WHAT IS RAID?

• Redundant Array of Independent Disks
  - storage technology that combines multiple disk drives into what a computer’s OS will recognize as one or more logical units

• Goals - Increased reliability, availability, performance, and capacity

• “RAID Levels”
BEFORE RAID

• 1956: International Business Machines Corporation (IBM) announces the RAMAC 305, the first hard disk system that holds 5MB of data

• 1961: Ampex develops helical scanning video recording which will later be adapted for high-capacity tape storage

• 1973: IBM’s hermetically sealed Winchester Hard Disks become the standard design for disc drives

• 1979: Seagate Technology begins producing hard disk drives for desktop computers

• 1986: Small Computer System Interface (SCSI) is standardized by the American National Standards Institute
RESEARCH AT UNIVERSITY OF CALIFORNIA, BERKELEY

• 1983: Randy H. Katz joins Berkeley Faculty – works with Michael Stonebreaker on Ingres Database Project
  • Upper limits of performance in database systems
  • Found bottleneck in writing transaction commit log
  • Needed greater I/O rates
• XPRS Project – how to support an extensible database system on a “shared disk” multiprocessor architecture
  • Katz, Stonebreaker, and David A. Patterson
• 1986: Katz purchases an Apple MacPlus, possibly the first PC with SCSI connector
• 1987: Katz and Patterson begin research of large-scale multidisk storage systems
  • Reliability – Garth Gibson (a graduate student) became expert on performance-reliability tradeoffs
THE BERKELEY RAIDERS

- Summer 1987: Patterson and Gibson attend disk technology course at Santa Clara University taught by Al Hoagland
  - Hoagland – California Digital Computer Project (1951) – worked with IBM to build RAMAC disk drive in 1956
- Fall 1987: Katz, Patterson, and Gibson begin developing taxonomy for RAID
  - Tandem Computers – influence for “RAID 1”
  - Thinking Machines – influence for ”RAID 2”
  - Maxstor and Micropolis – influence for “RAID 3”
  - IBM – influence for “RAID 4” and “RAID 5”
- November 1987: send *A Case for Redundant Array of Inexpensive Disks (RAID)* to reviewers including Hoagland
- The report goes viral within the storage industry – is officially published in May 1988
FIRST RAID PROTOTYPE
RAID 5 ACROSS 32 DRIVES
RAID 5 AND 6
STRIPING WITH PARITY

• Striping – dividing a body of data into blocks and spreading those blocks across multiple storage devices

• Parity - technique that checks whether data has been lost or written over when it is moved from one place in storage to another or when it is transmitted between computers

• Parity bit - sometimes referred to as a check bit, is used to identify whether the moved bits arrived successfully. Also used to rebuild data after a drive failure
STRIPING CONFIGURATION

• Bits – 0, 1
• Bytes - 01101000
• Blocks – “size on disk”
• Chunks – abstract; amount of data that an application processes from a disk at a time
• Block and Stripe size is determined by RAID Controller
PARITY – EXCLUSIVE/OR (XOR)

- A computer processing function that produces a parity bit based on the sequence of 1s and 0s
TRADEOFFS

• "Fast, cheap, good: choose two”
• Capacity
• Performance
• Cost
• Reliability (Fault Tolerance)
**Cinema Studies Archive**
- QNAP NAS
- RAID 6
- 6-Bay – 3 TB/drive
- HGST Drives
- Kathy thinks drives were installed in 2014
- Software is browser based

**IndieCollect**
- Synology Server
- RAID 6
- 12-Bay – 10 TB/drive
- 10 GB Ethernet connection
<table>
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<th>FEATURES</th>
<th>RAID 6</th>
<th>RAID 5</th>
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<tr>
<td>Diagram</td>
<td><img src="image1" alt="Diagram of RAID 6" /></td>
<td><img src="image2" alt="Diagram of RAID 5" /></td>
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<tr>
<td>Minimum # of Drives</td>
<td>Requires a minimum of four drives. Pn and Qn represent two sets of parity.</td>
<td>Requires a minimum of three drives. Pn represents one set of parity.</td>
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<td>Data Protection</td>
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<td>Read Performance</td>
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<td>Read Performance (Degraded)</td>
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<td>Write Performance (Degraded)</td>
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<td>Capacity Utilization</td>
<td>Low</td>
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<td>Typical Applications</td>
<td>50% - 88%</td>
<td>67% - 94%</td>
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<td>Data Archive, Backup to Disk, High Availability Solutions, Web Servers, Servers With Large Capacity Requirements</td>
<td>Data Warehousing, Web Serving, Archiving</td>
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RAID VS. OBJECT-BASED STORAGE
OBJECT-BASED STORAGE

- Data stored as individual object rather than in a hierarchical file system
- Each object is assigned a unique identifier
- No limit on type or amount of metadata
- Erasure Coding (Polynomial Oversampling)