Title: Optimal deployment of 5G radio coverage by UAV

Supervisors: Frédéric LAUNAY and Patrick COIRAULT

Host laboratory: Laboratoire d'Automatique et d'Informatique pour les Systèmes (LIAS)

Abstract: 5G coverage is typically provided by node base-station (called gNB base stations). When an event occurs (Olympic Games, Game Event, Concert, ...) or for civil/military security exercises, the use of drones (UAV) provides additional radio coverage. This new coverage will be studied depending on different use cases, according to the following criteria: throughput, latency, density, energy consumption, link reliability (call drop, radio link failure) and energy minimization.

Keywords: Multi-agents control, graph theory algorithms, 5G services (mMTC, URLLC, eMBB), energy consumption optimization, radio channel, UAV, multi-tier deployment, COMP, massive MIMO

Context

Wireless communications, via public or private networks, use radio spectrum. Such communication can be between people, people and machines or systems (“things” more general) or between things; To prevent or limit interference between different users, coordinated radio management is necessary (like fCIC for 4G).

This thesis aims at optimizing the position of a fleet of drones and raising technological solutions to allow continuous and secure connectivity between each drone and 5G network. The robustness of the connectivity improves the coverage of the base station and help to provide higher data capacity in dense areas.

The optimization is based on current technical characteristics of drones, namely:

1) Real-time cooperation of location information with synchronized shared clock issues;
2) Real-time scheduling of radio resources between the base station and the radio relays (drones)
3) Management of radio spectrum since communication range and duration of a drone are limited.
   The total throughput (capacity) depends on the distance between the drones (called agents) and the UEs (targets) as well as interference between drones.
4) Drone autonomy is a limiting factor on drone flight time and range. The telecommunications solutions chosen must be optimized.

Work Description

Multi-tiers Deployements

The drones are declared as a mobile cell, activating a radio node or an IAB link with the base station

Figure 1 : Node base Station and Drone communication
The Radio link quality depends on several parameters such as the environment (RMa-AV, RMi_AV, UMa_AV), the height of the antenna, the choice of frequency, etc. [3]. As an example for propagation in non-direct visibility (NLOS), the attenuation is calculated [3] between the base station (height between 10 m and 300m) and the UAV (less than 10 km):

\[
\begin{align*}
PL_{\text{RMa-AV-NLOS}} &= \max(PL_{\text{RMa-AV-LOS}}, \\
-12 + (35 - 5.3 \log_{10}(h_T)) \log_{10}(d_{3D}) + 20 \log_{10}\left(\frac{40 \pi f_c}{3}\right), \\
\end{align*}
\]

In order to increase coverage, UAVs communicate with each other. The robustness of the radio link will be taken into account in relation to the attenuation of the signal. This provides UAV synchronization and UAV position control.

Key Performance Indicator : KPI

The radio link must be greater than a threshold value in order to be able to ensure a minimum throughput.

Performance indicators make it possible to assess:
1) The total flow
2) The probability of the loss of the radio link
3) The failure of a call
4) Energy consumption (flight autonomy)

In the case of multi-tier deployment, a UAV acts as a relay antenna. The calculation of the capacity of the node makes it possible to take into account the risk of bottleneck.

Modeling by a graph matrix will make it possible to simulate the performances reached according to the configuration.

Several optimizations will be studied in terms of convex or non-convex optimization functions:
- Global capacity
- Minimum Power Consumption according to a target BER

Radio spectrum resource allocation

The flying base station on UAV allocates radio resources, called PRB, to each user under coverage. Resource allocation is managed in real time, according to scheduling algorithms and based on channel attenuation.

Figure 2 : Real time resource allocation [5]

[5] propose efficiency optimization algorithms energy by taking into account the allocation of radio resources

We will consider a distributed optimization approach [8] for the fleet of the drones to solve dynamic resource allocation problem and interferences management.

The state of the art will present the analytical methods allowing to develop dynamic resource allocation policies, and to analyze the performance of D2D communications within a wireless network. Among other things, we will be interested in:
• Spatial fluid model [6] developed to assess network performance, such as signal-to-interference-to-noise ratio (SINR) and failure probability through analytical expressions.
• Modeling by stochastic geometry (Poisson law, queuing theory, Lyapunov optimization and “drift plus penalty” and “surrogate optimization” algorithms)
• Distributed optimization originally developed by [7] and average consensus problems in multi-agent systems [9]

**Vocabulary**

UMa-AV: Urban-macro with aerial vehicles
UMi-AV: Urban-micro with aerial vehicles
RMa-AV: Rural-macro with aerial vehicles

**Références**


[4] Loü Salaun, Thèse 2020, Resource allocation and optimization for the non-orthogonal multiple access

[5] Long D. Nguyen, Trung Q. Duong and Hoang D. Tuan, Real Time Convex Optimisation for 5G Networks and Beyond


**Problems to solve**

The subject of the thesis aims to study multi-agent radio resource allocation coupled with flexible fleet management (UAV). The objective is to optimize radio spectrum sharing without interference in a mobile multi-actor context to increase the transmission capacity (use case of a crowd when an event is planned).

The first problem to be solved is the impact on the transmission capacities when radio channels conditions are continuously changing between the terminals and the drones

Constraints and issues are identified in the context of 5G (specificities should also be taken into account, such as Network Slicing and associated use cases).

It will be important to explain how the thesis solution for spectrum management and interference management techniques can be used as extent resource allocation work carried out on mobile networks is adaptable to these.
The thesis will include a whole aspect relating to graph theory and optimization tools. Graph theory will be used to model the strategies of agents seeking to optimize their resources while reducing their interference to other agents or to describe the choices available to operators in their strategy for implementing new modes of spectrum management.

Subsequently, all the models developed will be optimized in order to propose a set of frequency allocations dynamically and offering the best possible compromise in terms of expected services (QoS).

**Expectation**: During this thesis, the student will have to prove the feasibility of controlling mobile agents based on performance indicators. This feasibility will be based on mathematical proofs and simulations under Matlab. A PoC (Proof of Concept) will validate the feasibility via an experimental 5G bench. The use of this bench will allow to present the concept to middle school and high school students as part of the feminization of technology and for the science festival. A patent study will be carried out as part of emergency missions (ProSe).

---

**Expected profile of the candidate**

**Required skill**

Applicants should have a strong desire to explore applied mathematics fields and have a first experience in operational research. They should have good communication skills, be self-motivated, adaptable and able to work in an innovative and challenging scientific environment. The candidate may have skills in applied mathematics, graph theory and optimization (convex, non-convex) and eventually basic knowledge of telecom (mobile networks). Rigor, autonomy and good communication are essential assets for your success in the position. A good knowledge of programming (Matlab) is necessary. A good level in English is fundamental. French would be appreciated.

**Location**: Poitiers (86000 France)

**PhD Country**: France

**Contract Duration**: 36 months starting date Nov 2023

**To Apply**: Applicants should submit a cover letter and a detailed CV in a zip files

**Contact**: frederic.launay@univ-poitiers.fr