**Research Projects**

1. **Fundamentals of Multi-hop Multi-flow Wireless Networks**

Multi-hop Multi-flow communication paradigms are expected to play an important role in allowing a better reuse of the wireless spectrum. However, little is known about the fundamental principles that govern the design of communication schemes for such systems, and, in most of these scenarios, an exact characterization of the Shannon capacity is out of the question. We seek alternative approaches such as formulating and studying deterministic models that mimic the behavior of their stochastic counterparts, and considering the high-SNR approximation provided by a *Degrees of Freedom* analysis. The characterization of the degrees of freedom of different network scenarios often leads to a conceptual understanding of how fundamental aspects of the network such as topology and traffic demands influence the design of reliable communication schemes.

**Papers:**

"Two-Unicast Wireless Networks: Characterizing the Degrees of Freedom"

"On the Role of Deterministic Models in K x K x K Wireless Networks"

"Degrees of Freedom of Two-Hop Wireless Networks: “Everyone Gets the Entire Cake”"

1. **Robustness of Theoretical Models**

Gaussian models are ubiquitous in data compression and data communication problems. The additive noise experienced by wireless receivers, for instance, is often modeled as a white Gaussian random process. Similarly, but perhaps less intuitively, data sources are also commonly modeled as Gaussian processes. While these models are formally justified in point-to-point setups as the worst-case assumptions, the same was not known to be the case in network setups. From a theoretical standpoint, a relevant question is: In what scenarios are these Gaussian models worst-case assumptions? And, from a practical perspective: How can compression and communication schemes designed under Gaussian assumptions be useful in non-Gaussian scenarios? We answered these questions in the context of data communication in wireless networks and joint source-channel coding in arbitrary networks, by providing a framework that allows coding schemes designed under Gaussian assumptions to be converted to coding schemes that achieve the same performance under arbitrary statistical assumptions.

**Papers:**

"Worst-Case Additive Noise in Wireless Networks"

"Network Compression: Worst-Case Analysis"

1. **Relay Networks with Practical Constraints**

The study of wireless systems is traditionally performed with simplified models whose goal is to capture the fundamental aspects of communication and provide insights into the design of optimal communication strategies. However, particularly for the case of large wireless relay networks, there are big discrepancies between these theoretical models and the practical systems that make the conversion from theory to practice a big research effort in itself. Examples of these discrepancies are the assumption of synchronization between nodes, full duplex versus half duplex antennas, and the availability of channel state information at the network nodes.

**Papers:**

"Diamond Networks with Bursty Traffic: Bounds on the Minimum Energy-Per-Bit"

"On Min-Cut Algorithms for Half-Duplex Relay Networks"