Network Information Theory : Syllabus

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I. Contents

1) Review of advanced concepts in typical sequences: packing lemma, covering lemma, conditional typicality, Markov lemma.
2) Lossy source coding and rate-distortion theory for memoryless sources.
3) Lossy compression of correlated Gaussian sources, bit-allocation and reserve waterfilling, connection with transform coding (image coding, video coding).
4) Binning schemes: Slepian-Wolf separated encoding of correlated sources.
5) Binning schemes: Wyner-Ziv lossy source coding with side information at the decoder.
6) Binning schemes: Gelfand-Pinsker coding for channels with state known at the transmitter.
7) The capacity region of discrete memoryless and Gaussian multiple access channels.
8) Applications: multiuser detection/decoding, CDMA, and Interleaved Division Multiple Access (IDMA).
9) The capacity region of discrete memoryless and Gaussian degraded broadcast channels.
10) Applications: NOMA schemes in 5G.
11) Multiuser MIMO schemes: Vector Gaussian MAC and BC, linear precoding, massive MIMO.
12) The 2-user Gaussian interference channel: approximate capacity and generalized degrees of freedom.
13) Optimality of treating interference as noise (TIN), in Gaussian interference channels.
14) Applications: link scheduling in device-to-device communications.
15) Relay channels and relay networks: decode-and-forward and noisy network coding.
16) Advanced topics: coded caching for efficient content distribution, the Maddah-Ali and Niesen scheme and its variants.

II. Main References

1) El Gamal, A. and Kim, Y.H., 2011. *Network information theory*. Cambridge University Press.
2) The course is based on a number of very recent results which are not yet collected in textbooks, therefore a collection of relevant papers (mainly from IEEE Transactions on Information Theory, IEEE Transactions on Communications, IEEE Transactions on Wireless Communications) will be provided as reading material for the course.

III. Course Objectives

The objective of this course consists of building on the basic information theory background built in the course 1005249 - INFORMATION THEORY, to develop advanced concepts in network (multi-terminal) information theory. The course provides a deep knowledge of basic results in network information theory, including the most fundamental network topologies building blocks such as the multiple access channel, the broadcast channel, the interference channel, and the relay channel. Then, the course provides also several contemporary advanced topics and applications, such as multiuser MIMO (with applications to 5G massive MIMO schemes), the relation between the information theoretic multiple access channel and successive/iterative multiuser detection/decoding in modern CDMA schemes, the regime of TIN (treating interference as noise) optimality, with relations on link selection and scheduling in Device-to-Device (D2D) networks, and relay networks with decode-and-forward multihop and noisy network coding (generalized compress-and-forward) approaches. Relations with the current trends of actual wireless standards and in particular with 5G systems will be pointed out.

Students taking this course will master the information-theoretic concepts at the basis of uplink (multiaccess) and downlink (broadcast) channels in wireless communications, interference management, and link scheduling in ad-hoc device-to-device networks, as well as the role of relaying in multi-terminal networks. They will be able to apply such concepts of actual problems arising in state of the art wireless communication systems, with special emphasis to 5G wireless networks.

IV. Prerequisites

1005249 - INFORMATION THEORY

V. Teaching Methods

Frontal teaching (42 hours?), project seminars (paper assignments and students' presentations, 6 hours).

VII. Modalitá di verifica dell' apprendimento

- Written test (basic theory questions and small problem solving).
- Seminar/Project oral presentation (with slides), with additional oral examination (discussion/theory questions).