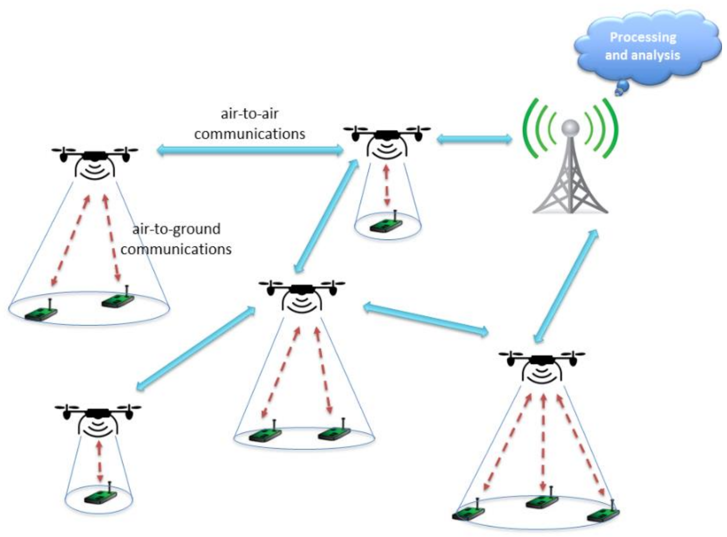
# Optimization of UAVs deployment and coordination for exploration and monitoring applications

Pre-requisite: Algorithmic, Linear Programming, Networking, Programming skills

## I. Introduction

Autonomous air systems extend the reach of conventional wireless networks by providing supervision and coverage solutions for wide area monitoring, healthcare management, or post-disaster management [1, 2, 9, 11, 14]. The density and node mobility are no longer constrained because the air system makes it possible to provide network connectivity and services and expand on-demand deployments for data recovery, for tracking mobile users or to recharge the batteries of the nodes using technologies such as radio frequency [4, 10]. The use of a single drone in an autonomous air system does not allow to generically respond to all the temporal and spatial constraints of sensor networks. On the other hand, the use of a fleet of drones would help to overcome these constraints. However, the use of a fleet in an autonomous air system presents several challenges in terms of coordination between drones, air-to-ground and air-to-air data transfer, and dynamic coverage for energy recharging or connectivity servicing for instance [8, 12].

The drones must be optimally positioned above the ground nodes to be able to cover a large area while minimizing the deployment cost of the drones and the energy cost spent by each drone. The three-dimensional space in which the drones are evolving complicates the optimization models, as they have to take into account the quality constraints of air-to-ground and air-to-air communications (see Figure 1).




The autonomous air system must be able to retrieve data from ground-based nodes and transfer them to a base station located on the edge or the center of the network. Network connectivity for air-to-ground and air-to-air communications must be ensured by the deployment while maintaining the cost constraints spent by the autonomous air system, and guaranty efficient data gathering and transfer to cloud services.

## II. Challenges

The use of drones or UAV involves the consideration and combination of a lot of parameters and objectives such as connectivity, coordination, mobility management, area coverage, traffic density, routing mechanism, computing power, energy consumption, etc. Optimizing the global application may lead to complex models and impractical solutions. In the context of flying networks deployed on a very large scale, the collection and processing of the data is delicate and ambitious [3].

One main challenge is to be able to provide scenarios with UAV that fit with the application and manage to alleviate the network or collect and process the data. We focus on the deployment of the flying networks by determining the positions of the drones on the monitored area [1, 2, 5]. The mobile sensors coverage implies to study the evolving structure of the positioning, by computing efficient drone trajectories through time. We do not focus on the path control, but our models must include the energy autonomy of the UAV, and ensure the reliability of the air-to-air transmissions.

Another challenge is to deal with the growing amount of collected data. Indeed, WSN can be used to measure some environmental parameters, and the data collection is periodically done by UAV that will collect once a large amount of data from the ground sensors. Since many common applications in agriculture or in environmental monitoring are not time-critical, a solution to the gateway unavailability problem is to allow sensing nodes to buffer their data in on-board storage and transmit in bulk when the drone flies over them. Over the past two decades, and more recently with the advent of Big Data issues, the need to process large amounts of information in potentially distributed, large-scale data streams has become paramount.

But the collecting and computing resources of the drones are limited. To compensate for the lack of computing power of UAVs, it is customary for all calculations to be centralized, in a remote cloud for example. However, this solution is not viable, on the one hand in terms of energy consumption linked to air-to-air communication and also because of the wireless bandwidth which will eventually become a bottleneck for data-intensive communication. One open challenge will be to use the unused memory on the drones, as well as local computing power, which often generates less power consumption [2, 13]. The objective is to build a decentralized system scaling up with the size of data to process.

This PhD will focus on the optimization of UAVs deployment and coordination for exploration and monitoring applications. The goal is to provide optimal solutions using tools from graph theory, linear programming and operations research (OR). The scalability of the algorithms is of primary concern to fit with the underlying applications. Sophisticated OR tools like column generation have to be investigated, as well as distributed algorithms to optimize the drone coordination and validate the solutions through simulations.

## Bibliography

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