RAID levels

• RAID – Redundant Array of Independent Disks
  • combines multiple drives into a single large storage

• Data distributed in one of the two ways
  • non-block – contiguously over array disks one by one
  • block – data is cut into the blocks, blocks are written to all the disks in pattern

• RAID Triangle
  • criteria – size, speed, and fault tolerance (F/T) – in vertices
  • RAID levels – on the sides
Non-block RAIDs

JBOD – Just a Bunch Of Disks (also called *span*)
- minimum two disks
- provides only capacity
- data is written to the first disk until it is full, then to the next disk

RAID 1 – also called *mirror*
- minimum two disks
- provides fault tolerance and faster reads
- two copies of data are stored on two disks
Block RAIDs

Block arrays can be
- non-redundant (RAID 0)
- redundant (RAID 10, RAID 5, RAID 6)

Redundancy can be provided by
- mirroring (writing multiple copies) – RAID 10, RAID 1E
- parity (storing computed extra blocks) – RAID 5, RAID 6

<table>
<thead>
<tr>
<th>Mirror technique</th>
<th>Parity technique</th>
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<tbody>
<tr>
<td>Disk 1</td>
<td>Disk 2</td>
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<td>1</td>
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RAID 0 – Non-redundant block array

Requirements
- at least two disks
- no CPU overhead

Redundancy
- none – any single drive failure destroys all data

Pros and cons
- Faster reads and writes
- No redundancy
Block, redundant RAIDs - mirroring

RAID 10 (also called RAID 01, 0+1, 1+0)
- minimum four disks
- faster reads and writes
- survives any single drive failure and some double failures

RAID 1E – similar to RAID 10 over odd number of disks
- at least three disks
- faster reads and writes
- survives any single drive failure and some double failures
- multiple variations of the layout
Block, redundant RAIDs – RAID 5

Standard single parity array
- minimum three disks
- faster reads, slower writes
- survives any single drive failure
- uses P-parity (XOR function)

Layout variations
- left and right parity ordering
- symmetric and asymmetric data ordering

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<th>Disk 3</th>
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<tr>
<td>1</td>
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Left asymmetric

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Left symmetric

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Right asymmetric

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Right symmetric
Block, redundant RAIDs – RAID 6

Double parity array
• minimum four disks
• faster reads, much slower writes
• survives any double drive failure
• uses P- and Q- parities (XOR and Reed-Solomon)

Layout variations
• left/right, symmetric/asymmetric same as RAID5
• Q- or P-parity on top in layout
• Calculation order: Q=Q(1, 2, P) or P=P(1, 2, Q)
• Wide pace (*Promise* controllers)
Block, redundant RAIDs – Exotics

Dedicated parity disk – RAID 4
- spare disk becomes a bottleneck

Hot spares
- regular – standalone hot spare drive
- RAID 5E – hot spare blocks at the end
- RAID 5EE – striped hot spare blocks

Delayed parity
- parity blocks larger than data blocks
- *HP SmartArray* controllers