FEC Analysis for 100G EPON

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Outline

- Background
- Factors that affect FEC code selection
- Two different types of LDPC codes
  - Regular/Quasi-regular LDPC code
  - Irregular LDPC code
- Conclusions

Background

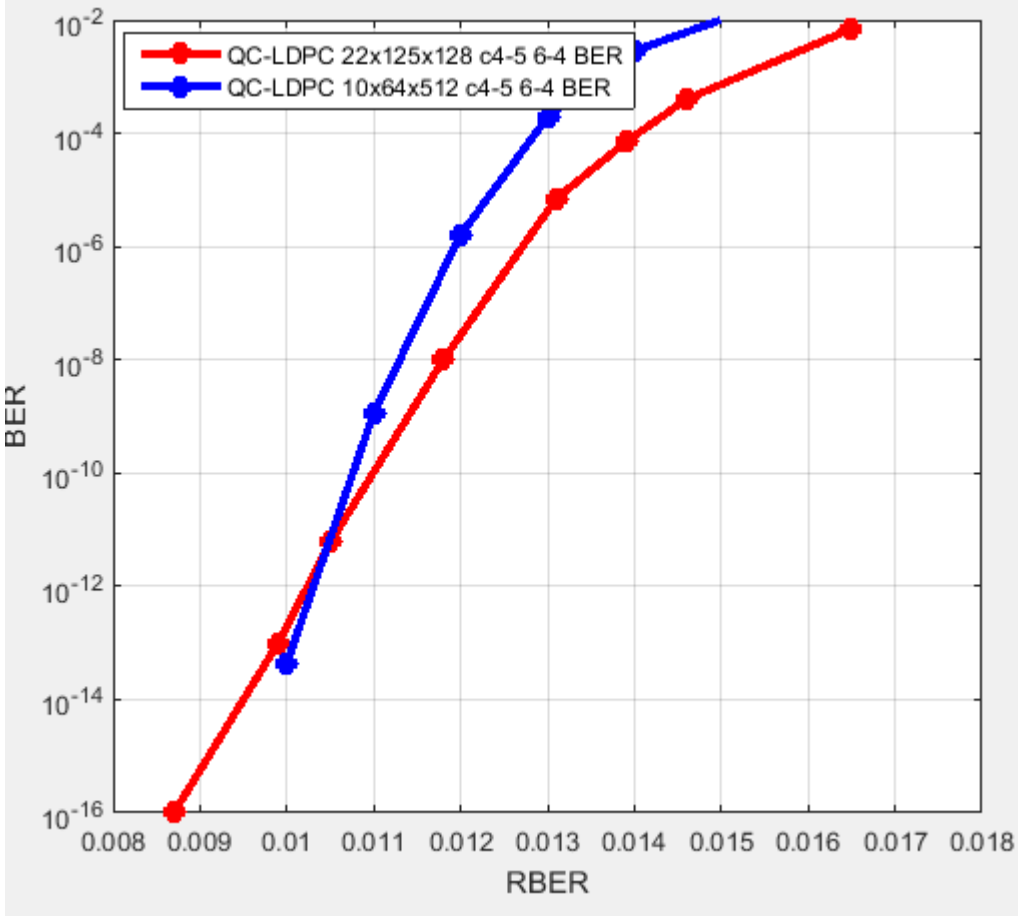
- There is 1.5~2dB optical power budget gap in 25G EPON system without amplifier.
- Enhanced FEC is a preferred way to fill the optical power budget gap.
- LDPC has been used widely, such as in Docsis 3.1, G.hn, WiMAX, 802.3an, 802.11n and so on and has the error correction capability of BER_in=1.0e-2@BER_out=1.0e-12 with a code rate larger than 0.8.
- Several LDPC codes have been proposed.

Factors that affect FEC code selection

- 1.5dB to 2dB optical coding gain to fill the loss budget gap, i.e., BER_in=1.0e-2 correlation capability.
- ≥80% code rates to support a minimum of 2*10Gbps links.
- 2k to 4k bytes codeword size to provide a balance of performance and complexity.
- Error floor bellow 1e-14.
- Low complexity to ensure low cost decoder implementation at the ONU.
  - Hard decision or soft decision.
  - Regular or non-regular code.
  - Number of non-zero blocks of H matrix.
  - …

Refer to houtsma_3ca_1_0916, laubach_3ca_1_0117.

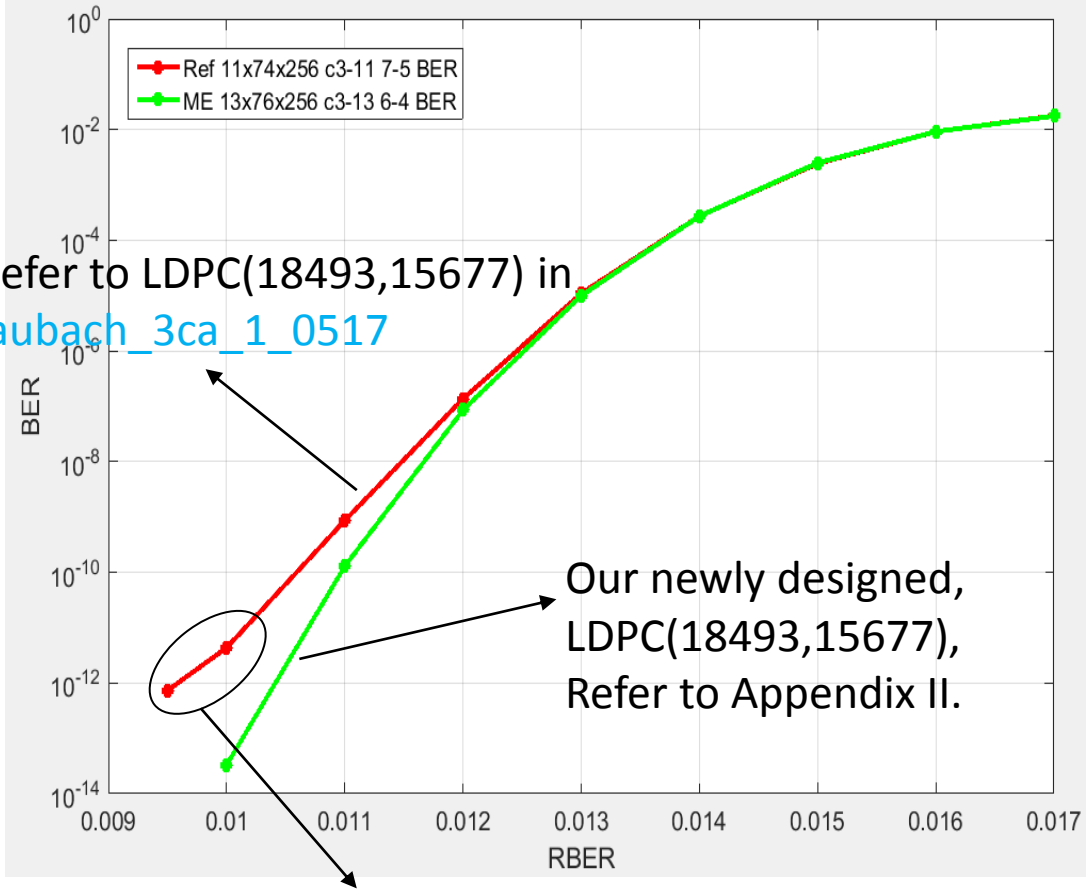
Quasi-Column-Regular LDPC code



- 16kbits and 32kbits codeword size.
- 0.824 and 0.844 code rate.
- Column weight: 4-5.
- LLR Bit width used for Sum process/Input LLR width: 6-4.
- BER_in=1.0e-2 correlation capability with hard decision.
- Below 1e-14 error floor.
- Resource requirements.
  - 16kbits code: ~2.3M gates.
  - 32kbits code: ~3.0M gates.

Refer to zhao_3ca_1_0517 and appendix I for the parity matrix of 16kbits code.

Irregular LDPC code



Need carefully study of the error floor.

- About 18kbits codeword length.
- Code rate: 84.8%.
- Column weight:
  - Ref 11*74*256: 3 or 11, 382 non-zero blocks
  - ME 13*76*256: 3 or 13, 296 non-zero blocks
- LLR bit width used for sum process/Input LLR width:
  - Ref 11*74*256: 7-5
  - ME 13*76*256: 6-4
- BER_in=1.0E-2 correlation capability with hard decision.
- Error floor:
  - Ref 11*74*256: appears around 1e-12 even with LLR 7-5.
  - ME 13*76*256: bellow 1e-14.
- Resource requirements.
  - Ref 11*74*256: ~4.8M gates@27Gbps.
  - ME 13*76*256: ~3.4M gates@27.5Gbps.

Comparison of the two kinds of LDPC codes

Quasi-Column-Regular code, lower complexity, higher overhead or longer code size

LDPC	Codeword size(bits)	Code Rate	RBER@BER=1e-12	Optical coding Gain relative to RS(255,223)(dBo)*	Resource Requirements(gates)	Throughput
LDPC 22*125*128	16000	0.824	1.00E-02	1.7~2.2	2.3M	25Gbps
LDPC 10*64*512	32768	0.844	1.00E-02	1.7~2.2	3.0M	25Gbps
LDPC 11*74*256	18493	0.848	9.60E-03	1.7~2.2	4.8M	27Gbps
LDPC 13*76*256	18493	0.848	1.05E-02	1.8~2.3	3.4M	27.5Gbps

Irregular code, higher complexity, lower overhead

- All the performance of the LDPC code can satisfy the basic requirement.
- How to get a balance between performance and complexity?
  - Just enough of performance/overhead, lower complexity?
  - Higher performance, higher complexity?

* Assume APD receiver with 1dBe=(0.7~0.9)dBo.

Conclusions

- There are serval LDPC codes that can satisfy the basic performance requirement.
- Before making the final choice, the criteria should be clarified.
  - Just enough of performance/overhead, lower complexity/resource requirements?
  - Higher performance, higher complexity/resource requirements?
- If choosing “just enough performance/lower complexity”, we recommend selecting LDPC 22 * 125 * 128. Otherwise, LDPC 13*76*256 may be a better choice.

Thank you

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Appendix I: LDPC(16000,13184) Parity Code Matrix

Rate=82.4% (18493,15677), m=22 rows x n=125 columns, L=128

0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 17 -1 -1 -1 106 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 0 -1 61 -1 -1 -1 -1 -1 -1 -1 -1 -1 117 -1 46 126 -1 -1 -1 -1 -1 -1 -1 -1 87 -1 -1 -1 -1 -1 -1 106 -1 -1 3 -1 -1 -1 -1 -1 62 -1 -1 -1 25 -1 -1 -1 -1 -1 121 -1 -1 -1 -1 27 -1 -1 -1 -1 -1 102 -1 -1 -1 -1 0 -1 -1 -1 59 -1 -1 99 -1 -1 -1 -1 -1 -1 -1 -1 0 125 -1 -1 -1 -1 32 -1 7 -1 -1

0 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 25 -1 -1 -1 57 -1 -1 -1 -1 -1 -1 -1 -1 108 -1 -1 -1 -1 -1 -1 32 -1 -1 89 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 115 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 55 -1 -1 -1 0 -1 -1 12 -1 -1 -1 -1 46 -1 -1 -1 -1 -1 -1 -1 123 -1 -1 22 -1 -1 -1 -1 -1 66 -1 -1 -1 81 -1 -1 -1 119 9 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 13 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 86

0 -1 -1 -1 -1 -1 2 -1 -1 -1 -1 31 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 0 -1 77 -1 -1 -1 -1 -1 -1 -1 -1 21 100 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 45 -1 8 -1 108 -1 -1 -1 -1 -1 -1 -1 -1 103 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 57 84 -1 -1 66 -1 -1 -1 -1 -1 -1 -1 -1 4 -1 -1 -1 107 -1 -1 -1 7 -1 -1 34 -1 -1 -1 -1 9 -1 83 -1 -1 -1 -1 -1 4 -1 -1 -1 -1 0

0 -1 -1 -1 -1 -1 3 -1 -1 -1 -1 -1 46 -1 -1 104 -1 -1 -1 -1 -1 -1 58 -1 -1 -1 -1 -1 107 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 14 71 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 18 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 86 -1 -1 -1 -1 0 -1 42 -1 -1 -1 -1 -1 47 -1 -1 -1 -1 -1 -1 94 -1 10 -1 -1 -1 -1 -1 -1 7 -1 0 -1 -1 -1 -1 -1 -1 82 -1 -1 -1 -1 110 100 -1 -1 -1 -1 12 -1 -1 -1 -1 -1 68 85 4 -1 -1 -1

-1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 37 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 48 111 -1 -1 -1 -1 -1 -1 -1 -1 120 23 -1 -1 -1 -1 -1 -1 8 -1 73 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 31 -1 -1 -1 60 -1 -1 -1 109 -1 -1 -1 -1 -1 -1 65 -1 -1 -1 -1 -1 -1 -1 7 -1 -1 -1 -1 -1 -1 0 51 -1 -1 -1 -1 -1 -1 15 -1 0 -1 -1 114 -1 -1 -1 94 -1 -1 -1 114 -1 -1 -1 -1 89 -1 -1 -1 -1 -1 0 -1 -1 -1 48 -1

-1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 62 -1 -1 -1 -1 -1 -1 -1 104 -1 -1 -1 -1 -1 8 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 77 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 34 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 21 -1 16 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 18 -1 -1 -1 -1 -1 43 10 -1 -1 -1 73 -1 -1 -1 12 -1 -1 -1 -1 -1 -1 -1 -1 110 -1 -1 -1 -1 110 -1 99 -1 -1 -1 -1 -1 -1 -1 26 -1 -1 -1 78 -1 -1 65 -1 -1 20 -1 -1 -1 -1 -1 -1 25

-1 0 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 88 -1 -1 -1 84 -1 -1 -1 -1 22 -1 -1 -1 58 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 57 -1 -1 -1 9 -1 -1 -1 -1 -1 -1 12 -1 -1 -1 29 -1 -1 -1 -1 -1 -1 -1 -1 65 -1 -1 -1 79 -1 -1 -1 -1 -1 -1 -1 -1 3 88 -1 -1 108 -1 -1 -1 -1 -1 -1 100 -1 -1 59 -1 -1 -1 -1 40 -1 -1 -1 -1 24 -1 -1 -1 -1 0 -1 -1 -1 40 -1 -1 -1 29 -1 -1 -1 -1 -1 -1 52 -1 0 -1

-1 0 -1 -1 -1 -1 -1 2 -1 -1 -1 -1 -1 96 -1 -1 -1 -1 -1 22 -1 -1 -1 -1 86 -1 -1 -1 -1 -1 50 -1 -1 -1 0 -1 -1 -1 -1 -1 101 -1 -1 -1 -1 -1 -1 -1 -1 -1 54 -1 -1 124 -1 -1 69 -1 -1 -1 87 -1 -1 -1 -1 -1 -1 44 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 39 -1 59 -1 -1 -1 -1 -1 0 -1 -1 -1 42 -1 -1 -1 -1 -1 -1 0 -1 -1 111 -1 -1 -1 -1 -1 0 -1 -1 30 -1 -1 60 -1 -1 -1 -1 68 -1 -1

-1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 114 -1 -1 -1 108 -1 -1 -1 -1 11 -1 -1 -1 -1 -1 -1 -1 60 -1 -1 -1 -1 -1 75 -1 -1 -1 -1 65 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 53 -1 -1 -1 -1 0 -1 -1 -1 72 -1 -1 -1 -1 -1 -1 72 -1 -1 -1 0 -1 -1 -1 -1 -1 55 -1 -1 -1 -1 -1 -1 -1 74 -1 -1 122 -1 -1 -1 -1 13 -1 -1 -1 -1 -1 0 56 -1 48 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 13 -1 -1 -1 -1 79 -1 -1 -1

-1 -1 0 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 101 -1 -1 -1 -1 -1 -1 78 -1 -1 -1 115 -1 53 -1 -1 -1 -1 -1 -1 122 -1 -1 -1 -1 -1 -1 -1 -1 48 -1 1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 14 -1 92 -1 -1 -1 -1 -1 -1 39 -1 -1 -1 93 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 98 101 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 40 -1 -1 -1 -1 -1 -1 0 -1 -1 67 -1 -1 0 -1 -1 -1 -1 -1 98 -1 -1 -1 -1 -1 0 17 -1

-1 -1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 88 -1 -1 -1 80 -1 117 -1 -1 -1 -1 -1 -1 36 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 110 -1 -1 0 -1 -1 126 -1 -1 -1 -1 -1 -1 -1 90 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 46 -1 -1 -1 -1 0 -1 -1 -1 32 -1 -1 -1 -1 -1 -1 0 87 -1 -1 -1 -1 -1 39 -1 -1 52 -1 -1 -1 -1 -1 -1 23 14 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1

-1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 7 -1 48 -1 -1 -1 79 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 25 -1 44 -1 -1 -1 -1 -1 -1 -1 -1 40 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 33 -1 -1 4 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 95 -1 -1 -1 -1 -1 115 -1 -1 -1 29 -1 -1 -1 20 -1 -1 -1 0 94 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 94 -1 33 -1 -1 -1 -1 -1 -1

-1 -1 -1 0 -1 -1 -1 -1 -1 1 -1 -1 0 -1 -1 -1 -1 50 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 78 -1 54 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 126 -1 -1 -1 -1 -1 120 -1 90 -1 -1 -1 -1 -1 -1 -1 -1 -1 105 56 -1 -1 -1 -1 123 -1 -1 -1 -1 -1 -1 -1 -1 79 -1 27 -1 -1 -1 50 -1 -1 -1 -1 -1 -1 -1 -1 0 55 -1 -1 -1 -1 -1 45 -1 -1 46 -1 63 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 124 -1

-1 -1 -1 0 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 25 -1 6 -1 -1 -1 -1 -1 -1 -1 -1 92 -1 -1 -1 -1 -1 37 -1 -1 -1 -1 -1 -1 64 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 31 -1 -1 -1 65 -1 -1 -1 32 -1 -1 -1 -1 -1 -1 -1 -1 0 93 -1 -1 -1 -1 -1 -1 -1 5 -1 -1 15 -1 -1 0 -1 -1 -1 110 -1 -1 -1 -1 -1 -1 -1 123 -1 79 -1 -1 40 -1 -1 -1 -1 -1 55 -1 -1 21 -1 -1 -1 -1 -1 -1

-1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 49 -1 -1 -1 2 -1 -1 -1 -1 -1 -1 -1 43 -1 -1 -1 -1 -1 118 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 10 -1 -1 -1 0 -1 -1 -1 -1 100 -1 -1 -1 -1 -1 -1 104 -1 -1 -1 -1 -1 -1 65 -1 -1 -1 -1 69 -1 -1 -1 5 -1 -1 -1 -1 54 -1 -1 40 -1 -1 -1 -1 -1 35 -1 -1 56 -1 -1 -1 4 -1 -1 -1 -1 0 -1 -1 -1 -1 115 -1 -1 69 -1 -1 -1 -1 -1 117 -1 -1 -1 -1 -1 0 -1 -1 -1

-1 -1 -1 -1 0 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 112 -1 -1 -1 -1 -1 -1 -1 61 -1 -1 0 -1 -1 -1 85 -1 -1 -1 -1 59 -1 -1 -1 -1 76 -1 -1 -1 -1 -1 -1 -1 -1 49 -1 120 -1 -1 -1 -1 77 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 61 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 0 -1 -1 -1 -1 -1 0 -1 -1 0 -1 -1 -1 -1 72 -1 -1 -1 -1 43 -1 -1 -1 -1 -1 125 -1 69 -1 -1 -1 0 -1 81 -1 -1 -1 -1 -1 -1

-1 -1 -1 -1 0 -1 -1 -1 -1 -1 1 -1 -1 0 -1 -1 -1 -1 -1 21 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 64 -1 -1 -1 63 -1 -1 -1 -1 -1 -1 -1 115 -1 85 -1 -1 11 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 47 -1 -1 -1 94 -1 -1 -1 -1 -1 -1 104 -1 -1 -1 24 -1 -1 -1 -1 0 -1 -1 -1 -1 107 -1 -1 -1 -1 58 -1 -1 -1 0 -1 105 -1 -1 -1 -1 58 -1 -1 -1 -1 -1 76 -1 -1 -1 80 -1 81 -1 -1

-1 -1 -1 -1 0 -1 -1 -1 -1 -1 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 36 -1 -1 -1 -1 -1 86 -1 -1 -1 105 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 26 -1 -1 -1 -1 46 -1 -1 101 -1 -1 -1 -1 -1 125 67 -1 -1 -1 -1 -1 -1 -1 -1 -1 33 -1 -1 -1 -1 73 -1 -1 -1 -1 51 -1 -1 -1 -1 -1 46 68 -1 -1 -1 76 -1 -1 -1 -1 124 -1 -1 -1 -1 -1 -1 -1 -1 0 40 -1 -1 -1 -1 -1 -1 0 -1 123 -1 -1 -1 -1 -1

-1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 9 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 10 -1 -1 0 -1 -1 90 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 56 -1 -1 65 -1 -1 -1 23 -1 -1 -1 -1 -1 -1 83 -1 -1 -1 -1 -1 -1 68 -1 -1 -1 96 -1 -1 -1 -1 -1 -1 124 -1 -1 -1 -1 -1 -1 -1 -1 4 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 127 -1 -1 -1 -1 -1 -1 38 -1 -1 -1 -1 2 -1 110 -1 1 -1 -1 -1 -1 -1 32 -1 -1 -1 -1 -1 108 -1 -1 -1 -1 -1 -1 35 -1 -1 53

-1 -1 -1 -1 -1 0 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 17 -1 -1 93 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 7 -1 -1 -1 -1 -1 -1 76 -1 -1 -1 -1 -1 -1 -1 -1 106 -1 -1 -1 54 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 -1 96 -1 -1 -1 -1 108 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 83 -1 -1 -1 -1 5 96 -1 -1 -1 -1 -1 61 -1 -1 -1 -1 -1 -1 110 -1 -1 -1 0 -1 -1 -1 82 -1 -1 -1 -1 113 -1 51 -1 -1 -1 -1 -1

-1 -1 0 -1 -1 -1 -1 -1 -1 -1 10 -1 -1 -1 -1 -1 -1 2 -1 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 66 -1 -1 -1 -1 -1 -1 -1 -1 39 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 54 -1 -1 -1 -1 -1 35 -1 32 -1 -1 -1 -1 -1 -1 97 -1 -1 -1 -1 16 -1 -1 38 -1 -1 -1 -1 -1 95 -1 -1 -1 59 34 -1 -1 -1 -1 -1 -1 -1 -1 -1 80 13 -1 -1 -1 -1 -1 -1 74 -1 -1 -1 -1 35 -1 -1 100 -1 4 -1 -1

-1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 0 -1 -1 -1 34 -1 -1 -1 -1 16 -1 -1 -1 -1 21 -1 -1 -1 -1 -1 -1 -1 -1 2 -1 -1 -1 -1 -1 -1 -1 0 -1 96 40 -1 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 47 -1 -1 -1 -1 -1 -1 0 -1 -1 -1 -1 -1 0 -1 16 -1 113 -1 -1 -1 -1 -1 -1 -1 66 49 -1 -1 -1 -1 97 -1 -1 -1 -1 15 -1 -1 10 -1 -1 -1 108 -1 -1 -1 -1 -1 62

Appendix II: LDPC(18493,15677) Parity Code Matrix

Rate=84.8% (18493,15677), m=11 rows x n=74 columns, L=256, refer to laubach_3ca_1_0517 382 non-zero blocks

0 -1 -1 -1 0 -1 -1 -1 0 -1 0 -1 0 -1 -1 -1 -1 -1 -1 0 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
-1 0 -1 -1 -1 0 -1 -1 0 -1 -1 0 -1 -1 -1 -1 0 -1 0 -1 -1 -1 -1 0 -1 -1 88 -1 -1 0 -1 -1 -1 62 -1 -1 -1 176 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 0 -1 -1 236 85 177 113 11 52 246 234 90 87 137 75 209 223 127 96 255 118 224 47;
-1 33 -1 -1 -1 -1 0 -1 -1 0 -1 -1 1 -1 -1 -1 160 0 -1 -1 -1 -1 -1 -1 0 -1 -1 0 -1 149 -1 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 -1 -1 0 -1 243 -1 0 81 7 144 11 187 109 77 214 14 120 231 239 135 115 202 195 124 234 99;
7 -1 -1 -1 -1 -1 42 0 -1 -1 -1 115 -1 -1 0 -1 -1 -1 -1 250 -1 -1 -1 -1 -1 0 -1 207 -1 -1 180 -1 -1 -1 -1 0 -1 -1 39 -1 -1 -1 212 -1 170 -1 -1 -1 -1 -1 -1 36 -1 0 128 223 10 156 119 108 97 220 81 158 211 8 151 66 166 25 115 138 196 70;
-1 -1 0 -1 -1 -1 -1 210 2 -1 -1 -1 -1 0 -1 -1 -1 16 -1 36 -1 -1 -1 46 -1 -1 242 -1 -1 -1 -1 0 -1 -1 106 -1 -1 244 -1 -1 -1 -1 72 -1 -1 -1 129 -1 -1 -1 236 -1 -1 -1 42 223 83 49 108 194 228 98 248 87 121 216 16 160 181 162 60 234 63 187;
-1 -1 -1 0 -1 -1 244 -1 -1 -1 124 -1 -1 11 -1 -1 -1 -1 221 -1 0 -1 -1 -1 21 -1 -1 -1 0 -1 -1 -1 0 -1 -1 4 0 -1 -1 -1 -1 -1 -1 0 -1 82 -1 -1 -1 230 -1 -1 -1 255 18 211 255 196 25 77 17 142 158 203 167 244 88 217 21 225 236 52 186 121;
-1 -1 0 179 -1 -1 -1 -1 -1 -1 -1 165 1 -1 -1 0 -1 -1 -1 -1 -1 0 117 -1 -1 -1 -1 -1 -1 244 -1 17 -1 -1 -1 -1 0 -1 70 -1 -1 -1 -1 212 -1 -1 -1 0 184 -1 -1 -1 41 -1 150 146 162 142 158 239 206 94 194 13 213 164 222 66 207 40 132 110 199 251;
-1 -1 -1 112 96 -1 -1 -1 -1 50 -1 -1 -1 -1 220 -1 22 -1 -1 -1 30 -1 -1 251 -1 -1 -1 229 -1 -1 -1 -1 148 -1 -1 -1 0 -1 -1 0 -1 -1 -1 117 17 -1 -1 -1 -1 109 -1 233 -1 -1 218 204 76 48 21 133 172 28 215 214 43 36 70 193 5 123 191 84 66 170;
-1 19 -1 -1 23 -1 -1 12 -1 -1 -1 -1 -1 -1 -1 7 -1 76 -1 -1 159 -1 -1 -1 -1 197 -1 -1 152 -1 -1 176 -1 251 -1 -1 -1 -1 -1 255 72 -1 -1 -1 -1 -1 -1 251 -1 -1 147 -1 -1 -1 178 214 144 187 211 52 60 190 186 167 46 14 172 117 96 198 179 113 142 217;
166 -1 -1 -1 -1 116 -1 -1 -1 158 -1 -1 -1 113 -1 136 -1 -1 -1 -1 -1 64 -1 -1 -1 177 -1 -1 22 -1 136 -1 -1 -1 -1 38 -1 -1 -1 94 -1 165 -1 -1 -1 -1 177 -1 201 -1 -1 -1 -1 191 186 59 39 239 70 158 100 69 91 87 127 81 126 105 60 192 10 5 193 182;
-1 -1 1 -1 -1 98 -1 -1 -1 -1 31 -1 -1 -1 226 -1 -1 -1 188 -1 -1 94 202 -1 161 -1 -1 -1 -1 -1 -1 -1 75 -1 233 -1 -1 -1 -1 -1 236 29 -1 -1 -1 190 -1 19 -1 -1 -1 -1 -1 -1 136 88 33 241 129 177 70 82 47 154 60 145 234 98 173 219 152 186 62 124;

Rate=84.8% (18493,15677), m=13 rows x n=76 columns, L=256 296 non-zero blocks

-1 124 -1 91 -1 -1 -1 -1 -1 -1 144 -1 -1 -1 -1 165 -1 44 -1 -1 -1 231 -1 -1 -1 -1 -1 -1 180 -1 225 -1 35 -1 -1 -1 -1 58 -1 -1 20 -1 -1 -1 -1 -1 -1 -1 -1 -1 121 -1 -1 -1 -1 -1 130 -1 -1 19 77 -1 -1 -1 -1 -1 -1 -1 97 1 128 179 86 -1 113
-1 -1 -1 -1 -1 -1 -1 16 -1 -1 -1 -1 -1 187 -1 235 76 -1 -1 -1 -1 -1 16 44 -1 203 -1 -1 -1 -1 121 -1 -1 -1 -1 13 146 151 194 -1 -1 -1 -1 133 -1 -1 -1 -1 228 -1 -1 -1 -1 -1 -1 14 -1 -1 1 -1 -1 -1 73 91 -1 -1 -1 -1 -1 209 -1 -1 -1 -1 116 130
-1 6 -1 -1 -1 -1 33 -1 -1 -1 -1 208 -1 212 -1 249 -1 -1 -1 -1 175 -1 -1 -1 -1 226 -1 -1 -1 -1 -1 -1 211 -1 -1 -1 226 104 -1 82 181 -1 -1 -1 -1 179 -1 56 -1 -1 98 0 -1 -1 -1 -1 -1 -1 -1 228 -1 -1 -1 -1 -1 -1 -1 146 -1 -1 206 -1 197 55 192
-1 -1 -1 -1 -1 -1 233 98 -1 -1 163 -1 -1 -1 231 -1 -1 -1 65 -1 -1 -1 -1 -1 -1 178 -1 -1 140 -1 172 -1 -1 145 -1 -1 -1 -1 92 224 -1 -1 72 -1 -1 -1 2 -1 71 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 33 64 121 108 -1 -1 -1 -1 -1 126 94 -1 105 -1 6 12
206 -1 -1 -1 -1 -1 -1 -1 -1 111 -1 -1 -1 -1 -1 -1 -1 -1 205 -1 -1 97 -1 157 -1 72 -1 155 -1 -1 91 -1 -1 138 -1 -1 -1 -1 -1 -1 -1 -1 148 -1 137 -1 -1 -1 194 192 -1 -1 -1 -1 -1 110 235 -1 193 94 -1 -1 -1 -1 -1 -1 87 -1 -1 242 -1 191 -1 -1 -1 41 98
-1 -1 189 92 -1 -1 -1 94 155 -1 13 -1 -1 46 -1 -1 -1 -1 -1 -1 226 -1 172 -1 -1 -1 -1 -1 -1 174 -1 210 -1 -1 19 -1 -1 -1 -1 -1 27 -1 197 -1 -1 -1 -1 123 22 -1 100 -1 -1 -1 -1 155 16 -1 199 -1 -1 17 -1 85 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 185 233
-1 158 -1 -1 73 228 83 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 249 -1 21 -1 -1 -1 -1 2 -1 240 -1 -1 206 -1 -1 -1 -1 -1 -1 -1 -1 15 -1 110 -1 -1 182 -1 -1 -1 59 252 -1 -1 -1 74 121 -1 242 28 -1 75 -1 -1 142 -1 -1 -1 -1 -1 186 -1 -1 146 49
-1 -1 230 -1 -1 94 -1 -1 4 219 -1 -1 -1 95 -1 -1 212 -1 149 212 -1 -1 -1 -1 -1 -1 -1 190 -1 -1 -1 -1 -1 -1 250 36 7 -1 -1 -1 -1 -1 -1 11 -1 -1 -1 -1 -1 -1 -1 -1 -1 175 18 -1 -1 -1 31 -1 48 -1 33 -1 -1 178 -1 -1 -1 -1 -1 208 -1 18 -1 220 180
-1 -1 -1 -1 -1 -1 -1 -1 -1 31 189 -1 -1 -1 -1 -1 -1 -1 -1 -1 107 42 -1 125 -1 -1 -1 233 -1 118 -1 -1 -1 -1 255 -1 -1 134 135 -1 -1 -1 217 -1 -1 -1 -1 -1 -1 -1 -1 -1 127 -1 93 -1 -1 155 222 -1 165 -1 -1 -1 135 -1 109 140 -1 28 -1 -1 -1 160 70 193
-1 26 -1 212 -1 -1 167 -1 -1 46 -1 -1 143 -1 -1 92 -1 -1 -1 -1 -1 216 232 -1 146 -1 -1 -1 -1 110 -1 -1 235 -1 141 -1 -1 -1 -1 248 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 91 -1 -1 123 -1 -1 -1 -1 -1 -1 -1 235 -1 -1 231 -1 11 224 -1 -1 60 -1 -1 7 228
-1 -1 -1 152 144 -1 -1 174 -1 -1 -1 7 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 38 137 -1 2 -1 -1 -1 -1 -1 -1 36 227 -1 237 -1 -1 -1 -1 -1 94 72 82 -1 -1 105 -1 -1 -1 -1 62 20 198 -1 -1 -1 -1 -1 -1 -1 -1 -1 23 8 203 -1 -1 -1 170 251 155 105
239 -1 118 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 113 -1 80 -1 43 10 -1 31 -1 -1 -1 229 119 -1 -1 145 -1 -1 -1 60 -1 -1 -1 79 -1 -1 -1 -1 21 -1 -1 96 26 -1 -1 -1 -1 54 22 23 152 13 -1 -1 -1 -1 -1 -1 -1 45 -1 -1 -1 166 -1 -1 -1 -1 -1 -1 -1 -1 134 107
99 -1 -1 -1 8 228 -1 -1 137 -1 -1 31 118 -1 252 -1 209 -1 177 69 -1 -1 -1 -1 -1 -1 180 -1 -1 -1 -1 94 -1 26 -1 -1 -1 -1 -1 241 -1 38 -1 -1 -1 46 226 -1 -1 231 -1 -1 -1 174 -1 -1 -1 -1 -1 -1 -1 -1 -1 75 69 -1 212 -1 -1 -1 -1 -1 -1 -1 76 219

Appendix III: Throughput and complexity

LDPC	column weight	LLR width	core number	Throughput (Gbps)	Resource (Million Gates)
LDPC 22*125*128	4-5	4-6	9	25	2.3
LDPC 11*74*256	3-11	5-7	8	24	4.5
			9	27	4.8
LDPC 13*76*256	3-13	4-6	6	24.5	3.1
			7	27.5	3.4

Reference: http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_AH/NR_AH_1701/Docs/R1-1700093.zip