

A message from the general chairs

Having started off from Brest in 1997 on the initiative of Claude Berrou and his co-workers, once again, the 8th International Symposium on Turbo Codes & Iterative Information Processing is a meeting point for many colleagues that have determined the developments in iterative methods since many years together with their students and many that just like to get first-hand information on a technology that has meanwhile made its way into almost every current transmission system.

Following a bit of tradition, we also chose a Honorary Chair from the country where the symposium takes place, after having had Rolf Johannesson representing Sweden, we selected Joachim Hagenauer who significantly contributed to the “Turbo” domain over many years.

Furthermore, we realized that quite some colleagues from our field – initiated again by Gerard Battail, Claude Berrou, Joachim Hagenauer, widened their view to look into life-science topics in parallel to their own experience, leading to very interesting insights. We hence included a separate session dealing with life-science-related aspects. This field is expected to grow, despite of the effort it needs to build bridges to another field of research.

Such a conference is, of course, not realizable without many helping hands. Of central importance is, like always, the TPC and especially the TPC chairs that had in the end the difficult duty to organize the review process and finally determine the program contents. We thank Johannes Huber, Gerhard Kramer, and Stephan ten Brink for serving as the TPC chairs putting a lot of effort into shaping the conference program. Locally, our team assistant, Anja Müller has taken over so many duties. Without her organizational experience and engagement, this conference would simply not have taken place. We also thank the members of the research group at Jacobs and Christoph Rachinger at the University of Erlangen-Nuremberg.

At some point, the financial side of a conference is crucial, too. We especially appreciate the funding by **DFG**, the German Research Foundation, the **IEEE** for the technical co-sponsorship and final publication through Xplore, the German engineering societies, **VDE/ITG** and **VDI** for advertising the conference through their channels and some supply with stationery. Last, but not least, we thank the City State of Bremen for welcoming the participants in an evening reception inside the impressive City Hall and, of course, Jacobs University for providing the conference facilities.

We are looking forward to welcoming you to Bremen – to the 8th Turbo Symposium and to hopefully even more enjoyable and unforgettable social events.

Werner Henkel & Michel Jezequel & Han Vinck – General Chairs

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Website

<http://www.jacobs-university.de/turbo-symposium-2014/>

Program overview

Monday, August 18

- 13:20-13:30 Welcome
- 13:30-14:10 Mo-1: *Dan Costello (Invited Speaker)*
- 14:10-15:10 Mo-2: *Coded Modulation*
- 15:30-16:50 Mo-3: *Soft Decoding*
- 18:00-18:45 Reception at the City Hall
- 18:45-19:45 Guided city tour

Tuesday, August 19

- 08:40-09:20 Tu-1: *Shu Lin (Invited Speaker)*
- 09:20-10:00 Tu-2: *Andrea Montanari (Invited Speaker)*
- 10:20-11:00 Tu-3: *Analog Processing*
- 11:00-12:00 Tu-4: *Trapping Sets and Graphs*
- 13:30-15:10 Tu-5: *Spatially Coupled Codes*
- 15:30-17:10 Tu-6: *Hardware Design*
- 17:30-18:30 Tu-7: *Source-Channel Coding*

Wednesday, August 20

- 09:00-09:40 We-1: *David Tse (Invited Speaker)*
- 09:40-10:00 We-2: *Gerard Battail (Invited Speaker)*
- 10:20-12:00 We-3: *Genetic Codes*
- 12:10-23:00 Excursion to the Wadden Sea and Cuxhaven

Thursday, August 21

- 09:00-09:40 Th-1: *Claude Berrou (Invited Speaker)*
- 09:40-10:20 Th-2: *Frank Kschischang (Invited Speaker)*
- 10:40-12:00 Th-3: *Satellite Channels*
- 13:30-15:10 Th-4: *Non-Binary LDPC Codes*
- 15:30-17:10 Th-5: *Latency, Polar Codes, Erasure Codes*

Friday, August 22

- 09:00-09:40 Fr-1: *Boris Kudryashov and Irina Bocharova (Invited Speakers)*
- 09:40-10:20 Fr-2: *Relay Codes*
- 10:40-11:40 Fr-3: *MIMO Codes*

Monday, August 18

13:30 - 14:10

Mo-1: Dan Costello (Invited Speaker)

Chair: Johannes Huber (University of Erlangen-Nuremberg, Germany)

[Randomly Punctured Spatially Coupled LDPC Codes](#)

David G. M. Mitchell (University of Notre Dame, USA); Michael Lentmaier (Lund University, Sweden); Ali E. Pusane (Bogazici University, Turkey); Daniel J. Costello, Jr. (University of Notre Dame, USA)

In this paper, we study random puncturing of protograph-based spatially coupled low-density parity-check (SC-LDPC) code ensembles. We show that, with respect to iterative decoding threshold, the strength and suitability of an LDPC code ensemble for random puncturing over the binary erasure channel (BEC) is completely determined by a single constant $\theta \geq 1$ that depends only on the rate and iterative decoding threshold of the mother code ensemble. We then use this analysis to show that randomly punctured SC-LDPC code ensembles display near capacity thresholds for a wide range of rates. We also perform an asymptotic minimum distance analysis and show that, like the SC-LDPC mother code ensemble, the punctured SC-LDPC code ensembles are also asymptotically good. Finally, we present some simulation results that confirm the excellent decoding performance promised by the asymptotic results.

14:10 - 15:10

Mo-2: Coded Modulation

Chair: Han Vinck (University of Duisburg-Essen, Germany)

[Design of Systematic GIRA Codes for CPM](#)

Tarik Benaddi (IRIT & CNES, France); Charly Poulliat (INP - ENSEEIHT Toulouse, France); Marie-Laure Boucheret (University of Toulouse IRIT Enseeiht, France); Benjamin Gadat (Thales Alenia Space, France); Guy Lesthievant (CNES, France)

In this paper, we derive an asymptotic analysis for a capacity approaching design of serially concatenated turbo schemes that works for both systematic generalized irregular repeat accumulate (GIRA) and low density generator matrix (LDGM) codes concatenated with a continuous phase modulation (CPM). The proposed design is based on a semi analytic EXIT chart optimization method. By considering a particular scheduling, inserting partial interleavers between GIRA accumulator and CPM and allowing degree-1 variable nodes, we show that designed rates perform very close to the maximum achievable rate (R_{\square}).

A Low Complexity Iterative Soft Detection for Bit Interleaved Coded CPM

Malek Messai (Télécom Bretagne, France); Karine Amis (Institut TELECOM ; TELECOM Bretagne & Université européenne de Bretagne, France); Frederic Guilloud (Institut Telecom - Telecom Bretagne, France)

In this paper, we propose a low-complexity iterative soft detection algorithm for a bit interleaved coded Continuous Phase Modulation (CPM). The reduction of complexity is obtained by using a modulation index at the receiver side which is different from the one used at the transmitter side. This difference is balanced thanks to a Soft-Input Soft-Output (SISO) coherent CPM demodulator based on the Per Survivor Processing (PSP) technique. Compared to the state of the art, the error rate performance is improved. We also show that our algorithm converges close to the coherent maximum a posteriori (MAP) algorithm, with a few additional iterations.

Improved Performance of Coded OFDM-MFSK Using Combined Alphabets and Extended Mapping

George Yammine (University of Ulm, Germany); Eva Peiker-Feil (University of Ulm, Germany); Werner G. Teich (Ulm University, Germany); Juergen Lindner (Uni Ulm, Germany)

OFDM-MFSK is a robust noncoherent transmission scheme that is able to cope with fast fading channels. The disadvantage of OFDM-MFSK is a lower end-to-end bandwidth efficiency in comparison to other transmission schemes, such as quadrature amplitude modulation. In this paper we describe two methods, combined alphabets and extended mapping, to improve the bandwidth efficiency and/or the bit error rate performance of coded OFDM-MFSK using iterative demapping and decoding. We provide the suitable log-likelihood metrics for different channel models, and analyze the performance of the system with the help of extrinsic information transfer charts. Finally simulation results are given.

15:30 - 16:50

Mo-3: Soft Decoding

Chair: Frank R. Kschischang (University of Toronto, Canada)

Advanced Hardware Architecture for Soft Decoding Reed-Solomon Codes

Stefan Scholl (University of Kaiserslautern, Germany); Norbert Wehn (University of Kaiserslautern, Germany)

Soft decision decoding of Reed-Solomon codes can improve decoding performance considerably in comparison to hard decision decoding. In this paper we propose an advanced architecture based on information set decoding for processing soft information. The architecture features efficient order 2 reprocessing and handling of multiple information sets.

Complexity and performance of the architecture for the widely used RS(255,239) are evaluated on a Virtex 5 FPGA. A communications gain of 1.3 dB is achieved, which outperforms to our best knowledge all other state-of-the-art implementations by over 0.5 dB.

Soft-In Soft-Out Algorithms for the Nordstrom-Robinson code

Yannick Saouter (Ecole Nationale Supérieure des Telecommunications de Brest, France)

The Nordstrom-Robinson code is a binary nonlinear code of length 16 with $2^8=256$ codewords. Its minimum distance which is equal to 6 is greater than that of any binary linear code of length 16 and encoding rate 1/2. For this reason, the Nordstrom-Robinson code has attracted interests in practical applications of the communication area. In this paper, we present two new algorithms for soft decoding of this code.

Iterative Multi-Step Decoding for a Class of Multi-Step Majority-Logic Decodable Cyclic Codes

Hsiu-Chi Chang (National Chiao Tung University, Taiwan); Hsie-Chia Chang (National Chiao Tung University, Taiwan)

This paper presents an iterative multi-step decoding algorithm for a class of multi-step majority-logic (MS-MLG) decodable cyclic codes. The proposed algorithm is capable of efficient decoding the MS-MLG decodable cyclic codes with large number of short cycles of length 4. In addition, we decompose the parity-check matrices into several submatrices by utilizing the orthogonal structure of the codes. The decomposition scheme allows efficient decoding for MS-MLG decodable cyclic codes. Simulation results demonstrate that the MS-MLG decodable cyclic codes decoded with the proposed algorithm outperforms BCH codes with similar lengths and rates decoded with the hard-decision algorithm.

Highly Flexible Design of Multi-Rate Multi-Length Quasi-Cyclic LDPC Codes

Moritz Beermann (RWTH Aachen University, Germany); Florian Wickert (RWTH Aachen University, Germany); Peter Vary (RWTH Aachen, Germany)

The design of Low-Density Parity-Check (LDPC) codes with fixed code rate and block length for a fixed channel condition has been well investigated and very close-to-capacity performance can be achieved by careful optimization of a code's degree distributions. The growing variety of services supported by mobile communication systems, however, constitutes the need for highly flexible Forward Error Correction (FEC) schemes. Pursuing this need, we present a design method for the construction of quasi-cyclic (QC) LDPC codes supporting arbitrarily many block lengths and code rates using only a single common mother code. Different block lengths are achieved by an optimized expansion of the mother code's lifting matrix. For the support of multiple code rates, a joint optimization of shortening and puncturing distributions as well as an optimized check matrix construction based on the progressive edge-growth algorithm is employed.

Tuesday, August 19

08:40 - 09:20

Tu-1: Shu Lin (Invited Speaker)

Chair: Gerhard Kramer (Technische Universität München, Germany)

[Error Floors and Finite Geometries](#)

Shu Lin (UC Davis, USA); Qiuju Diao (University of California, Davis, USA); Ian Blake (University of British Columbia, Canada)

The structure of certain subgraphs of the Tanner graph of an LDPC code, the trapping sets, has been identified as important for the error floor performance of iterative decoding algorithms. To investigate such sets requires the parity check matrix of the code to be generated with sufficient structure that allows useful information to be obtained while giving good codes. Structures that have been considered include combinatorial designs and classical finite geometries. More recently other finite geometric notions such as partial geometries and generalized d-gons have been considered with some success. This work considers aspects of this approach.

09:20 - 10:00

Tu-2: Andrea Montanari (Invited Speaker)

Chair: Michael Lentmaier (Lund University, Sweden)

[Message passing algorithms on dense graphs](#)

Andrea Montanari (Stanford University, USA)

I will review some recent applications of message passing algorithms to statistical estimation problems on dense graphs, and describe mathematical tools that allow to analyze rigorously these algorithms. Examples will include compressed sensing, community detection, constrained principal component analysis, tensor decompositions. I will discuss a number of fascinating connections with optimization, computational complexity, and probability theory.

10:20 - 11:00

Tu-3: Analog Processing

Chair: Jossy Sayir (University of Cambridge & Signal Processing and Communications Laboratory, United Kingdom)

Variational Message Passing Without Initialization Using A Free Energy Constraint

Murthy V.R.S. Devarakonda (Consultant, India)

In iterative algorithms with graphical models, it is common to initialize messages. But this approach is not suitable in certain applications. In this paper, it is conjectured that if some messages are confined to a ball around their initialized values, then initialization can be avoided. Towards this goal, for networks specified with a bipartite graph, a variant of the sum-product algorithm is derived by adding an inequality constraint on the variable free energy in the underlying Bethe optimization problem. In the binary case, this leads to an upper bound that restricts the l_1 norm of the extrinsic message (vector) to a ball around its (otherwise) initial value. Results are reported for binary LDPC decoders through simulations which confirm that initialization between decoding attempts can be eliminated and show that the algorithm tends to outperform the standard sum-product. A few more observations and comments on this approach, relation with other variational methods, and applications to analog processing and inference over distributed networks are outlined in the end.

Approximation of Activation Functions for Vector Equalization based on Recurrent Neural Networks

Mohamad Mostafa (University of Ulm, Germany); Werner G. Teich (Ulm University, Germany); Juergen Lindner (Uni Ulm, Germany)

Activation functions represent an essential element in all neural networks structures. They influence the overall behavior of neural networks decisively because of their nonlinear characteristic. Discrete- and continuous-time recurrent neural networks are a special class of neural networks. They have been shown to be able to perform vector equalization without the need for a training phase because they are Lyapunov stable under specific conditions. The activation function in this case depends on the symbol alphabet and is computationally complex to be evaluated. In addition, numerical instability can occur during the evaluation. Thus, there is a need for a simpler evaluation. Especially for the continuous-time recurrent neural network, the evaluation must be suitable for an analog implementation. In this paper, we introduce an approximation of the activation function for vector equalization with recurrent neural networks. The activation function is approximated as a sum of shifted hyperbolic tangent functions, which can easily be realized in analog by a differential amplifier. Based on our ongoing research in this field, the analog implementation of vector equalization with recurrent neural networks is expected to improve the power/speed ratio by several order of magnitude compared with the digital one.

11:00 - 12:00

Tu-4: Trapping Sets and Graphs

Chair: Daniel J. Costello, Jr. (University of Notre Dame, USA)

On the Guaranteed Error-Correction of Decimation-Enhanced Iterative Decoders

Shiva K. Planjery (ETIS lab. ENSEA/Cergy University/CNRS UMR, USA); David Declercq (ETIS lab. ENSEA/Cergy University/CNRS UMR, France); Madiagne Diouf (ETIS lab. ENSEA/Cergy University/CNRS UMR, France); Bane Vasić (University of Arizona, USA)

Finite alphabet iterative decoders (FAIDs) were proposed for LDPC codes on the binary symmetric channel which are capable of surpassing the belief propagation (BP) decoder in the error floor region with lower complexity and precision, but these decoders are difficult to analyze for finite code lengths. Recently, decimation-enhanced FAIDs (DFAIDs) were proposed for column-weight-three codes wherein the technique of decimation was incorporated into the message update rules of FAIDs to make them more amenable to analysis while maintaining their good performance. Decimation involves fixing the bit values of certain variable nodes during message-passing based on the messages they receive after some number of iterations. In this paper, we address the problem of proving the guaranteed error-correction capability of DFAIDs for column-weight-three LDPC codes. We present the methodology of the proof to derive sufficient conditions on the Tanner graph that guarantee the correction of a given error pattern in a finite number of iterations. These sufficient conditions are described as a list of forbidden graphs that must not be contained in the Tanner graph of the code. As a test case, we consider the problem of guaranteeing the correction of four errors. We illustrate the analysis for a specific 4-error pattern and provide the sufficient conditions for its correction. We also present results on the design of codes satisfying those sufficient conditions and their impact on the achievable code rate.

On Characterization of Elementary Trapping Sets of Variable-Regular LDPC Codes

Mehdi Karimi (Carleton University, Canada); Amir Banihashemi (Carleton University, Canada)

In this paper, we study the graphical structure of elementary trapping sets (ETS) of variable-regular low-density parity-check (LDPC) codes. ETSs are known to be the main cause of error floor in LDPC coding schemes. For the set of LDPC codes with a given variable node degree d_1 and girth g , we identify all the non-isomorphic structures of an arbitrary class of (a, b) ETSs, where a is the number of variable nodes and b is the number of odd-degree check nodes in the induced subgraph of the ETS. Our study leads to a simple characterization of dominant classes of ETSs (those with relatively small values of a and b) based on short cycles in the Tanner graph of the code. For such classes of ETSs, we prove that any set S in the class is a layered superset (LSS) of a short cycle, where the term "layered" is used to indicate that there is a nested sequence of ETSs that starts from the cycle and grows, one variable node at a time, to generate S . This characterization corresponds to a simple search algorithm that starts from the short cycles of the graph and finds all the ETSs with LSS property in a guaranteed fashion. Specific results on the structure of ETSs are presented for $d_1 = 3, 4, 5, 6$, $g = 6, 8$ and $a, b \leq 10$ in this paper. The results of this work can be used for the error floor analysis and for

the design of LDPC codes with low error floors.

On the Equivalence of the ACE and the EMD of a Cycle for the ACE Spectrum Constrained LDPC Codes

Kuntal Deka (Indian Institute of Technology, India); Alentattil Rajesh (Indian Institute of Technology, India); Prabin Kumar Bora (Indian Institute of Technology, India)

The Extrinsic Message Degree (EMD) of a cycle in the Tanner graph of a low density parity check (LDPC) code measures the connectivity of the cycle. As it is difficult to calculate the EMD, the Approximate EMD (ACE) is generally used. However, the ACE of a cycle is not always equal to its EMD. This paper presents some sufficient conditions for the equivalence of the ACE and the EMD of a cycle for the ACE spectrum constrained LDPC codes.

13:30 - 15:10

Tu-5: Spatially Coupled Codes

Chair: David Declercq (ETIS lab. ENSEA/Cergy University/CNRS UMR, France)

Improving the finite-length performance of long SC-LDPC code chains by connecting consecutive chains

Pablo M. Olmos (Universidad Carlos III de Madrid, Spain); David G. M. Mitchell (University of Notre Dame, USA); Dmitri Truhachev (University of Alberta, Canada); Daniel J. Costello, Jr. (University of Notre Dame, USA)

In this paper, we propose a novel encoding/transmission scheme called continuous chain (CC) transmission that is able to improve the finite-length performance of a system using long spatially coupled low-density parity-check (SC-LDPC) code chains. First, we show that the decoding of SC-LDPC code chains is more reliable for shorter chain lengths, i.e., the scaling between block error rate and gap to threshold is more favorable for shorter chains. This motivates the use of CC transmission in which, instead of transmitting a sequence independent codewords from a SC-LDPC long chain, we connect multiple chains in a layered format, where encoding, transmission, and decoding are now performed in a continuous fashion. Finally, we show that CC transmission can be implemented with only a small increase in decoding complexity or delay with respect to a system employing a single SC-LDPC code chain for transmission.

Laterally Connected Spatially Coupled Code Chains for Transmission over Unstable Parallel Channels

Laurent Schmalen (Alcatel-Lucent, Bell Laboratories, Germany); Kaveh Mahdaviyani (University of Toronto & Isfahan Mathematics House, Canada)

We propose a new coding scheme for parallel binary erasure channels that may have time-varying characteristics. The proposed scheme consists of several spatially coupled codes, each assigned to a different channel, that are sparsely coupled between each other. This sparse

coupling, denoted lateral connectivity helps the decoding waves of the different sub-codes to propagate, even if the associated channel undergoes a burst error event. The new ensemble is analyzed using density evolution and it is shown that it outperforms parallel, independent spatially coupled codes.

Spatially Coupled Turbo Codes

Saeedeh Moloudi (Lund University, Sweden); Michael Lentmaier (Lund University, Sweden); Alexandre Graell i Amat (Chalmers University of Technology, Sweden)

In this paper, we introduce the concept of spatially coupled turbo codes (SC-TCs), as the turbo codes counterpart of spatially coupled low-density parity-check codes. We describe spatial coupling for both Berrou et al. and Benedetto et al. parallel and serially concatenated codes. For the binary erasure channel, we derive the exact density evolution (DE) equations of SC-TCs by using the method proposed by Kurkoski et al. to compute the decoding erasure probability of convolutional encoders. Using DE, we then analyze the asymptotic behavior of SC-TCs. We observe that the belief propagation (BP) threshold of SC-TCs improves with respect to that of the uncoupled ensemble and approaches its maximum a posteriori threshold. This phenomenon is especially significant for serially concatenated codes, whose uncoupled ensemble suffers from a poor BP threshold.

Rate-Compatible Spatially Coupled LDPC Codes via Repeat-Accumulation Extension

Wei Hou (Doshisha University, Japan); Shan Lu (Doshisha University, Japan); Jun Cheng (Doshisha University, Japan)

We propose the construction of rate-compatible spatially coupled low-density parity-check (SC-LDPC) codes. For a given high-rate SC-LDPC mother code, a family of low-rate member codes can be obtained by extending the protograph of the mother code with repeat-accumulation (RA). Rate compatibility is obtained by adjusting the RA-extension parameters. Continuous code rate is achieved without extra cost. Density evolution analysis shows that the iterative decoding thresholds of all the member codes of the rate-compatible family are very close to the Shannon limits over the binary erasure channels.

A General Procedure to Design Good Codes at a Target BER

Chulong Liang (Sun Yat-sen University, P.R. China); Xiao Ma (Sun Yat-sen University, P.R. China); Qiutao Zhuang (Sun Yat-sen University, P.R. China); Baoming Bai (Xidian University, P.R. China)

This paper presents a systematic design methodology for block Markov superposition transmission (BMST) systems to approach the channel capacity at any given target bit-error-rate (BER) of interest. To simplify the design, we choose the basic code as the Cartesian product of a short block code. The encoding memory is then inferred from the genie-aided lower bound according to the performance gap of the short block code to the corresponding Shannon limit at the target BER. In addition to the sliding-window decoding algorithm, we propose to perform one more phase decoding to remove residual (rare) errors. A new technique that assumes a noisy genie is proposed to upper bound the performance. Under

some assumptions, these genie-aided bounds can be used to predict the performance of the proposed two-phase decoding algorithm in the extremely low BER region. Using the Cartesian product of a repetition code as the basic code, we construct a BMST system with an encoding memory 30 whose performance at the BER of 10^{-15} can be predicted over the binary-input additive white Gaussian noise channel (BI-AWGNC).

15:30 - 17:10

Tu-6: Hardware Design

Chair: Laurent Schmalen (Alcatel-Lucent, Bell Laboratories, Germany)

On the Performance of SC-MMSE-FD Equalization for Fixed-Point Implementations

Michael Schwall (Karlsruhe Institute of Technology (KIT), Germany); Tamal Bose (University of Arizona, USA); Friedrich K. Jondral (Karlsruhe Institute of Technology, Germany)

A fixed-point implementation of a minimum mean square error (MMSE) based frequency domain (FD) equalizer with soft interference cancellation (SC) is studied. The equalizer additionally processes a priori information about the transmitted symbols and is used for turbo equalization. In this paper, we analyze the quantization and the clipping for different fixed-point representations and modulation schemes. The analysis allows to derive efficient representations for all symbols within the equalizer. This procedure is demonstrated for a generic system configuration featuring a 16-QAM. Finally, a fixed-point implementation in an integrated design environment for FPGAs verifies the theoretical studies and shows the device utilizations for different FPGAs that are embedded in current software defined radios. The results show, that on average 10 bits per symbol are required for a near-optimum equalization performance utilizing less than 8% area of state of the art FPGAs.

Hardware-friendly Probabilistic Min-Sum Algorithm for Fully-parallel LDPC Decoders

Huang Chang Lee (National Tsing Hua University, Taiwan); Chung-Chao Cheng (National Tsing Hua University, Taiwan); Yeong-Luh Ueng (National Tsing Hua University, Taiwan)

In order to simplify the check node operation of the low-density parity-check (LDPC) decoders, this paper presents a Normalized Probabilistic Min-Sum Algorithm (NPMSA), where the second minimum value is replaced by a probabilistic second minimum value. For NPMSA, the number of required comparisons can be reduced to about half compared to that of the conventional Normalized Min-Sum Algorithm (NMSA). It is shown that the simplification only introduces negligible impact on the bit-error rate performance, especially for codes with a high check node degree. When the proposed NPMSA is applied to the (2048, 1723) RS-LDPC code, the degradation in the error-rate performance is only about 0.05 dB. The hardware implementation shows that a throughput of 45.42 Gbps can be achieved using the proposed NPMSA.

Finite Alphabet Iterative Decoders Robust to Faulty Hardware: Analysis and Selection

Elsa Dupraz (ETIS, CNRS, ENSEA, UniversityCergy-Pontoise, France); David Declercq (ETIS lab. ENSEA/Cergy University/CNRS UMR, France); Bane Vasić (University of Arizona, USA); Valentin Savin (CEA LETI, France)

In this paper, we analyze Finite Alphabet Iterative Decoders (FAIDs) running on faulty hardware. Under symmetric error models at the message level, we derive the noisy Density Evolution equations, and introduce a new noisy threshold phenomenon (called functional threshold), which accurately characterizes the convergence behavior of LDPC code ensembles under noisy-FAID decoding. The proposed functional threshold is then used to identify FAIDs which are particularly robust to the transient hardware noise. Finite-length simulations are drawn to verify the validity of the asymptotical study.

Faulty Stochastic LDPC Decoders Over the Binary Symmetric Channel

Christiane Kameni Ngassa (CEA-LETI, France); Valentin Savin (CEA LETI, France); David Declercq (ETIS lab. ENSEA/Cergy University/CNRS UMR, France)

The analysis of error correction decoders running on faulty hardware has attracted an increased interest in recent years, due to the inherent unreliability of emerging nanodevices. In this paper we investigate the performance of the stochastic decoder running on faulty hardware. To this end, we first introduce two error models to describe the noisy components of the decoder. We then provide a finite-length statistical analysis for each error model and, based on the obtained performance, we conclude that stochastic decoders have an inherent fault tolerant capability.

Design and implementation of an adaptive coding and modulation system for microwave radio transmission in mobile backhaul networks

Stefano Chinnici (Ericsson Telecomunicazioni S.p.A., Italy); Enrico Carni (Ericsson Telecomunicazioni SpA, Italy); Marco Manfredi (Ericsson Telecomunicazioni SpA, Italy); Leonardo Tufaro (Ericsson Telecomunicazioni SpA, Italy); Guido Montorsi (Politecnico di Torino, Italy); Sergio Benedetto (Politecnico di Torino, Italy); Christian Camarda (Politecnico di Torino, Italy)

The design of an adaptive coding and modulation (ACM) system for microwave radio transmission in mobile backhaul networks must comply with a number of application related constraints. The system gain should be maximized within the block length limits imposed by the maximum admissible transmission delay. The microwave channel characteristics require that the ACM system possess a high flexibility in terms of code rates and modulation alphabet. This paper describes the industrial application of a pragmatic ACM system, starting from system design down to architectural design and implementation in FPGA and ASIC technologies. The performance of the implemented scheme is compared against traditional codes in simulations and in a real-time radio link FPGA-based prototype

17:30 - 18:30

Tu-7: Source-Channel Coding

Chair: Amir Banihashemi (Carleton University, Canada)

Information shortening for joint source-channel coding schemes based on low-density parity-check codes

Humberto Beltrão Neto (Jacobs University Bremen, Germany); Werner Henkel (Jacobs University Bremen, Germany)

We propose a simple shortening algorithm for joint source-channel coding schemes based on low-density parity-check codes. Due to finite-length effects, such systems present high error floors when optimised for low-entropy binary symmetric sources and transmission over an AWGN channel. To mitigate such effects, we propose the reduction of the compression rate by inserting infinite reliability on the variable nodes which form cycles with length equal to the girth of the code used as source compressor. Simulation results show that such strategy is able to efficiently exchange a slight reduction of the compression rate for a significant performance enhancement.

Optimized codes for the binary coded side-information problem

Anne Savard (CNRS / ENSEA / University Cergy-Pontoise, France); Claudio Weidmann (CNRS / ENSEA / University Cergy-Pontoise, France)

This paper analyzes a practical scheme for the binary coded side-information problem based on LDPC codes and trellis quantization. A recently proposed improved decoder is shown to be amenable to numerical density evolution and thus to LDPC code optimization. First results display significant gains compared to off-the-shelf codes, which could be further improved by refined modeling of the system.

Low-complexity fixed-to-fixed joint source-channel coding

Irina Bocharova (St. Petersburg University of Information Technologies, Mechanics and Optics, Russia); Albert Guillén i Fàbregas (ICREA and Universitat Pompeu Fabra & University of Cambridge, Spain); Boris Kudryashov (St. Petersburg University of Information Technology, Mechanics and Optics, Russia); Alfonso Martinez (Universitat Pompeu Fabra, Spain); Adrià Tauste Campo (Universitat Pompeu Fabra, Spain); Gonzalo Vazquez-Vilar (Universitat Pompeu Fabra, Spain)

We study a source-channel coding scheme in which source messages are split into two classes and encoded using a channel code that depends on the class index. It is shown that a low-complexity implementation of this scheme using two optimized quasi-cyclic LDPC codes with belief-propagation decoding achieves a better frame error rate (FER) performance compared to optimized separate coding. The coding gain obtained by simulation is consistent with the recently predicted theoretical gain of the proposed scheme.

Wednesday, August 20

09:00 - 09:40

We-1: David Tse (Invited Speaker)

Chair: Werner Henkel (Jacobs University Bremen, Germany)

[RNA-Seq Assembly: Fundamental Limits, Algorithms, and Software](#)

David Tse (Stanford University)

Extraordinary advances in sequencing technology in the past decade have revolutionized biology and medicine. Many high-throughput sequencing based assays have been designed to make various biological measurements of interest. One of the most important assays is RNA sequencing (RNA-Seq). A key computational problem in RNA-Seq is that of assembly: how to reconstruct from the many millions of short reads the underlying RNA transcripts? Traditionally, assembler design is viewed mainly as a software engineering project, where time and memory requirements are primary concerns while the assembly algorithms themselves are designed based on heuristic considerations with no optimality guarantee. In this talk, we outline an alternative approach to assembly design based on information theoretic principles. Starting with the question of when there is enough information in the reads to reconstruct, we design a near-optimal assembly algorithm that can reconstruct with minimal amount of read information. We implemented the algorithm in a software ShannonRNA and compare its performance on both simulated and real data with state-of-the-art software in the field.

09:40 - 10:00

We-2: Gerard Battail (Invited Speaker)

Chair: Claude Berrou (Télécom Bretagne, France)

[Fleeting objects, enduring information](#)

Gerard Battail (Ecole nationale supérieure des télécommunications, Paris, (retired), France)

Information can only be defined as an equivalence class of sequences with respect to alphabet changes and encodings, hence it is an abstract entity. However, a sequence is necessarily borne by a physical support. Information thus appears as a bridge between the abstract and the concrete. In the living world, the information borne by genomes acts on matter by instructing the assembly of objects. Physical perturbations degrade the supports, hence the sequences they bear, but the information they represent can be almost indefinitely conserved provided they are endowed with error-correcting codes as powerful as to enable their regeneration, and regenerated frequently enough. Codes made of nested components which successively originated over the ages account for the conservation of the oldest parts of the genomes. The

component codes are 'soft', meaning that they result from any kind of non-mathematical constraint, e.g., physical-chemical or linguistic. The genomic information instructs the assembly of living structures by the agency of interwoven semantic feedback loops which lock themselves because the synthesized enzymes catalyse their own assembly.

10:20 - 12:00

We-3: Genetic Codes

Chair: Martin Bossert (Ulm University, Germany)

Using the Davey-MacKay code construction for barcodes in DNA sequencing

David Kracht (Ulm University, Germany); Steffen Schober (Ulm University, Germany)

In this paper we explain how we modify the Davey-MacKay code construction to generate so called DNA barcodes, a kind of label sequences used in the context of DNA sequencing. Davey and Mackay proposed the concept of watermark codes to communicate over binary channels with insertion and deletion errors. Such synchronization errors are likely to occur during DNA sequencing and may lead to serve problems in decoding the DNA barcodes. In order to use the watermark concepts in the DNA context we need adapt and extend the original ideas. We mainly give a quaternary adaptation of the channel model and modifications of the elementary hidden Markov models for decoding. An extended transmission model and a strategy to acquire synchronization for barcodes, that are embedded in an unknown DNA context is also proposed. We show simulation results indicating that watermark inspired barcodes are applicable for DNA sequencing. Apart from other approaches that have been proposed for barcoding in the presence of synchronization errors, we do not depend on greedy search algorithms for code words, but are able to use a code construction and a well-defined decoding procedure.

Iterative Learning of Single Individual Haplotypes from High-Throughput DNA Sequencing Data

Zrinka Puljiz (The University of Texas at Austin, USA); Haris Vikalo (The University of Texas at Austin, USA)

In recent years, advancements in high-throughput DNA sequencing technologies enabled heretofore impractical studies of genetic variations. Cells of diploid organisms, including humans, have a number of chromosome pairs that are homologous - they encode essentially the same genetic information and are almost identical but vary in certain location. These variations are referred to as single nucleotide polymorphisms. The complete information about genetic variations in an individual genome is given by haplotypes, ordered sequences of single nucleotide polymorphisms for each homologous pair of chromosomes. In this paper, we derive a graphical formulation of the haplotype assembly problem, propose an iterative scheme for single individual haplotyping, and demonstrate the performance of the algorithm on experimental data. The results demonstrate that the proposed method has better accuracy than state-of-the-art haplotype assembly techniques.

Investigation of genetic code optimality for overlapping protein coding sequences

Katharina Mir (Ulm University, Germany); Steffen Schober (Ulm University, Germany)

An analytical model to determine codon transitions in alternative reading frames based on the statistical properties of prokaryotic genomes within annotated genes is developed. This model predicts the codon usage in alternative reading frames and is applied to study overlapping genes. We investigate the standard genetic code that has a highly nonrandom structure which improves the robustness of the code against several types of errors. A comparison of the standard code with alternative genetic codes is presented investigating if the standard code is optimized to allow long overlapping genes.

Splicing System and Sofic Shift

Hiroshi Kamabe (Gifu University, Japan)

Splicing systems are mathematical models that are used for sets of DNA sequences generated through repeated chemical reactions of DNA sequences, which were introduced by Head in 1987. Although a splicing system specifies a regular language, it is known that all regular languages cannot be generated by a splicing system. Symbolic dynamical systems are sets of infinite sequences that are closely related to formal languages. In this manuscript, several characterizations of the splicing system are given using the theory of symbolic dynamical systems.

DNA Inspired Bi-directional Lempel-Ziv-like Compression Algorithms

Attiya Mahmood (Jacobs University Bremen, Germany); Nazia Islam (Jacobs University Bremen, Germany); Dawit Nigatu (Jacobs University Bremen, Germany); Werner Henkel (Jacobs University Bremen, Germany)

The bi-directional reading processes in DNA replication and gene expression together with the similarities between the so-called alternative splicing and Lempel-Ziv (LZ) algorithms has motivated us to incorporate bi-directional readings into LZ algorithms. LZ77, LZ78, and LZW84 are universal lossless data compression algorithms. A modified version of these algorithms that takes into account both forward and reverse readings is presented in this work. It is shown that bi-directional reading can improve the compression ratio at the expense of slight modifications in LZ algorithms provided that there exists some symmetry in the information content. Results are presented for text, image, and audio files.

Thursday, August 21

09:00 - 09:40

Th-1: Claude Berrou (Invited Speaker)

Chair: Joachim Hagenauer (TU Munich, Germany)

Information, Noise, Coding, Modulation: What about the Brain?

At the microscopic level, the brain is fundamentally a matter of physics and chemistry, as all the components of the universe are. At the macroscopic scale, behavior, psychology and affects are the main dimensions of its life. To convert atoms and molecules into intelligence, some kind of information has to be fixed in the grey matter of the cerebral cortex. The way this "mental information" is materialized and processed is still an enigma, probably the most puzzling problem addressed to science nowadays. At this mesoscopic level of the brain functioning, the concepts to consider are likely the same as those considered in communication and information theory, mainly information, noise, coding and modulation. This paper proposes some ideas that could help understand some features of the brain in an information-processing perspective.

09:40 - 10:20

Th-2: Frank Kschischang (Invited Speaker)

Chair: Stephan ten Brink (University of Stuttgart, Germany)

Staircase Codes for High-Speed Optical Communications

Frank R. Kschischang (University of Toronto, Canada)

Staircase codes are a hardware-friendly spatially-coupled product-code ensemble with hard-decision component decoders, aimed at optical communication systems which require very high decoding throughputs (100 Gbps or higher) and very low bit error rates (10^{-15} or lower). We describe a rate 239/255 ITU-T G.709-compatible design, and various other high-rate designs. We also describe a peeling-decoder ensemble analysis that gives binary symmetric channel threshold estimates for large systems. (These are the results of joint work with Lei Zhang, Dmitry Trukhachev, Benjamin Smith, Arash Farhood, Andrew Hunt, and John Lodge).

10:40 – 12:00

Th-3: Satellite Channels

Chair: Catherine Douillard (Institut Telecom - Telecom Bretagne, France)

Asymptotic Analysis and Design of Iterative Receivers for Non Linear ISI Channels

Bouchra Benammar (University of Toulouse/ ENSEEIHT, France); Nathalie Thomas (University of Toulouse, France); Charly Poulliat (INP - ENSEEIHT Toulouse, France); Marie-Laure Boucheret (University of Toulouse IRIT Enseeiht, France); Mathieu Dervin (Thales Alenia Space, France)

In this paper, iterative receiver analysis and design for non linear satellite channels is investigated. To do so, an EXtrinsic Information Transfer (EXIT) chart-based optimization is applied using two major assumptions: the equalizer outputs follow a Gaussian Mixture distribution since we use non-binary modulations and partial interleavers are used between the Low Density Parity Check (LDPC) code and the mapper. Achievable rates, performance and thresholds of the optimized receiver are analysed. The objective in fine is to answer the question: Is it worth optimizing an iterative receiver for non linear satellite channels?

Analysis and Design of Radial Basis Function-Based Turbo Equalizers

Hasan Abdulkader (University of Toulouse, INPT-ENSEEIH/IRIT, Toulouse, France., France); Bouchra Benammar (University of Toulouse/ ENSEEIHT, France); Charly Poulliat (INP - ENSEEIHT Toulouse, France); Marie-Laure Boucheret (University of Toulouse IRIT Enseeiht, France); Nathalie Thomas (University of Toulouse, France)

This paper investigates radial basis function-based turbo equalization (TEQ) applied to non linear communication channels via satellite. This channel is considered as a Volterra model. The paper deduce the soft input soft output (SISO) radial basis function (RBF) equalizer that can be implemented in an iterative algorithm to improve the system performance. Reduced complexity implementations are also presented, especially feedback (FB) method is considered in this paper. The aim of this paper is to analyse equalizer design considerations, namely delay and feedback, they are analysed in order to point to the optimal design of the TEQ. The paper shows the ability to choose optimal equalizer parameters using the EXIT chart technique. Achievable rate curves, from source to destination.

On Linear Frequency Domain Turbo-Equalization Of Non Linear Volterra Channels

Bouchra Benammar (University of Toulouse/ ENSEEIHT, France); Nathalie Thomas (University of Toulouse, France); Charly Poulliat (INP - ENSEEIHT Toulouse, France); Marie-Laure Boucheret (University of Toulouse IRIT Enseeiht, France); Mathieu Dervin (Thales Alenia Space, France)

This article deals with iterative Frequency Domain Equalization (FDE) for Single Carrier (SC) transmissions over Volterra non linear satellite channels. SC-FDE has gained much

importance in recent research for its efficient implementation at the receiver and its interesting low Peak to Average Power Ratio (PAPR) at the transmitter. However, nearly saturated power amplifiers on board satellites generate linear and non linear Inter Symbol Interference (ISI) at the receiver. It is thus interesting to investigate the implementation of SC-FDE for non linear channels. To do so, a frequency domain equivalent satellite channel is derived based on the time domain Volterra series representation of the non linear channel. Then a Minimum Mean Square Error (MMSE)-based iterative frequency domain equalizer is designed. It is shown that the proposed equalizer consists of a Soft Interference Canceller (SIC) which subtracts both the linear and non-linear soft frequency symbols. The equalizer performance is then compared to the equivalent time domain implementation. Results show that a channel-memory independent efficient implementation is achieved at the price of a negligible spectral efficiency loss due to cyclic prefix insertion.

Iterative Demodulation and Channel Estimation for Joint Random Access Satellite Communications

Paul Dickson (Dalhousie University, Canada); Christian Schlegel (Dalhousie University, Canada)

Future high-density multiple-user interactive satellite communications is investigated by proposing advancements in receiver design for random access on the uncoordinated satellite up-link. Joint detection and multiple packet reception (MPR) techniques are applied to show that it is possible to surpass the capacity of the current single-user random access channel. This is accomplished through adaptation of the concept of generalized modulation and the use of iterative estimation coupled with advanced interference cancellation techniques.

13:30 - 15:10

Th-4: Non-Binary LDPC Codes

Chair: Irina Bocharova (St. Petersburg University of Information Technologies, Mechanics and Optics, Russia; Lund University, Sweden)

The PPM Poisson Channel: Finite-Length Bounds and Code Design

Flavio Zabini (University of Bologna, Italy); Balazs Matuz (German Aerospace Center (DLR), Germany); Gianluigi Liva (DLR - German Aerospace Center, Germany); Enrico Paolini (University of Bologna, Italy); Marco Chiani (University of Bologna, Italy)

This work investigates finite-length block error probability for the pulse position modulation (PPM) Poisson channel. Amongst, expressions for the Gallager random coding bound (RCB) and the Polyanskiy-Poor-Verdu' converse bound are derived. Likewise, we introduce an erasure channel (EC) approximation that allows the application of known EC bounds to the PPM Poisson channel by matching the channel capacities. We show that the derived bounds are not only simple to compute, but also accurate. Additionally, the design of protograph-based non-binary low-density parity-check (LDPC) codes for the (PPM) Poisson channel is addressed. The order q of the finite field is directly matched to the PPM order, so that no iterative message exchange between the decoder and the modulator is required. The suggested

design turns out to be robust w.r.t. different channel parameters, yielding performances within 0.5 dB from theoretical bounds.

Estimation of the Decoding Threshold of LDPC Codes over the q -ary Partial Erasure Channel

Rami Cohen (Technion - Israel Institute of Technology, Israel); Yuval Cassuto (Technion, Israel)

In this paper, we discuss bounds and approximations for the decoding threshold of LDPC codes over the q -ary partial erasure channel (QPEC), introduced in [1]. The QPEC has a q -ary input, and its output is either one symbol or a set of $2 \leq M \leq q$ possible symbols. We show how an upper bound on the decoding threshold can be derived using a single-letter recurrence relation, when $M > q/2$. In addition, we discuss complexity issues in the calculation of the threshold, and provide two approximation models that lead to reasonable results with a fraction of the complexity required for the exact calculation.

A Symbol Flipping Decoder for NB-LDPC relying on Multiple Votes

Francisco-Garcia Herrero (Universidad Politecnica de Valencia, Spain); David Declercq (ETIS lab. ENSEA/Cergy University/CNRS UMR, France); Javier Valls (Universidad Polit cnica de Valencia, Spain)

In this paper, we present an algorithm to decode non-binary LDPC (NB-LDPC) codes, inspired from very-high throughput symbol-flipping decoders that have been proposed recently. Usually, the symbol-flipping decoders suffer from a non-negligible performance degradation compared to soft-decision NB-LDPC decoders. Our improved decoder makes use of a list of syndrome computations instead of a single one, and builds soft information at the symbol node input by assigning votes with different weights to the elements of the list. We show by simulations that using multiple votes results in better performance, while still maintaining the high throughput feature.

Construction of Non-binary LDPC Codes: A Matrix-Theoretic Approach

Juane Li (University of California at Davis, USA); Keke Liu (Department of ECE, University of California, Davis, USA); Shu Lin (UC Davis, USA); Khaled Abdel-Ghaffar (University of California, USA)

This paper presents a matrix-theoretic approach to the construction of non-binary LDPC codes. Several algebraic methods for constructing non-binary LDPC codes are presented. The proposed construction methods have several ingredients including base matrix, matrix-dispersion, masking and superposition. By proper choice and combination of these ingredients, nonbinary LDPC codes with good performance can be constructed.

Low-Complexity LDPC-coded Iterative MIMO Receiver Based on Belief Propagation algorithm for Detection

Ali Haroun (Telecom Bretagne, France); Charbel Abdel Nour (Institut Telecom - Telecom Bretagne, France); Matthieu Arzel (Telecom Bretagne, France); Christophe Jego (IMS CNRS

Laboratory & IPB ENSEIRB-MATMECA, France)

A low-complexity Multiple Input Multiple Output receiver based on Belief Propagation (MIMO-BP) detector associated with a Non-Binary Low Density Parity Check (NB-LDPC) decoder is proposed in this paper. Such detection and decoding algorithms are represented thanks to a larger Joint Factor Graph. Shuffle schedule is also applied to efficiently exchange information between the detector and the decoder. Actions are undertaken at the detector, decoder and the iterative receiver levels in order to reduce overall computational complexity. An important reduction in terms of operations per iteration is obtained with a negligible performance penalty. Then, EXtrinsic Information Transfer (EXIT) charts are used to find a schedule in terms of number of iterations to be performed for which the proposed receiver achieves error correction performance similar to that of a full-complexity iterative MIMO receiver.

15:30 - 17:10

Th-5: Latency, Polar Codes, Erasure Codes

Chair: Boris Kudryashov (St. Petersburg University of Information Technology, Mechanics and Optics, Russia; Lund University, Sweden)

Low Latency-Constrained High Rate Coding: LDPC Codes vs. Convolutional Codes

Christoph Rächinger (University of Erlangen-Nuremberg, Germany); Johannes Huber (University of Erlangen-Nuremberg, Germany); Ralf R. Müller (University of Erlangen-Nuremberg, Germany)

This paper complements and generalizes the results in some previous publications while taking new performance bounds into account. We compare convolutional and LDPC codes of different rates with respect to their structural delay. This property is intrinsic to the en- and decoding process and gives a fundamental limit to the achievable latency for end-to-end communication, even when infinite processing speed is assumed. We show that in the case of very low delay convolutional codes perform better than LDPC codes and even break fundamental existence bounds for block codes for some rates. Furthermore, we show that non-punctured convolutional codes can benefit from their shorter constraint length and reduce the delay further.

Low-latency Polar Codes via Hybrid Decoding

Bin Li (Huawei Technologies, P.R. China); Hui Shen (Huawei, USA); David Tse (Stanford University, USA); Wen Tong (Huawei, Canada)

In this paper, we propose a family of hybrid decoders for Polar codes. By decomposing the overall Polar code into an inner code and an outer code, a hybrid decoder in the family uses successive cancellation (SC) to decode the inner code and maximum-likelihood (ML) to decode the outer code. At one extreme in the family is the ML decoder, when the entire Polar code is viewed as the outer code; at the other extreme is the SC decoder, when the entire Polar code is viewed as the inner code. Since ML decoding has lower latency than SC decoding, a

hybrid decoder can achieve lower latency than the conventional SC decoder, at the expense of higher complexity due to the ML decoding of the outer code. We propose a reduction in the complexity of ML decoding by exploiting the structure of Polar codes.

A New Code Construction for Polar Codes Using Min-Sum Density

Daniel Kern (University of Rostock, Germany); Sebastian Vorkoeper (University of Rostock, Germany); Volker Kuehn (University of Rostock, Germany)

Polar codes are capacity achieving codes for binary-input symmetric memoryless channels (B-SMCs) if the code word length tends to infinity. Its encoding and decoding complexity is low. However, low complexity in code construction holds only for some special B-SMCs like the binary erasure channel (BEC). For all other B-SMCs, the code construction becomes a trade off between complexity and construction accuracy. This paper gives an overview on the most popular code construction methods including a new approach yielding to near optimum code construction while reducing the complexity and increasing robustness against numerical problems. In addition, we compare the performance of the presented methods in terms of frame error rates (FERs) for codes of length 2048.

Density Evolution for SUDOKU Codes on the Erasure Channel

Caroline Atkins (University of Cambridge, United Kingdom); Jossy Sayir (University of Cambridge & Signal Processing and Communications Laboratory, United Kingdom)

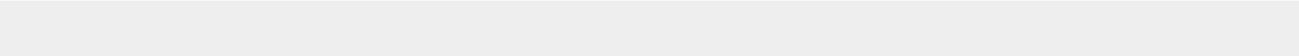
Codes based on SUDOKU puzzles are discussed, and belief propagation decoding introduced for the erasure channel. Despite the non-linearity of the code constraints, it is argued that density evolution can be used to analyse code performance due to the invariance of the code under alphabet permutation. The belief propagation decoder for erasure channels operates by exchanging messages containing sets of possible values. Accordingly, density evolution tracks the probability mass functions of the set cardinalities. The equations governing the mapping of those probability mass functions are derived and calculated for variable and constraint nodes, and decoding thresholds are computed for long SUDOKU codes with random interleavers.

An Efficient Complexity-Optimizing LDPC Code Design for the Binary Erasure Channel

Vahid Jamali (Friedrich-Alexander-University Erlangen-Nuremberg, Germany); Yasser Karimian (K. N. Toosi University of Technology, Germany); Johannes Huber (University of Erlangen-Nuremberg, Germany); Mahmoud Ahmadian (K N Toosi University of Technology, Iran)

The complexity-performance trade-off is a fundamental aspect of the design of low-density parity-check (LDPC) codes. In this paper, we consider LDPC codes for the binary erasure channel (BEC), use code rate for performance metric, and number of decoding iterations to achieve a certain residual erasure probability for complexity metric. The available complexity-optimizing problems in the literature for the BEC are either non-convex or belong to the class of semi-infinite problems which are computationally challenging to be solved. Hence, in this paper, we first propose a lower bound on the number of iterations for the BEC.

Moreover, a simple but efficient utility function corresponding to the number of iterations is developed. Using this utility function, an optimization problem w.r.t. complexity is formulated to find complexity-optimized code degree distributions. We prove that the considered problem with the proposed utility function falls into the class of semi-definite programming (SDP) and thus, the global solution can be found efficiently using available SDP solvers. Numerical results reveal the superiority of the proposed code design compared to existing code designs from literature.



Friday, August 22

09:00 - 09:40

Fr-1: Boris Kudryashov and Irina Bocharova (Invited Speakers)

Chair: Shu Lin (UC Davis, USA)

[A unified approach to optimization of LDPC codes for various communication scenarios](#)

A unified approach to construct and optimize codes determined by their sparse parity-check matrices is presented. Parity-check matrices of quasi-cyclic (QC) LDPC block codes are obtained by replacing the nonzero elements of a base (seed) matrix by circulants. Replacing the nonzero elements either by companion matrices of elements from a finite field $GF(2^m)$ or by a formal variable D gives parity-check matrices of binary images of nonbinary LDPC block codes and LDPC convolutional codes, respectively. A set of performance measures applicable to different classes of LDPC codes are considered and a greedy algorithm for code performance optimization is presented. For a few classes of LDPC codes examples of codes combining good error-correcting performance with compact representation are obtained. Moreover, a specific channel model can easily be embedded into the optimization loop. Thereby, the code can be optimized for a specific channel. The efficiency of such an optimization is demonstrated via an example of Faster Than Nyquist (FTN) signaling using LDPC codes.

09:40 - 10:20

Fr-2: Relay Codes

Chair: Claudio Weidmann (CNRS / ENSEA / University Cergy-Pontoise, France)

[Cooperative Communication using Turbo Product Codes with Multiple-source Spatial and Temporal Correlations](#)

Zribi Amin (Higher Institute of Communication Technology & Telecom Bretagne, Tunisia);
Ramesh Mahendra Pyndiah (Institut Telecom/TELECOM Bretagne, France)

In this article, we study a cooperative coding scheme for densely deployed wireless sensor networks (WSNs) where a number of sensors transmit data to a single destination with the help of a relay. The latter applies algebraic network coding to the source codewords and forwards only the additional redundancy to the destination that observes a product code matrix built based on source codewords and relay-generated redundancy. However, for such an application two types of correlation can be found between the different sensors' observations. The first type is due to the high density of the WSN that results in a correlation between observations delivered by neighbor sensors, and we call it spatial correlation. The nature of the measured physical phenomena induces also some correlation between successive observations of the same sensor, and this type is called temporal correlation. Spatial and temporal correlations represent extra source information that was neglected in previous contributions dealing with cooperative communications. In this contribution, we investigate a

joint source channel decoding scheme that exploits the source memory structure to improve the product code iterative decoding performance. Significant performance improvements are demonstrated depending on the spatial and temporal correlation level. A performance gain achieving 0.8 dB for the additive white Gaussian noise (AWGN) channel, and 1.5 dB for the fast Rayleigh fading channel are demonstrated.

Cooperative Relaying with Low-Density Lattice Coding and Joint Iterative Decoding

Bin Chen (University College Dublin, Ireland); Dushantha N. K. Jayakody (University College Dublin, Ireland); Mark F. Flanagan (University College Dublin, Ireland)

Low-density lattice codes (LDLCs) are known for their high decoding efficiency and near-capacity performance on point-to-point Gaussian channels. In this paper, we present a distributed LDLC-based cooperative relaying scheme for the multiple-access relay channel (MARC). The relay node decodes LDLC coded packets from two sources and forwards a network-coded combination to the destination. At the destination, a joint iterative decoding structure is designed to exploit the diversity gain as well as coding gain. For the LDLC-based network coding operation at the relay, we consider two alternative methods which offer a tradeoff between implementation complexity and performance, called superposition LDLC(S-LDLC) and modulo-addition LDLC(MA-LDLC). Simulation results show that under perfect source-channel link conditions the proposed scheme can provide more diversity gain and up to 6.2dB coding gain when compared with non-cooperative LDLC coding and uncoded network-coded transmission.

10:40 - 11:40

Fr-3: MIMO Codes

Chair: Khodr A. Saaifan (Jacobs University Bremen, Germany)

Generalized concatenated MIMO system with GMD decoding

Alexey Kreshchuk (Institute for information transmission problems, Russia); Victor V. Zyablov (Institute for Information Transmission Problems (IITP) RAS, Russia)

In this paper we propose new coded modulation for multiple-input and multiple-output (MIMO) communication systems. This coded modulation is a generalized concatenated code. Its inner code is embedded Golden code which we introduce in this paper with a decoding algorithm. Its outer code is a product code with component Reed-Solomon code. We propose iterative decoding algorithm for this product code. We also propose an generalized minimum distance decoder for generalized concatenated code. The performance of the proposed system is estimated with a computer simulation.

Joint FEC Encoder and Linear Precoder Design for MIMO Systems with Antenna Correlation

Chongbin Xu (City University of Hong Kong, Hong Kong); Peng Wang (The University of Sydney, Australia); Zh Zhang (CityU of Hong Kong, Hong Kong); Li Ping (City University of Hong Kong, Hong Kong)

We study transmissions in multiple-input multiple-output (MIMO) systems with antenna correlation. We focus on joint forward error correction (FEC) encoder and linear precoder design based on channel covariance information at the transmitter (CCIT). We aim to optimize the system performance using the extrinsic information transfer (EXIT) chart type curve matching principle. By adopting a Hadamard precoding technique, we show that, the EXIT chart type curve of the precoded system is asymptotically determined by the channel correlation matrix at the transmitter as the number of receive antennas tends to infinity. The encoder-precoder curve matching can be made asymptotically accurate even in the lack of full channel state information at the transmitter (CSIT). Excellent performance based on this strategy is demonstrated by simulation results in systems with only a moderately large number of receive antennas.

Transmit Antenna Selection for Coded Multiple-Input Dual-Output Systems

Ammar El Falou (Telecom Bretagne, France); Charlotte Langlais (Télécom Bretagne, France); Walaa Hamouda (Concordia University, Canada); Charbel Abdel Nour (Institut Telecom - Telecom Bretagne, France); Catherine Douillard (Institut Telecom - Telecom Bretagne, France)

Antenna selection (AS) in multiple input multiple output (MIMO) systems has been introduced to benefit from MIMO gains with tolerable cost and complexity. In the literature, the AS has been addressed only for the case of uncoded MIMO systems. In this paper, we assess the benefits of transmit AS technology for coded multiple-input dual-output (MIDO) systems. First, we design an SNR-dependent adaptive space time block code suited for capacity achieving coded MIDO systems with transmit antenna selection. In the context of a turbo-coded WiMAX system, the designed adaptive STBC matches or outperforms WiMAX MIMO profiles in terms of bit error performance. We show that using transmit antenna selection provides a substantial SNR gain of more than 3 dB with respect to a 2x2 turbo coded WiMAX system, and this, with a low cost and complexity increase.