Neighbor-cell Assisted Error Correction for MLC NAND Flash Memories

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Motivation & Background

Measurement and Analysis

1. Optimum read reference voltage at cross point of neighbor states
2. Minimum BER can be achieved with optimum reading
3. Conditional distribution has similar distance but smaller variance than overall reading
4. Read with conditional distribution achieves smaller minimum raw BER than read with overall distribution

Distribution distance
\[ E(Y^{(N_i)}) - E(Y^{(N)}) = \frac{1}{N} \sum_i (E(Y_{N_i}) - E(Y_{N})) \]

Distribution variance
\[ \text{Var}(X) = \frac{1}{N} \sum \text{Var}(x_i) + \frac{1}{N} \sum \left( \sum (x_i - E(x)) \right)^2 \]

Flow of NAC

NAC inside SSD

ECC Correct

NAND DATA OUT

READ REQUEST

Micro-Processor

SSD Management

Host Interface

Buffer

NAC Buffer

Flash Interface

ECC (e.g., BCH)

Neighbor Assisted Correction Engine

NAND Flash Interface

NAC Microarchitecture

Page-to-be-Corrected Buffer

Pass Circuit Vector

Local-Optimum-Read Buffer

Comparator Vector

Neighbor LSB Page Buffer

Neighbor MSB Page Buffer

Key Results: Lifetime extension and performance evaluation

Lifetime extension: up to 39%
ECC relaxation: reduce cost by 40%

Within nominal lifetime: No performance degradation
Extended lifetime: Less than 5% performance overhead