RFC 5170 / LDPC-* codes: recommendations for their optimal use

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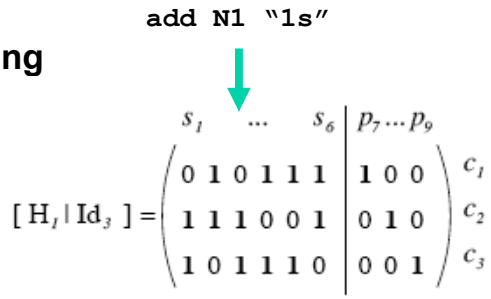
Summary

- recent results have shown LDPC-staircase /triangle codes are:
  - ❍ **very close to ideal codes**
  - ❍ **one order of magnitude faster than Reed-Solomon over GF(2^8) (using Rizzo's reference codec)**

  …in **many** use-cases
- made possible by
  - ❍ **hybrid Zyablov Iterative decoding/Gaussian elimination scheme, and…**
  - ❍ **the new N1 parameter**

Summary… (cont')

- N1 parameter
  - ❍ **number of "1s" in each column of the parity check matrix during the first step of the algorithm**



  - ❍ **N1 was fixed and equal to 3 until 08 version, but now:**
    - N1 belongs to {3; 10} (N1=3 remains the default)
    - N1 is set by the encoder…
    - …and communicated to the decoder (in EXT_FTI or FDT)
    - increases the density of the matrix… and the probability it is invertible!

LDPC performances

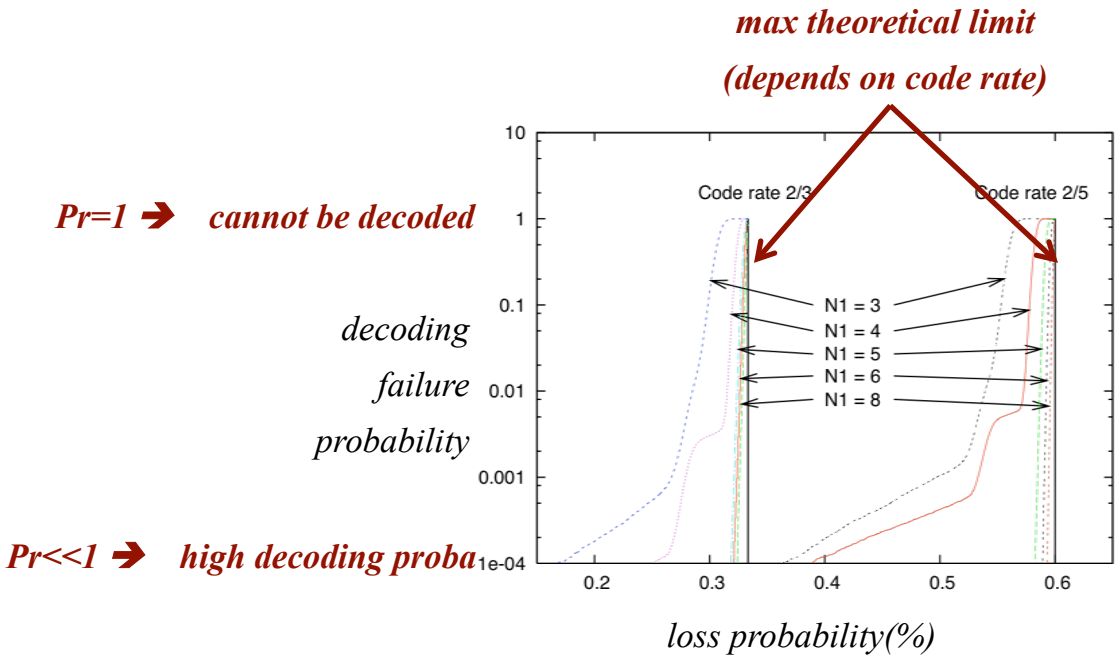
- depend on:
  - ❍ **decoding scheme used**
  - ❍ **N1 parameter with LDPC-staircase codes (≠ triangle)**
- more specifically
  - ❍ **the decoder has to solve a system of linear equations**
  - ❍ **possible with Zyablov Iterative Decoding (ID) scheme**
    - fast but sub-optimal erasure recovery
  - ❍ **or Gaussian elimination (GE)**
    - optimal erasure recovery but more costly
  - ❍ **or intelligent variants of ID**
    - see Raptor/RFC 5053 and associated US patent 6,856,263

LDPC performances… (cont')

- ...or with a **hybrid ID/GE** scheme
  - ❍ **recommended for small to medium sized objects**
  - ❍ **start decoding with ID**
    - it's perhaps sufficient…
    - if not, it will anyway simplify the system
  - ❍ **finish with GE (e.g., if it's known that no additional symbols will be received)**
    - works on the system simplified by the ID, not the original one!

Erasure recovery results

- example: LDPC-staircase, various N1 values



Erasure recovery results… (cont')

- LDPC-staircase results (N1=5, k=1,000)

code rate	average overhead	overhead for a failure proba ≤ 10^{-4}
2/3 (=0.66)	0.63%	2.21%
2/5 (=0.4) (worst case!)	2.04%	4.41%

❍ **then results further improve as the code rate decreases**

- not shown here, see [SPSC08]
- means that small-rate codes are feasible…

❍ **results remain excellent with smaller objects**

- no need to artificially increase the number of symbols…
  - **symbols groups are no longer needed ➔ use G=1 (default)**
- this is the opposite with ID!

Decoding complexity results

- complexity depends on:

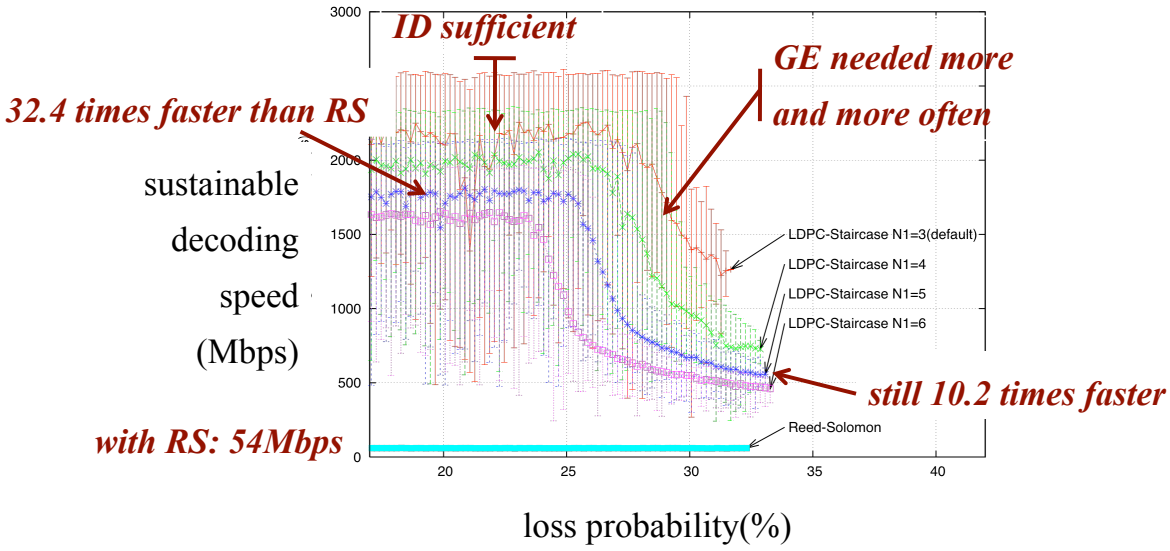
❍ **block size** **(GE complexity increases)**

❍ **loss rate** **(is ID sufficient or should GE be used too?)**

❍ **N1 parameter with LDPC-staircase codes (the linear system complexity increases with N1)**

Decoding complexity results… (cont')

- example: LDPC-staircase, code rate 2/3, k=1,000
  - ❍ **the higher N1, the mode complex the decoding**
  - ❍ **yet with N1=5, between 32 to 10 times faster than RS(2^8)**



Decoding complexity results… (cont')

- we see that:
  - ❍ **decoding complexity isn't prohibitive at all with objects that are a few thousands of symbols long ☺**
  - ❍ **it requires a careful implementation though**
    - take into account the specific parity check matrix structure
  - ❍ **these results are not the ultimate ones and we should be able to further reduce the decoding complexity…**

To conclude

- with small/medium sized objects
  - **prefer hybrid decoding**
  - **use G=1 (no symbol grouping), it's useless now**
  - with larger objects, fall back to ID
- optimal LDPC-triangle codes performances
  - **achieved with N1=3 (default) for ID or hybrid decoding**
- optimal LDPC-staircase codes performances
  - **require an appropriate N1 value**
    - N1=3 (default) is the best for ID
    - N1=4 or 5 is recommended with hybrid decoding

References

General idea triangle results…

- **"Improving the Decoding of LDPC Codes for the Packet Erasure Channel with a Hybrid Zyablov Iterative Decoding/Gaussian Elimination Scheme"**, INRIA Research Report RR-6473, March 2008
  http://hal.inria.fr/inria-00263682/en/

Additional results for staircase codes…

- **"Optimizing the Error Recovery Capabilities of LDPC -staircase Codes Featuring a Gaussian Elimination Decoding Scheme"**, June 2008, to appear in SPSC'08.
  http://hal.inria.fr/inria-00291656/en/