



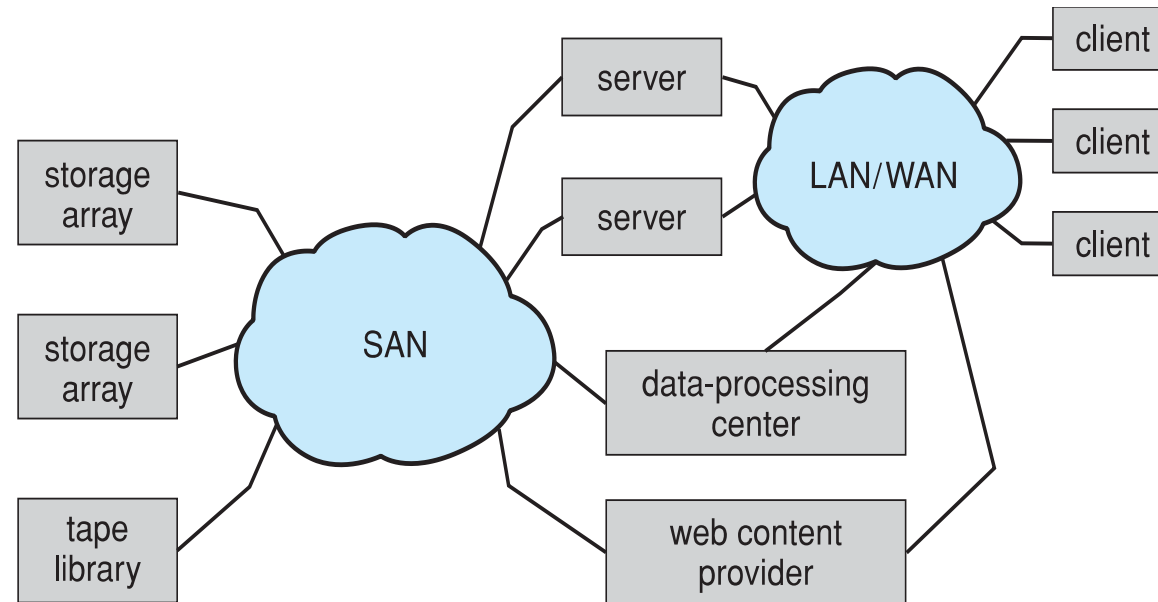
## L32- STORAGE ARRAYS & RAID

# Storage Array

- ❖ Attach multiple disks - arrays of disks
- ❖ Storage array has controller that provides features to attached hosts
  - ❖ A few to thousands of disks
  - ❖ Ports to connect hosts to array
  - ❖ Memory, controlling software
  - ❖ Support RAID, hot spares, hot swap
  - ❖ Shared storage → more efficiency

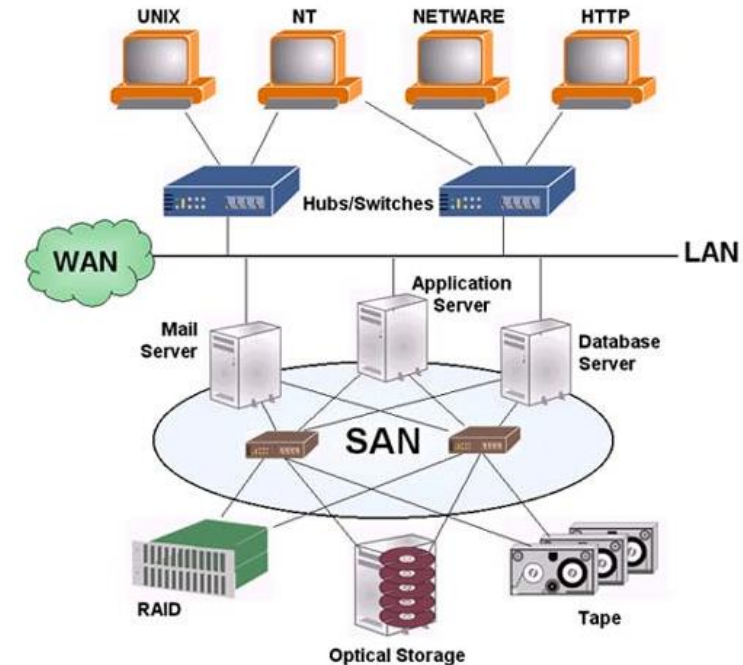
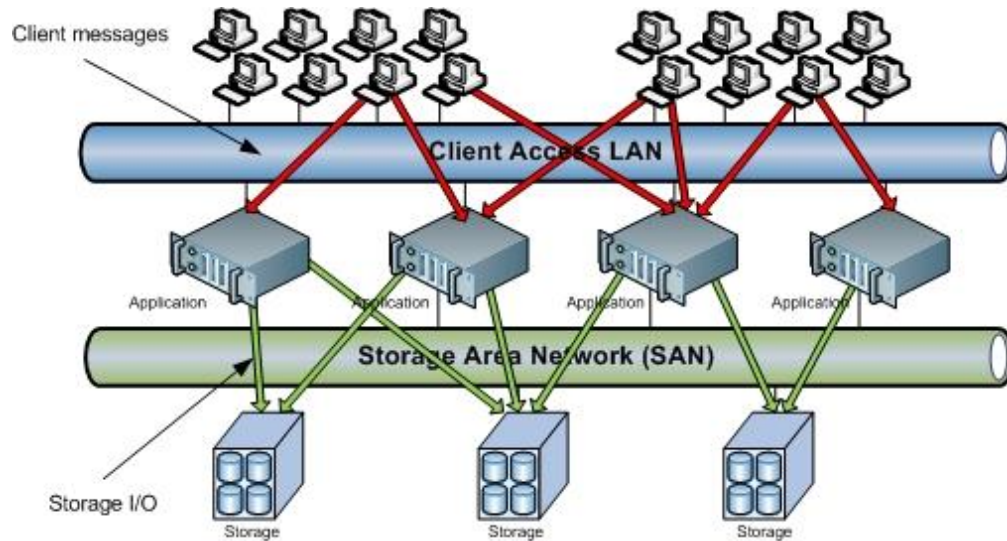
# Storage Area Network

- ❖ Common in large storage environments
- ❖ Multiple hosts attached to multiple storage arrays - flexible



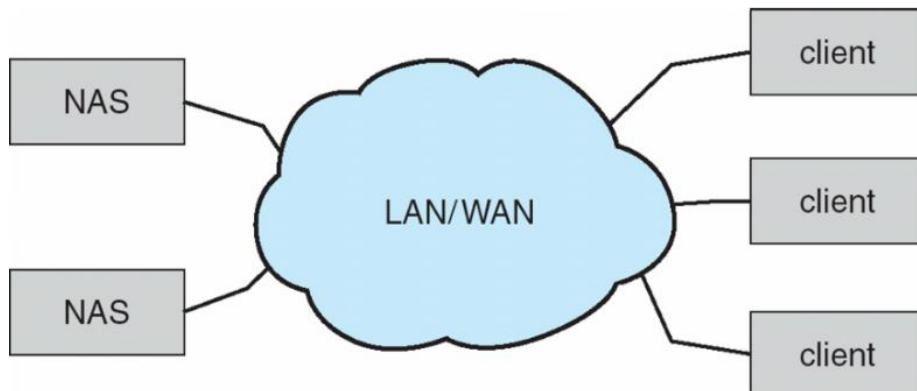
# Storage Area Network

- ❖ SAN is one or more storage arrays
  - ❖ Connected to one or more Fibre Channel switches
- ❖ Hosts also attach to the switches
- ❖ Easy to add or remove storage, add new host and allocate it storage

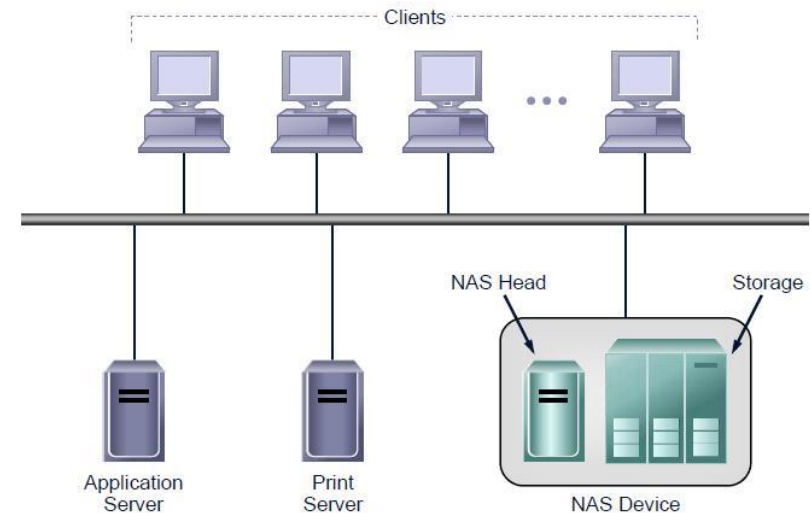


# Network-Attached Storage

- ❖ Network-attached storage (**NAS**) is storage made available over a network rather than over a local connection (such as a bus)
- ❖ Remotely attaching to file systems
- ❖ Implemented via remote procedure calls (RPCs) between host and storage over typically standard computer network protocols.



NAS is shared storage on a network infrastructure



# RAID Structure

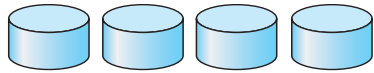
- ❖ RAID – redundant array of inexpensive disks
- ❖ Multiple disk drives provides reliability via **redundancy**
- ❖ Use of multiple disks working cooperatively
- ❖ Increases the **mean time to failure**
- ❖ Frequently combined with **NVRAM** to improve write performance
- ❖ Disk **striping** (**RAID 0**) uses a group of disks as one storage unit
- ❖ RAID is arranged into six different levels

# RAID Structure

- ❖ RAID schemes improve performance and improve the reliability of the storage system by storing redundant data
  - ❖ **Mirroring** or **shadowing** (**RAID 1**) keeps duplicate of each disk
  - ❖ Striped mirrors (**RAID 1+0**) or mirrored stripes (**RAID 0+1**) provides high performance and high reliability
  - ❖ **Block interleaved parity** (**RAID 4, 5, 6**) uses much less redundancy
- ❖ RAID within a storage array can still fail if the array fails, so automatic **replication** of the data between arrays is common
- ❖ Frequently, a small number of **hot-spare** disks are left unallocated, automatically replacing a failed disk and having data rebuilt onto them



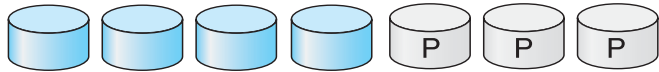
# RAID Levels



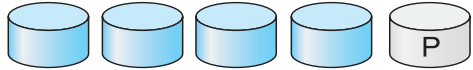
(a) RAID 0: non-redundant striping.



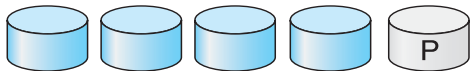
(b) RAID 1: mirrored disks.



(c) RAID 2: memory-style error-correcting codes.



(d) RAID 3: bit-interleaved parity.



(e) RAID 4: block-interleaved parity.

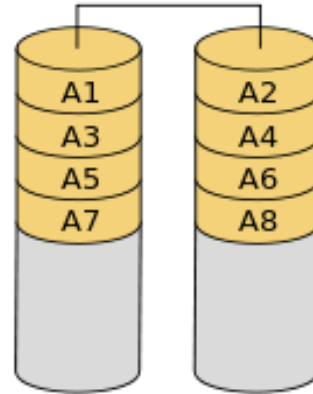


(f) RAID 5: block-interleaved distributed parity.



(g) RAID 6: P + Q redundancy.

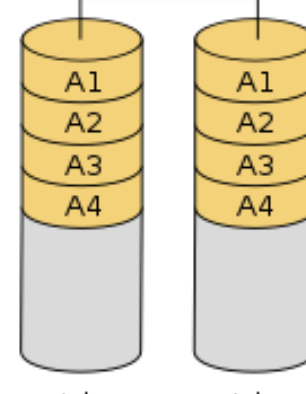
## RAID 0



Disk 0

Disk 1

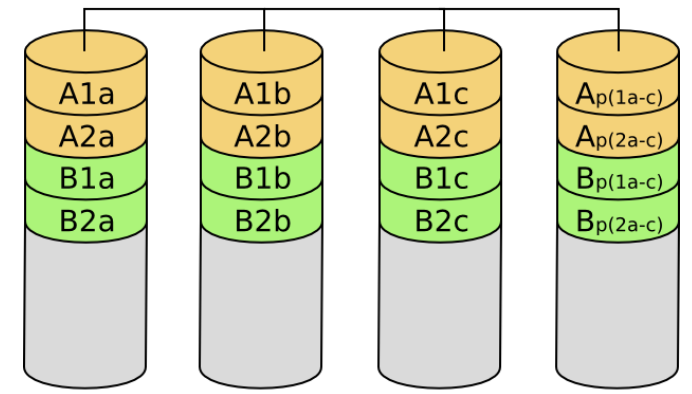
## RAID 1



Disk 0

Disk 1

## RAID 3



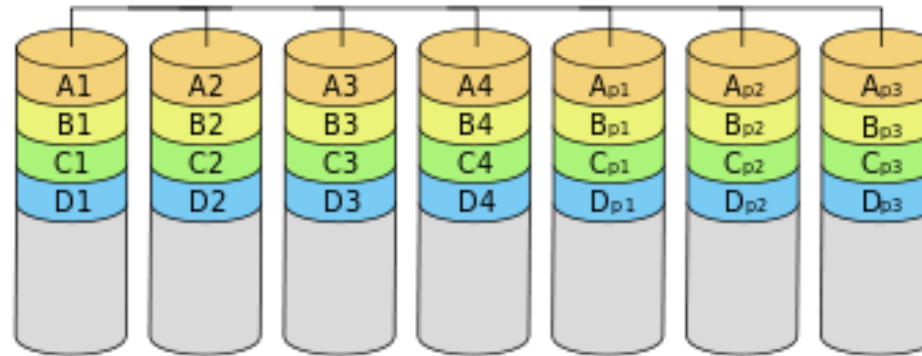
Disk 0

Disk 1

Disk 2

Disk 3

## RAID 2



Disk 0

Disk 1

Disk 2

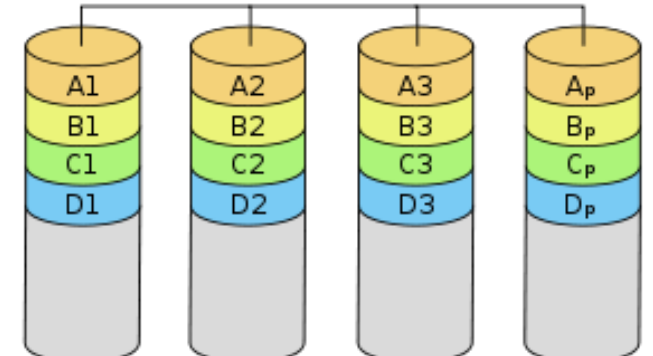
Disk 3

Disk 4

Disk 5

Disk 6

## RAID 4



Disk 0

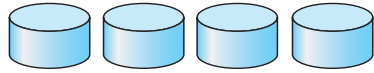
Disk 1

Disk 2

Disk 3



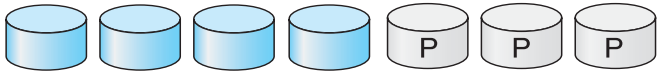
# RAID Levels



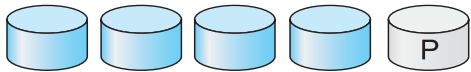
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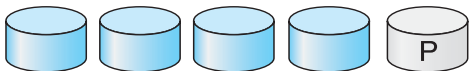
(b) RAID 1: mirrored disks.



(c) RAID 2: memory-style error-correcting codes.



(d) RAID 3: bit-interleaved parity.



(e) RAID 4: block-interleaved parity.

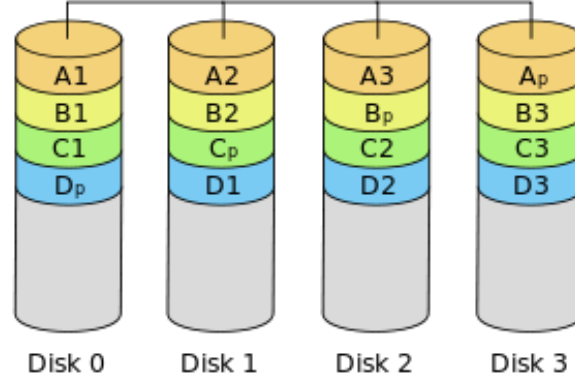


(f) RAID 5: block-interleaved distributed parity.

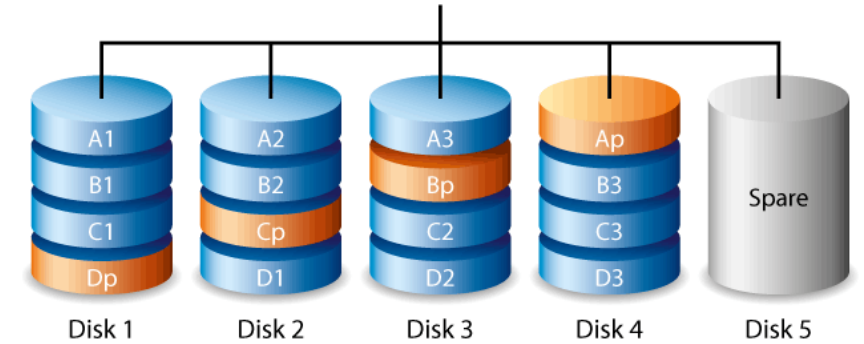


(g) RAID 6: P + Q redundancy.

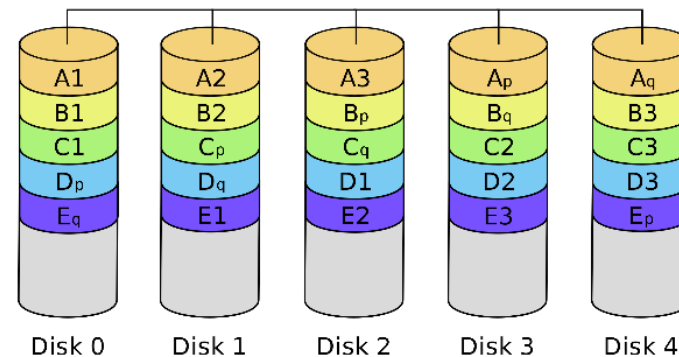
RAID 5



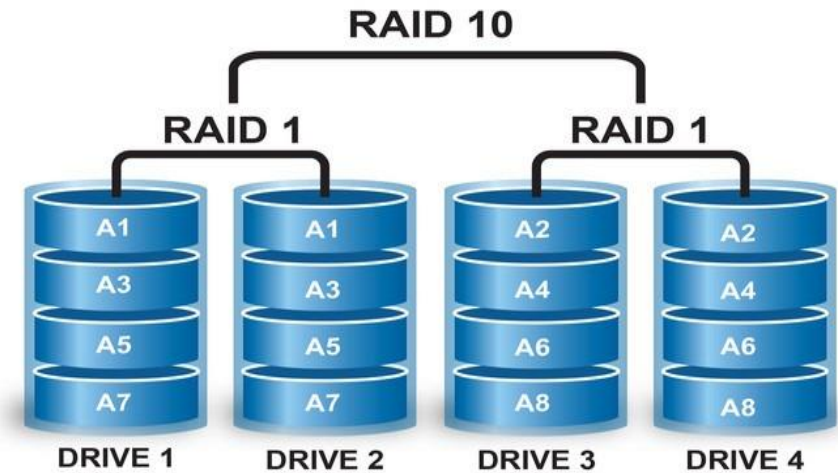
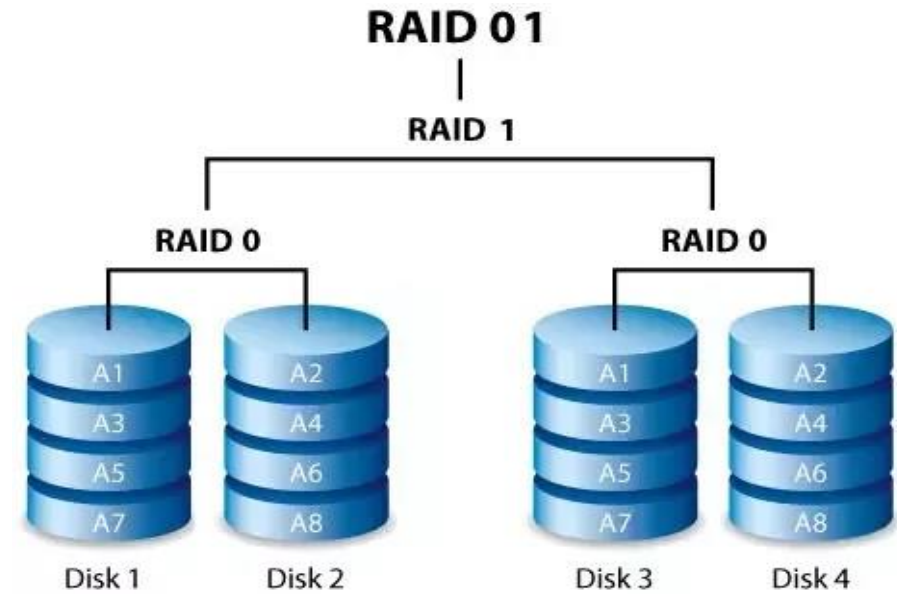
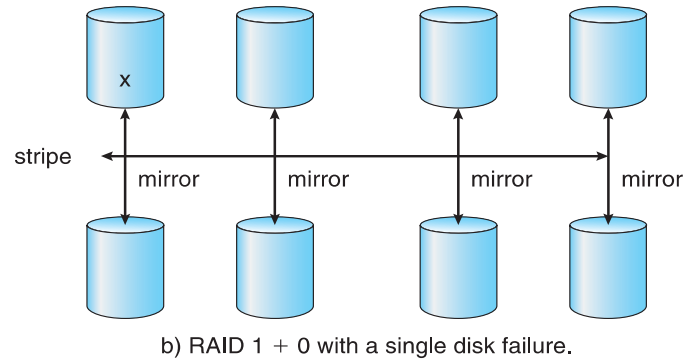
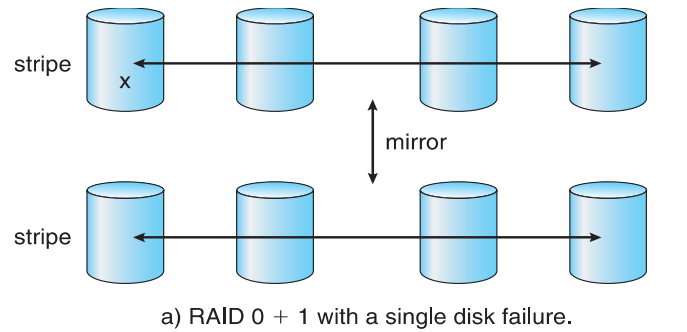
RAID 5+Spare



RAID 6



# RAID Levels





Thank You