

# Efficient Resource Allocation in 5G and Beyond Networks

## Newsletter 1: Project objectives and target – Project progress during the first year

### Project objectives and target

The proposed project, ERA5G-Beyond, aims to address the challenges posed by the growing number of connected devices and the need for efficient resource allocation in 5G and Beyond Networks. The project has two main phases. In the first phase, the researchers will explore current promising technologies such as Multi-User Multiple-Input Multiple-Output (MU-MIMO) and Downlink and Uplink Decoupling (DUDe). They will investigate any limitations that may hinder their performance and propose new mechanisms or algorithms to achieve efficient allocation of physical resources. In the second phase, the project will leverage Machine Learning (ML) and Game Theory (GT) to enhance the proposed mechanisms.

In terms of the state-of-the-art and innovation, several research programs in Europe and the United States have already financed projects related to 5G networks. However, the continued growth of users and the introduction of IoT devices necessitate efficient resource utilization. DUDe and MU-MIMO technologies have emerged as promising solutions for resource allocation, and the project aims to further enhance their performance through ML and GT techniques. ML techniques are seen as crucial for addressing dynamic problems in 5G networks, such as real-time distribution of network resources. These techniques, including data mining, big data analysis, and deep learning, can automate network management tasks and optimize network parameters.

During the first year of the project we mainly focus in the first phase of the ERA5G-Beyond project. The research team focus on exploring and evaluating various approaches for DUDe, in order to address the challenges of resource allocation in 5G and Beyond Networks. More specifically the research team focus on user and bandwidth allocation and in power optimization in DUDe networks. Moreover, the research team examine the benefits and potential limitations of MU-MIMO and propose new mechanisms and algorithms to improve their performance in 5G networks. More specifically during the reporting period we evaluated user and bandwidth allocation in MU-MIMO 5G networks. The implementation of the first phase will lay the groundwork for further research and advancements in the field of resource allocation in 5G and Beyond Networks using ML and GT. Additionally, the research team, in the context of phase two of the project, leverage techniques inspired by ML and Game Theory GT to enhance the above technologies (DUDe and MU-MIMO) and optimize resource allocation.

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The project aims to have a scientific impact by contributing to the foundations of 5G and Beyond Networks. It seeks to improve network capabilities through innovative resource allocation mechanisms, enhancing performance metrics such as throughput, capacity, spectral efficiency, and energy consumption. The economic impact is expected to be significant, with the deployment of these technologies driving productivity growth, creating new markets, and fostering investments in network infrastructure and technology innovations. From a societal perspective, 5G and Beyond Networks have the potential to transform various aspects of society, including the development of smart cities. The project recognizes the need for efficient resource allocation to enable the full potential of these networks in creating interconnected smart cities that enhance the quality of life for residents.

Project progress during the first year

### **Project progress during the first year**

In the following paragraphs we present the project progress during the first year.

#### **WP1: Extensive state-of-the-art analysis**

The objective of this WP includes the extensively literature and ongoing research projects review regarding: (a) the possibilities that the technologies under study (MU-MIMO, DUDe) offer towards efficient resource allocation and possible efficiency shortcomings that limit their performance and (b) the application of ML and GT techniques towards efficient resource allocation and the advantages they may provide. This review is considered as a cornerstone in the development of the efficient resource allocation mechanisms/algorithms and will lead to the publication of one conference paper.

WP1 has been completed and the following paper has been published on ICOIN conference 2023: C. Bouras, I. Caragiannis, A. Gkamas, N. Protopapas, T. Sardelis and K. Sgarbas, "State of the Art Analysis of Resource Allocation Techniques in 5G MIMO Networks," 2023 International Conference on Information Networking (ICOIN), Bangkok, Thailand, 2023, pp. 632-637, doi: 10.1109/ICOIN56518.2023.10049018.

#### **WP2: Decoupling in 5G and beyond networks**

Based on the extensive state-of-the-art analysis, we target to improve existing or propose innovative DUDe algorithms and mechanisms for 5G and Beyond Networks. The algorithms take advantage of the user-centric approach that DUDe follows, offering the ability for users to connect to different Base Stations (BSs) in the uplink and downlink direction. The improved/proposed algorithms and mechanisms are expected to exploit the macro BS

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infrastructure and more importantly the installed small BSs close to the macro BSs borders. In addition, they take into account the macro and small BSs available resources to determine the most efficient BS (in both directions) that the user should connect to, aiming at improving the overall downlink and uplink data rates and mitigating interference. The work of WP2 will lead to the publication of two conference papers and one journal article.

During the implementation of the WP, we focused on the following research areas in order to improve the operation of DUDe 5G networks:

1. Optimization of User Allocation: Optimization of user allocation in a DUDe 5G network is of paramount importance.
2. Optimization of Bandwidth Allocation: Optimization of bandwidth allocation in a DUDe 5G network holds significant importance.
3. Optimization of Energy Consumption: Optimization of energy consumption in a DUDe 5G network holds immense importance.

### WP3: MU-MIMO for improved spectral efficiency

Our work focuses on integrating and utilizing MU-MIMO technology in order to offer improved data rates to a larger number of users. The improvement of the communication system capacity, the enhanced reliability of the communication links and the improved overall spectral efficiency will be achieved using multiple antennas on both ends (user and BS) of the communication link. The ultimate goal of WP3 is to improve or propose new MU-MIMO algorithms and mechanisms, which will in turn lead to the publication of two conference papers and one journal article.

### WP4: Machine learning and game theory techniques for network optimization

The purpose of this WP is twofold. On the one hand we plan to evaluate several ML algorithms (supervised and unsupervised) and design/analysis techniques inspired by GT in order to gain network experience and optimize the network planning based on predictions and user fairness. On the other hand, we will apply the most efficient ML algorithms and GT techniques on the developed (in WP2 and WP3) DUDe and MU-MIMO mechanisms in order to further improve the spectral efficiency and optimize the overall network performance (e.g. in terms of number of supported devices, achieved data rates, etc.). The work of WP4 will lead to the publication of 2 conference papers and 2 journal articles.

### WP5: Management and dissemination

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This WP aims to meticulously monitor and oversee the progress of all WPs within the project. This includes both the experimental work being conducted and the management of administrative issues, such as coordinating meetings, tracking deliverables, and ensuring timely completion of reports.

Additionally, the administration WP recognizes the importance of effective communication and dissemination of project outcomes. To achieve this, it focuses on maintaining a dedicated website that serves as a comprehensive platform for sharing project updates, research findings, and relevant information. By providing a centralized hub for dissemination, the website helps to enhance awareness, visibility, and understanding of the project's objectives, achievements, and potential impact.

During the first year of the project the project web site was developed, and the following paper has been presented on ICOIN conference 2023: C. Bouras, I. Caragiannis, A. Gkamas, N. Protopapas, T. Sardelis and K. Sgarbas, "State of the Art Analysis of Resource Allocation Techniques in 5G MIMO Networks," 2023 International Conference on Information Networking (ICOIN), Bangkok, Thailand, 2023, pp. 632-637, doi: 10.1109/ICOIN56518.2023.10049018.

#### Web Site

<https://era5g.upatras.gr/>

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