How LDPC Enables New NAND Flash for Enterprise SSDs

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- New NAND Flash Memory
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Enterprise SSD Requirements

Demanding list of requirements, makes it more challenging!
NAND Flash Proliferation

NAND Memories evolving
- Shrinking Geometry
- Scaling Capacity
- Increased ECC Requirements
New NAND Characteristics

Increased Error Rate

- 2D TLC
- 3D TLC
- 3D MLC
- 2D MLC

Decreased P/E Cycles

RBER versus PE Cycle for a 2x nm NAND Flash Device

- 10th Percentile
- 90th Percentile
- Average
Contending ECC Algorithms

LDPC performs slightly better in Hard Decode, but it really shines more in Soft Decode.

BCH vs LDPC (Hard)

Frame Error Rate

1.00E-01
1.00E-03
1.00E-05
1.00E-07
1.00E-09
1.00E-11

1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3

Raw BER x1e-3

BCH
LDPC

RBER vs PE Cycle for Current Generation NAND Flash

10^1
10^2
10^3
10^4
10^5

LDPC
BCH

0 0.5 1 1.5 2 2.5 3

PE Cycle

x 10^4

0 1 1.5 2 2.5 3

Average RBER per Page
The BCH probability of false decode is bounded to $1/T!$\(^1\).

So for BCH:

- $P(\text{False}) = P(\text{Uncorrectable})/T!$
- $\sim 1e^{-176}$.
- So $P(\text{False})$ for BCH is astronomically low.


BCH codes can be mathematically proven to not have an error floor (distance spectrum).
• Industry standard UBER is $1e^{-23}$ or better.
• LDPC has very strong ECC but does suffer from hard-to-predict error floors.
• With additional CRC protection, it can be extended further
• $P(\text{False}) \leq P(\text{LDPC False}) \times P(\text{CRC False})$.
• $P(\text{False}) \leq 1e^{-25}$. 
Why LDPC is better suited for Enterprise SSDs

- Hard Decode & Soft Decode
- Adaptive Code Rate
- LDPC + CRC + RAID increases error tolerance
- Allow the software to perform intelligent operations

LDPC in a Software Defined Flash Controller is the key to the success!!
Summary

- Enterprise SSD requirements keep growing
- Next Generation NAND Flash Memory continue to evolve
- LDPC is better equipped to combat the challenges of new NAND types
- Combination of LDPC, CRC, RAID and Software is required to meet the Enterprise SSD needs
Q & A
Thanks!