Generalized Concatenated Codes for Flash Memories

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Outline

- Standard ECC Options for Flash
  - BCH
  - LDPC

- Generalized Concatenated (GC) Codes
  - Introduction
  - GC codes based on LDPC for Flash
  - Simulation results

- Summary
Storage Technology is Improving

- New types of storage media:
  - 3D NAND, RRAM, MRAM, PCM, ...
More complicated storage media requires a more sophisticated coding

- Hamming codes
- BCH codes
- LDPC codes
- Polar codes
- Non-binary LDPC
- Soft-decision BCH
- ???

Old flash controllers | Industry standard | State of the art | Future controllers
BCH Codes

- Introduced more than 50 years ago
- Very well studied
  - Analytically predictable performance
  - Efficient algebraic encoder/decoder
- Wide range of rates and code word lengths
- Guaranteed error correction capability
LDPC Codes

- Almost the same age as BCH
- Gained a significant attention only recently
- Efficient soft-decision decoding
- Small guaranteed error correction capability
## BCH vs LDPC for Flash

<table>
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<tr>
<th>Pros:</th>
<th>Pros:</th>
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<tr>
<td>• Easy to support a wide range of rates &amp; length (no ROM)</td>
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<tr>
<td>• Beat high rate LDPC in the error floor region for BSC</td>
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<tr>
<td>• Large family of codes (need to find the good ones)</td>
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<td>• Excellent waterfall performance</td>
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<table>
<thead>
<tr>
<th>Cons:</th>
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<tr>
<td>• Hard-decisions</td>
<td></td>
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<tr>
<td>• Waterfall performance</td>
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<td>• Error floors</td>
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<td>• Large memory</td>
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Generalized Concatenated Codes

- Concatenated codes (Forney, 1966)
- Generalized concatenated (GC) codes (Blokh and Zyablov, 1974)
- Error location (EL) codes (Wolf, 1965)
- Generalized error location (GEL) codes (Zyablov, 1972)
LDPC-based GC codes

Erasure code

Codeword 1

Codeword n
Simulation Results (2x2K GCC)
Simulation Results (2x2K GCC)
Summary

- New GC code based on LDPC
- Better UBER with the same complexity
- Better error-floor
- Soft sensing support
Thank you!