PhD thesis proposal

Towards Cross-layer MIMO for 5G networks

Context

By 2020, Cisco estimates the number of connected devices to reach 50 billion. At the same time, bandwidth requirements increase spectacularly with new multimedia applications such as 8K UHDTV streaming. More and more heterogeneous devices and applications with differentiated needs will all have to share the scarce wireless medium. Next generation wireless networks shall therefore provide much higher spectral efficiency compared to 4G. MIMO advanced techniques and cross-layer mechanisms are key to provide higher capacity and optimized communication taking into account both the different applications needs and the physical channel characteristics.

Recently, major innovations in cross-layer wireless communication have been proposed that provide significant throughput gains. For example, OpenRF proposed by researchers at MIT [1] enables wireless access points on the same channel to cancel their interference at each other's clients, while beamforming their signal to their own clients. These new cross-layer designs are likely to be deployed soon as they use commodity WiFi cards.

However, cross-layer mechanisms are very complex to design, analyze their performance and debug. Indeed, it is particularly complex to work out cross-layer mechanisms such as optimized physical rate selection algorithms that take into account both specific applications requirements and the varying channel conditions [2,3]. Not only this requires expertize in all layers of the communication stack but also a development environment that allows experiment reproducibility.

Scientific evaluation of network protocols requires that experiment results must be reproducible before they can be considered as valid. But experiment reproducibility requires full knowledge of the experiment methodology and parameters, and it is known to be challenging, especially in the wireless networking area, where physical characteristics of wireless channels are known to be variable, unpredictable and hardly controllable. For instance, even when a research paper include all the details of the experimentation scenario, without a continuous monitoring of the network environment, it is very difficult to understand deeply in detail the performance results obtained and consequently, almost impossible to reproduce them.

To solve this issue, we recently built an open network laboratory (R^2LAB) in an anechoic chamber with RF absorbers with the objective of eliminating variability of the wireless channel and finely configuring the level of interferences to emulate realistic wireless environments. Thanks to this lab, realistic environment fitting with WiFi or LTE channel models in terms of number of taps, delay spread, number of clusters and angular spreading could be set. Then, different antenna configurations (position, polarization, directivity) could be investigated and linked with system-level performances.

Furthermore, we added to R^2LAB an original software experimentation framework, called IDEV [4,5], where simulated and real components of a network system can be arbitrarily combined to easily build custom test environments. The main idea is to allow refining and improving new network protocols and applications implementations by gradually increasing the level of realism of the evaluation environment.

Work Description

The final objective of this PhD is to investigate cross-layer optimization for next generation MIMO-based networks. The first step will be to determine the impact of physical layer parameters on upper layer performance. This step includes several experimental scenarios using different types of antennas on different nodes dedicated to create a database allowing a comparison in terms of quality of service. Figures of merit at the different stack layer levels (received power, SNR, RSSI, BER before and after decoding, data rate, QoS) will be measured to determine the layers mutual effect. The second step will be to optimize the tuning of these parameters by controlling the MIMO signal processing at the physical layer, according to the needs of real network applications. The proposed mechanisms will be implemented and tested on R^2LAB with the experiment methodology described above.

Many challenging problems must be addressed. One problem is how to determine optimal power allocation at each transmitting node, optimal bandwidth allocation for each transmission, beamforming techniques to limit data collision. All these points concern the physical network topology and therefore the definition of a new and generic type of radiating element dedicated to large multi-node networks is crucial for efficient cross-layer control [6,7]. Another problem is to define adequate interference management techniques. The study of this problem can also lead to the definition of new efficient MAC mechanisms for this type of infrastructures.

Positioning with regard to the UCN@Sophia Labex

This PhD topic is at the heart of the scientific theme D Infrastructures: Heterogeneity and Efficiency on the of design novel wired/wireless infrastructures, offering high performance and autonomous operation.

Complementarity of the two teams

As explained above, such research topic requires expertize in all layers of the communication stack. The student will benefit from the expertize of the CMA team at LEAT on signal propagation, radiating elements and physical layer, and of the DIANA team at Inria on MAC, network and application layers. Furthermore, the student will benefit from a unique experimental development environment that will facilitate the design and test of the proposed solutions. Both teams are excited to start this new collaboration on advanced cross-layer communication mechanisms to enhance their understanding of each other's expertize domains. The student will be recruited by Inria. The thesis director will be Walid Dabbous and the co-director will be Robert Staraj. Thierry Turletti from the Diana team at Inria and Fabien Ferrero, Leonardo Lizzi and Aliou Diallo from the CMA team at LEAT, UNS will also participate to this project.

Pre-requisites

Strong knowledge on both physical layer and network architecture. Physical channel propagation models, statistical analysis, data fitting, programming in C++ and/or Python.

References

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