Binary Information Sensing and Multiterminal Source Coding: Rate-Distortion Analysis and Transmission Design

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Abstract

In this thesis, a binary chief executive officer (CEO) problem is investigated with the application to a binary information sensing network, where noise-corrupted versions of a binary sequence are forwarded by a group of sensors to a single destination over orthogonal multiple access channels. The primary goal of this thesis is to provide theoretical analysis of the system performance and to design practical transmission techniques by applying recent results of multiterminal rate-distortion theory.

Concatenated convolutional codes and a joint decoding scheme are proposed for the binary information sensing network. First of all, the achievable rate and bit error rate (BER) floor of the binary information sensing network are investigated. The main theoretical results are: 1) the signal-to-noise ratio (SNR) limit is converted from the achievable rate based on the Slepian-Wolf theorem and source-channel separation theorem in orthogonal additive white Gaussian noise (AWGN) channels; 2) the BER floor, which is a common phenomenon in the binary sensing network caused by the observation error, is analytically calculated using the Poisson binomial process and binary rate-distortion function. Then, a series of computer simulations is conducted to verify these limits, including the threshold SNR and the error floor. Finally, a three-dimensional extrinsic information transfer chart analysis is performed to confirm the simulation results.

Furthermore, we derive an outer bound for the binary CEO problem based on the relationship with binary multiterminal source coding. The outer bound is applied to obtain the lower bound on Hamming distortion for the binary information sensing network with respect to the encoding rate and channel SNR. The BER performance obtained by performing practical encoding/decoding algorithm verify the theoretical lower bound on Hamming distortion.

Finally, an optimal power allocation scheme is proposed for the binary information sensing network from rate-distortion perspective. Based on the simulation results, our proposed power allocation scheme outperforms the uniform power allocation method.

Keywords: CEO problem, multiterminal source coding, rate-distortion, achievable rate, Hamming distortion, sensor network