Rate Splitting for MIMO Wireless Networks: A Promising PHY-Layer Strategy for 5G

Bruno Clerckx and Hamdi Joudeh, Imperial College London, UK

Abstract

MIMO processing plays a central part towards the recent increase in spectral efficiencies of wireless networks. MIMO has grown beyond the original point-to-point channel and nowadays refers to a diverse range of centralized and distributed deployments. The fundamental bottleneck towards enormous spectral efficiencies in multiuser MIMO networks lies in a huge demand for accurate channel state information at the transmitter (CSIT). This has become increasingly difficult to satisfy due to the increasing number of antennas and access points in 5G networks relying on dense heterogeneous networks and transmitters equipped with a large number of antennas. CSIT inaccuracy results in a multi-user interference problem that is the primary bottleneck of MIMO wireless networks. Looking backward, the problem has been to strive to apply techniques designed for perfect CSIT to scenarios with imperfect CSIT. This tutorial departs from this conventional approach and introduces the audience to a promising strategy based on rate-splitting. Rate-splitting relies on the transmission of common messages (decoded by multiple users) and private messages (decoded by their corresponding users). This strategy is shown to provide significant benefits in terms of spectral efficiencies, reliability and CSI feedback overhead reduction over conventional strategies used in LTE-A and exclusively relying on private messages. The benefits of rate-splitting will be further demonstrated in a wide range of scenarios: multi-user MIMO, massive MIMO, multi-cell MIMO, overloaded systems, Non-Orthogonal Multiple Access (NOMA), multigroup multicast and caching. Open problems, impact on standard specifications and operational challenges will also be discussed.

Objectives

1. Introduction to MIMO networks: Point-to-Point, Multi-user, Multi-cell, Massive
2. The fundamental role of (imperfect) Channel State Information at the Transmitter for interference management in MIMO networks
3. Limitations of 4G and current 5G approaches and motivation for a new PHY layer
4. Introduction to Rate Splitting
5. Design and optimization of Rate Splitting
6. Potentials of Rate Splitting in various scenarios: multi-user MIMO, massive MIMO, multi-cell MIMO, overloaded systems, Non-Orthogonal Multiple Access (NOMA), multigroup multicast, caching
7. Rate Splitting in 5G standardization
8. Open problems and future challenges

Structure and Content

1. Introduction to MIMO networks, interference management and 4G design (15min)
    a. Point to point MIMO
    b. Multi-user MIMO
    c. Multi-cell MIMO and HetNets
    d. Massive MIMO
    e. Interference Management
2. Problem of current 4G and emerging 5G architecture (15min)
    a. LTE-A performance and limitations: MU-MIMO, CoMP, HetNets
    b. Motivation for a new physical layer
3. Fundamentals of Rate Splitting (50min)
    a. Interference Channel
    b. Broadcast Channel with imperfect CSIT
    c. Performance Limits and Degrees of Freedom
    d. Sum-Rate Enhancement and CSI Feedback Reduction
4. Transceiver Optimization of Rate-Splitting (25min)
    a. Problem formulation
    b. Robust beamforming (sum-rate maximization, max-min fairness)

5. Extensions of Rate Splitting (50min)
    a. Multiple receive antennas
    b. Massive MIMO
    c. Multi-Cell MIMO
    d. Overloaded systems and NOMA
    e. Multigroup Multicast
    f. Caching
6. Rate-Splitting in 5G (15min)
    a. Standardization issues and efforts
7. Future Challenges (10min)

Audience

This tutorial is aimed at PhD students, researchers, and engineers in academia and industry interested in the lower layers of wireless communication systems and in particular the design of 5G physical layer. The tutorial is designed to be accessible for anyone with a background in at least one of the following areas: (wireless) communication theory, MIMO, interference management, signal processing for communication.

Novelty

Rate Splitting is an emerging paradigm in wireless networks that is in its infancy. Through rate splitting and the transmission of common and private message, MIMO networks move away from conventional unicast-only transmission to superimposed unicast multicast transmission.
The tutorial is given by experts with a diverse range of expertise, including years of research experience in academia and in industry (on designing and defining 4G specifications in 3GPP and IEEE 802.16m) and familiar with latest advances in academic and industrial research.

Speakers

Bruno Clerckx is a Senior Lecturer (Associate Professor) in the Electrical and Electronic Engineering Department at Imperial College London (London, United Kingdom). He received his M.S. and Ph.D. degree in applied science from the Université catholique de Louvain (Louvain-la-Neuve, Belgium) in 2000 and 2005, respectively. From 2006 to 2011, he was with Samsung Electronics (Suwon, South Korea) where he actively contributed to 3GPP LTE/LTE-A and IEEE 802.16m and acted as the rapporteur for the 3GPP Coordinated Multi-Point (CoMP) Study Item. Since 2011, he has been with Imperial College London, first a Lecturer (Assistant Professor) and now as a Senior Lecturer. From April 2014 till March 2016, he also occupied an Associate Professor position at Korea University, Seoul, Korea. He also held visiting research positions at Stanford University, EURECOM, NUS and HKU. He is the author of 2 books, 110 peer-reviewed international research papers, 150 standard contributions and the inventor of 75 issued or pending patents among which 15 have been adopted in the specifications of 4G (3GPP LTE/LTE-A and IEEE 802.16m) standards. Dr. Clerckx served as an editor for IEEE TRANSACTIONS ON COMMUNICATIONS from 2011-2015 and is currently an editor for IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS. His area of expertise is communication theory and signal processing for wireless networks.
Hamdi Joudeh is a post-doctoral research associate in the Communications and Signal Processing (CSP) Group, Department of Electrical and Electronic Engineering at Imperial College London. He obtained his BSc in Electrical Engineering from the Islamic University of Gaza in 2010 and his MSc and PhD in Communications and Signal Processing from Imperial College London in 2011 and 2016, respectively. During the autumn of 2011, he was with the Mobile Communication Division at Samsung Electronics, Suwon, South Korea, as an engineering intern. His research interests include signal processing and optimization for wireless communication systems, and communication theory.