Using LDPC Codes in SSD
--- Challenges and Solutions

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Introduction and Motivation

Cheaper flash

Floating-Gate Transistor

20nm

Floating-Gate Transistor

Less and less reliable

More and more powerful

System & Controller

Stronger Error Correction Codes
Introduction and Motivation

LDPC codes for SSD

Hard disk drive
LDPC for SSDs: Challenges

- Error floor of LDPC codes
- Memory read latency overhead
- Low-cost, high-speed LDPC decoder implementation
Error Floor of LDPC Codes

- Nature of iterative codes
- Impossible to eliminate error floor 😞
- Sufficient coding gain in practically interested frame error rate region

→ Estimate LDPC code error floor

→ Construct LDPC code with sufficiently low error floor
Solutions

❖ General-purpose Parallel Computing Facility

❖ A software tool set for LDPC code error floor estimation

❖ Fully tested by running on 8192 cores in a super computer cluster

❖ Many algorithms/techniques to improve both accuracy and speed

❖ Estimate the error floor of a 16k-bit LDPC code in just one day

A tool set to construct LDPC codes with low error floor
Verification

Rate-0.625, 2400-bit
Performance of Our LDPC Codes (1)
Performance of Our LDPC Codes (2)
Performance of Our LDPC Codes (3)
LDPC for SSDs: Challenges

- Estimation of LDPC code error floor
  - SOLVED

- Construction of low-error-floor LDPC codes
  - SOLVED

? Memory read latency overhead
Memory Read Latency

- Longer memory sensing latency
- Longer data transfer latency
- Longer NAND flash memory read latency

Controller

LDPC Code

NAND Flash

NAND Flash

NAND Flash
Progressive Soft-Decision Memory Sensing

- Hard-decision memory sensing
  - LDPC code decoding
    - Yes: Success
      - Yes: Increase the success rate
      - No: No
    - No: No
  - No: No
  - No: Failure
    - Yes: Success
    - No: Higher precision memory sensing

A set of cross-layer design solutions

Reduce data transfer latency

Flash-to-controller data transfer
Reduce Read Latency Overhead

- Non-uniform quantization memory sensing

![Diagram showing reducing read latency overhead through non-uniform quantization memory sensing.](image)
Non-uniform quantization memory sensing

Memory cell threshold distribution

Reduce Flash-Controller Data Transfer Latency
One Step Further

Progressive soft-decision sensing

1st step: 4-level hard-decision sensing

2nd step: 7-level soft-decision sensing

1st step sensing results

Reduce 2nd step sensing result coding overhead
Zoned Entropy Coding

Progressive soft-decision sensing ➞ zoned entropy coding

Four entropy coding zones

Threshold voltage
Probabilities and codewords of 2nd-step soft-decision sensing results.

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<th>Entropy coding</th>
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20.4% reduction of transfer latency
64.8% reduction of transfer latency
LDPC for SSDs: Challenges & Solutions

Error floor of LDPC codes

- A tool set for LDPC code error floor estimation
- A tool set for low-error-floor LDPC code construction

Memory read latency overhead

- A set of cross-layer design solutions to
  1. Increase decoding success rate at lower sensing precision
  2. Reduce soft-sensing data transfer latency