Update on Non-Binary LDPC Codes for NGU

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Codes For Next-Generation Up-Link Overview

- At the Fall Meeting 2011, DLR and UniBo presented results for a class of non-binary turbo/LDPC codes which significantly outperform binary turbo/LDPC codes in the short/moderate block length regime

- Example: (128,64) LDPC code
  - 16 variable nodes
  - 8 check nodes
  - Field order q=256
  - Decoding with fast Hadamard transform

![Graph showing CER vs. Eb/N0 for different codes and bounds with a 1 dB gain marked.]
Codes For Next-Generation Up-Link Overview

- In de Cola, Paolini, Liva, G. Calzolari, “Reliability Options for Data Communications in the Future Deep-Space Missions,” Proceedings of the IEEE, Nov. 2011, the performance of a eBCH with ordered statistics decoding (OSD) has been shown.

- Despite its excellent performance, the eBCH code was discarded due to

  - The high OSD complexity (which does not scale favourably at larger block lengths, e.g. 256 and 512 bits)

  - The lack of error detection capability
Codes For Next-Generation Up-Link Overview

- The performance of the non-binary code has been confirmed down to very low error rates

- No undetected errors have been recorded during the simulation

- A very low number of iterations (e.g., 1) is required at $Eb/N0>4$ dB
On the Decoding Complexity

- In the past few years, an increasing number of near-optimum low-complexity decoding algorithms for non-binary LDPC codes have been proposed.

- The most powerful low-complexity decoders are based on the Extended Min-Sum (EMS) and have only 0.05 dB to 0.15 dB loss in the waterfall compared to Belief Propagation.
On the Decoding Complexity: hardware implementation

- The **Worst Case** complexity of EMS algorithm is dominated by $O(n_m \log(n_m))$ for both parity and variable nodes computation, with $n_m << q$.
- The **Average** complexity of EMS algorithm is $O(n_m + \varepsilon)$
- The edge memory scales as $N.d_v.n_m(N_{quant} + \log_2 q)$ bits

<table>
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<tbody>
<tr>
<td>Code length (bits)</td>
<td>576-2304</td>
<td>576-2304</td>
<td>576-2304</td>
<td>288-2880</td>
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<tr>
<td>F clock (MHz)</td>
<td>150</td>
<td>333</td>
<td>400</td>
<td>300</td>
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<td>Iterations</td>
<td>20</td>
<td>10-15</td>
<td>15</td>
<td>18</td>
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<tr>
<td>throughputs</td>
<td>105</td>
<td>133-928</td>
<td>128-746</td>
<td>100-200</td>
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<td>Technology</td>
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<td>130 nm</td>
<td>65 nm</td>
<td>45 nm</td>
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<tr>
<td>area</td>
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<td>3.83</td>
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<td>Area equiv. 45nm</td>
<td>1.56</td>
<td>0.48</td>
<td>0.3</td>
<td>1.28</td>
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Conclusions

- In the moderate-short block length regimes, there are solutions largely outperforming binary LDPC codes with iterative decoding → up to 1.5 dB gain

- Standardization of a binary LDPC codes might be premature

- A deeper look into the non-binary solutions is worth

- A lot of work has been carried out on the implementation of non-binary decoders

  - Complexity is increased compared to binary solutions, but not greatly,

  - Semiconductor companies have already developed prototypes for reduced complexity and fast NB-LDPC decoding

- DLR contribution to the Orange Book is on-going
References: Code construction


References: Low complexity NB-LDPC decoders


Thanks for your attention