



UNIVERSITÀ DI PISA
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

Probabilistic Models for Networks: Random Graphs and Stochastic Geometry

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Short Abstract: Nowadays, complex networks can be found in a wide range of scientific areas, from biology to sociology, from psychology to information science. Some of them, like the Internet, or the social networks, have even become pervasive in everyday life. Analyzing this kind of networks can reveal important features or properties, but also shed light on some peculiar behaviors which can be empirically observed in real scenarios. At the same time, the analysis and modeling of complex networks is often quite involved. Fortunately, there exist reliable mathematical tools which make it possible to build simple and effective models, and to obtain, through elegant analysis, useful and accurate results. These models can be applied to any kind of networks, and are therefore potentially useful for a number of applications (network design, studying epidemics spreading, analyzing social networks behaviors etc.). The main aim of the course is to offer an introduction on some useful mathematical tools suitable for analyzing complex networks, while giving examples on how these methods can be applied to real networks.

The course will include the following topics:

Course Contents in brief:

- Mathematical preliminaries, definition of tools, metrics and measures (adjacency matrix, degree, assortativity, homophily...);
- Models of Random Graphs, their properties (degree distribution, clustering coefficient...), their components (Giant component and Small component, distributions of their size, appearance of the Giant component...). Path lengths, “small world effect”, drawbacks of Random Graphs when applied to real networks
- Random Graphs with general degree distribution (power law distribution, Configuration Model, Small World model, Exponential Random Graphs)
- Models of Network Formation (Preferential Attachment, Barabasi model and its properties)
- Basic Percolation Theory (bond and edge percolation, appearance of components, phase transition behavior)
- Epidemics on Networks (SI, SIR, SIS and SIRS models)
- Elements of Stochastic Geometry and its applications (Point Process Theory, Poisson Processes, Cox Processes, Gibbs Processes, Moment Generating functionals, Probability Generating Functionals, characterization of interference and outage in Poisson networks)

Total # of hours of lecture: 16

References:

- [1] M. Newman. *Networks: An Introduction*. Oxford Academic, 2010
 - [2] S.N. Chiu, D. Stovan, W. S. Kendall, J. Mecke. *Stochastic Geometry and Its Applications*, John Wiley and sons, 2013
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CV of the Teacher

Federico Librino is a Senior Researcher at the Institute of Informatics and Telematics of the CNR in Pisa, Italy. He received an M.Sc. degree (with honors) and a Ph.D. in telecommunication engineering from the University of Padova in 2006 and 2010, respectively. During 2009, he pursued an internship at Qualcomm Inc., San Diego, California. From 2010 to 2012, he was a post-doctoral researcher at the University of Padova. Since November 2012, he has been with the Informatics and Telematics Institute of the Italian National Research Council, where he is currently working on vehicular networks, energy harvesting techniques and network models for smart mobility systems.

His main research interests include cooperation techniques in both ad hoc and cellular networks, cross-layer protocol design for wireless networks, vehicular networks, energy harvesting technologies and cognitive network modeling by means of Markovian models and Stochastic Geometry.

He has worked on the concept of Shareability Networks, a paradigm developed to employ graph and network theory to solve resource sharing problems, which he has applied to both vehicle fleets management and spectrum allocation problems in 4.0 Industry scenarios. He has also carried out research on D2D communications in 4G cellular networks by exploiting probabilistic graphical models.

He has participated in both Italian and European (FP7 and H2020) Projects (VEHICONG, SAPHYRE, MOBIWALLET), and is author or co-author of 32 publications on both international conferences and peer-to-peer journals.

MOST RELEVANT RECENT PUBLICATIONS

- [1] F. Librino and P. Santi, "Resource Allocation and Sharing in URLLC for IoT Applications Using Shareability Graphs," in *IEEE Internet of Things Journal*, vol. 7, no. 10, pp. 10511-10526, Oct. 2020, doi: 10.1109/JIOT.2020.2999645
- [2] F. Librino and P. Santi, "The Complexity-Performance Tradeoff in Resource Allocation for URLLC Exploiting Dynamic CSI," in *IEEE Internet of Things Journal*, vol. 8, no. 17, pp. 13266-13277, 1 Sept.1, 2021, doi: 10.1109/JIOT.2021.3066104
- [3] F. Librino and P. Santi, "EH From V2X Communications: The Price of Uncertainty and the Impact of Platooning," in *IEEE Transactions on Vehicular Technology*, vol. 73, no. 1, pp. 385-401, Jan. 2024, doi: 10.1109/TVT.2023.3310582.
- [4] F. Librino, F. Martelli, G. Resta, G. Cecchi, A. Motroni and A. Ria, "Monitoring Urban Environment Through Wireless Sensor Nodes Powered by Mobile RF Sources," in *IEEE Internet of Things Journal*, vol. 12, no. 15, pp. 31272-31288, 1 Aug.1, 2025, doi: 10.1109/JIOT.2025.3573083

TEACHING and RECENT SEMINARS

4 July 2017 – Seminar lecture titled “Vehicular Networks” for the Ph.D School in Informatics of the University of Pisa

2023-2024 – co-lecturer (20 hours) for the course “Segnali Aleatori” in the Electronic Engineering Bachelor Program of the University of Pisa.

1 March 2024 – Seminar lecture titled “Towards a Green Smart City: Harvesting RF Energy from V2X Communications”, Department of Information Engineering and Computer Science (DISI), University of Trento

24 May 2024 – Seminar lecture titled “Towards a Green Smart City: Harvesting RF Energy from V2X Communications”, Department of Electronic and Informatics (DEI), University of Padova

Room and Schedule

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

Schedule:

06/05/26 – 9:00-13:00

13/05/26 – 9:00-13:00

20/05/26 – 9:00-13:00

27/05/26 – 9:00-13:00