Row-Diagonal Parity for Double Disk Failure Correction

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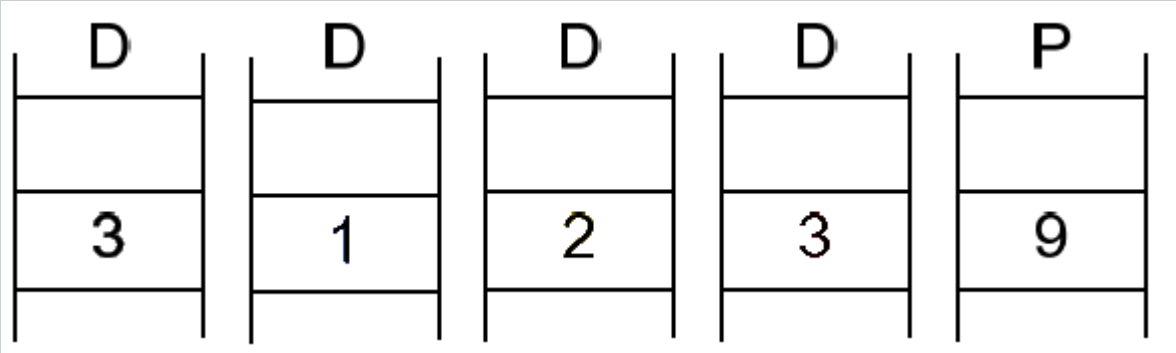
Background and Motivation

- Data is important
- Disks fail
  - Types of disk failures
    - Media
    - Full Disk
  - RAID
    - Parity
    - Example
  - Double failures?
    - Mirrored disks

Single Disk Failure Example



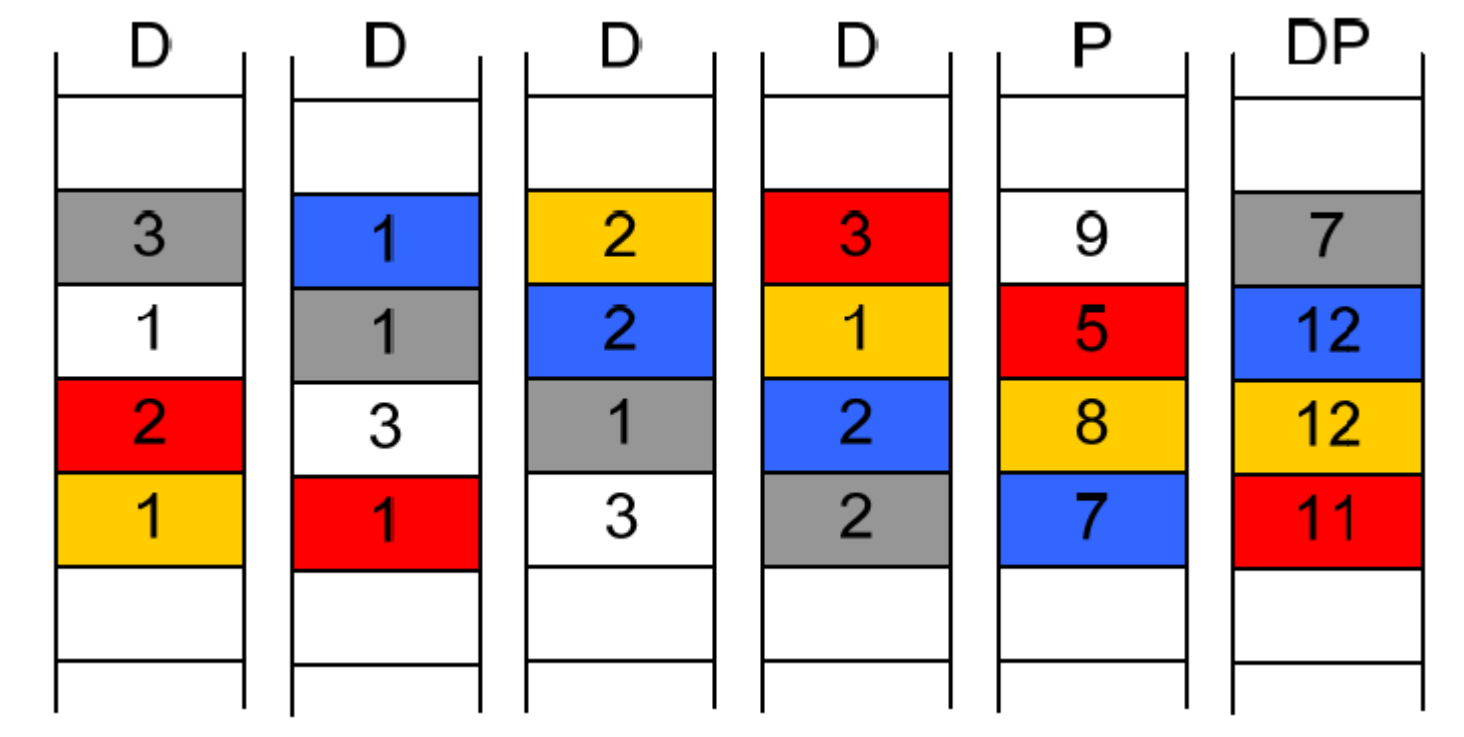
Algorithm

- Goal
  - Any 2 disks failing should still allow all data to be reconstructed
- Hardware Setup
  - 2 Parity Disks
  - Data disks
- Strategy
  - Row and diagonal parity for every block of data
  - Stagger parity
  - For single failure: Reconstruct disk from row parity

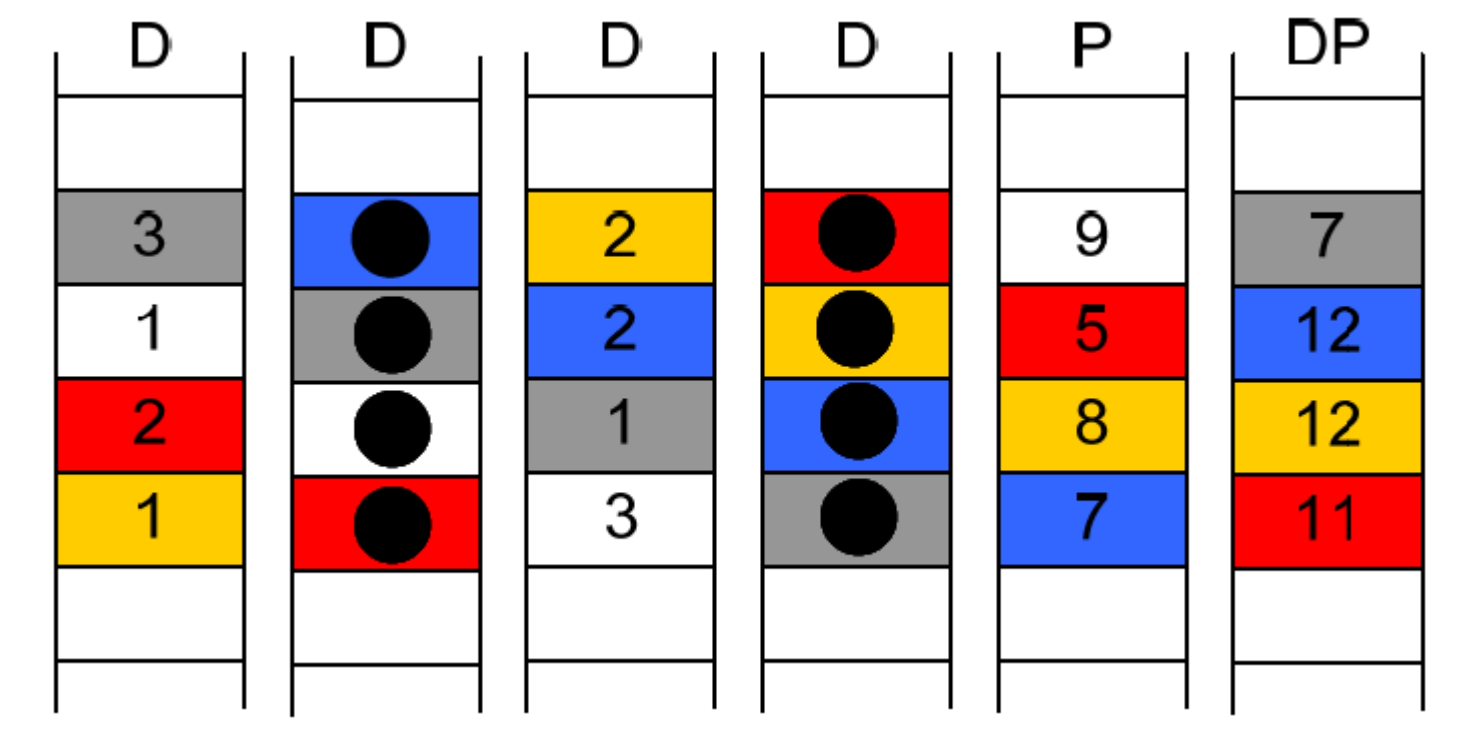
Algorithm

- Strategy (cont.)
  - 2nd failure during reconstruction
    - Row and diagonal parity are staggered in such a way that some data block will always have only 1 missing disk
    - Reconstruct whichever block you can using diagonal parity
    - Then reconstruct block using row parity
    - Can now reconstruct another block from diagonal parity, repeat
  - Example

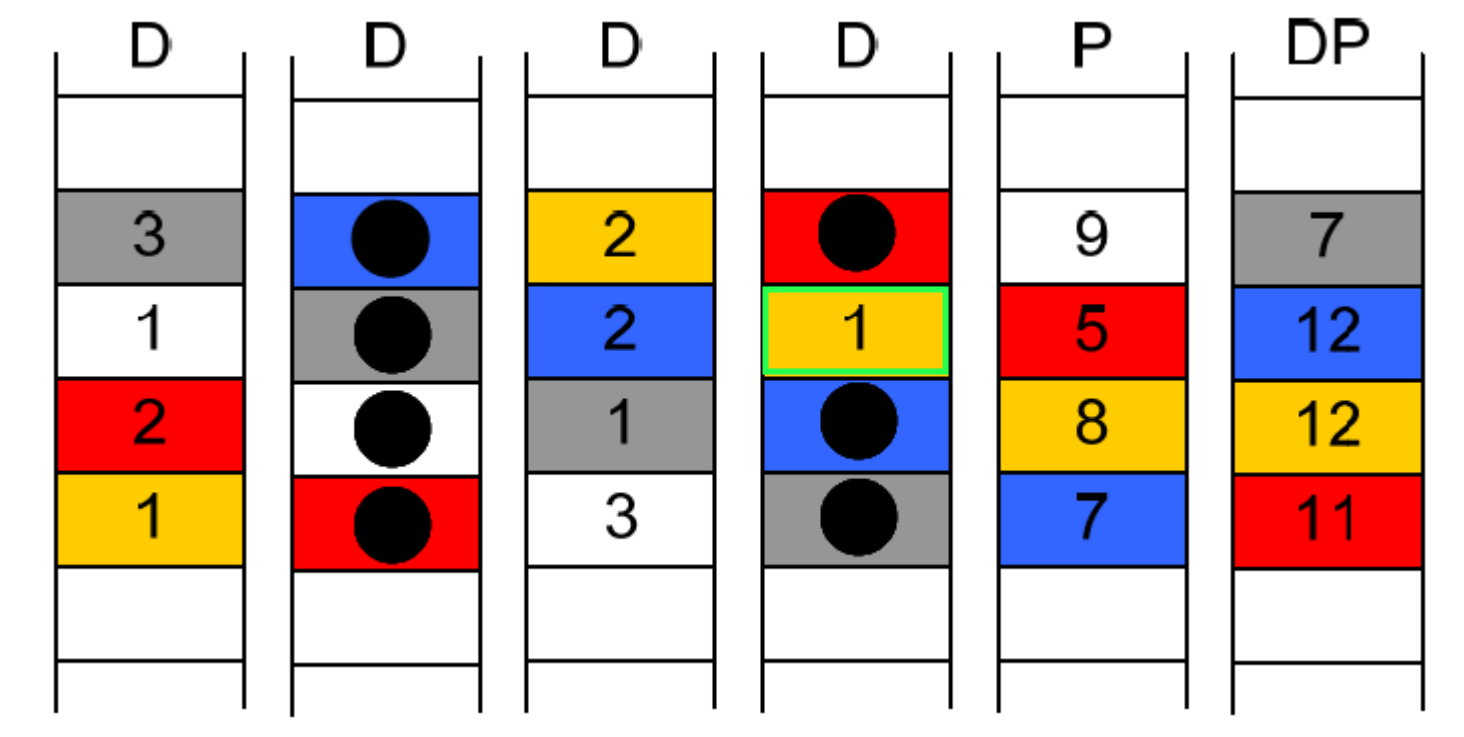
Double Disk Failure Example



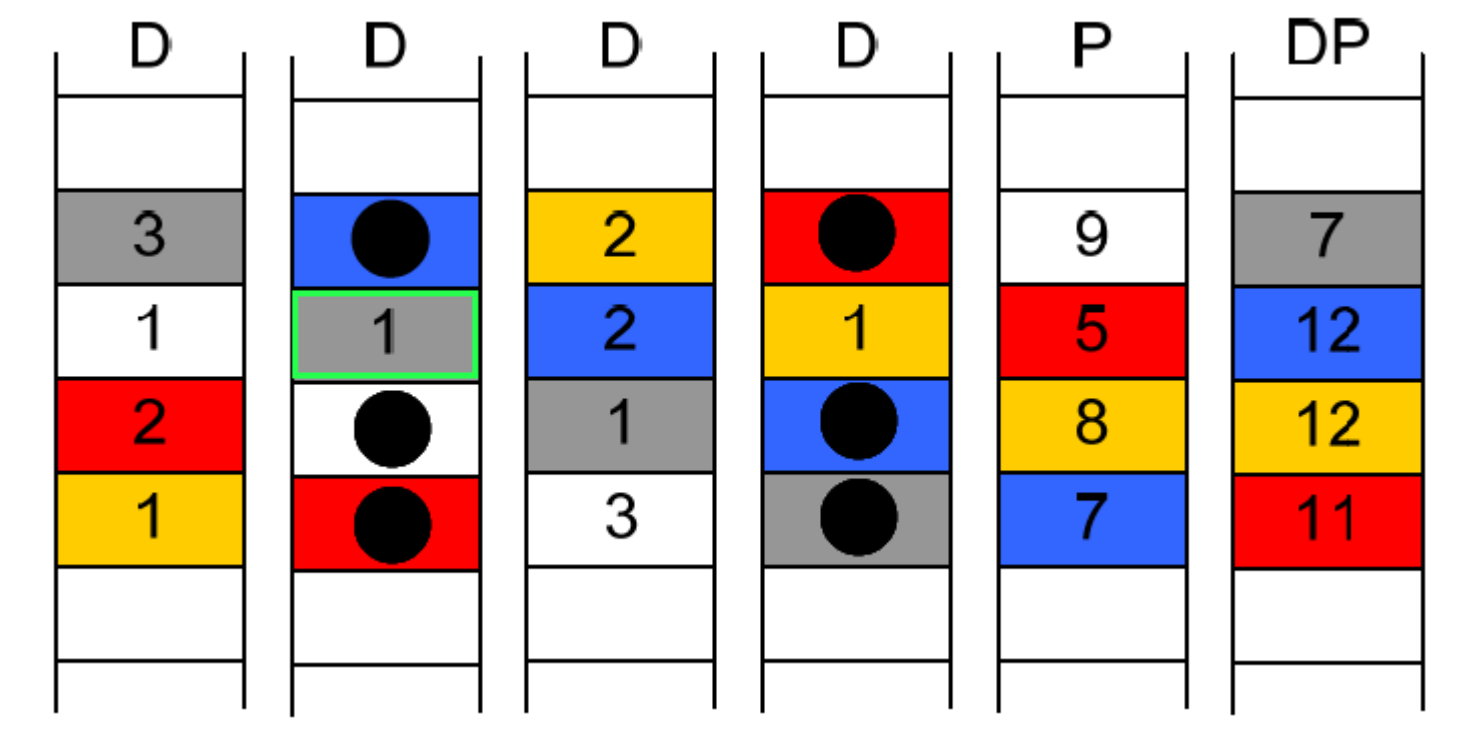
Double Disk Failure Example



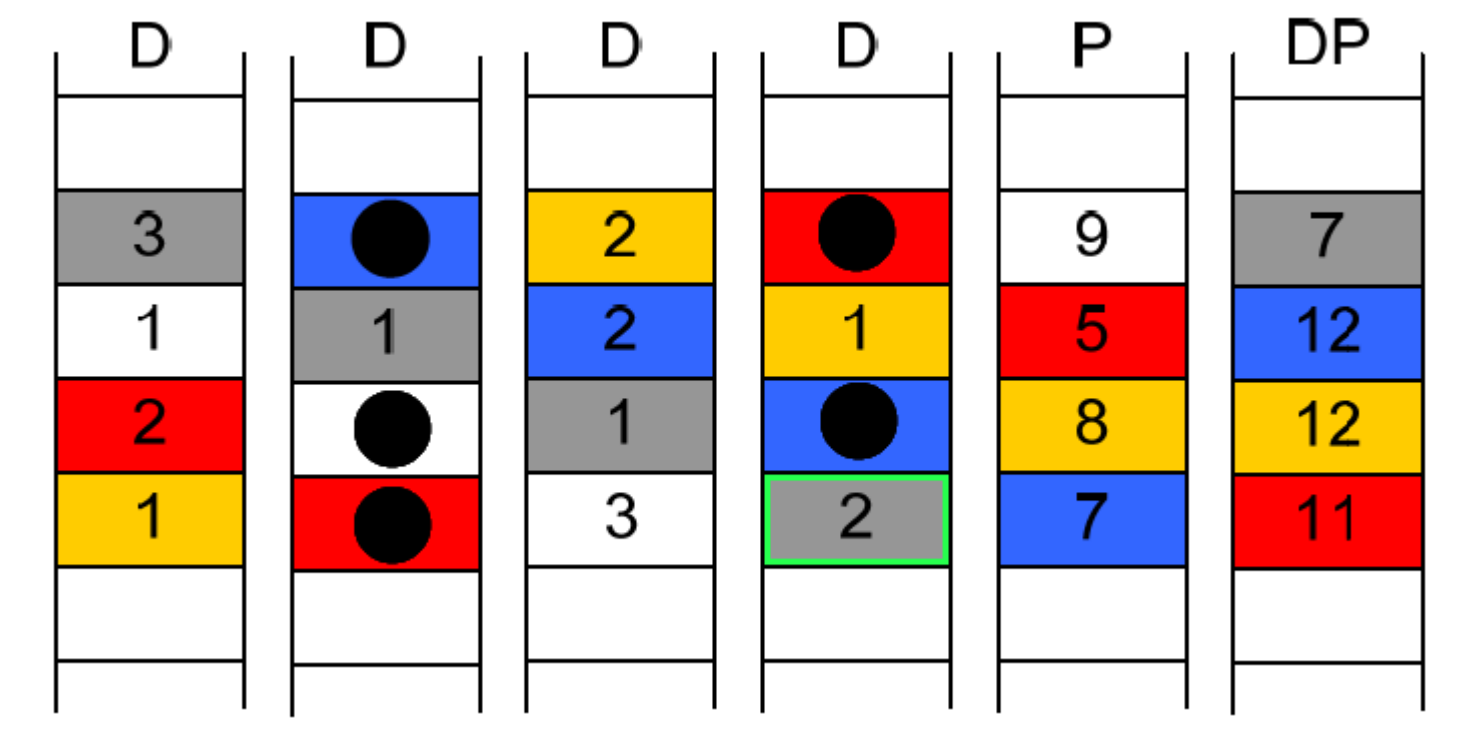
Double Disk Failure Example



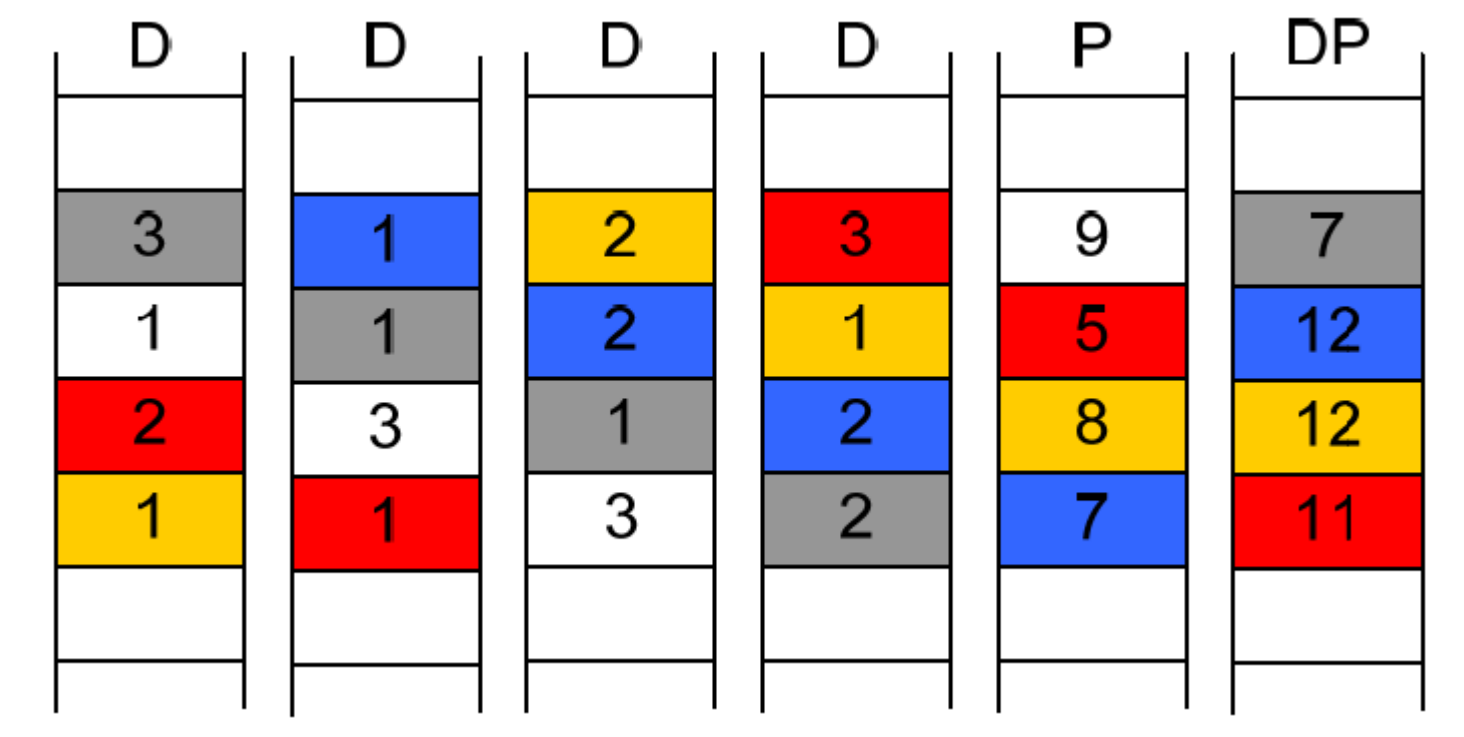
Double Disk Failure Example



Double Disk Failure Example



Double Disk Failure Example



Performance

- Theoretical
  - Read
    - Data stored in the clear
  - Write
    - Creating double parity cost = 2(p-1)(p-2) xors
    - Provably optimal when creating double disk failures
  - Reconstruction
    - Reconstruction from double parity cost = 2(p-1)(p-2) xors

Construction Per Row XOR Counts

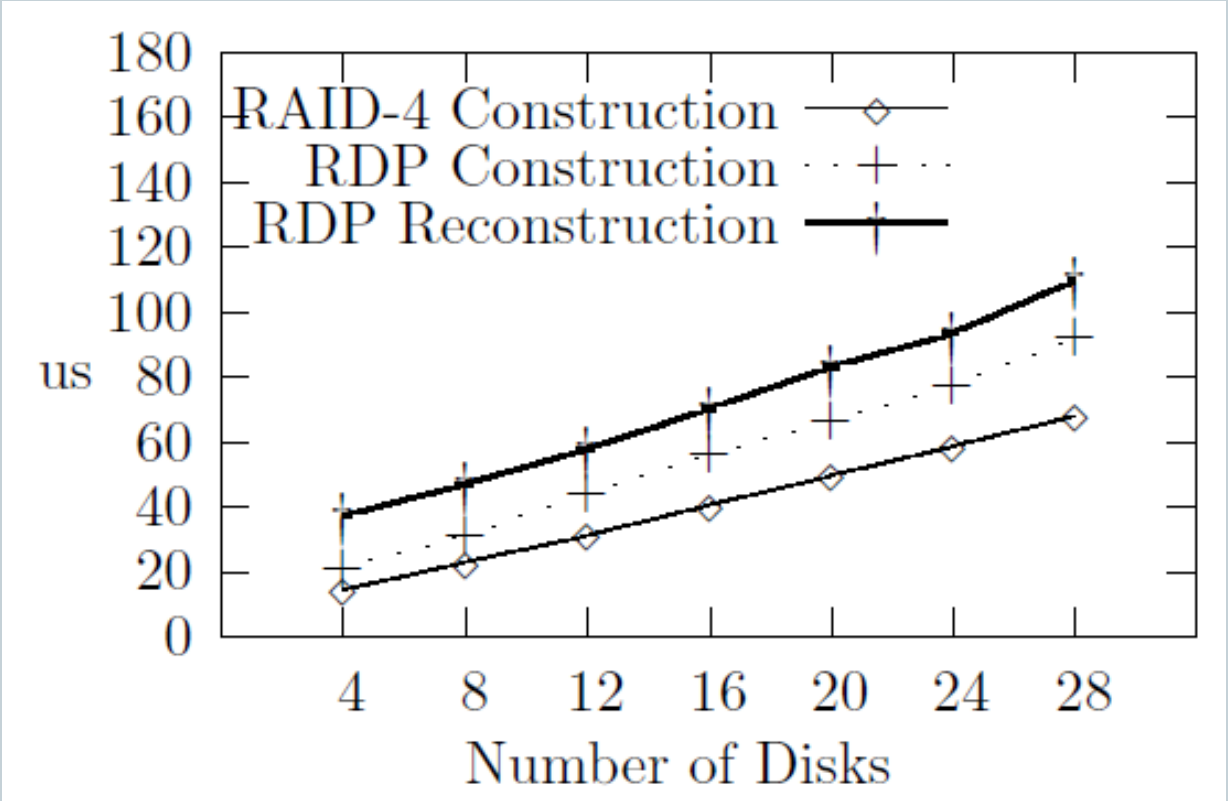
Data Disks	RDP	EVENODD	Difference
4	6	6.67	11.1%
6	10	10.8	8.0%
8	14	14.86	6.1%
12	22	22.91	4.1%
16	30	30.93	3.1%

Reconstruction Per Row XOR Counts

Data Disks	RDP	EVENODD	Difference
4	6	9.67	61.2%
6	10	13.80	38.0%
8	14	17.86	27.6%
12	22	25.91	17.8%
16	30	33.93	13.1%

Performance

- Implemented



Questions?

- References:
  - **RAID-DP: NETWORK APPLIANCE IMPLEMENTATION OF RAID DOUBLE PARITY FOR DATA PROTECTION A HIGH-SPEED IMPLEMENTATION OF RAID 6; Chris Lueth, Network Appliance, Inc. [12/2006]**