RSMA-Based Robust Rate-Matching Framework in Multibeam Satellite Communications

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Abstract— Multibeam satellite communications is attracting considerable attention as one of the promising key technologies for providing broadband services over a wide area. In satellite networks, the traffic demand of each beam or user is highly heterogeneous since the satellite serves a wide area. Also, it is difficult to obtain accurate channel state information at the satellite due to the high propagation delay caused by the high altitude of the satellite. To tackle these issues, we propose a rate-splitting multiple access-based robust rate-matching framework that effectively fulfills the traffic demands even when satellites have inaccurate channel phase information.

Keywords—Multibeam satellite communications, rate-matching, rate-splitting multiple access

I. Introduction

Multibeam satellite communications (SATCOM) is emerging as one of the key technologies to provide broadband services over a wide area with ubiquitous connectivity. Within the broad coverage for the multibeam SATCOM, the traffic demands of users in wide coverage areas are highly heterogeneous to each other. Also, due to the high altitude of satellites, obtaining accurate channel state information (CSI) at the satellite is a challenging issue. To tackle this inevitable issue in satellite communications, we propose a robust rate-matching (RM) framework, which can efficiently satisfy non-uniform traffic requirements, based on the rate-splitting multiple access (RSMA) that has robustness over imperfect CSI conditions.

II. System Model and Simulation Results

We consider a multibeam SATCOM system, wherein a satellite is equipped with N_t antenna feeds and serves K users, equipped with a single antenna. Herein, the satellite illuminates various regions, and the users in each region have uneven traffic demands. Moreover, imperfect CSI at the transmitter (CSIT) is considered due to the phase perturbation caused by channel estimation and feedback errors. Also, imperfect CSI at the receiver (CSIR) is considered due to the phase perturbation caused by the channel estimation error. On the other hand, the satellite is assumed to exactly know the traffic demand of each user.

In order to efficiently satisfy the traffic demands, the satellite first splits the messages into common and private messages, and then, combines all common messages into one common message and encodes it into the common stream s_c using a codebook that is known by all users. On the other hand, the private messages are encoded into each private stream $s_1, \cdots, s_K$ using a codebook that is known by only a corresponding user. Subsequently, generated streams are superimposed as $\mathbf{x} = \mathbf{p}_c s_c + \sum_{j=1}^{K} \mathbf{p}_j s_j$ using the common precoder $\mathbf{p}_c$ and each private precoder $\mathbf{p}_k$, and $\mathbf{x}$ is transmitted through the satellite channel vector $\mathbf{h}_k$. Consequently, the received signal at the k-th user can be indicated as $y_k = \mathbf{h}_k^H \mathbf{x} + n_k$ in which n_k denotes the additive white Gaussian noise that follows the independent and identical distribution such that $n_k \sim CN(0, \sigma_n^2)$. During such procedure, the satellite flexibly designs the optimal common and private precoders according to the traffic demands to efficiently satisfy traffic demands.

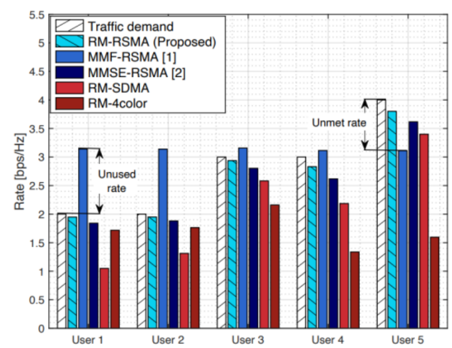

Fig. 1. Rate comparison under imperfect CSIT and CSIR.

We show the simulation result when $N_t = 4$, $K = 5$, and Traffic demand $= 2,2,3,3,4$. Fig. 1 illustrates the demand satisfaction performance of the proposed scheme ("RM-RSMA") compared to the max-min fairness (MMF) based scheme ("MMF-RSMA") [1]. Also, the proposed scheme is compared to the other benchmark schemes for satisfying the traffic demands that are the spatial division multiple access (SDMA) based scheme ("RM-SDMA"), minimum mean square error (MMSE) based scheme ("MMSE-RSMA") [2], and four-color frequency reuse scheme ("RM-4color"). As can be observed from Fig. 1, "RM-RSMA" shows superiority in terms of demand matching compared with various benchmark schemes thanks to the flexible precoder design according to traffic demands.

References

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