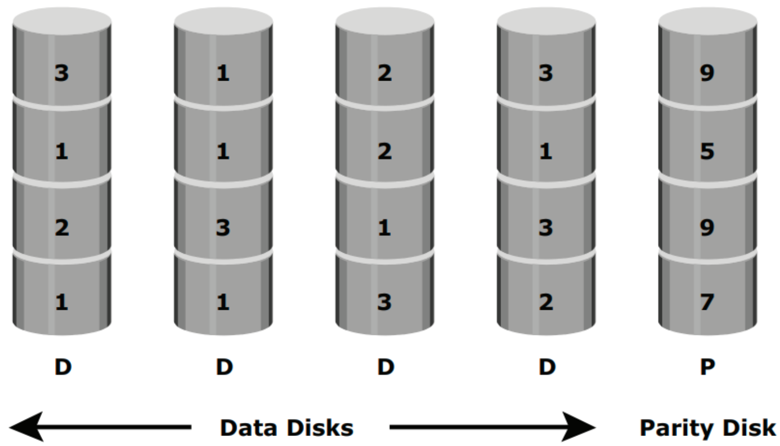


Figure 3-4: Parity RAID

- Parity is a method to protect striped data from disk drive failure without the cost of mirroring.
- Parity is a redundancy technique that ensures the protection of data without maintaining a full set of duplicate data.
- Calculation of parity is a function of the RAID controller.
- Parity information can be stored on separate, dedicated disk drives or distributed across all the drives in a RAID set.

7. Explain RAID 3 and RAID 4 in detail

RAID 3

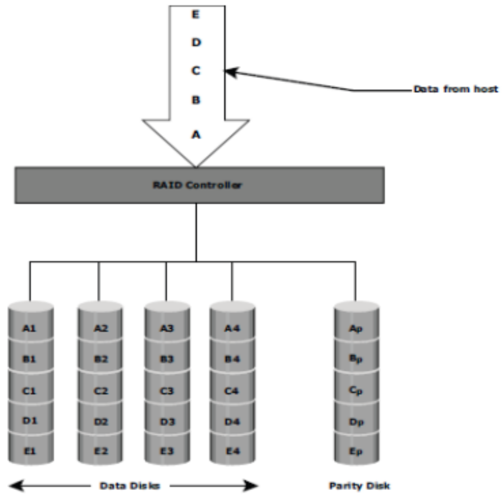


Fig 1.17: RAID 3

- RAID 3 stripes data for high performance and uses parity for improved fault tolerance.
- Data is striped at byte level.
- Parity information is stored on a dedicated drive so that data can be reconstructed if a drive fails. For example, of five disks, four are used for data and one is used for parity.
- RAID 3 always reads and writes complete stripes of data across all disks, as the drives operate in parallel. There are no partial writes that update one out of many strips in a stripe.
- RAID 3 provides good bandwidth for the transfer of large volumes of data. RAID 3 is used in applications that involve large sequential data access, such as video streaming.

RAID 4

- RAID 4 stripes data for high performance and uses parity for improved fault tolerance. Data is striped across all disks except the parity disk in the array.
- Data is striped at block level.
- Parity information is stored on a dedicated disk so that the data can be rebuilt if a drive fails. Striping is done at the block level.

- Unlike RAID 3, data disks in RAID 4 can be accessed independently so that specific data elements can be read or written on a single disk without the reading or writing of an entire stripe. RAID 4 provides good read throughput and reasonable write throughput.

8. Compare RAID 5 and RAID 6

RAID 5

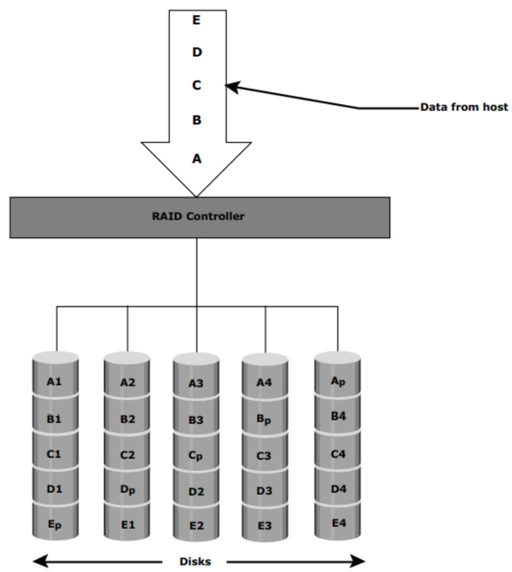


Figure 3-9: RAID 5

- RAID 5 is a versatile RAID implementation.
- It is similar to RAID 4 because it uses striping. The drives (strips) are also independently accessible.
- The difference between RAID 4 and RAID 5 is the parity location. In RAID 4, parity is written to a dedicated drive, creating a write bottleneck for the parity disk.
- In RAID 5, parity is distributed across all disks. The distribution of parity in RAID 5 overcomes the Write bottleneck. The Figure illustrates the RAID 5 implementation.
- RAID 5 is good for random, read-intensive I/O applications and preferred for messaging, data mining, medium-performance media serving, and relational

database management system (RDBMS) implementations, in which database administrators (DBAs) optimize data access.

RAID 6

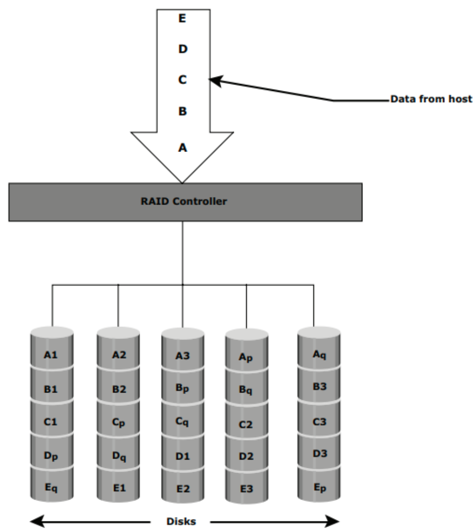


Figure 3-10: RAID 6

- RAID 6 includes a second parity element to enable survival in the event of the failure of two disks in a RAID group. Therefore, a RAID 6 implementation requires at least four disks.
- RAID 6 distributes the parity across all the disks. The write penalty in RAID 6 is more than that in RAID 5; therefore, RAID 5 writes perform better than RAID 6. The rebuild operation in RAID 6 may take longer than that in RAID 5 due to the presence of two parity sets.

9. Explain the various components of the disk drive.

Key components of a disk drive are platter, spindle, read/write head, actuator arm assembly, and controller:

Platter

A typical HDD consists of one or more flat circular disks called platters. The data is recorded on these platters in binary codes (0s and 1s). The set of rotating platters is sealed in a case, called a Head Disk Assembly (HDA). A platter is a rigid, round disk coated with magnetic material on both surfaces (top and bottom). The data is encoded by polarizing the magnetic area, or domains, of the disk surface. Data can be written to or read from both surfaces of the platter. The number of platters and the storage capacity of each platter determines the total capacity of the drive.

Spindle

A spindle connects all the platters and is connected to a motor. The motor of the spindle rotates at a constant speed. The disk platter spins at a speed of several thousands of revolutions per minute (rpm). Disk drives have spindle speeds of 7,200 rpm, 10,000 rpm, or 15,000 rpm. Disks used on current storage systems have a platter diameter of 3.5” (90 mm). When the platter spins at 15,000 rpm, the outer edge is moving at around 25% of the speed of sound. The speed of the platter is increasing with improvements in technology, although the extent to which it can be improved is limited.

Read/Write (R/W) heads

Read and write data from or to a platter. Drives have two R/W heads per platter, one for each surface of the platter. The R/W head changes the magnetic polarization on the surface of the platter when writing data. While reading data, this head detects magnetic polarization on the surface of the platter. During the reads and writes, the R/W head senses the magnetic polarization and never touches the surface of the platter.

Actuator Arm Assembly

The R/W heads are mounted on the actuator arm assembly which positions the R/W head at the location on the platter where the data needs to be written or read. The R/W heads for all platters on a drive are attached to one actuator arm assembly and move across the platters simultaneously. Note that there are two R/W heads per platter, one for each surface.

Controller

The controller is a printed circuit board, mounted at the bottom of a disk drive. It consists of a microprocessor, internal memory, circuitry, and firmware. The firmware controls power to the spindle motor and the speed of the motor. It also manages communication between the drive and the host. In addition, it controls the R/W operations by moving the actuator arm and switching between different R/W heads and performs the optimization of data access.

10. Compare different RAID levels.

RAID Level Comparison

Features	RAID 0	RAID 1	RAID 5	RAID 6
Minimum number of drives	2	2	3	4
Fault tolerance	None	Single-drive failure	Single-drive failure	Two-drive failure
Read performance	High	Medium	Low	Low
Write Performance	High	Medium	Low	Low
Capacity utilization	100%	50%	67% – 94%	50% – 88%
Typical applications	High end workstations, data logging, real-	Operating systems, transaction	Data warehousing, web serving,	Data archive, backup to disk, high availability

Table 3-2: Comparison of Different RAID Types

RAID	MIN. DISKS	STORAGE EFFICIENCY %	COST	READ PERFORMANCE	WRITE PERFORMANCE	WRITE PENALTY
0	2	100	Low	Very good for both random and sequential read	Very good	No
1	2	50	High	Good. Better than a single disk.	Good. Slower than a single disk, as every write must be committed to all disks.	Moderate
3	3	(n-1)*100/n where n= number of disks	Moderate	Good for random reads and very good for sequential reads.	Poor to fair for small random writes. Good for large, sequential writes.	High
4	3	(n-1)*100/n where n= number of disks	Moderate	Very good for random reads. Good to very good for sequential writes.	Poor to fair for random writes. Fair to good for sequential writes.	High

Continued

Table 3-2 *(continued)*

RAID	MIN. DISKS	STORAGE EFFICIENCY %	COST	READ PERFORMANCE	WRITE PERFORMANCE	WRITE PENALTY
5	3	(n-1)*100/n where n= number of disks	Moderate	Very good for random reads. Good for sequential reads	Fair for random writes. Slower due to parity overhead. Fair to good for sequential writes.	High
6	4	(n-2)*100/n where n= number of disks	Moderate but more than RAID 5	Very good for random reads. Good for sequential reads.	Good for small, random writes (has write penalty).	Very High
1+0 and 0+1	4	50	High	Very good	Good	Moderate

11. What is a hot spare? Explain with a neat diagram.

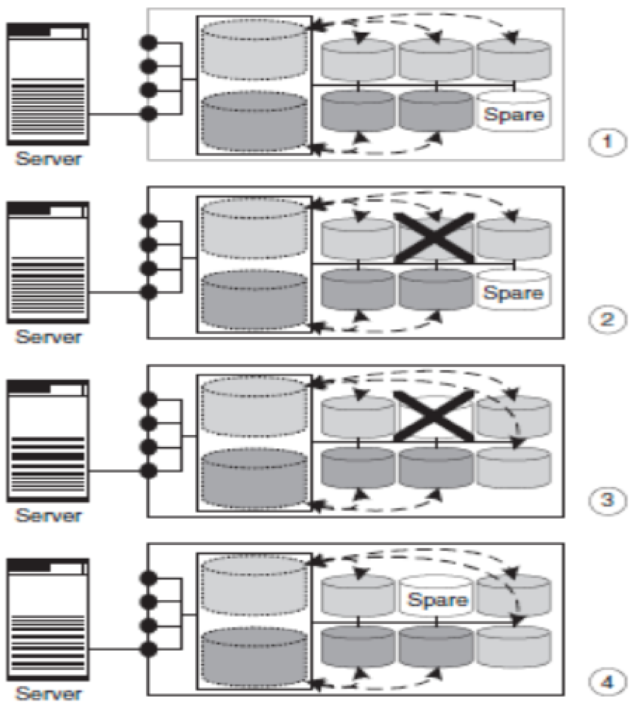


Figure 2.8 Hot spare disk: The disk subsystem provides the server with two virtual disks for which a common hot spare disk is available (1). Due to the redundant data storage the server can continue to process data even though a physical disk has failed, at the expense of a reduction in performance (2). The RAID controller recreates the data from the defective disk on the hot spare disk (3). After the defective disk has been replaced a hot spare disk is once again available (4).

A hot spare refers to a spare HDD in a RAID array that temporarily replaces a failed HDD of a RAID set. A hot spare takes the identity of the failed HDD in the array. One of the following methods of data recovery is performed depending on the RAID implementation:

- If parity RAID is used, then the data is rebuilt onto the hot spare from the parity and the data on the surviving HDDs in the RAID set.
- If mirroring is used, then the data from the surviving mirror is used to copy the data.

When the failed HDD is replaced with a new HDD, one of the following takes place:

- The hot spare replaces the new HDD permanently. This means that it is no longer a hot spare, and a new hot spare must be configured on the array.

- When a new HDD is added to the system, data from the hot spare is copied to it. The hot spare returns to its idle state, ready to replace the next failed drive.

A hot spare should be large enough to accommodate data from a failed drive. Some systems implement multiple hot spares to improve data availability. A hot spare can be configured as automatic or user-initiated, which specifies how it will be used in the event of disk failure. In an automatic configuration, when the recoverable error rates for a disk exceed a predetermined threshold, the disk subsystem tries to copy data from the failing disk to the hot spare automatically.

12. What is the impact of RAID on disk performance?

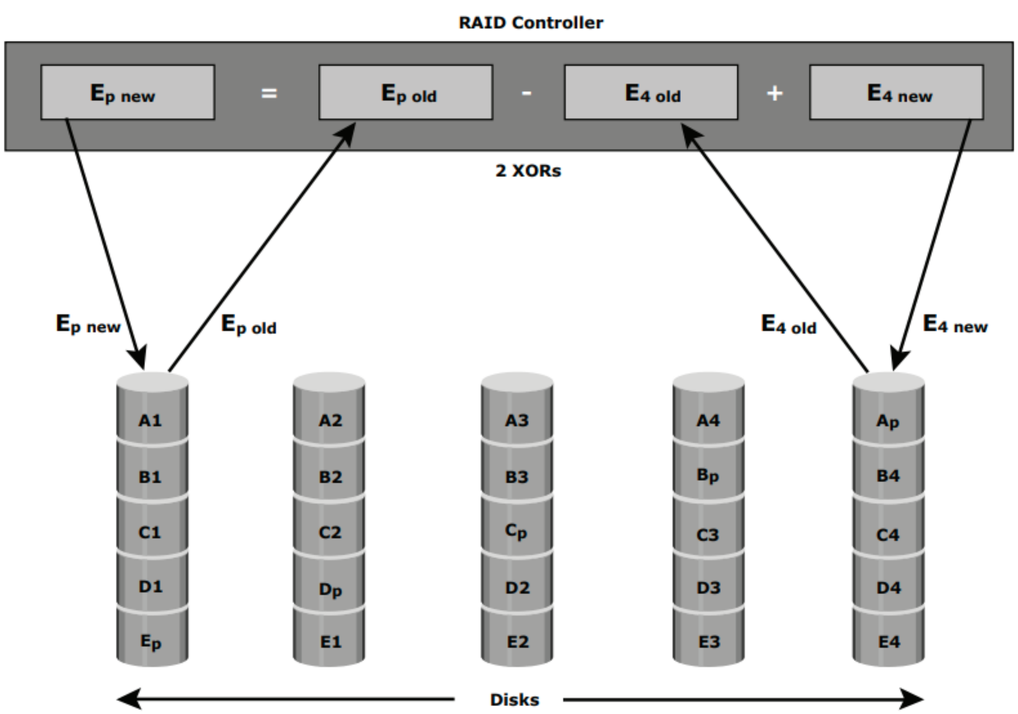


Figure 3-11: Write penalty in RAID 5

- When choosing a RAID type, it is imperative to consider the impact on disk performance and application IOPS.
- In both mirrored and parity RAID configurations, each `write` operation translates into more I/O overhead for the disks which is referred to as *write penalty*.

- In a RAID 1 implementation, every `write` operation must be performed on two disks configured as a mirrored pair while in a RAID 5 implementation, a `write` operation may manifest as four I/O operations.
- When performing small I/Os to a disk configured with RAID 5, the controller has to read, calculate, and write a parity segment for every data `write` operation.
- The figure illustrates a single write operation on RAID 5 that contains a group of five disks.
- Four of these disks are used for data and one is used for parity.
- The parity (P) at the controller is calculated as follows:
    - $E_p = E_1 + E_2 + E_3 + E_4$ (XOR operations)
- After computing the new parity, the controller completes the write I/O by writing the new data and the new parity onto the disks, amounting to two write I/Os.
- Therefore, the controller performs two disk reads and two disk writes for every `write` operation, and the write penalty in RAID 5 implementations is 4.
- In RAID 6, which maintains dual parity, a disk write requires three read operations; after calculating the parity, the controller performs at least three `write` operations for every minute change.
- Therefore, in a RAID 6 implementation, the controller performs six I/O operations for each write I/O, and the write penalty is 6.

13. Explain the challenges of designing applications.