Tutorial T-5: Device-centric cooperative wireless networks: Theory and applications in 5G and beyond

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Tutorial Overview

Conventional cellular architectures have long promoted a network-centric view, whereby communication with a user device is almost always placed under the tight control of an element of the infrastructure such as a base station and where the optimization of global spectral resources is managed centrally from the network itself. This situation is changing with the **new opportunities** offered by direct device communications in 5G and beyond.

Although the practical exploitation of **device-to-device (D2D) communications** is today still limited to commercially-oriented proximity discovery services, such direct communication capabilities can offer *much more*. When suitably exploited, direct communications between devices can enable a **powerful collective intelligence** among user terminals, allowing them to cooperate effectively in view of improving the link quality, the spectral density or the power efficiency. Because device cooperation is carried out on the basis of partial and noisy channel state measurements, a framework for robust decentralized decision making is essential. This problem is rooted in so-called **coordination and team decision** theories, which have gained importance lately due to wide-reaching applications, even beyond telecoms.

This tutorial is dedicated to device-centric cooperation and their application in 5G and beyond. As an introduction, we will show how fundamental limitations of cellular (and more) networks can be addressed via *device-centric cooperation*. This includes wide ranging issues such as interference management, MIMO feedback design, Massive MIMO coordination.

As a second part of the tutorial we will give an introduction to the general fields of *coordination and team decision theories*. We will present an overview of the different approaches, their main principles, advantages and limitations. This section provides the **fundamental tools** used in the rest of the tutorial, showcased in a didactic manner. Importantly, coordination and team decision theories are transversal topics which are useful to other fields as well (such as artificial intelligence, control and robotics). This cross-disciplinarily will be briefly touched upon.

In the third part, we review **practical applications** of *device-centric cooperation* to the problem of wireless network optimization. Considering the most common and practically relevant scenarios (including resource allocation problems such as power control, scheduling, and beamforming), we show how important gains can be realized by the device-centric cooperation and how the **obstacles initially formulated can be overcome**. Practical gains for wireless networks are illustrated.

Detailed organization:

- Part I: Emergence of device-centric cooperation in wireless networks (40min)
  - Interference management
  - Power control cooperation
  - Coordinated beamforming/alignment
  - Coordinated Multipoint transmission

- Part 2: Coordination and Team decision Theory: A primer (1h)
  - Principles of coordination theory
  - Implicit coordination
  - Learning
  - Principles of team decision theory
  - Optimal device-to-device signaling design
  - Connections with cooperative game theory
  - Robust algorithms

- Part 3: Applications of team-decision to device-centric cooperation (1h)
  - Device-centric coordinated multi-point transmission
  - Cooperative power control problems
  - Cognitive radio optimization
  - Cooperative feedback design in MIMO systems and Massive MIMO

- Part 4: Perspectives (20min)
  - Standardization issues
  - Open research problems

Presenter Biographies

David Gesbert (IEEE Fellow) is Professor and Head of the Mobile Communications Department, EURECOM, France, where he also heads the Communications Theory Group. He obtained the Ph.D degree from Ecole Nationale Superieure des Telecommunications, France, in 1997. From 1997 to 1999 he has been with the Information Systems Laboratory, Stanford University. In 1999, he was a founding engineer of Iospan Wireless Inc, San Jose, Ca.,a startup company pioneering MIMO-OFDM (now Intel). Between 2001 and 2003 he has been with the Department of Informatics, University of Oslo. D. Gesbert has published about 230 papers (five of which won paper awards), several patents and guest edited 7 special issues all in the area of signal processing, communications, and wireless networks. He co-authored the book "Space time wireless communications: From parameter estimation to MIMO systems", Cambridge Press, 2006. He is currently working towards the organization of for IEEE ICC 2017, to be held in Paris, as a Technical Program co-Chair . In 2014, he was named in the Thomson-Reuters List of Highly Cited Researchers in Computer Science.

Paul de Kerret (IEEE Member) is currently an Assistant Professor at Télécom Bretagne. He graduated in 2009 from Telecom Bretagne and obtained a diploma degree in electrical engineering from the Munich University of Technology (TUM). In 2010, he has been a research assistant at the Institute for theoretical Information Technology, RWTH Aachen University. He obtained in 2013 his Ph. D. degree from EURECOM under the supervision of David Gesbert and then pursued its work there for one year as a post-doctoral researcher. He has been working in several key European projects focused on the cooperation of transmitters in future networks. He is co-author of several articles in prestigious IEEE journals and has published 20 articles in highly selective IEEE conferences.