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論文の内容の要旨

In this thesis, cooperative wireless communications are intensively investigated from the perspective of exploiting correlations among multiple sources. The primary goal is to create theoretical bases and establish practical coding frameworks for cooperative wireless communications that exploit multi-dimensional correlations, and finally achieve new paradigm shift in wireless communication system design. Particularly, we focus on three representative problems to demonstrate the impact of the source correlations on the performance of the cooperative wireless communication systems and how we can best utilize the correlation knowledge among the distributed multiple sources. Creation of the design concept and the algorithms of the conventional point-to-point (P2P) systems are the basis for solving the problems arising in cooperative wireless communications.

Initially, the problem of transmitting binary Markov sources from a single source to a single destination over wireless channels is studied. The achievable compression rate region is determined by the source coding theorem. The performance limits in Additive White Gaussian Noise (AWGN) channels and outage probability in Rayleigh fading channels are then derived. Furthermore, we propose a new joint source-channel (JSC) decoding scheme, based on serial-concatenated convolutional codes (SCCC). By combining the trellis diagrams of Markov source and the outer code, a super trellis is constructed to exploit the time-domain correlation of the source. A novel modified version of Bahl-Cocke-Jelinek-Raviv (BCJR) algorithm is derived based on this super trellis and used for decoding of the joint outer code.

Then, we investigate the problem of transmitting Markov source over a one-way single relay channel,

which consists of one source, one relay and one destination. The relay just extracts and forwards the source information sequence to the destination, even though the extracted information sequence may contain some errors. Therefore, the information sent from the source and relay nodes are correlated, which is referred to as source-relay correlation. The achievable compression rate region of this system is determined by the Slepian-Wolf theorem. Lower bound of the performance limit in AWGN channels and the outage probability in block Rayleigh fading channels can be derived based on them achievable compression rate region. We also propose a distributed joint source-channel (DJSC) decoding scheme to exploit the source-relay correlation and the source memory simultaneously. In our proposed technique, a Log-likelihood Ratio (LLR) updating function, which is supported by the Slepian-Wolf theorem, is used to estimate and exploit the source-relay correlation, while the JSC technique proposed above is used to exploit the source memory.

Finally, we consider the problem of transmitting two correlated sources over orthogonal multiple access relay channel (MARC). The MARC consists of two sources communicating with a common destination with the assistance of a single relay. The role of the relay is to perform network coding, followed by channel coding, to assist the two sources to improve the probability of successful signal reception at the destination. In this case, the achievable compression rate region is derived based on the theorem for source coding with side information. The performance limits in AWGN channels and the outage probability in block Rayleigh fading channels are derived based on the achievable compression rate region. Furthermore, we propose a novel joint source-channel-network (JSCN) decoding technique to fully exploit the correlation between the two sources, as well as the benefit of network coding. In our proposed technique, modified versions of boxplus operation that takes into account the correlation between the two sources are derived for the relay and source nodes.

In the three problems described above, the impacts of source correlations on the performance of the corresponding systems are investigated through asymptotic analysis. The convergence properties of the proposed JSC and DJSC techniques are verified through Extrinsic Information Transfer (EXIT) chart analysis. Moreover, the effectiveness of the proposed JSC, DJSC, and JSCN decoding techniques and the accuracy of the theoretical analysis are verified through a series of simulations, including bit-error-rate (BER) performance in AWGN channels and frame-error-rate (FER) performance in Rayleigh fading channels.

論文審査の結果の要旨

First of all, the chairman of the evaluation committee declared opening of the final defense ceremony of the candidate, MSc Xiaobo Zhou, where all the participants, including the candidate,

examiners and chairman, were requested to stand up. The chairman then explained the status update of the dissertation after the pre-defense, and also the procedure of the final defense. Two external examiners, Prof. Markku Juntti and Prof. Li Ping participated via a TV-conference system. The defense ceremony followed the procedure specified by University of Oulu, which the main supervisor, Prof. Matsumoto, is familiar with. The process of the defense ceremony is summarized as follows:

- (1) Since throughout the public defense, the main supervisor, Prof. Matsumoto, has to keep his position neutral and hence must not say anything at all (he closed his mouth during the defense), the chairmanship was passed on to Prof. Brian Kurkoski.
- (2) The candidate made a presentation, where he clearly explained the importance of the establishment of theoretical bases on the cooperative wireless communications techniques, major achievements of his research work and their novelty. The presentation was required to be relatively short and introductory because the ceremony is open to public (On the contrary, in the pre-defense, the candidate was requested to make relatively long, in-depth presentation (60 minutes), which was followed by highly technical discussions, page-by-page of the dissertation).
- (3) Following the introductory presentations, the two foreign examiners, Prof. Markku Juntti and Prof. Li Ping, explained the importance and the relevance of the topics the candidate has researched, also to the public, and hence not at too deep technical level.
- (4) The two foreign examiners' speech session was followed by the chapter-by-chapter Q-and-A session, in part, to verify that the requirements and suggestions, raised in the pre-defense, have been all satisfied and the questions well answered in the final dissertation, and, in part, to check the candidate's general knowledge of the basics of information science as well.
- (5) After the committee's Q-and-A session, the chairman declared that the Q-and-A is open to the public, where the candidate was asked three questions raised by the public participants. The candidate clearly answered those questions and the answers were all correct.
- (6) After the public Q-and-A session, the chairmanship was passed back on to Prof. Matsumoto, and he requested all the participants, except for the examiners and the supervisor, to leave the room.
- (7) Examiners exchanged their opinions about the evaluation of the quality, skills and general knowledge of the candidate, represented in his answers to the questions. They all agreed that the reference for the score (A, B, C, and D) is based on the quality level defined by the universities which each examiner is working at. The results of the rating provided by the examiners are three A's and two B's.
- (8) The chairman asked the participants from the public and the candidate to return to the room. The chairman and the candidate stood up, and the others sat. Finally the chairman reported the evaluation results, where he clearly stated that the evaluation is only tentative. The final authorization to the scores is to be provided at the faculty meeting taking place on September 4th,

2013.

The importance and relevance of the topics, significance and novelty of the candidate's achievements, and quality assessments for the dissertation and the final defense are summarized in the examiners' reports. I, as a chairman of the committee (not as a main supervisor of the candidate), hereby declare that the entire process towards the closing of the candidate's final defense, including in-depth and highly technical discussions in the pre-defense, is totally fair, unbiased, and at an international level. The candidate has three first-authored journal papers, and five first-authored conference papers (one from each category, totaling two, as of the date August 10, 2013, is currently under review), both at internationally highly recognized journals/conferences. I, again as a chairman of the committee, representing the committee, totally agree with the results of the scores provided by the examiners. The committee hereby suggests that a Doctor-of-Philosophy degree should be provided to the candidate, MSc Xiaobo Zhou.