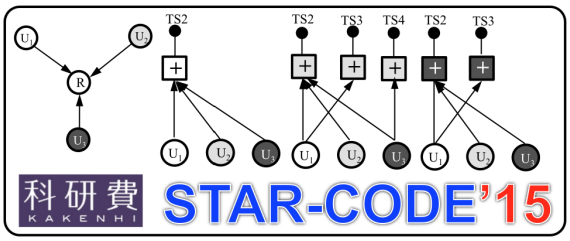
Results of Joint Steering Committee Meeting STAR-CODE and LatticeNet 2015



LatticeNet 2015

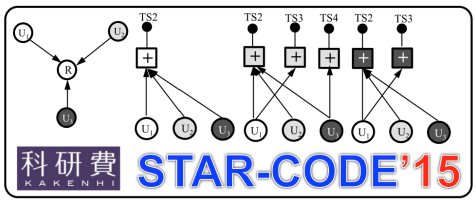
科研費 KAKENHI

Room 31, Information Technology Center,
University of Electro-Communications (UEC)
Tokyo, 22–23 June 2015

Comments:

- These are General Comments for the STC meeting:
- Kimmo is very much satisfied with the results of our work as well as STC event.
- Dirk: Order of the presentation should be made better: Summary presentation should be made block-wise (indicates which presentation is for which project). Place 5-15 minutes summary time after each block-wise session (for each project).
- Previous publications should be included in the last ppt page.
- External evaluators suggested that we should hold another STC meeting even after project expires because this meeting is a very good place to exchange information.

LatticeNet 科研費 KAKENHI 2015



STC Meeting and Technical Presentations

LatticeNet & STAR-CODE 2015

Tokyo, 22–23 June 2015

Monday, 22 June 2015

09:00 – 09:15 Preparation
09:15 – 09:30 Opening by Prof. Tad Matsumoto
09:30 – 10:00 (1) *Brian Kurkoski*, "LatticeNet Project Updates"
10:00 – 10:30 (2) *Khoirul Anwar*, "STAR-CODE Project Updates"
10:30 – 11:00 (3) *Tad Matsumoto*, "RESCUE Project Updates and Brief Summary of Applicability Considerations of LatticeNet and STAR-CODE to RESCUE"
11:00 – 11:30 (4) *Hideki Yagi*, "Toward Construction of Polar Lattice Codes for the Bi-directional Broadcast Channel"
11:30 – 12:00 (5) *Yuichi Kaji*, "A Study Toward the Maximum Likelihood Decoding of Spatially-Coupled LDPC Codes"
12:00 – 13:00 — BREAK 1 —
13:00 – 13:30 Preparation
13:30 – 14:15 (6) *Emanuele Viterbo*, "Lattice Index Coding"
14:15 – 15:00 (7) *Krishna Narayanan*, "An Overview of Lattice Constructions for Harnessing Interference"
15:00 – 15:15 — BREAK 2 —
15:15 – 16:00 (8) *Dirk Wübben*, "Distributed Consensus-based Estimation for Small Cell Cooperative Networks"
16:00 – 16:45 (9) *Kimmo Kansanen*, "State Estimation Over Fading Channels: Outage and Diversity Effects"
16:45 – 17:00 Closing & Announcement

Tuesday, 23 June 2015

09:00 – 09:30 (10) *Weiwei Jiang*, "Finite-SNR Diversity-multiplexing Tradeoff for a Lossy Forwarding Relay System"
09:30 – 10:00 (11) *Ade Irawan*, "Network Coding-based Hybrid ARQ Outage Analysis for Correlated Packets"
10:00 – 10:30 (12) *Shen Qian*, "A Comparative Study on Outage Probabilities of Decode-and-Forward and Lossy-Forward Relay Techniques
10:30 – 11:00 (13) *Xin He*, "A Lower Bound on Bit Error Probability for a Binary CEO Problem"
11:00 – 11:30 (14) *Nguyen Xuan Thanh*, "Robust Content-based Image Hash Function using Lattice Codes"
11:30 – 12:00 (15) *Antonio Ricardo PARRAO HERNANDEZ*, "The Three/Two Gaussian LDLC Lattice Decoding Algorithm"
12:00 – 13:00 — BREAK 1 —
13:00 – 13:30 (16) *Erick Christian GARCIA ALVAREZ*, "WOM Codes for the Binary-Symmetric AMAC:" Efficient Decoding and Achievable Rates
13:30 – 14:00 (17) *Mohammad Nur Hasan*, "Massive Uncoordinated Wireless Multiway Relaying Systems Employing Irregular Repetition Codes and Iterative Demapping Algorithm"
14:00 – 14:30 (18) *Ardimas Andi Purwita*, "Doubly Irregular Coded Slotted ALOHA for Massive Uncoordinated Transmission in Multiway Relay Networks"
14:30 – 14:45 — BREAK 2 —
14:45 – 16:30 Evaluation (Chair: Prof. Tad Matsumoto, Minutes of Meeting: K. Anwar)
16:30 – 17:00 Final Closing

LatticeNet Project Updates

Presenter: *Brian M. Kurkoski*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Japan

Abstract.

STAR-CODE Project Updates

Presenter: *Khoirul Anwar*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Japan

This talk will first review the vision of STAR-CODE project, system model and targets. The talk will then present all achievements up to date as well as topic research and preliminary results of on-going reserch topics. This talk will also provide the planning for the rest of the year (until March 2016).

RESCUE Project Updates and Brief Summary of Applicability Considerations of LatticeNet and STAR-CODE to RESCUE

Presenter: *Tad Matsumoto*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Japan

This talk will be started by briefly reviewing the historical background and progress of Information Theory and Signal Processing for Wireless Communications. Especially, how and why iterative (turbo) decoding can achieve asymptotically the close-limit performance will be addressed. Then, the focus of this talk is shifted to cooperative communications, where Decode-and-forward (DF) relaying has long been considered as one of themost suitable and promising techniques for the applications to practical systems, because it does not require source-relay (referred to as intra-links) channel state information at the destination. Then, this talk further expands the idea, from lossless-link-design-based to lossy-based. In this part, we assume that none of the relays at the final stage has no errors in the information parts of the frames. This talk introduces conceptual bases of the lossless (Slepian Wolf) and lossy-link-design based network design, and provides basic ideas for signal detection algorithms for the both cases based on the turbo principle. Finally, this talk briefly introduces "Links-on-the-fly Technology for Robust, Efficient and Smart Communication in Unpredictable Environments (RESCUE), an EU FP7 ICT-2013 project, of which concept was motivated by the technological bases described above.

The results are expected to be applicable to machine-to-machine and vehicle-to-vehicle communications as well as communication for internet-of-things since they should also require the robustness against the network topology change, and have to be highly energy-efficient.

Toward Construction of Polar Lattice Codes for the Bi-directional Broadcast Channel

Presenter: *Hideki Yagi*

University of Electro-Communications, Tokyo, Japan

A problem of information transmission over the bi-directional broadcast channel (BBC) is addressed, where the BBC subject to Gaussian additive noise is quantized via modulo-Λ based-on a lattice Λ (modulo-Λ Gaussian BBC). It is shown that any modulo-Λ Gaussian BBC with an input alphabet of size 2^r can be decomposed into r binary-input sub-BBCs for which the direct-sum of the capacity regions coincides with the capacity region of the original modulo-Λ Gaussian BBC. This result indicates that it suffices to arrange a sequence of binary polar codes that achieve the capacity region for each level of the r sub-BBCs and construct a lattice via Construction D developed by Conway and Sloane. Indeed, it is shown that any interior point of the capacity region of the original modulo-Λ Gaussian BBC can be achieved by the constructed polar lattice with computational complexity proportional to $N \log N$, where N denotes the block length. The use of a shaping lattice needs to be addressed so that a polar lattice code with good error performance can be obtained.

Comments:

- The auhtor uses construction-D
- Each capacity is achieved by each level
- Nice talk.
- Shaping region intersection will not make no problems with this results.

A Study Toward the Maximum Likelihood Decoding of Spatially-Coupled LDPC Codes

Presenter: *Yuichi Kaji*

School of Information Science,
Nara Institute of Science and Technology (NAIST), Japan

The optimal performance of an error correcting is of great interest in the coding theory, and several algorithms for the optimum maximum likelihood decoding have been studied so far. Unfortunately, however, none of those algorithms works for most of todays practical error correcting codes including LDPC codes because of the large complexity of the algorithm. In this study, we focus on a class of Spatially-Coupled (SC) LDPC codes, and try to employ the recursive maximum likelihood decoding (RMLD) algorithm for the code, because the nearly-diagonal structure of the parity check matrix of an SC LDPC code is favorable to the RMLD algorithm. It is explained how the trellis-structure of the code is characterized in terms of submatrices of a parity check matrix, and the principle of the decoding algorithm is described.

Comments:

- Should consider worst case complexity
- Extend to Polar Code and Reed-Muller
- Do it fast
- Consideration on complexity for MLD decoding of Reed Muller and Polar codes is versus performance is right direction.
- Especially, complexity analysis for the worst case is important, even though average complexity analysis is also important.

Lattice Index Coding

Presenter: *Emanuele Viterbo*

Monash University, Australia

Index codes are bandwidth-efficient coding schemes for broadcast channels where each receiver has prior knowledge of some part of the message being transmitted. Applications include automatic repeat request in broadcast channels, on-demand multimedia broadcasting services, content distribution in caching networks, and coding for multi-way relay channels. The index coding problem over noiseless broadcast channels has received significant attention in the literature, and is known to be representative of all noiseless network coding problems. However, physical media in real-world applications are often error-prone and noisy. The practically more relevant case of index coding over noisy broadcast channels is comparatively less understood in the literature. In this talk, we introduce a framework for index coding over Gaussian broadcast channels where every receiver demands all the messages from the transmitter. We first review the capacity results for the Gaussian broadcast channels with receiver side information, and review binary error-correcting codes that exploit prior knowledge at the receivers. Then we introduce a code design metric for index codes over the Gaussian broadcast channel, and a framework for

constructing good codes using the theory of lattices and Euclidean domains. These lattice index codes are efficient in converting side information into coding gains, but are not robust against the channel noise. To mitigate this problem, we then propose a coded modulation technique that uses these lattice index codes as modulation schemes. We analyze the achievable rate region of this coded modulation scheme, and show that this approach converts the considered index coding problem into the problem of designing good codes for a multiple-access channel with many receivers.

An Overview of Lattice Constructions for Harnessing Interference

Presenter: *Krishna Narayanan*

Texas A&M University, USA

We will provide an overview of several constructions of lattices and lattice codes that are useful for harnessing interference in multi-terminal information theory problems such as compute-and-forward, integer-forcing, two-way relaying and the interference channel. Traditionally, information-theoretic proofs that are used to show the existence of good lattices for these problems have been based on a construction of lattices known as construction A over the ring of integers. There are two limitations of this construction - (i) This naturally allows the receiver to only decode integer linear combinations of codewords and (ii) Using construction A to construct practical codes results in lattice codes which requires high decoding complexity. In this talk, I will provide an overview of some recent results that overcome both these limitations. We first show the existence of good lattices over algebraic number fields which permits the recovery of algebraic integer linear combinations. We then introduce a multilevel lattice construction called construction-pi A which has lower decoding complexity than construction A. Finally, we show how to design good construction-D lattices based on spatially coupled codes which are optimal under iterative decoding. This talk is more about coding and modulation design as a way to approach the information-theoretic limits of compute-and-forward/integer-forcing with practical decoding complexities.

Distributed Consensus-based Estimation for Small Cell Cooperative Networks

Presenter: *Dirk Wübben*

Department of Communications Engineering, University of Bremen, Germany

The dense deployment of small cells is a promising approach to realize the ever-growing rate demand in future wireless communication systems and centralizing RAN functionality permits joint multi-cell processing at the cost of backhaul traffic. In order to limit the backhaul requirements, cooperative processing among distributed radio access points is an interesting alternative for, e.g., advanced radio resource management, joint cooperative transmission, or joint reception. This paper focuses on cooperative multi-user detection by applying the Distributed Consensus-based Estimation (DiCE) algorithm and recently proposed modifications for accelerating the iterative approach and to reduce communication overhead. The proposed schemes are investigated by means of computational complexity, communication overhead, and estimation performance.

State Estimation Over Fading Channels: Outage and Diversity Effects

Presenter: *Kimmo Kansanen*

Norwegian University of Science and Technology, Norway

"Uncoded (analog) transmission offirst-order Gauss-Markov processes over fading channels is considered. The optimal MMSE estimator at the receiver is the Kalman filter with random instantaneous estimation error variance, assuming perfect channel estimation. We analyze the estimation error outage probability as a means of characterizing the estimation quality. We consider the cases of scalar processes over fading and parallel diversity channels, and find the diversity order of the outage probability. We then show extended results on Wiener filtering of oversampled vectors, and discuss initial results for a more detailed characterization of the estimation outage at high SNR."

Finite-SNR Diversity-multiplexing Tradeoff for a Lossy Forwarding Relay System

Presenter: *Weiwei Jiang*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Japan

We present the analysis of finite-SNR diversity-multiplexing tradeoff (f-DMT) for a recently emerging decode-and-forward relaying system allowing intra-link errors (DF-IE). In this framework, an adaptive system spectrum efficiency which is assumed to be used in the system, is proportional to the capacity of an additive white Gaussian noise (AWGN) channel. The proportionality is referred as multiplexing gain to describe the aggressiveness of scaling the data rate by the system. The diversity gain is given by the negative log-log slope of outage probability to depict the reliability enhanced with increasing signal-to noise ratio (SNR). The f-DMT for DF-IE is derived according to the Slepian-Wolf theorem-based outage analysis. We have discovered: (i) the DF-IE system outperforms the conventional decode-and-forward (DF) system in whole SNR region, (ii) additional 0.25 multiplexing gain can be achieved by the DF-IE system. Furthermore, the verification based on Monte Carlo simulations is also been conducted.

Comments:

- Do there exist information theoretic bound for DMT.
- Information theoretic bounds should be more clearly explained besides the DMT he presented—are there any other bounds?

Network Coding-based Hybrid ARQ Outage Analysis for Correlated Packets

Presenter: *Ade Irawan*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Japan

Network coding based hybrid automatic repeat request (NC-HARQ) technique is a promising technique to increase the throughput efficiency as well as reliability in single-hop wireless networks. In particular, the transmitter does not retransmit lost packets immediately, but it maintains a queue of lost packets and retransmits the binary eclusive-OR(XOR)-ed version of those lost packets to the destination. The existence of correlation among the packets is an interesting point to be exploited in this research work. Accordingly, we derive the outage probabilities of NC-HARQ over block Rayleigh fading channels, where the maximum number of the XOR-ed packets at the transmitter is three and the retransmission chance is one. Performance analysis in various configurations of packet correlations will also be presented.

Comments:

- Without considering the source correlation, the technique can be seen equivalent to packet-based incremental redundancy ARQ.

A Comparative Study on Outage Probabilities of Decode-and-Forward & and Lossy-Forward Relay Techniques

Presenter: *Shen Qian*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Japan

The primary objective of this work is to make a performance comparison in terms of outage probability between decode-and-forward with joint decoding (DF-JD) and lossy-forward (LF) techniques. With DF-JD, only if the relay's received information sequence is found to have no error(s), it is forwarded to the destination. On the contrary, with LF, the relay node always forwards decoded information sequence to the destination even if a decoding error is detected. Interleaving is used at relay and joint decoding is utilized at the destination to exploit the source-relay correlation for both techniques. The outage probability of conventional DF system with maximum ratio combining (DF-MRC) performed at the destination is also presented. Asymmetric statistical properties of the fading variations for each link are taken into account. It is shown that regardless of the presence of line-of-sight component, the outage probability with LF relay system is significantly smaller than that with DF-JD and DF-MRC relay systems. The impact of the per-link spectrum efficiency, representing the modulation multiplicity and channel coding rate, on outage probability is also investigated. It is found that, given that the specified per-link spectrum efficiency is satisfied, LF relay system always achieves lower outage performance than that with DF-JD and DF-MRC systems. The accuracy of the analytical results are verified by a series of Monte Carlo simulations.

Comments:

- For fair comparison, performance curves should be in terms of total transmit power.
- Also, total rate should be used for normalization.

A Lower Bound on Bit Error Probability for a Binary CEO Problem

Presenter: *Xin He*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Japan

The presentation focuses on analyzing a two-node binary chief executive officer (CEO) problem where noise-corrupted versions of a binary sequence are forwarded by two nodes to a single destination node over orthogonal multiple access channel. A lower bound of the bit error probability (BEP) is obtained by minimizing a distortion function subject to constraints obtained based on the source-channel separation theorem. We first reduce the binary CEO problem to a binary multiterminal source coding problem, of which an outer bound of the rate-distortion region is derived. The distortion function is then established by evaluating the relationship between the binary CEO and multiterminal source coding problems. Encoding/decoding algorithms using concatenated convolutional codes and a joint decoding scheme are used to verify the lower bound of the BEP. It is found that the theoretical lower bounds of the BEP and the computer simulation based bit error rate performance curves have the same tendencies. The differences in the threshold signal-to-noise ratio between the theoretical lower bounds and those obtained by simulations are around 1.5 dB in additive white Gaussian noise channel. The theoretical lower bound of the BEP in block Rayleigh fading channel is also evaluated by performing Monte Carlo simulation.

Comments:

- Difficult problem. Introductory part is neeed.
- Easy but short introductory pages are preferable.
- Nice results.

Robust Content-based Image Hash Function using Lattice Codes

Presenter: *Nguyen Xuan Thanh*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Ishikawa, Japan

This contribution improves the content-based hash functions using nested lattice codes for image retrieval systems. Lattice codes are used to quantize image's feature vectors to final hash values. The goal is to develop a lattice indexing scheme such that there is a proportional relationship between Euclidean distance and Hamming distance in order to increases the hash function's robustness. The proposed two dimensional nested lattice code reduces the mean square error (MSE) by 30% compared to two dimensional gray code.

Comments:

- Emanuele suggested that he should use other metrics such as Lee metric.
- Clarify how to map the bit patterns to lattice points
- Rather the hamming metric, use first position where sequences disagree.
- Emanuele suggested that he should use other metrics such as Lee metric.
- Instead of weighted Hamming distance (metric), use first position where the sequences disagree.

The Three/Two Gaussian LDLC Lattice Decoding Algorithm

Presenter: *Antonio Ricardo PARRAO HERNANDEZ*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Ishikawa, Japan

Low density lattice codes (LDLC) can be decoded efficiently using iterative decoding. In the iterative LDLC decoder the messages are Gaussian mixtures. In any implementation, the Gaussian mixtures must be approximated. This work describes a three/two Gaussian parametric decoding algorithm. Internally at the variable node the periodic Gaussian mixtures are approximated with three or two Gaussians, while the messages between nodes are single Gaussians. The strength of the algorithm is its simplicity and its suitability for analysis. The approximation using three Gaussians and the approximation using two Gaussians are more accurate than a single Gaussian moment matching approximation. For $n = 1000$ two Gaussian approximation is sufficient enough for an accurate performance. But when the dimension is $n = 10,000$, the three Gaussian approximation is needed. The proposed decoding algorithm presents similar performance to the quantized decoder, while keeping a low complexity and low storage requirement.

Comments:

- Consider complexity and performances
- Analysing complexity in terms of memory size and decoding time is encouraged.
- Comparison with construction A and D is also encouraged.
- Use LDLC in multiser channels is a right direction.

WOM Codes for the Binary-Symmetric AMAC: Efficient Decoding and Achievable Rates

Presenter: *Erick Christian GARCIA ALVAREZ*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Ishikawa, Japan

Consider the problem of data exchange and transmission in an asymmetric multiple access channel (AMAC). In this problem users share the same medium to transmit its data at the same time. In the AMAC, users exchange information that is used for the encoding process. We took advantage of this characteristic of the AMAC to apply Write-Once Memory (WOM) codes. The central concept of this work is that using WOM codes on a specific "binary-symmetric AMAC" leads to low complexity decoding by easily separating the received sequence into two estimated sequences, one for each user. A threshold demapping and a soft-decision decoder are evaluated in the BS-AMAC system. For the threshold demapping decoding achievable rates are given. For soft-decision decoding, mutual information is evaluated to obtain the highest information rate that a capacity-approaching code could achieve.

Comments:

- Compare the performance with and without SIC
- Consider DMC after summation, and look at more practical use.
- Consider the relationship between AMAC and MAC with correlated source.

Massive Uncoordinated Wireless Multiway Relaying Systems Employing Irregular Repetition Codes and Iterative Demapping Algorithm

Presenter: *Mohammad Nur Hasan*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Ishikawa, Japan

We consider wireless multiway relay systems serving massive number of users. We propose an uncoordinated transmission scheduling where all users are allowed to transmit their information in any time slot. Prior to transmission, each user encodes its information using a repetition code that randomly chosen from set of irregular repetition codes according to a probability distribution. Iterative successive interference is exploited in the decoding scheme to iteratively resolve the collided information. To further increase the decoding success rate probability, a multiuser detection technique, named iterative demapping (IDM) algorithm which has capability of decoding two users simultaneously, is adopted in the decoding scheme. The systems itself can be seen as a graph-based code structure, to which density evolution can be applied. The results of theoretical analysis show that the proposed systems are capable of offering maximum throughput of 2 packets/slot, which is higher than the conventional coded slotted ALOHA (CSA) with maximum throughput of 1 packet/slot. We also evaluate the bit-error-rate (BER) performance of the proposed technique via computer simulations. The results confirm that with offered traffic of more than 1 packet/slot, the proposed systems achieve reliable communications. It is also validated that the proposed systems work very well even in relatively low signal-to-noise ratio (SNR) environments. Furthermore, the results of packet-loss-rate (PLR) evaluation verify that the proposed systems also outperform the conventional CSA without simultaneous detection in term of PLR.

Comments:

- Consider Internal and external rate, total rate, normalized by MAC sum rate.
- A lot of gain may be obtained in the finite number of users.
- Presentation is very good. Step-by-step explanation is clear.
- When analyzing the total network level performance and optimization based on the analysis, the correlation between erased packets in after MUD should be taken into account.
- Considering the network level performance analysis assuming finite number of users is encouraged.
- Very good presentation! The order of component techniques were well arranged.

Doubly Irregular Coded Slotted ALOHA for Massive Uncoordinated Transmission in Multiway Relay Networks

Presenter: *Ardimas Andi Purwita*

School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST), Ishikawa, Japan

In this talk, we propose doubly irregular coded slotted ALOHA (dir-CSA) to solve a problem in massive uncoordinated multiway relay channel (mRC) having a capability of decoding multiple sub-packets $K > 1$. About $10\times$ of network traffic enhancement is achievable with $K = 4$; however, we found that extrinsic information transfer (EXIT) curve for slot node is no longer convex. Therefore,

multiway relay with irregular repetition slotted ALOHA (IRSA) and coded slotted ALOHA (CSA) even with optimization still cannot approach the random access bounds for $K > 1$. The proposed dir-CSA increases probability of successful decoding by allowing a packet to be splitted into different sub-packets. Consequently, the massive uncoordinated mRC using dir-CSA with smaller number of codes n_c significantly outperforms that of using IRSA and CSA with larger n_c in both asymptotic analysis and finite length simulations.

Comments:

- What is the relationship between the convexity.
- What is the convexity of the irregular internal code EXIT chart should be better explained, why it happens?