Energy-Efficient Protograph-Based LDPC codes *

Mohamed Yaoumi[1], **Elsa Dupraz**[2], **François Leduc-Primeau**[3], **Frederic Guilloud**[4]

[1,2,4] *IMT Atlantique, Lab-STICC, UBL, 29238 Brest, France*

[3] *Polytechnique Montréal, Canada*

E-mail: [1] mohamed.yaoumi@imt-atlantique.fr, [2] elsa.dupraz@imt-atlantique.fr,
[3] francois.leduc-primeau@polymtl.ca, [4] frederic.guilloud@imt-atlantique.fr

Keywords

LDPC codes; Protographs; Energy optimization; Min-Sum decoder

Summary

Energy consumption of electronic systems has become a major issue, both for environmental reasons and to augment the learning ability of systems with strict energy budgets. In communication systems, the standard approach consists of reducing transmission energy. However, it was shown in [1] that for short-distance communications, the energy consumption of the receiver becomes non-negligeable compared to the transmission energy. In this context, this paper considers the design of Low Density Parity Check (LDPC) codes that both show energy efficiency and good decoding performance.

For this problem, [6] considers hard-decision decoders, and proposes two models to represent the energy consumption. The first model considers the decoding complexity, and the second one measures the energy needed for data transfer inside the decoder. In addition, [4] considers discrete message alphabets and evaluates the memory requirements of the decoder. To finish, [5] optimizes the code degree distribution in order to reduce the decoding complexity, but does not explicitly relate this complexity to the decoder energy consumption.

In this paper, we consider a quantized Min-Sum decoder which, due to its discrete nature, can be easily implemented on a circuit. In addition, we consider LDPC codes constructed from protographs. Protographs allow to build Quasy-cyclic LDPC codes which are also very convenient for LDPC encoder and decoder implementation [3]. We use density evolution to evaluate the decoding performance of the Min-sum decoder for a given protograph, and we apply the method of [2] to predict the finite-length performance of the decoder.

We then introduce two models to evaluate the decoder energy consumption of the quantized Min-Sum decoder for a given protograph. The first model evaluates the number of operations realized by the decoder, and the second model measures the energy needed to write data into memory. From these two models, we propose to optimize the protograph so as to minimize the decoder energy consumption, while guaranteeing a certain performance level fixed as a criterion. As a result, we obtain two protographs that minimize the decoder energy consumption, while showing performance close to the protograph optimized without energy constraint.

To finish, we extend our approach to the case where the LDPC decoder operates under faulty hardware. We incorporate into the energy models the proportion of faults introduced inside the decoder. We then optimize both the amount of faults and the quantization level so as to minimize the decoder energy consumption.

References

[1] Christopher G Blake and Frank R Kschischang. Energy consumption of vlsi decoders. *IEEE Transactions on Information Theory*, 61(6):3185–3198, 2015.

[2] François Leduc-Primeau and Warren J Gross. Finite-length quasi-synchronous ldpc decoders. In *2016 9th International Symposium on Turbo Codes and Iterative Information Processing (ISTC)*, pages 325–329. IEEE, 2016.

[3] David GM Mitchell, Roxana Smarandache, and Daniel J Costello. Quasi-cyclic LDPC codes based on pre-lifted protographs. *IEEE Transactions on Information Theory*, 60(10):5856–5874, 2014.

[4] Thien Truong Nguyen-Ly, Khoa Le, Valentin Savin, David Declercq, Fakhreddine Ghaffari, and Oana Boncalo. Non-surjective finite alphabet iterative decoders. In *Communications (ICC), 2016 IEEE International Conference on*, pages 1–6. IEEE, 2016.

[5] Benjamin Smith, Masoud Ardakani, Wei Yu, and Frank R Kschischang. Design of irregular ldpc codes with optimized performance-complexity tradeoff. *IEEE Transactions on Communications*, 58(2), 2010.

[6] Wei Yu, Masoud Ardakani, Benjamin Smith, and Frank Kschischang. Complexity-optimized low-density parity-check codes for gallager decoding algorithm b. In *Proceedings. International Symposium on Information Theory, 2005. ISIT 2005.*, pages 1488–1492. IEEE, 2005.

*This work was supported by grant ANR-17-CE40-0020 of the French National Research Agency (ANR) and by the French MEAE and MESRI through the Pavle Savic program.