Multi-Dimensional Correlation Exploited Cooperation Wireless Communications

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Abstract

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.

Keywords: Cooperative wireless communications, source correlation, achievable compression rate region, performance limit, outage probability, relay channel, multiple access relay channel, Slepian-Wolf theorem, source coding with side information theorem