CSE 421/521 - Operating Systems
Fall 2014

LECTURE - XX

MASS STORAGE & IO - II

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RAID Structure

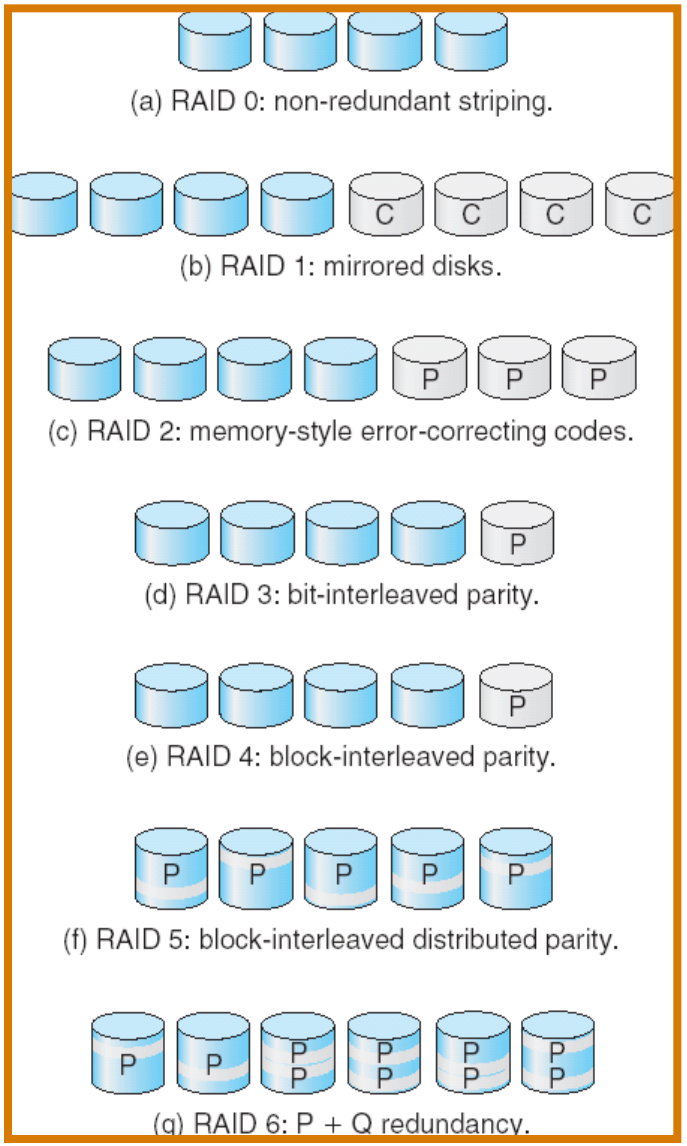
- As disks get cheaper, adding multiple disks to the same system provides increased storage space, as well as increased reliability and performance.

- **RAID: Redundant Array of Inexpensive Disks**
  - multiple disk drives provides **reliability** via **redundancy**.

- RAID is arranged into seven standard levels.
  - (RAID 0 -- 6)

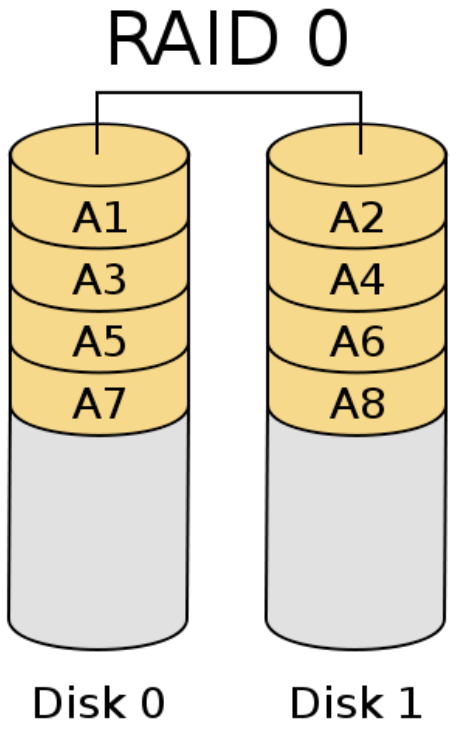
RAID (cont)

- RAID schemes improve performance and improve the reliability of the storage system by storing redundant data.
  - Data Striping: splitting each bit (or block) of a file across multiple disks.
  - *Mirroring (shadowing): duplicate each disk*
    - *Simplest but most expensive approach*
  - *Block interleaved parity* uses much less redundancy.



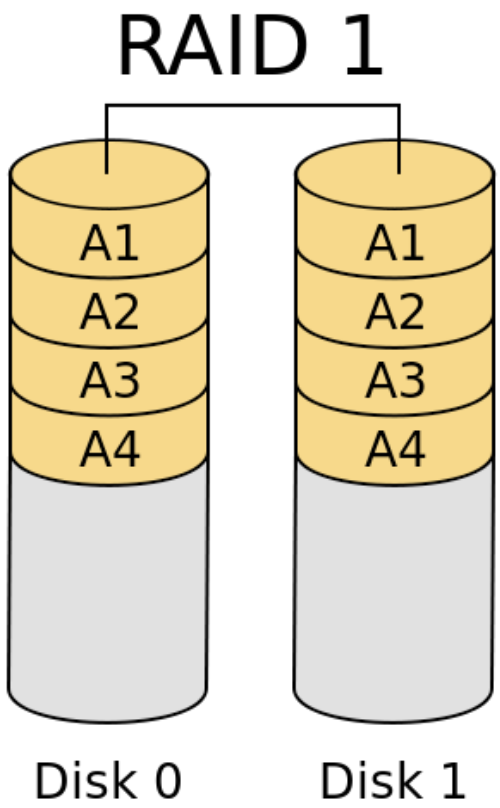
RAID Level 0

- Data is divided into blocks and is spread in a fixed order among all the disks in the array
- does not provide any fault tolerance
- also known as disk striping
- improves read and write performance via parallel access



RAID Level 1

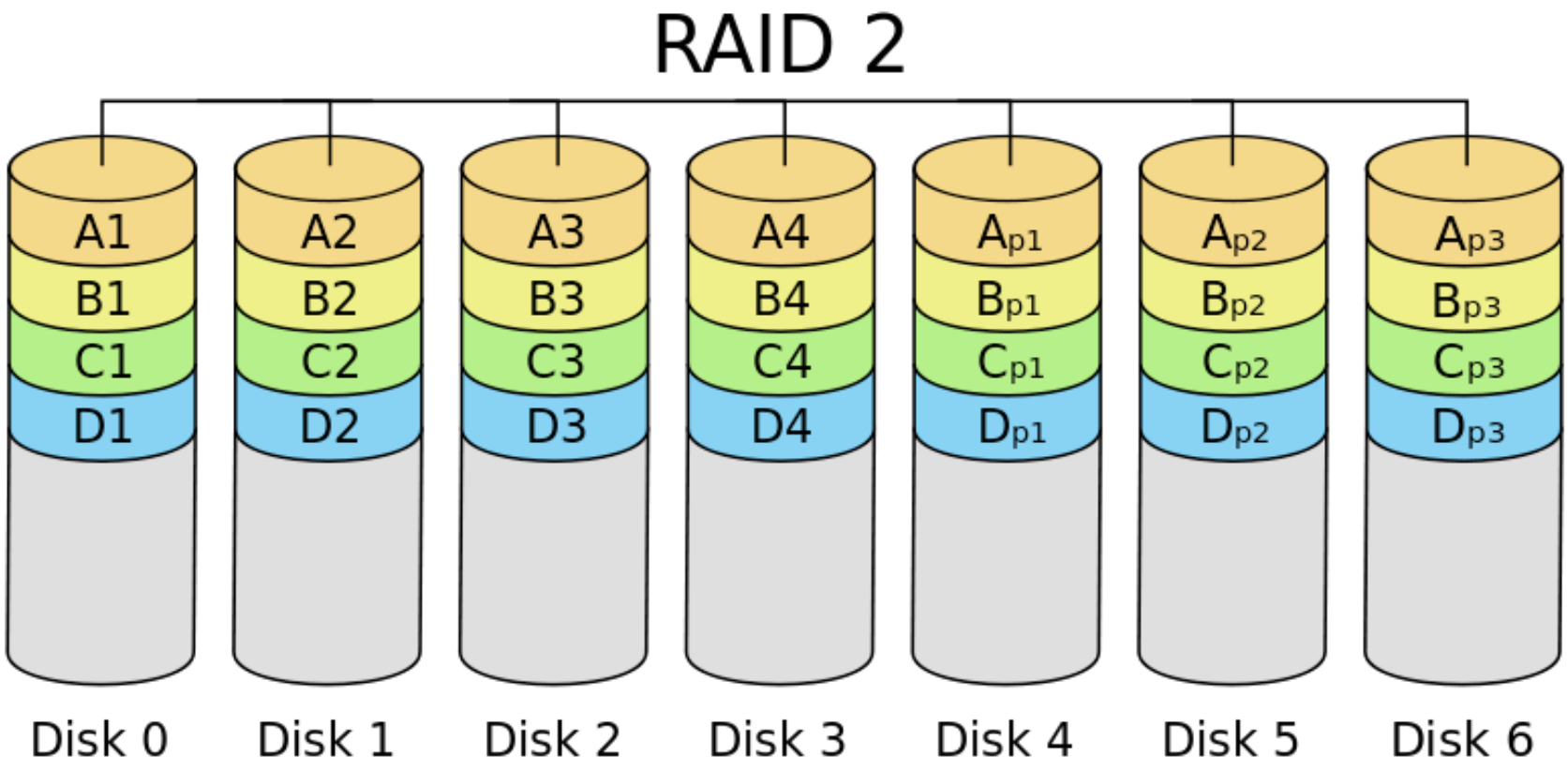
- All data written to the primary disk is written to the mirror disk
- provides a redundant, identical copy of all data
- provides fault tolerance
- also known as disk mirroring
- also generally improves read performance (but may degrade write performance).



RAID Level 2

- uses memory-style error correcting code (ECC) that employs disk-striping strategy that breaks a file into bits and spreads it across multiple disks
- The error-correction method requires three extra disks for four data disks
- provides fault tolerance (Hamming Code [7,3])
  - can both detect & recover from single bit failures
  - can detect but not correct double bit failures
- but is not as efficient as other RAID levels

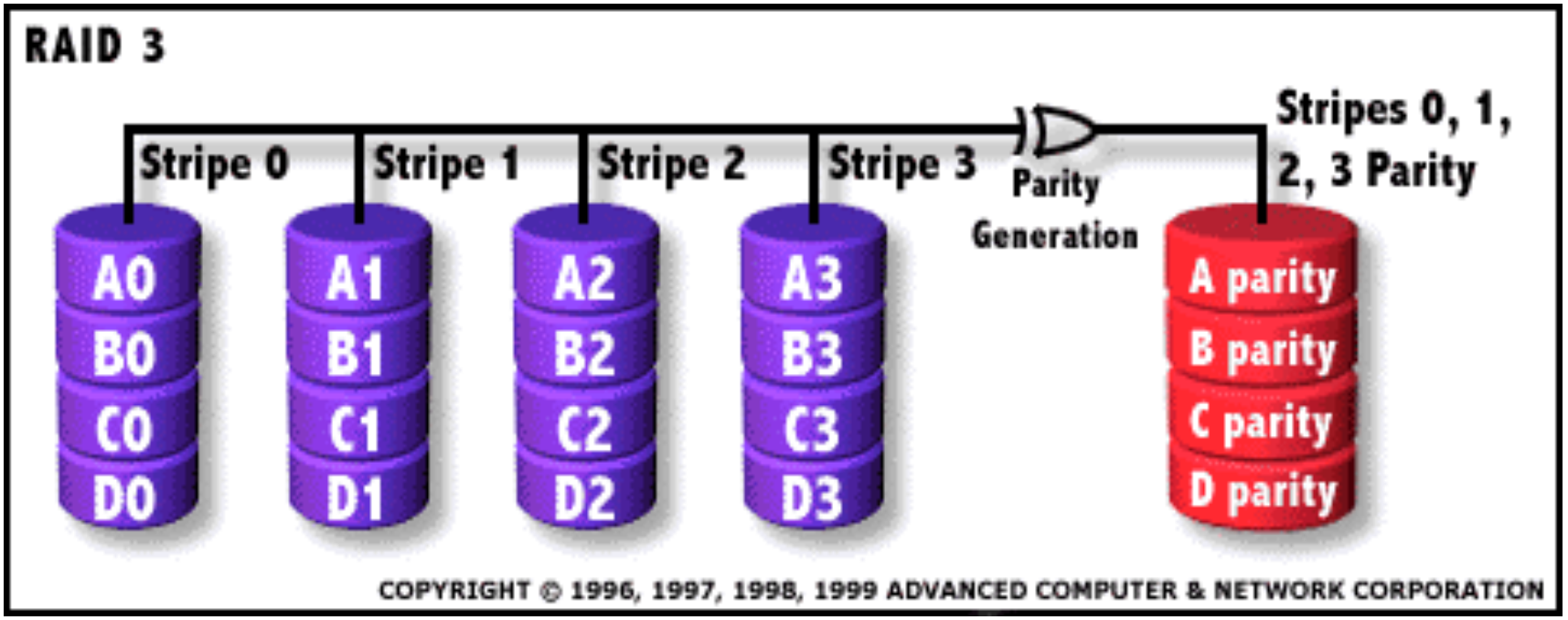
RAID Level 2 - bit level



RAID Level 3

- similar to RAID level 2, but it requires only one disk for parity for 4 data disks
- byte-level striping
- suffers from a write bottleneck, because all parity data is written to a single drive
- but provides some read and write performance improvement.
- RAID 2 & 3 cannot serve multiple requests simultaneously

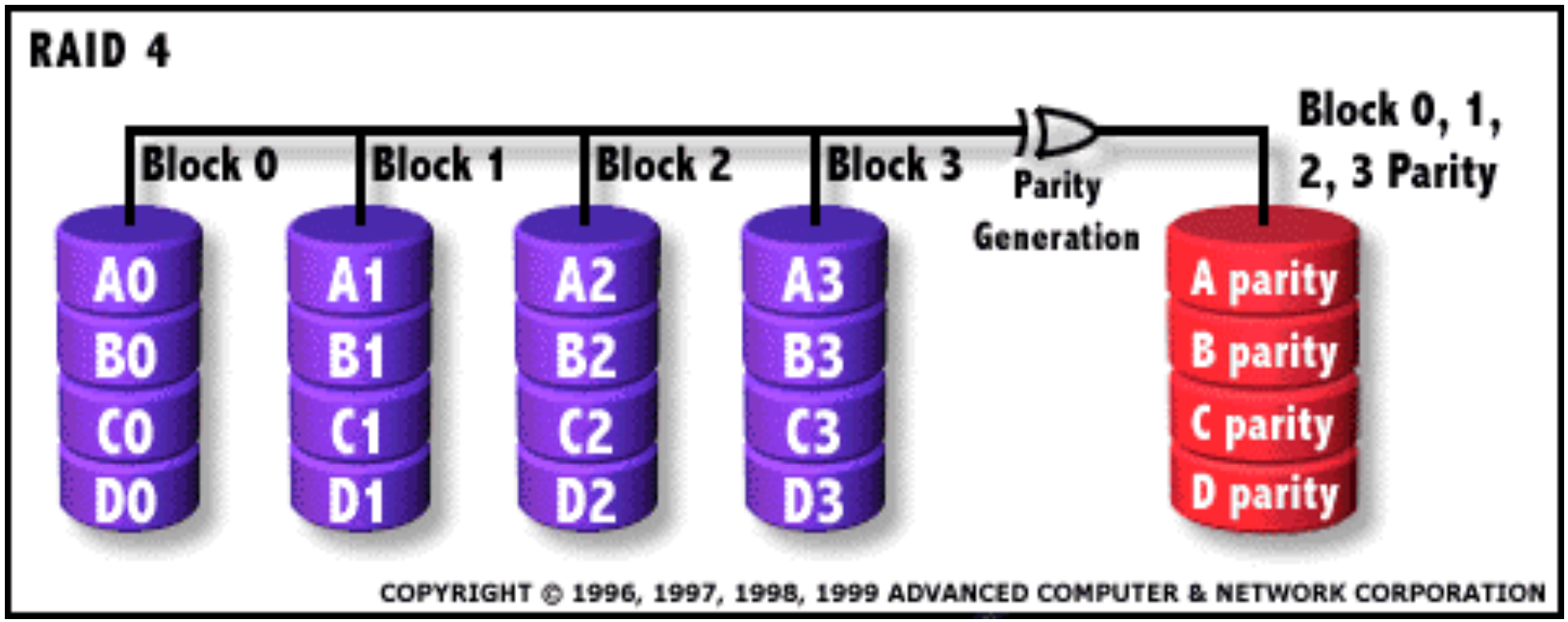
RAID Level 3 - byte level



RAID Level 4

- Similar to RAID level 3, but it employs striped data in much larger blocks or segments
- Not as efficient as RAID level 5, because (as in RAID level 3) all parity data is written to a single drive
- RAID level 4 suffers from a write bottleneck (due to parity disk) and is not generally used.

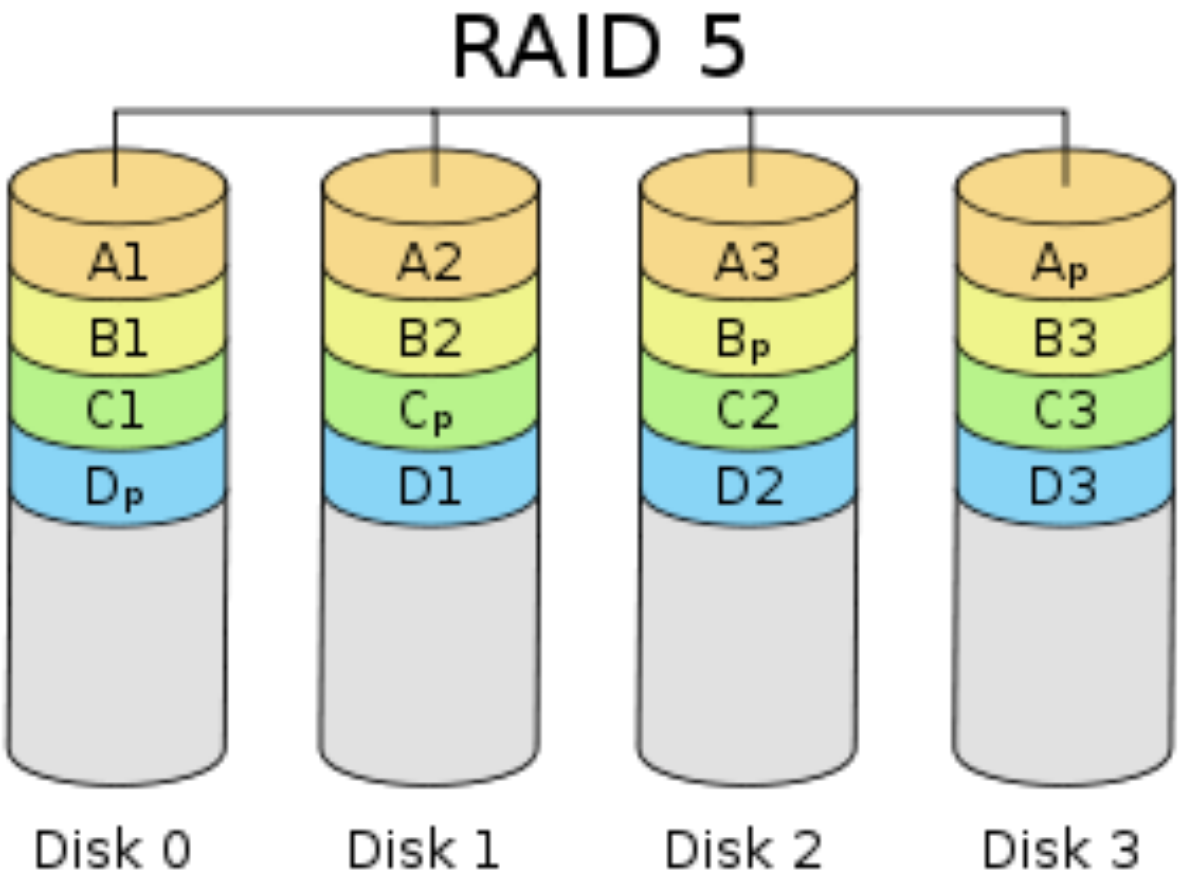
RAID Level 4 - block level



RAID Level 5

- known as striping with parity
- the most popular RAID level, replaced RAID 3 & 4
- similar to level 4 in that it stripes the data in large blocks across all the disks in the array
- It differs in that it writes the parity across all the disks
- The data redundancy is provided by the parity information
- The data and parity information are arranged on the disk array so that the two are always on different disks

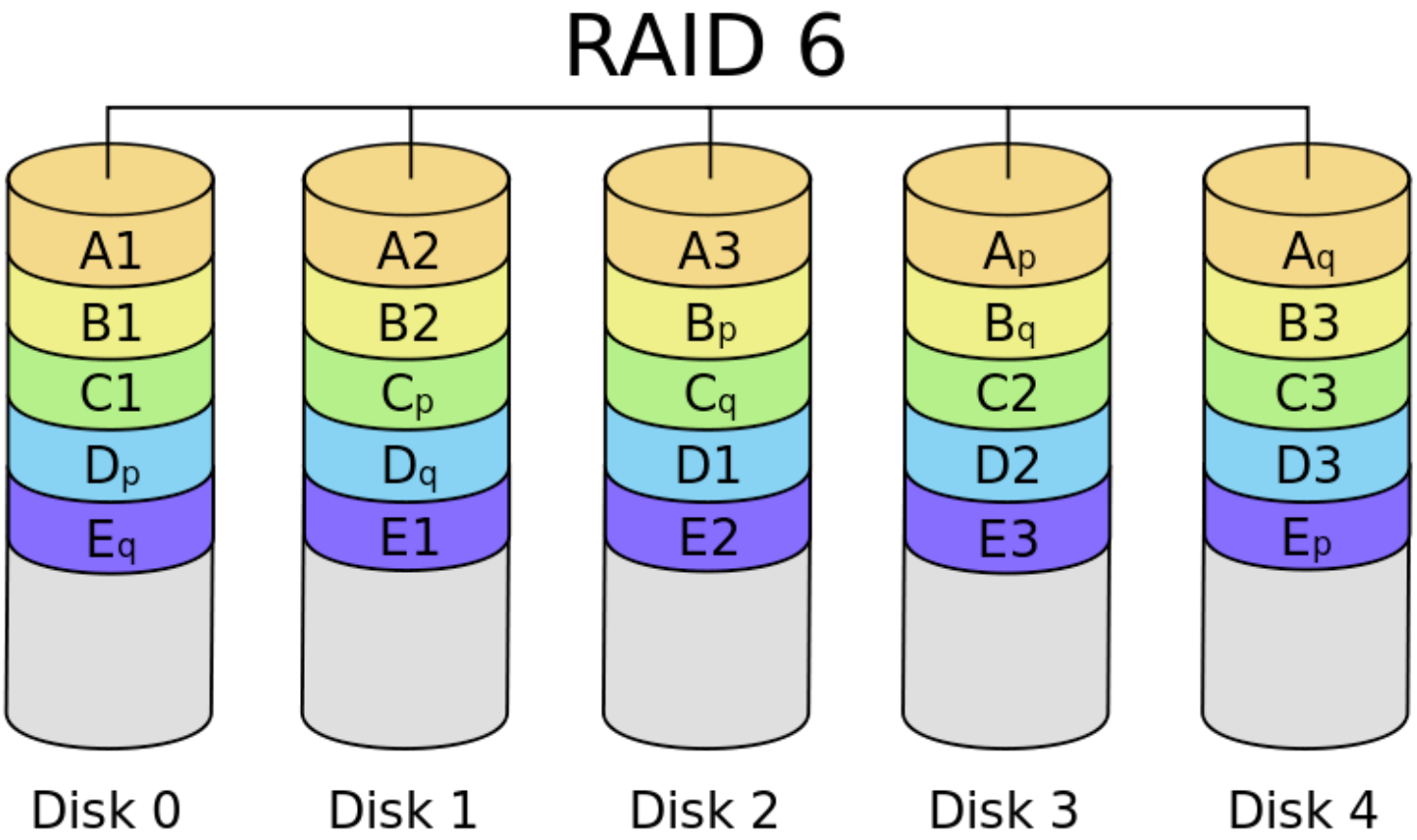
RAID Level 5


RAID 5
A1
B1
C1
Dp
A2
B2
Cp
D1
A3
Bp
C2
D2
Ap
B3
C3
D3
Disk 0
Disk 1
Disk 2
Disk 3

RAID Level 6

- stores extra redundant info to recover from multiple disk failures
- would need 2 additional disks for each 4 data disks
  - more reliability versus less data space
- uses Reed-Solomon error correcting code

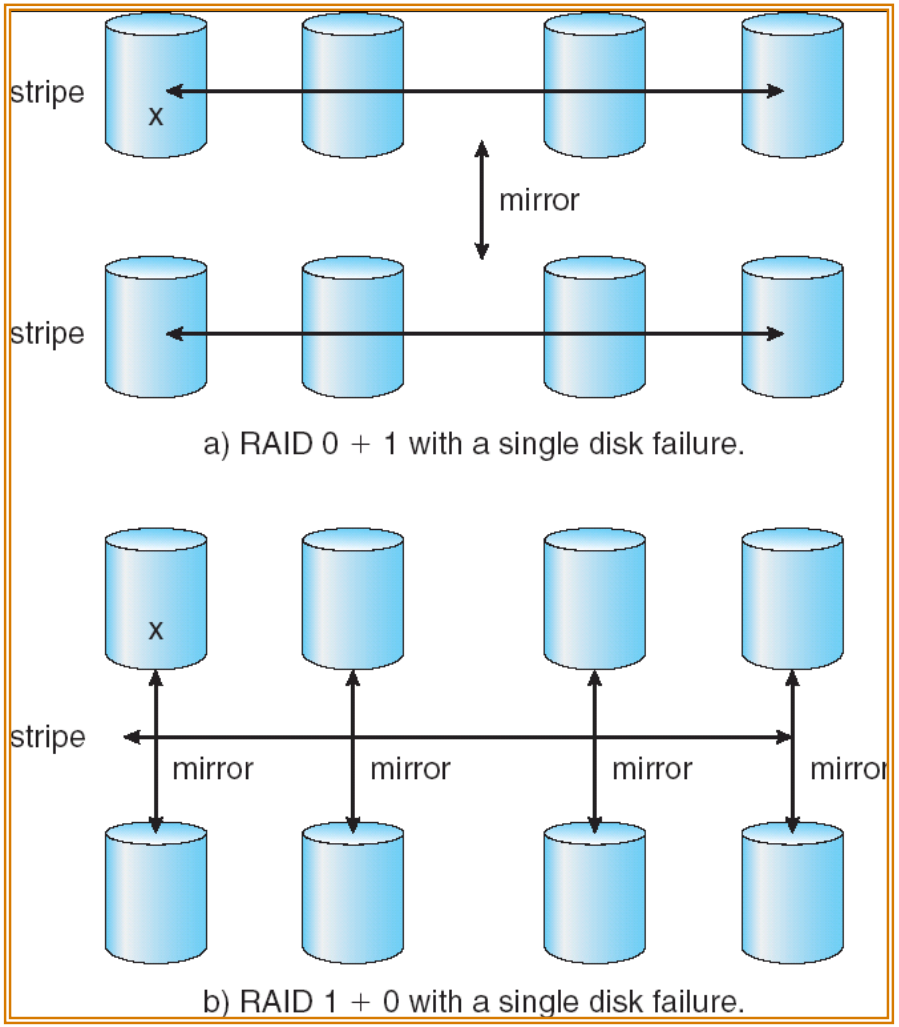
RAID Level 6


RAID 6
A1
B1
C1
Dp
Eq
A2
B2
Cp
Dq
E1
A3
Bp
Cq
D1
E2
Ap
Bq
C2
D2
E3
Aq
B3
C3
D3
Ep
Disk 0
Disk 1
Disk 2
Disk 3
Disk 4

RAID (0+1) and (1+0)

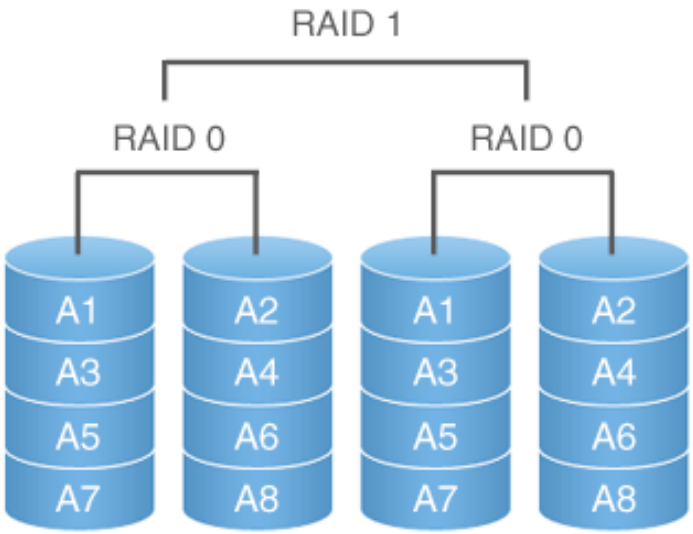
- Combination of RAID 0 & 1
- better performance & reliability, but doubles the disk storage requirement

RAID (0+1) and (1+0)

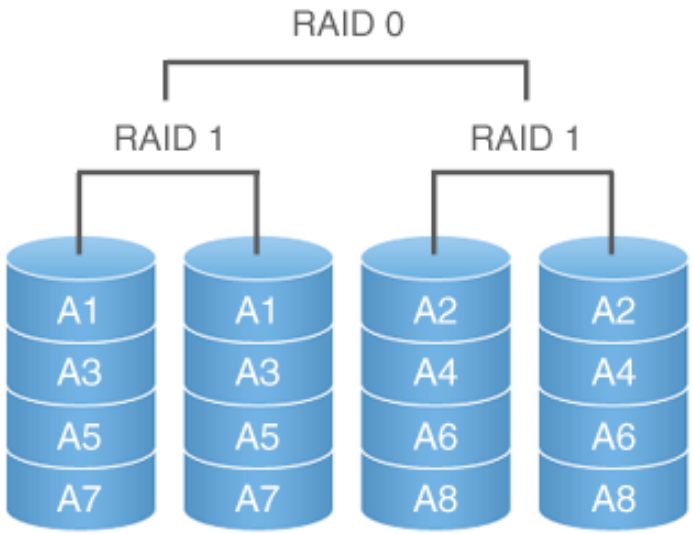


RAID (0+1) and (1+0)

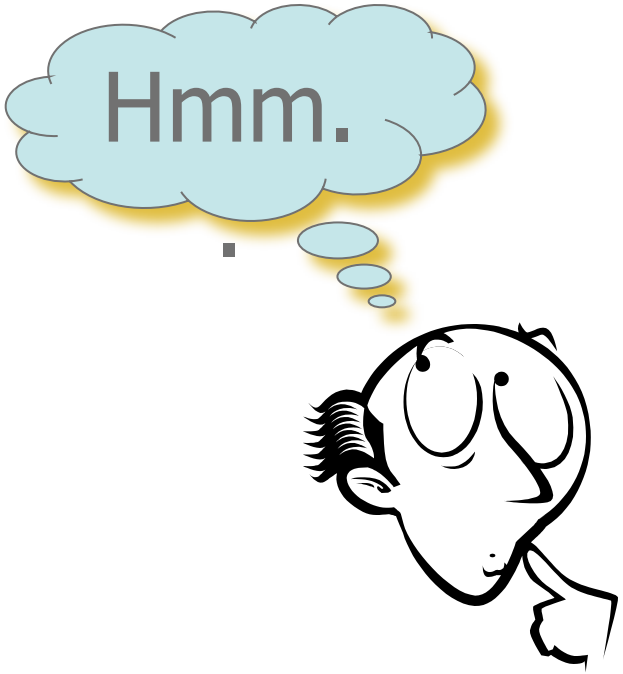
RAID 0+1



RAID 1+0



Any Questions?



Acknowledgements

- “Operating Systems Concepts” book and supplementary material by A. Silberschatz, P. Galvin and G. Gagne
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