

Title	分散符号化に基づくワイヤレス協調通信の場所率解析とパワー配分最適化問題
Author(s)	程, 猛
Citation	
Issue Date	2014-03
Type	Thesis or Dissertation
Text version	ETD
URL	http://hdl.handle.net/10119/12108
Rights	
Description	Supervisor:松本 正, 情報科学研究科, 博士

氏名	程 猛		
学位の種類	博士(情報科学)		
学位記番号	博情第 293 号		
学位授与年月日	平成 26 年 3 月 24 日		
論文題目	Outage Analysis and Optimal Power Allocation for Distributed Coding Based Wireless Cooperative Communications (分散符号化に基づくワイヤレス協調通信の場所率解析とパワー配分最適化問題)		
論文審査委員	主査	松本 正	北陸先端科学技術大学院大学 教授
		田中 清史	同 准教授
		Brian Kurkoski	同 准教授
		Dirk Wubben	University of Bremen 教授
		Sumei Sun	Institute for InfoComm Research , Singapore
		村田 英一	京都大学 准教授

論文の内容の要旨

The primary objective of this dissertation is to analyze performances of distributed coding based wireless cooperative communication systems from the perspective of Slepian-Wolf theorem. The particular system assumption in this dissertation is a one-way decode-and-forward relay model, where the original bit sequence at the source and the re-constructed bit sequence at the relay are independently encoded and transmitted to a common destination. The research fundamental lies in the utilization of the correlation knowledge between the two bit sequences, of which concept has potential of significantly improving wireless communication system performance. In this dissertation, both practical coding/decoding algorithms and the theoretical framework setup are focused on.

First of all, we propose a one-way Slepian-Wolf relay system adopting bit-interleaved coded modulation with iterative decoding (BICM-ID) for high spectrum efficiency. It is shown that the extrinsic information transfer (EXIT) curve of the BICM-ID demapper combined with the decoder of doped accumulator (DACC) is well matched with that of the decoders, which enables the EXIT tunnel open until (1,1) mutual information point. Although errors may happen in the source-relay channel (it is referred to as intra-link

errors in this dissertation), the re-constructed sequences that may contain some errors are to be forwarded to the destination. Strong codes are not needed, and even the systematic part of the coded bit sequences can be simply extracted at the relay node, regardless of whether or not some errors are occurring in the sequences. Therefore, the computational complexity of the relay can be significantly reduced, which indicates that our proposed system is highly energy-efficient.

Moreover, the theoretical outage probability of the proposed Slepian-Wolf relay system is derived over block Rayleigh fading channels. Two cases are considered: in Case 1, we simplify the intra-link transmission as a bit-flipping model, where some of the bits, re-constructed after decoding at the relay, are the flipped versions of the original information bits transmitted from the source. In other words, the intra-link error probability is used as a parameter representing the correlation between the sequences, of the practical transmission chain design. As one of the main contributions, the theoretical outage probability expression is derived on the basis of the admissible Slepian-Wolf rate region, with transmission channels being either temporally independent or correlated. In addition, asymptotic properties of the outage curves are mathematically proven. The theoretical results are verified through a series of simulations. In Case 2, block Rayleigh fading is also assumed for the intra-link, and we express the intra-link error probability by the Hamming distortion represented by the inverse rate distortion function. The outage probability of the Case 2 setup is derived for different relay location scenarios which provides us with more practical performance assessment than with Case 1.

Finally, the power allocation schemes are proposed for the both cases based on the outage derivations described above. Specifically, we aim to (1) minimize the outage probability while keeping the total transmit power fixed and (2) minimize the total transmit power given a fixed outage requirement. By assuming that the source-destination and the relay-destination channels are with high signal-to-noise power ratios, the approximated closed-form of the outage probability expression is derived in Case 1. It is shown that the power allocation scheme for the proposed Slepian-Wolf relay system can be formulated as a convex optimization problem. In Case 2, the power allocation

scheme is also applied for different relay location scenarios.

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 Meng Cheng, 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. Dirk Wubben and Dr. Sumei Sun participated via TV-conference systems. The defense ceremony exactly 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 for the outage calculation of 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. Dirk Wubben and Dr. Sumei Sun, 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 four 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/organization which each examiner is working at; any bias from other evaluators' scoring should be avoided. The results of the rating provided by the examiners are three B's, one B⁺ and one A.
- (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 February 25th, 2014.

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 two first-authored journal papers, one second-authored journal paper, and one second-authored journal paper under review. He has four first-authored conference papers, and one second-authored conference papers, and two second-authored conference papers under review, as of the date February 17, 2014. All publications are in 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 Meng Cheng.