

# Constellation Rearrangement in Cooperative Relay-HARQ Network

**Abstract**—We study the constellation rearrangement (CoRe) problem in a relay-HARQ network to achieve symbol mapping diversity for reliable communication. Specifically, we formulate the bit error rate (BER) maximization into a quadratic three-dimensional assignment problem (Q3AP) and make use of the recent development of numerical method to find the optimal CoRe solution. Performance gains on various channel settings are demonstrated with simulations.

## I. INTRODUCTION

In modern wireless communication systems, Automatic Repeat reQuest (ARQ) or Hybrid ARQ (HARQ) are recognized as key technologies for reliable transmission. HARQ combined with relay networks has attracted great research interest in recent years [1]. Since in practice the transmitted symbols are modulated from a finite-size constellation (e.g., PSK, QAM), the performance of cooperative relay-HARQ system can be further enhanced with Constellation Rearrangement (CoRe) [2], [3], in which a same series of bits are mapped to different constellation points across different links.

There are a wide variety of works on CoRe for cooperative relay systems with different channel settings and design criteria. For the simple three-node single hop relay network, CoRe is designed to minimize symbol error rate (SER) in [4] and the bit error rate (BER) in [5]. The rate optimized CoRe is studied in [6]. For relay-HARQ systems, CoRe is designed based on BER maximization in [7]. CoRe is also studied in Nakagami- $m$  channel [8] and in combination with power allocation [9]. Nevertheless, all the abovementioned works assume cooperative relay-HARQ schemes with orthogonality between the source-to-destination (S-D) link and the relay-to-destination (R-D) links, i.e. the (re)transmissions on the S-D link and the R-D links can not be on a same time slot or band, resulting in low bandwidth efficiency. Moreover, since the CoRe problem is usually formulated into a NP-complete binary linear programming (BIP) problem, existing CoRe implementation are mostly based on fixed rearrangement [4], [9], heuristic approaches such as simulated annealing [6] and genetic algorithm [7], or by impractically dropping the binary constellation mapping constraints [10].

Historically, various CoRe problem for HARQ system fall within the realm of Quadratic Assignment Problem (QAP) or its extensions like Quadratic 3-dimensional Assignment Problem (Q3AP) [11]. Recent development in the numerical approaches to QAP/Q3AP [12] has enabled us to efficiently derive CoRe schemes with high quality.

In this work, we study the CoRe for cooperative relay-HARQ channel based on BER maximization. The main contributions of this paper are as follows:

- We propose to use CoRe for the relay-HARQ scheme

similar to [13]. As depicted in Fig 1, the source and the relay jointly perform the retransmission to the destination simultaneously, practically forming a 2-by-1 MIMO system.

- In our cooperative relay-HARQ settings, we formulate the CoRe design into a Q3AP problem. By taking advantage of the latest numerical solvers, we demonstrate significant performance gain of the optimized CoRe over non-CoRe and simple CoRe schemes for various channel settings.

The rest of this paper is organized as follows. Section II describes the cooperative relay-HARQ system model. Section III formulates the CoRe design into a Q3AP solution and provides a brief description of the numerical algorithm. The numerical results are presented in Section IV. Finally, Section V concludes the paper.

## II. SYSTEM MODEL AND PROBLEM FORMULATION

### III. OPTIMAL CONSTELLATION REARRANGEMENT

- A. BER Maximization via Q3AP solution
- B. Computation of the Pair-wise Symbol Rate
- C. Q3AP Solution

## IV. NUMERICAL RESULTS

## V. CONCLUSION

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