Efficient Resource Allocation in 5G and Beyond Networks

Newsletter 3: Project objectives and target – Project progress during the third year

Project objectives and target

The ERA5G-Beyond project aimed to address the challenges posed by the increasing number of connected devices and the growing demand for efficient resource allocation in 5G and Beyond Networks. The project was structured into two main phases. In the first phase, researchers explored promising existing technologies, such as Multi-User Multiple-Input Multiple-Output (MU-MIMO) and Downlink and Uplink Decoupling (DUDe). They analyzed potential limitations that could hinder their performance and developed new mechanisms or algorithms to optimize the allocation of physical resources. In the second phase, the project integrated Machine Learning (ML) and Game Theory (GT) to enhance these mechanisms.

Several research initiatives in Europe and the United States had already funded projects related to 5G networks. However, the rapid expansion of users and the widespread adoption of IoT devices required even more efficient resource utilization. Technologies such as DUDe and MU-MIMO had emerged as promising solutions for resource allocation, and the ERA5G-Beyond project sought to further refine and improve their performance using ML and GT techniques. ML played a crucial role in addressing dynamic challenges in 5G networks, such as real-time resource distribution. Techniques like data mining, big data analysis, and deep learning automated network management and optimized key network parameters.

During the third year, the project primarily focused on the second phase. The research team explored and evaluated various MU-MIMO approaches to tackle resource allocation challenges in 5G and Beyond Networks. Specifically, they analyzed the benefits and limitations of MU-MIMO and proposed new mechanisms and algorithms to enhance its performance. A key aspect of this phase involved evaluating user and bandwidth allocation in MU-MIMO-based 5G networks. Additionally, the team conducted further research on resource allocation, applying ML and GT techniques to optimize performance. By leveraging these advanced methodologies, the project improved DUDe and MU-MIMO technologies, ensuring more efficient resource allocation.

The scientific impact of the ERA5G-Beyond project lay in its contributions to the foundational knowledge of 5G and Beyond Networks. By developing innovative resource allocation

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mechanisms, the project improved key network performance metrics, such as throughput, capacity, spectral efficiency, and energy consumption. The economic impact was expected to be substantial, as the adoption of these technologies drove productivity growth, created new market opportunities, and encouraged investments in network infrastructure and technological innovations. From a societal perspective, 5G and Beyond Networks had the potential to transform various aspects of daily life, particularly in smart city development. The ERA5G-Beyond project recognized the importance of efficient resource allocation in unlocking the full potential of these networks, fostering interconnected smart cities that enhanced the overall quality of life.

Project progress during the third year

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

WP2: Decoupling in 5G and beyond networks

Based on an extensive state-of-the-art analysis, we aimed to enhance existing DUDe algorithms or propose innovative mechanisms for 5G and Beyond Networks. These algorithms leverage DUDe's user-centric approach, which allows users to connect to different Base Stations (BSs) for uplink and downlink transmissions. The improved or newly proposed algorithms and mechanisms were designed to maximize the potential of macro BS infrastructure, with a particular focus on utilizing small BSs located near macro BS borders. Additionally, they considered the available resources of both macro and small BSs to determine the most efficient BS selection for each direction. The goal was to improve overall uplink and downlink data rates while effectively reducing interference. The work conducted in WP2 resulted in the publication of at least two conference papers and one journal article.
During the third year of the project in the context of WP2 the following papers has been published:

- Power Consumption Analysis in DUDe 5G MIMO Networks, Chrysostomos-Athanasios Katsigiannis, Apostolos Gkamas, Konstantinos Tsachrelias, Christos Bouras, Vasileios Kokkinos, Philippos Pouyioutas, 15th International Conference on Network of the Future (NoF 2024), October 2 – 4, 2024, Barcelona, Spain, 2024.
- Energy Efficiency Analysis of DUDe 5G Networks, Mr. Chrysostomos Athanasios Katsigiannis, Prof. Apostolos Gkamas, Mr. Konstantinos Tsachrelias, Prof. Christos J Bouras, Dr. Vasileios Kokkinos and Prof. Philippos Pouyioutas 2024 Fifteenth International Conference on Ubiquitous and Future Networks (ICUFN)
- Simulation Based Energy Efficiency Analysis of DUDe 5G Networks, Chrysostomos Athanasios Katsigiannis, Apostolos Gkamas, Konstantinos Tsachrelias, Christos J

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Bouras and Vasileios Kokkinos, Philippos Pouyioutas, The Twentieth Advanced International Conference on Telecommunications (AICT 2024), April 14 – 18, 2024, Venice, Italy

- Simulation Based Energy Efficiency Analysis and Evaluation of DUDe 5G Networks, Chrysostomos Athanasios Katsigiannis, Apostolos Gkamas, Konstantinos Tsachrelias, Christos J Bouras and Vasileios Kokkinos, Philippos Pouyioutas, International Journal On Advances in Networks and Services, vol 17, no 3&4, year 2024

WP3: MU-MIMO for improved spectral efficiency

Our work focuses on integrating and utilizing MU-MIMO technology to provide higher data rates to a larger number of users. The capacity of the communication system, the reliability of communication links, and the overall spectral efficiency are improved by deploying multiple antennas on both ends of the communication link—at the user side and the Base Station (BS). During the third year of the project, we concentrated on designing and implementing user and bandwidth allocation techniques for MU-MIMO 5G networks. Additionally, we investigated the power consumption of the proposed techniques. The ultimate goal of WP3 is to refine existing MU-MIMO algorithms or develop new mechanisms, ultimately leading to the publication of at least two conference papers and one journal article.
During the third year of the project in the context of WP3 the following paper has been published:

- Enhancing Real – Time IoT Applications: Latency Reduction Techniques in 5G MIMO Networks, Chrysostomos-Athanasios Katsigiannis, Konstantinos Tsachrelias, Vasileios Kokkinos, Apostolos Gkamas, Christos Bouras, Philippos Pouyioutas, The 19th International Conference on Broadband and Wireless Computing, Communication and Applications Communication and Applications (BWCCA 2024), November 13 – 15, 2024, San Benedetto del Tronto, Italy, pp.1-6, 2024.
- Optimizing Network Slices: A Comparative Analysis of Allocation Algorithms for 5G Environments, Nikolaos Prodromos, Damianos Diasakos, Vasileios Kokkinos, Apostolos Gkamas, Philippos Pouyioutas, Christos Bouras, 2024 International Conference on Future Communications and Networks (FCN 2024), November 18 – 22, 2024, Valetta, Malta, no. 1- 6, 2024.
- Optimizing Resource Allocation in 5G MIMO Networks Using DUDe Techniques, Mr. Konstantinos Tsachrelias, Mr. Chrysostomos Athanasios Katsigiannis, Dr. Vasileios Kokkinos, Prof. Apostolos Gkamas, Prof. Christos J Bouras and Prof. Philippos Pouyioutas 2024 14th International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP)

The research project was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the “2nd Call for H.F.R.I. Research Projects to support Faculty Members & Researchers” (Project Number: 2440).

- Dynamic Bandwidth Allocation in MIMO 5G Networks, Mr. Nikolaos Prodromos, Mr. Damianos Diasakos, Dr. Vasileios Kokkinos, Prof. Apostolos Gkamas, Prof. Christos J Bouras and Prof. Philippos Pouyioutas 2024 International Wireless Communications and Mobile Computing (IWCMC)

WP4: Machine learning and game theory techniques for network optimization

The purpose of this Work Package (WP4) is twofold. First, we aim to evaluate various Machine Learning (ML) algorithms (both supervised and unsupervised) and Game Theory (GT)-inspired design and analysis techniques. This will allow us to gain valuable insights into network behavior and optimize network planning based on predictive analytics and user fairness. Second, we will apply the most effective ML algorithms and GT techniques to the DUDe and MU-MIMO mechanisms developed in WP2 and WP3. This will further enhance spectral efficiency and optimize overall network performance, including the number of supported devices, achieved data rates, and other key metrics. The work conducted in WP4 will result in the publication of two conference papers and two journal articles. During the third year of the project, the four deliverables of the WP4 have been completed. In addition, during the third year of the project in the context of WP4 the following paper has been published:

- A Deep Learning Approach to User Allocation in a 5th Generation Network, Ioannis Konstantoulas, Iliana Loi, Kyriakos Sgarbas, Apostolos Gkamas, Christos Bouras, 28th Pan-Hellenic Conference on Progress in Computing Informatics with International Participation, 13-15 December 2024, Athens, Greece

WP5: Management and dissemination

This Work Package (WP) is dedicated to meticulously monitoring and overseeing the progress of all WPs within the project. This includes both the experimental work being conducted and the management of administrative tasks, such as coordinating meetings, tracking deliverables, and ensuring the timely completion of reports. Additionally, this WP emphasizes the importance of effective communication and dissemination of project outcomes. To achieve this, it maintains a dedicated website that serves as a central platform for sharing project updates, research findings, and relevant information. By providing a comprehensive and accessible hub, the website enhances awareness, visibility, and understanding of the project's objectives, achievements, and potential impact.

Web Site

https://era5g.upatras.gr/

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