UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Massive MIMO – Fundamentals and State-of-the-Art"

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Short Abstract: The next generation wireless networks need to accommodate around 1000x higher data volumes and 50x more devices than current networks. Since the spectral resources are scarce, particularly in bands suitable for wide-area coverage, the main improvements need to come from a more aggressive spatial reuse of the spectrum; that is, many more concurrent transmissions are required per unit area. This can be achieved by the Massive MIMO (massive multi-user multiple-input multiple output) technology, where the access points are equipped with hundreds of antennas and can serve tens of users on each time-frequency resource by spatial multiplexing. The large number of antennas provides a great separation of users in the spatial domain, which is a paradigm shift from conventional multi-user technologies that mainly rely on user separation in the time or frequency domains.

In recent years, massive MIMO has gone from being a mind-blowing theoretical concept to one of the most promising 5G-enabling technologies. Everybody seems to talk about massive MIMO, but do they all mean the same thing? What is the canonical definition of massive MIMO? What are the main differences from the classical multi-user MIMO technology from the nineties? What are the key characteristics of the transmission protocol? How can massive MIMO be deployed? Is pilot contamination an actual problem? Are there any widespread misunderstandings?

These lectures build upon our recent book:

E. Bjornson, J. Hoydis, L. Sanguinetti
"*Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency*"
Foundations and Trends in Signal Processing (under review)

which provide answers to all of the above questions and aims at giving a clear and balanced picture of the fundamentals of Massive MIMO, as well as an up-to-date survey of the state-of-the-art results in the main areas of spectral efficiency for spatially correlated channels, channel modeling, array deployments, energy efficiency.

Course Contents in brief:

Massive MIMO: Motivation and Introduction

- Introduction: Trends and 5G goals
- Evolving cellular networks for higher area throughput
- Key aspects of having massive antenna numbers
- Achieving a scalable Massive MIMO protocol

Spectral efficiency

- Basic communication theoretical results
- Methodology for performance evaluation
- Channel estimation
- Spectral efficiency in uplink and downlink
- The limiting factors of Massive MIMO

Asymptotic analysis

- Linearly independent and orthogonal covariance matrices
- Asymptotic Insights
- The unlimited capacity of Massive MIMO
- Acquiring covariance matrices

Practical deployment considerations

- Power allocation
- Spatial resource allocation
- Array deployments – different antenna geometries, effect of antenna element spacing
- Massive MIMO at mmWave frequencies
- Co-existence with heterogeneous networks

Energy efficiency

- Why care about energy efficiency?
- Transmit power – asymptotic insights
- Mathematical definition of energy efficiency
- Importance of accurate power consumption modeling
- Energy Efficiency and Throughput Tradeoff
- Network Design for Maximal Energy Efficiency

Total # of hours: 16 hours

References:

[1] T. L. Marzetta, "Noncooperative cellular wireless with unlimited numbers of base station antennas," IEEE Trans. Wireless Commun., vol. 9, no. 11, pp. 3590–3600, 2010.

[2] E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta, "Massive MIMO for next generation wireless systems," IEEE Commun. Magazine, vol. 52, no. 2, pp. 186–195, 2014.

[3] J. G. Andrews, S. Buzzi, W. Choi, S. V. Hanly, A. Lozano, A. C. K. Soong, and J. C. Zhang, "What will 5G be?" IEEE J. Sel. Areas Commun., vol. 32, no. 6, pp. 1065–1082, 2014.

CV of the Teacher

Dr. L. Sanguinetti is an Assistant Professor in the Dipartimento di Ingegneria dell'Informazione of the University of Pisa. He received the Telecommunications Engineer degree (cum laude) and the Ph.D. degree in information engineering from Pisa University, Italy, in 2002 and 2005. In 2004, he was a visiting Ph.D. student at the German Aerospace Center (DLR), Oberpfaffenhofen, Germany. During the period June 2007 - 2008, he was a postdoctoral associate in the Department of Electrical Engineering at Princeton. Since July 2013, he is also with CentraleSupelec, Paris, France. He is serving as an Associate Editor for IEEE Trans. Wireless Commun. and IEEE Signal Process. Lett. He is the Lead Guest Associate Editor for IEEE JSAC - Game Theory for Networks. From June 2015 to June 2016, he was in the editorial board of IEEE JSAC - Series on Green Commun. and Networking. Dr. Sanguinetti served as Exhibit Chair of ICASSP14 and as the general co-chair of the 2016 Tyrrhenian Workshop on 5G&Beyond. His expertise and general interests span the areas of communications and signal processing with special emphasis on multiuser MIMO, game theory and random matrix theory for wireless communications. He was the co-recipient of 2 best paper awards: IEEE Wireless Commun. and Networking Conference (WCNC) 2013 and IEEE Wireless Commun. and Networking Conference (WCNC) 2014. He was also the recipient of the FP7 Marie Curie IEF 2013 "Dense deployments for green cellular networks". Dr. Sanguinetti is a Senior IEEE Member.

Room and Schedule

July 10: Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Piano 6, Largo Lucio Lazzarino 1, Pisa*

July 12, 14, 17: Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

July 10	9am-1pm
July 12	9am-1pm
July 14	9am-1pm
July 17	9am-1pm