

ANNUAL REPORT  
3<sup>rd</sup> year

Name: Atieh

Surname: Rajabi Khamesi

Cycle: XXX

Supervisor: Prof. Michele Zorzi

Priority research grant (eventual): CARIPARO

Courses, trainings and summer school activities

- Seminars

- *"Research Challenges for Intermittently Powered Wireless Embedded Systems"*, Nov. 3, 2016, Kasım Sinan Yıldırım (TU Delft).
- *"Distributed Computation of Large-Scale Graph Problems"*, Jan. 12, 2017, Prof. Michele Scquizzato (University of Houston TX USA).
- *"Non-coherent MIMO massive"*, Jan. 31, 2017, Dr. Ana García Armada (Universidad Carlos III de Madrid, Spain).
- *"Information transmission in balanced neuronal networks: the role of matrix non-normality"*, Feb. 28, 2017, Prof. Sandro Zampieri (Unipd).
- *"Machine learning and complex networks and systems for precision biomedicine"*, Mar. 2, 2017, Prof. Carlo Vittorio Cannistraci (Technical University Dresden, Germany).
- *"Pricing Relational Data with Formal Guarantees"*, Mar. 24, 2017, Prof. Paris Koutris (University of Wisconsin-Madison, USA).
- *"Introduction to the computational theory of argumentation"*, Mar. 30, 2017, Prof. Massimiliano Giacomini (University of Brescia).
- *"Socially intelligent robots"*, Apr. 7, 2017, Dr. Salvatore Anzalone (Paris University in Saint Denis, France).
- *"Technology Transfer Is a Dream or a Reality?"*, May 12, 2017, Prof. Alberto Sangiovanni Vincentelli (University of Berkeley (CA), USA).
- *"Automotive Security in a Connected World"*, May 25, 2017, Rudi Hackenberg, Enrico Pozzobon, Nils Weiss (OTH Regensburg University, Germany).
- *"From Data Mining to Knowledge Mining in Smart Infrastructure"*, June 21, 2017, Prof. Reza Arghandeh (Florida State University, USA).
- Weekly internal SIGNET meetings.

## Scientific activities

During the third year of my PhD program, I have extended my prior works regarding green communications in 5G. Specifically, I have investigated the Energy Efficiency (EE) and Spectral Efficiency (SE) in random cellular networks in different scenarios and system models.

In recent years, addressing the requirements and new challenges of the 5th generation of mobile communications, 5G, is of interest for both academia and industry counterparts. On one hand, 5G is supposed to improve the properties of current networks such as 4G/LTE in terms of capacity, latency and etc. On the other hand, several new features such as Internet of Things (IoT) and Machine-to-Machine (M2M) communications have been introduced in 5G.

In addition to fulfillment of all these requirements and new applications, energy consumption in cellular networks becomes an important concern which needs to be taken into consideration. Both economic and environmental points of view encourage us to move towards green communications in 5G.

Among all possible solutions for 5G, we have focused on three main concepts in our research, namely, Heterogeneous Random Cellular Networks (HetNets), Multiple-Input and Multiple-Output (MIMO) system and Cell Zooming (CZ).

In the first part, we have studied the EE and Spatial Spectral Efficiency (SSE) of MIMO HetNets where the locations of Base Stations (BSs) and mobile users follow some random distributions. To this aim, we considered a 2-tier random MIMO cellular network, namely, Macro and Pico tiers whose BS locations follow a Poisson Point Process (PPP) and a Poisson Hole Process (PHP), respectively. In fact, PHP generalizes Homogeneous Independent Poisson (HIP) by exploiting a spatial interference management technique which is useful and realistic, since both HetNets and MIMO systems are typically interference-limited. In this study, we firstly derived the distance distribution between the typical user and the nearest interferer BS in PHP model. Then, we evaluated the outage and coverage probabilities of each tier. Moreover, we derived a new expression for the Ergodic capacity in this network as a function of Laplace transforms of the signal and interference power. Although using PHP to model Pico BS locations is a more realistic and accurate distribution model, the obtained results are more complex than well-known HIP model. However, numerical evaluation showed the advantage of the 2-tier PHP model over 2 and 3-tier HIPs, which gives theoretical guidelines for BS deployment for the next generation of mobile communication systems. Although the numerical results suggest offloading traffic of the Macro tier to the Pico tier in order to achieve higher network SSE, the call arrival rate should be considered precisely, as it may cause degradation in the network EE.

In the second part, we studied the performance of K-tier HetNets in terms of EE and SE, while in order to improve efficiency, two Cell Zooming (CZ) techniques, namely telescopic and ON/OFF schemes, have been applied to these networks. Accordingly, we investigated two scenarios in this piece of work. First, we focused on a single tier scenario and derived a new expression for the ergodic capacity of a Poisson Voronoi Tessellation (PVT) random cellular network using stochastic geometry. Besides, the EE and SE of this model have been depicted for several user densities and CZ parameters. In the second scenario, we investigated multi-tier HetNets in which the Base Stations gather their required energy from the environment. Therefore, two important concepts in green cellular networks, namely CZ and Energy Harvesting (EH), have been addressed in this work.

Subsequently, numerical results showed the performance improvement in terms of the coverage and blocking probabilities in addition to EE and SE.

### Publications

1. A. Biason, A. R. Khamesi, N. Laurenti, and M. Zorzi, "Achievable secrecy rates of an energy harvesting device with a finite battery," in IEEE Global Communications Conference (GLOBECOM), Dec 2015. (\* IEEE ComSoc Student Travel Grant)
2. A. R. Khamesi, B. Yang, X. Ge, and M. Zorzi, "Energy and spatial spectral efficiency analysis of random MIMO cellular networks," in 22nd European Wireless Conference (EW), May 2016. (\*Best Paper Award)
3. A. R. Khamesi and M. Zorzi, "Energy and Area Spectral Efficiency of Cell Zooming in Random Cellular Networks," *accepted for presentation and publication in IEEE GLOBECOM*, Dec 2016. (\* IEEE ComSoc Student Travel Grant)
4. A. R. Khamesi and M. Zorzi, "Energy Harvesting and Cell Zooming in K-Tier Heterogeneous Random Cellular Networks," Accepted for publication in IEEE Transactions on Green Communications and Networking.
5. M. Zorzi, A. R. Khamesi and F. Lahouti "Exact Assessment of the Delay-Rate Trade-off in Ergodic Interference Alignment" submitted in Communications Letters.
6. A. R. Khamesi and M. Zorzi, "Energy and spatial spectral efficiency in MIMO Heterogeneous Networks," *in preparation to be submitted in IEEE TWireless or TCOM*.

### Mobility actions

From Aug. 2017

Visiting scholar with the Bradley Department of Electrical and Computer Engineering, Virginia Tech Blacksburg, VA, USA.

Date

Signature of PhD student

Signature of Supervisor