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SE Comps A-3

OPERATING SYSTEMS
ASSIGNMENT - 1

1. **Describe RAID disk management. Provide detailed description of all the levels of RAID.**

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 to protect data in the case of a drive failure. There are different RAID levels, however, and not all have the goal of providing redundancy.

RAID works by placing data on multiple disks and allowing input/output (I/O) operations to overlap in a balanced way, improving performance. Because the use of multiple disks increases the mean time between failures (MTBF), storing data redundantly also increases fault tolerance.

RAID arrays appear to the operating system (OS) as a single logical drive. RAID employs the techniques of disk mirroring or disk striping. Mirroring will copy identical data onto more than one drive. Striping partitions helps spread data over multiple disk drives. Each drive's storage space is divided into units ranging from a sector (512 bytes) up to several megabytes. The stripes of all the disks are interleaved and addressed in order.

Disk mirroring and disk striping can also be combined in a RAID array.

In a single-user system where large records are stored, the stripes are typically set up to be small (perhaps 512 bytes) so that a single record spans all the disks and can be accessed quickly by reading all the disks at the same time.

In a multi-user system, better performance requires a stripe wide enough to hold the typical or maximum size record, allowing overlapped disk I/O across drives.

RAID controller

A RAID controller is a device used to manage hard disk drives in a storage array. It can be used as a level of abstraction between the OS and the physical disks, presenting groups of disks as logical units. Using a RAID controller can improve performance and help protect data in case of a crash.

A RAID controller may be hardware- or software-based. In a hardware-based RAID product, a physical controller manages the array. The controller can also be designed to support drive formats such as SATA and SCSI. A physical RAID controller can also be built into a server's motherboard.

With software-based RAID, the controller uses the resources of the hardware system, such as the central processor and memory. While it performs the same functions as a hardware-based RAID controller, software-based RAID controllers may not enable as much of a performance boost and can affect the performance of other applications on the server.

If a software-based RAID implementation isn't compatible with a system's boot-up process, and hardware-based RAID controllers are too costly, firmware or driver-based RAID is another potential option.

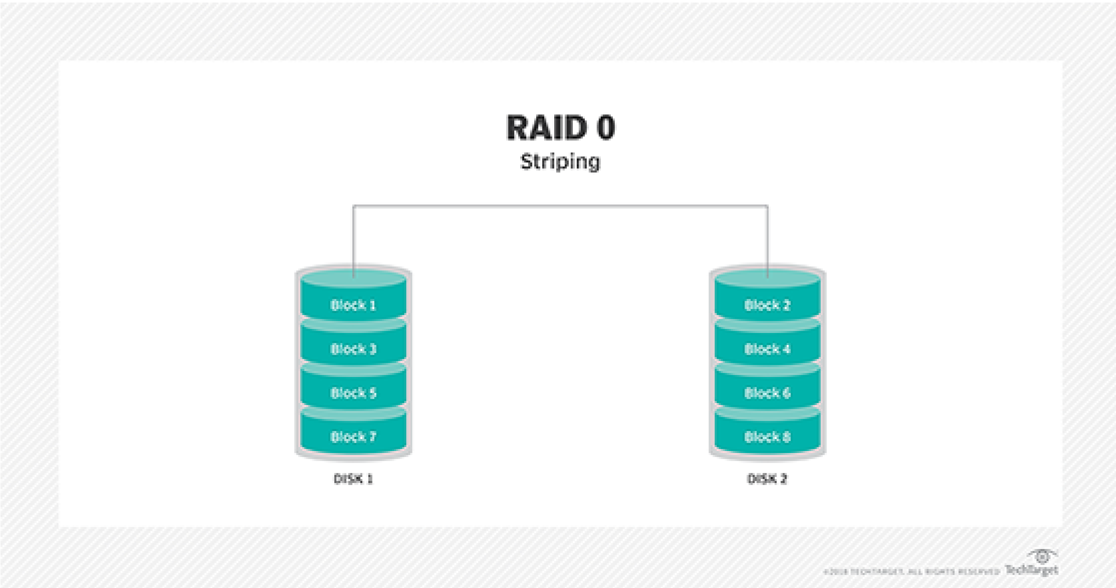
Firmware-based RAID controller chips are located on the motherboard, and all operations are performed by the CPU, similar to software-based RAID. However, with firmware, the RAID system is only implemented at the beginning of the boot process. Once the OS has loaded, the controller driver takes over RAID functionality. A firmware RAID controller isn't as pricey as a hardware option, but it puts more strain on the computer's CPU. Firmware-based RAID is also called hardware-assisted software RAID, hybrid model RAID and fake RAID.

RAID levels

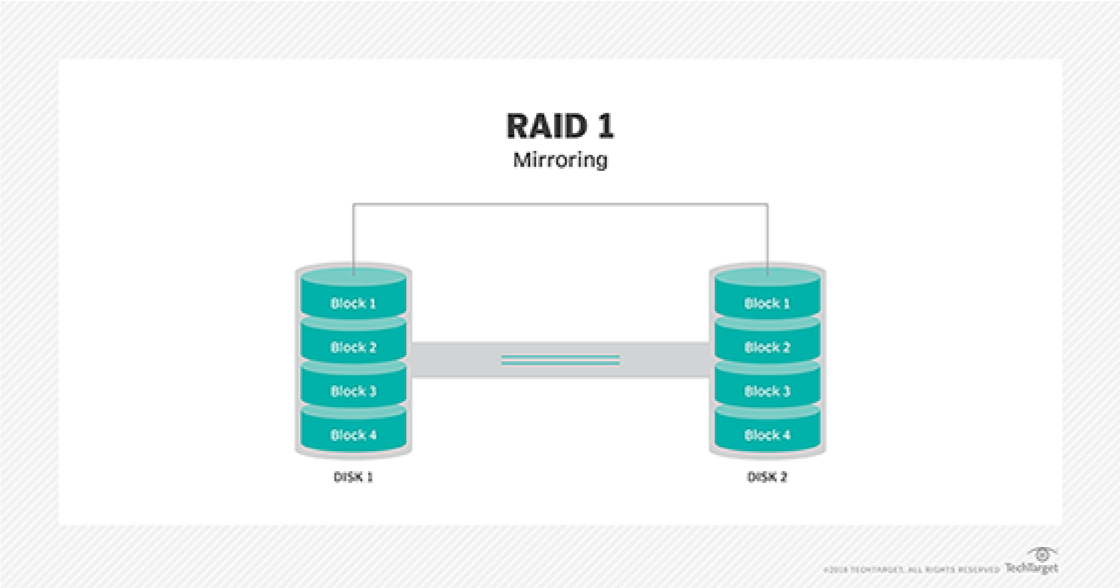
Raid devices will make use of different versions, called levels. The original paper that coined the term and developed the RAID setup concept defined six levels of RAID -- 0 through 5. This numbered system enabled those in IT to differentiate RAID versions. The number of levels has since expanded and has been broken into three categories: standard, nested and nonstandard RAID levels.

Standard RAID levels

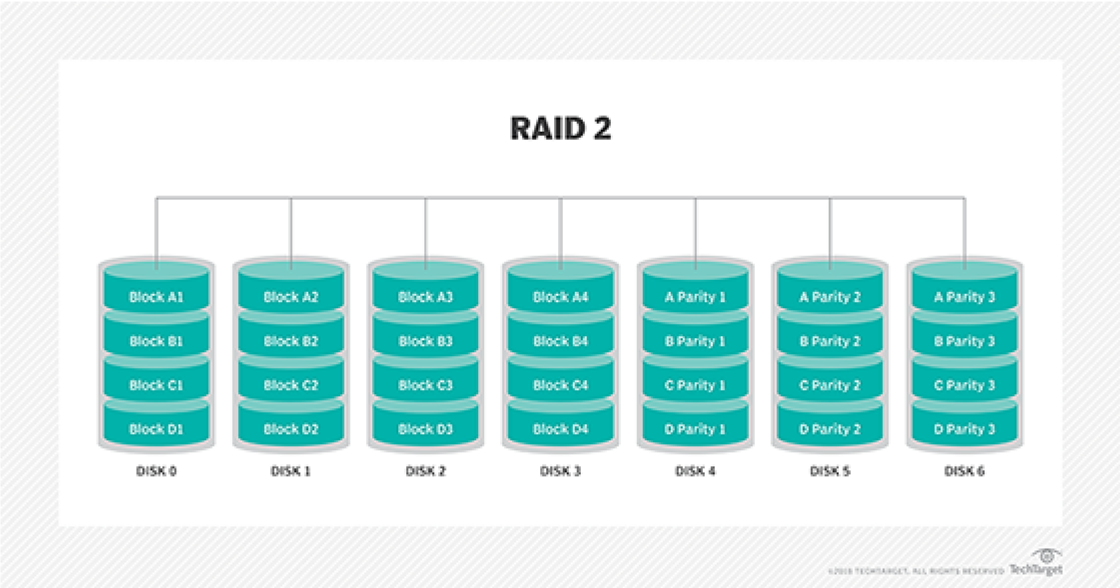
RAID 0. This configuration has striping, but no redundancy of data. It offers the best performance, but it does not provide fault tolerance.



RAID 1. Also known as *disk mirroring*, this configuration consists of at least two drives that duplicate the storage of data. There is no striping. Read performance is improved since either disk can be read at the same time. Write performance is the same as for single disk storage.

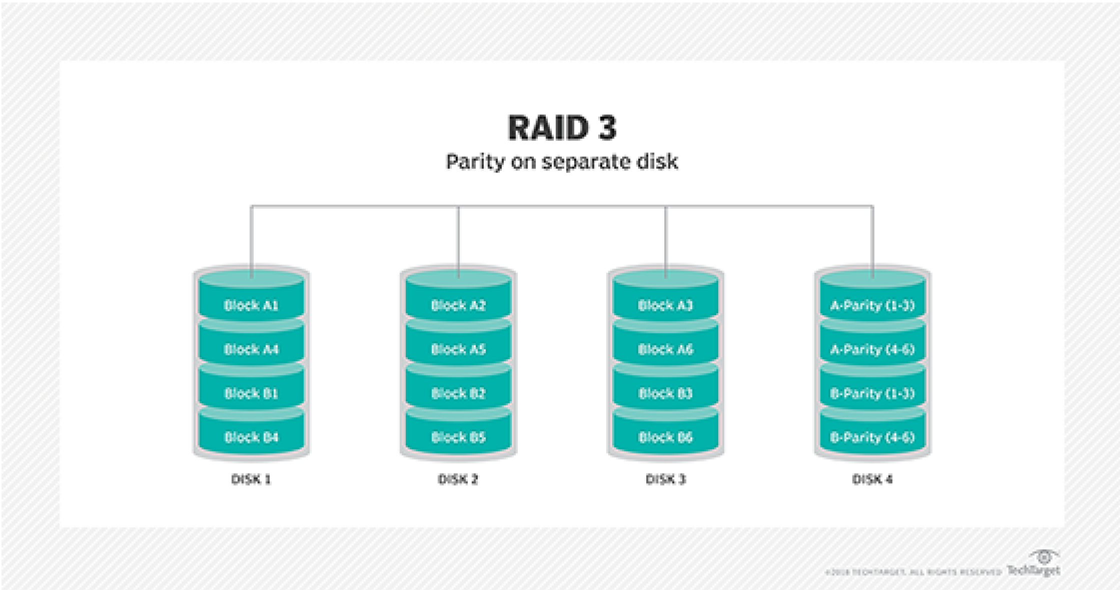


RAID 2. This configuration uses striping across disks, with some disks storing error checking and correcting (ECC) information. RAID 2 also uses a dedicated Hamming code parity; a linear form of error correction code. RAID 2 has no advantage over RAID 3 and is no longer used.

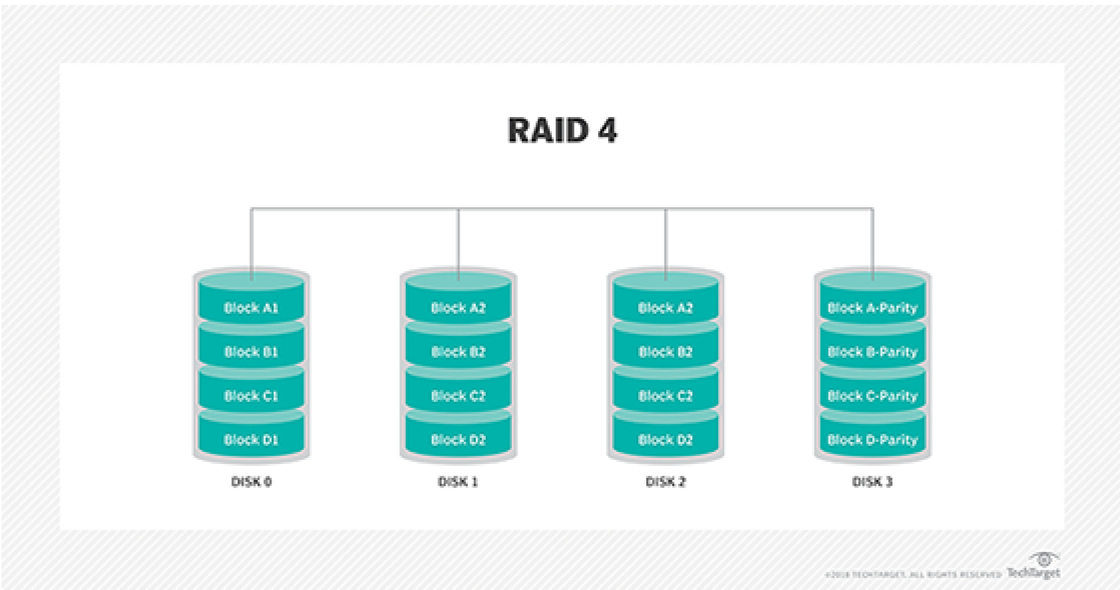


RAID 3. This technique uses striping and dedicates one drive to storing parity information. The embedded ECC information is used to detect errors. Data recovery is accomplished by

calculating the exclusive information recorded on the other drives. Since an I/O operation addresses all the drives at the same time, RAID 3 cannot overlap I/O. For this reason, RAID 3 is best for single-user systems with long record applications.

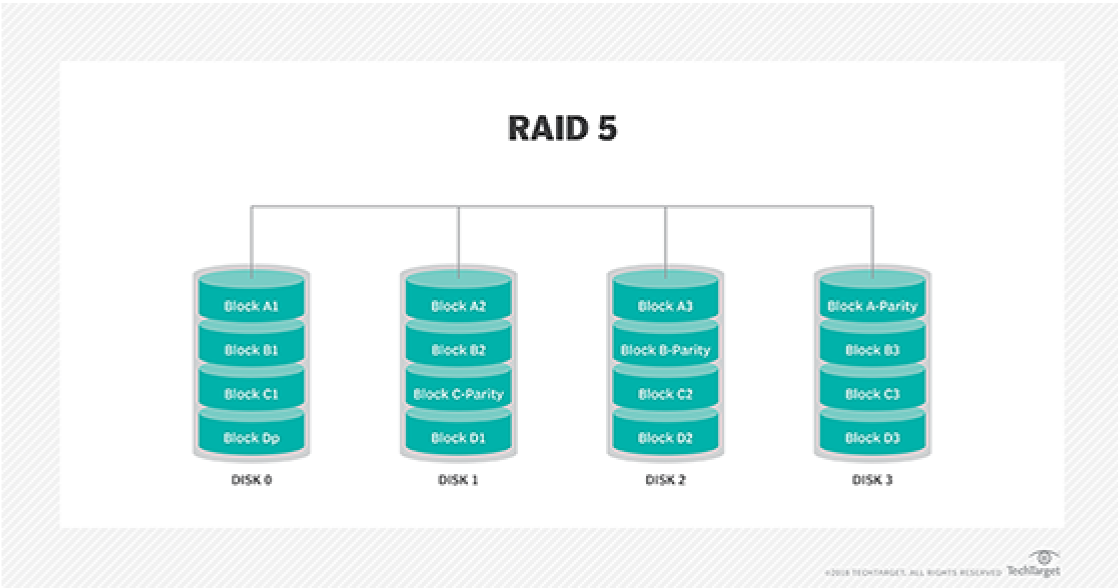


RAID 4. This level uses large stripes, which means a user can read records from any single drive. Overlapped I/O can then be used for read operations. Since all write operations are required to update the parity drive, no I/O overlapping is possible.

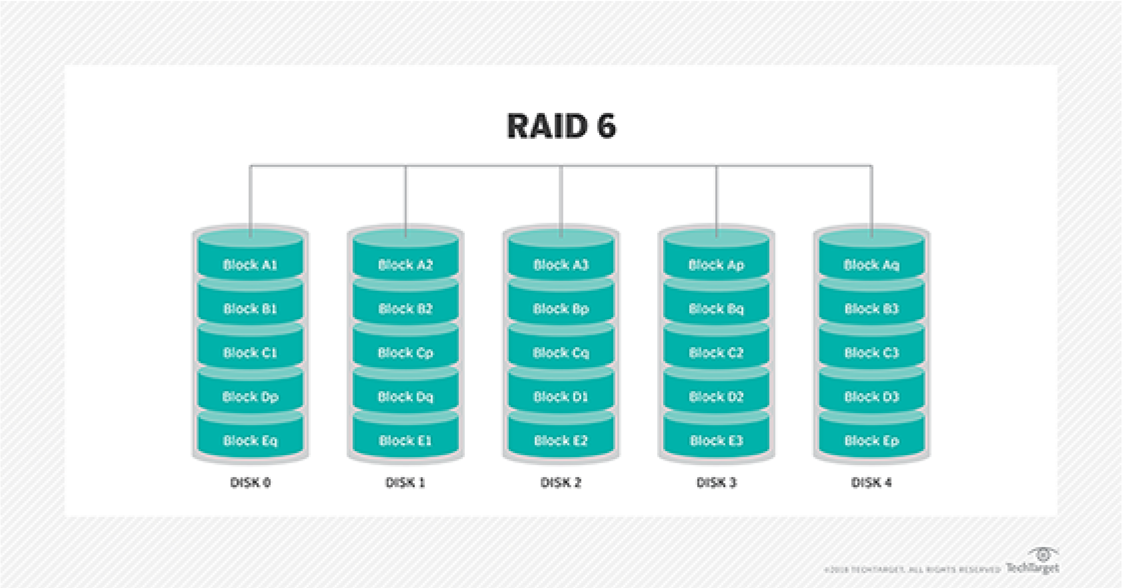


RAID 5. This level is based on parity block-level striping. The parity information is striped across each drive, enabling the array to function even if one drive were to fail. The array's architecture allows read and write operations to span multiple drives -- resulting in performance better than that of a single drive, but not as high as that of a RAID 0 array. RAID 5 requires at least three disks, but it is often recommended to use at least five disks for performance reasons.

RAID 5 arrays are generally considered to be a poor choice for use on write-intensive systems because of the performance impact associated with writing parity data. When a disk fails, it can take a long time to rebuild a RAID 5 array.



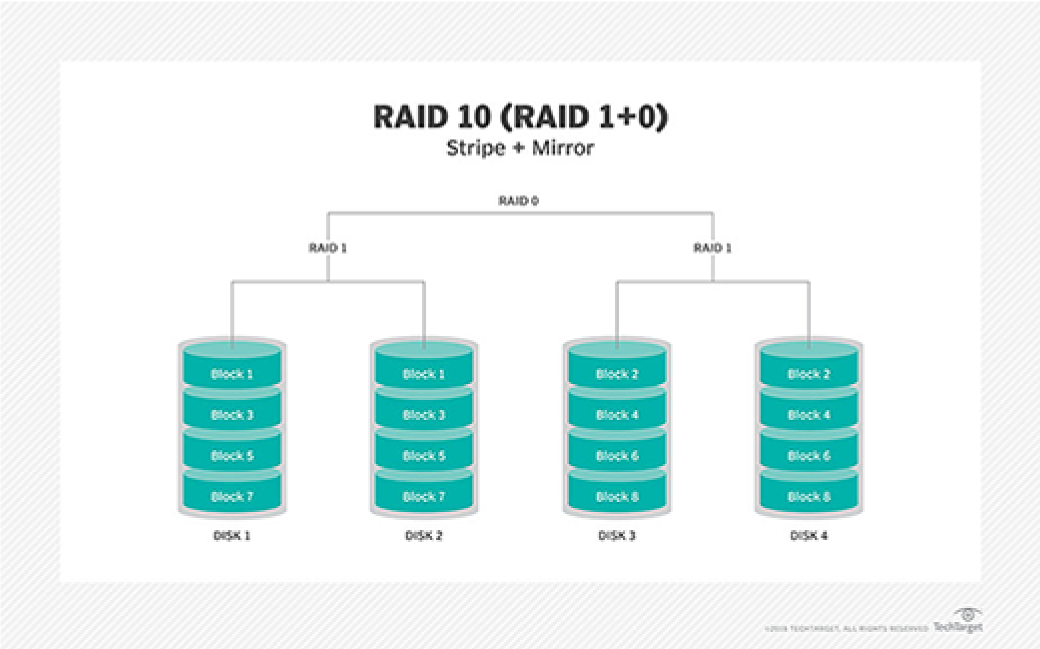
RAID 6. This technique is similar to RAID 5, but it includes a second parity scheme distributed across the drives in the array. The use of additional parity enables the array to continue to function even if two disks fail simultaneously. However, this extra protection comes at a cost. RAID 6 arrays often have slower write performance than RAID 5 arrays.



Nested RAID levels

Some RAID levels are referred to as *nested RAID* because they are based on a combination of RAID levels. Here are some examples of nested RAID levels.

RAID 10 (RAID 1+0). Combining RAID 1 and RAID 0, this level is often referred to as RAID 10, which offers higher performance than RAID 1, but at a much higher cost. In RAID 1+0, the data is mirrored and the mirrors are striped.



RAID 01 (RAID 0+1). RAID 0+1 is similar to RAID 1+0, except the data organization method is slightly different. Rather than creating a mirror and then striping the mirror, RAID 0+1 creates a stripe set and then mirrors the stripe set.

RAID 03 (RAID 0+3, also known as RAID 53 or RAID 5+3). This level uses striping (in RAID 0 style) for RAID 3's virtual disk blocks. This offers higher performance than RAID 3, but at a higher cost.

RAID 50 (RAID 5+0). This configuration combines RAID 5 distributed parity with RAID 0 striping to improve RAID 5 performance without reducing data protection.

Nonstandard RAID levels

Nonstandard RAID levels vary from standard RAID levels and are usually developed by companies or organizations for mainly proprietary use. Here are some examples.

RAID 7. A nonstandard RAID level based on RAID 3 and RAID 4 that adds caching. It includes a real-time embedded OS as a controller, caching via a high-speed bus and other characteristics of a stand-alone computer.

Adaptive RAID. This level enables the RAID controller to decide how to store the parity on disks. It will choose between RAID 3 and RAID 5, depending on which RAID set type will perform better with the type of data being written to the disks.

Linux MD RAID 10. This level, provided by the Linux kernel, supports the creation of nested and nonstandard RAID arrays. Linux software RAID can also support the creation of standard RAID 0, RAID 1, RAID 4, RAID 5 and RAID 6 configurations.

Benefits of RAID

Benefits of RAID include the following.

- An improvement in cost-effectiveness because lower-priced disks are used in large numbers.
- The use of multiple hard drives enables RAID to improve on the performance of a single hard drive.
- Increased computer speed and reliability after a crash -- depending on the configuration.
- Reads and writes can be performed faster than with a single drive with RAID 0. This is because a file system is split up and distributed across drives that work together on the same file.
- There is increased availability and resiliency with RAID 5. With mirroring, RAID arrays can have two drives containing the same data, ensuring one will continue to work if the other fails.

Downsides of using RAID

RAID does have its downsides, however. Some of these include:

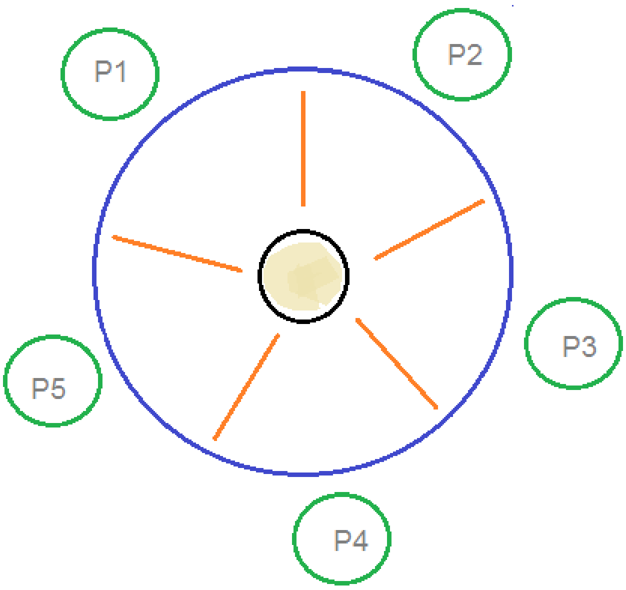
- Nested RAID levels are more expensive to implement than traditional RAID levels because they require a greater number of disks.
- The cost per gigabyte of storage devices is higher for nested RAID because many of the drives are used for redundancy.
- When a drive fails, the probability that another drive in the array will also soon fail rises, which would likely result in data loss. This is because all the drives in a RAID array are installed at the same time, so all the drives are subject to the same amount of wear.
- Some RAID levels (such as RAID 1 and 5) can only sustain a single drive failure.
- RAID arrays, and the data in them, are in a vulnerable state until a failed drive is replaced and the new disk is populated with data.

- Because drives have much greater capacity now than when RAID was first implemented, it takes a lot longer to rebuild failed drives.
- If a disk failure occurs, there is a chance the remaining disks may contain bad sectors or unreadable data -- which may make it impossible to fully rebuild the array.

However, nested RAID levels address these problems by providing a greater degree of redundancy, significantly decreasing the chances of an array-level failure due to simultaneous disk failures.

2. **Explain Dining Philosophers problem and its solution using semaphores.**

The dining philosophers problem is another classic synchronization problem which is used to evaluate situations where there is a need of allocating multiple resources to multiple processes.
Consider there are five philosophers sitting around a circular dining table. The dining table has five chopsticks and a bowl of rice in the middle as shown in the below figure.



Dining Philosophers Problem

At any instant, a philosopher is either eating or thinking. When a philosopher wants to eat, he uses two chopsticks - one from their left and one from their right. When a philosopher wants to think, he keeps down both chopsticks at their original place.

From the problem statement, it is clear that a philosopher can think for an indefinite amount of time. But when a philosopher starts eating, he has to stop at some point of time. The philosopher is in an endless cycle of thinking and eating.

An array of five semaphores, stick[5], for each of the five chopsticks.

The code for each philosopher looks like:

```
while(TRUE)
{
    wait(stick[i]);
    /*
        mod is used because if i=5, next
        chopstick is 1 (dining table is circular)
    */
    wait(stick[(i+1) % 5]);

    /* eat */
    signal(stick[i]);

    signal(stick[(i+1) % 5]);
    /* think */
}
```

When a philosopher wants to eat the rice, he will wait for the chopstick at his left and picks up that chopstick. Then he waits for the right chopstick to be available, and then picks it too. After eating, he puts both the chopsticks down.

But if all five philosophers are hungry simultaneously, and each of them picks up one chopstick, then a deadlock situation occurs because they will be waiting for another chopstick forever. The possible solutions for this are:

- A philosopher must be allowed to pick up the chopsticks only if both the left and right chopsticks are available.
- Allow only four philosophers to sit at the table. That way, if all the four philosophers pick up four chopsticks, there will be one chopstick left on the table. So, one philosopher can start eating and eventually, two chopsticks will be available. In this way, deadlocks can be avoided.