



EMP133

Novel Analysis and Design Tools for Low-Density Parity-Check Codes

University of Tartu and University of Bergen

Presented by Vitaly Skachek

21st September 2017

University of Tartu and University of Bergen

- **Goals of the project:**

development of new and analysis of the existing error-correcting methods for improved reliability of data communications and data storage systems

Personnel

- **Tartu, Estonia**

Vitaly Skachek (Assoc. Professor)

Nalin Jayakody (Research Fellow 2014-2016)

Irina Bocharova (Senior Research Fellow from 2016)

Yauhen Yakimenka (Ph.D. Student)

Ivo Kubjas (Ph.D. Student)

Akashkumar Rajaram (Master's Student 2015-2016)

- **Bergen, Norway**

Øyvind Ytrehus (Professor)

Eirik Rosnes (Research Scientist)

- **Valladolid, Spain**

Angela Barbero (Professor)

Scientific output

- **Journal articles:** 4 published, 4 submitted, one more is in preparation for submission
- **Peer-reviewed conferences with proceedings:** 24 published
- **Other talks and poster presentations (without publications):** at least 12

Master's Theses defended

- **Yauhen Yakimenka**, *“Optimization of Parity-Check Matrices of LDPC Codes”*, University of Tartu, June 2014
- **Ivo Kubjas**, *“Set reconciliation”*, University of Tartu, June 2014
- **Akashkumar Rajaram**, *“Energy Harvesting in Cooperative Communications”*, Tallinn University of Technology and University of Tartu, June 2016, Best Master's Thesis Award in Hardware and Systems

Selected scientific results

Development of new and efficient methods for elimination of small stopping/trapping sets.

We proposed an edge spreading approach to construct high rate array-based spatially-coupled LDPC codes by jointly optimizing the absorbing set (AS) spectrum and the minimum distance. By considering general edge spreadings and larger memory, we show that strictly better codes can be constructed, both in terms of achievable minimum distance for small-to-moderate block lengths and in terms of the number of small ASs.

Selected scientific results (cont.)

Development of efficient relaxations of the fundamental polytope of LP decoder that eliminates pseudocodewords of small weight.

This goal was achieved for codes over certain nonbinary fields. An explicit construction of valid inequalities (using no auxiliary variables) for the convex hull of the so-called constant-weight embedding of a single parity-check (SPC) code over any prime field was developed.

Selected scientific results (cont.)

Development of optimal strategies for adding redundant rows to the parity-check matrices in order to boost the performance of the code.

We improved techniques for estimating stopping redundancy of linear binary codes. We achieved improvement on the known upper bound by using a judicious selection of a few first rows in the parity-check matrix of the code, and then by applying a probabilistic analysis that appeared previously in the literature.

We also experimentally showed that adding redundant rows to the parity-check matrices of short LDPC codes leads to significant performance gains over BEC and AWGN channels, which approach the ML decoding.

Selected scientific results (cont.)

- A novel method for low-complexity approaching maximum-likelihood (ML) performance decoding of quasi-cyclic (QC) LDPC codes over the binary erasure channel has been developed. A new upper bound on the ensemble-average ML decoding error probability for a finite-length row-regular LDPC code family is derived.
- A new method for decoding of low-density parity-check codes on the AWGN channel was developed. In the proposed method, first, a standard belief-propagation decoder is applied, then a certain number of positions is erased using a combination of a reliability criterion and a set of masks. A list erasure decoder is then applied to the resulting word.

Research visits



Short-term visits

- Vitaly Skachek, University of Bergen, February 2014
- Øyvind Ytrehus, Eirik Rosnes and Angela Barbero, University of Tartu, August 2014
- Yauhen Yakimenka and Vitaly Skachek, University of Bergen, August 2015
- Irina Bocharova, University of Bergen, January 2016

Long-term visits

- Nalin Jayakody stayed in Bergen in September 2015 – January 2016
- Yauhen Yakimenka stayed in Bergen in January – June 2016

5th International Castle Meeting on Coding Theory and Applications

- Vihula, Estonia, 28-31 August 2017
- 38 participants from 13 countries
- Proceedings published with Springer





Thank You!