ROUTE56

Radio technologies for ubiquitous communications in the evolution from 5G to 6G

Document DP

Description of the activities to be done according to the tasks of the project, interactions, planning, and meetings

Author(s):	**All members of the research and work group**
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Abstract:

This document describes at the beginning of the ROUTE project the following issues:

* scenarios and use cases addressed in each technical task of the project,
* identification of the key performance indicators to be considered in each task,
* concrete description of the activities to be performed in each task,
* description of the planned organization of the project.

Keyword list: 5G and beyond, high frequency bands, channel modelling, energy efficiency, spectral efficiency, massive MIMO, massive machine type communications, next generation positioning, extremely large antenna arrays, artificial intelligence

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References

[3GPP TR 37.910] 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Study on self evaluation towards IMT-2020 submission (Release 16). Technical Report V16.1.0 (2019-09).

List of abbreviations & symbols

AI	Artificial Intelligence
AOA	Angle Of Arrival
AOD	Angle Of Departure
BS	Base Station
DQL	Deep Q Learning
eMBB	Enhanced Mobile Broadband
ELAA	Extremely Large Antenna Array
IRS	Intelligent Reconfigurable Surface
MAB	Multi Armed Bandit
MIMO	Multiple Input Multiple Output
MTC	Machine Type Communications
NLOS	Non Line of Sight
LIS	Large Intelligent Surfaces
LOS	Line Of Sight
OLOS	Obstructed Angle Of Arrival
QoE	Quality of Experience
QoS	Quality of Service
RAT	Radio Access Technology
RIS	Reflecting Intelligent Surface
SVM	Support Vector Machine
TFG/TFM	Final Degree Project / Final Master Project

1. INTRODUCTION

The objective of this document is to describe at the beginning of the ROUTE project the following issues:

- Scenarios and use cases addressed in each technical task of the project.
- Identification of the key performance indicators to be considered in each task.
- Concrete description of the activities to be performed in each task. This includes:
    - Objectives.
    - Description of the activities and temporal planning.
    - Expected results.
    - Interactions with other tasks.
- Description of the planned organization of the project:
    - Meetings.
    - Newsletters.
    - Webpage.

2. SCENARIOS AND KEY PERFORMANCE INDICATORS

2.1. Scenarios and use cases

In this subsection, the foreseen scenarios and use cases to be taken into account in each technical task are enumerated following the document [3GPP TR 37.910].

Task 3.1: Blocking analysis, coverage prediction, and network planning in mmWave networks

- Dense urban - eMBB
- Rural - eMBB

Task 3.2: Techniques for blocking mitigation in mmWave networks

- Dense urban - eMBB
- Rural – eMBB

Task 3.3: Coverage boosting through hybrid cooperation in heterogeneous communication networks

- Dense urban - eMBB
- Indoor hotspot – eMBB

Task 4.1: Channel model for the near-field propagation conditions

- Dense urban - eMBB
- Indoor hotspot – eMBB

Task 4.2: Cell-free implementation of LIS/ELAAs in wireless systems

- Dense urban - eMBB
- Indoor hotspot – eMBB

Task 4.3: IRS versus active antennas and conventional relays

- Dense urban - eMBB
- Indoor hotspot – eMBB

Task 5.1: Spatial modulation

- Dense urban - eMBB

- Rural – eMBB
- Indoor hotspot – eMBB
- mMTC

Task 5.2: Wireless power transfer for efficient energy transmission and reuse in mMTC networks

- Indoor hotspot
- mMTC

Task 5.3: Energy-efficient multiple access strategies in multiuser/MTC communications

- Indoor hotspot
- mMTC

Task 6.1: Multipath-assisted localization

- Indoor hotspot – eMBB
- Dense urban - eMBB

Task 6.2: Location-aided communication

- Indoor hotspot – eMBB
- Dense urban - eMBB

2.2. Key performance indicators

In this subsection, we enumerate the key indicators that will be used to evaluate the performance of the techniques developed in each task of the project.

Task 3.1: Blocking analysis, coverage prediction, and network planning in mmWave networks

- Blocking probability
- Lengths of LOS/NLOS
- Distance to closest visible BS

Task 3.2: Techniques for blocking mitigation in mmWave networks

- Blocking probability

Task 3.3: Coverage boosting through hybrid cooperation in heterogeneous communication networks

- Throughput
- Latency
- Packet Loss Rate

Task 4.1: Channel model for the near-field propagation conditions

- Coherence bandwidth
- MIMO channel rank

Task 4.2: Cell-free implementation of LIS/ELAAs in wireless systems

- Spectral efficiency in single user and multiuser setups
- Bit error probability
- Pilot overheads

Task 4.3: IRS versus active antennas and conventional relays

- MIMO channel rank
- Spectral efficiency
- Bit error probability
- Pilot overheads

Task 5.1: Spatial modulation

- Data rate
- Bit error rate
- System capacity in terms of number of users
- Energy consumption

Task 5.2: Wireless power transfer for efficient energy transmission and reuse in mMTC networks

- Sum rate
- Energy consumption

Task 5.3: Energy-efficient multiple access strategies in multiuser/MTC communications

- Energy consumption
- Latency
- Packet Throughput

Task 6.1: Multipath-assisted localization

- LOS/NLOS detection probability
- Position accuracy

Task 6.2: Location-aided communication

- Energy consumption
- Data rate
- Position accuracy

3. DESCRIPTION OF TECHNICAL TASKS AND PLANNED ACTIVITIES

This section, describes, for each task, the main objectives to be covered, a detailed list of the concrete activities to be performed in order to achieve the goals jointly with a temporal planning, and the expected results. It also mentions the expected interactions with other tasks in the project.

Task 3.1: Blocking analysis, coverage prediction, and network planning in mmWave networks

Main objectives of the task

- Objective 1: To characterize the blocking effects in mmWave networks from a statistical point of view.
- Objective 2: To use the previous characterization to derive metrics such as minimum distance to the closest visible BS, lengths of the NLOS/shadow intervals, probability of blocking, etc.
- Objective 3: To use the previous characterization to derive a predictor of the LOS/NLOS regions.

Concrete activities to be performed and temporal planning

- Activity 1 (M1 – M6): Statistical characterization of the blocking elements (positions, sizes and shapes) using random shape theory and stochastic geometry. Impact of the blockage probability. Generalization of previous results in the literature to include buildings with 3D volume.
- Activity 2 (M1 – M8): Statistical characterization of the lengths of the shadow/NLOS and light/LOS intervals. Obtention of simulation results using real data of a city.
- Activity 3 (M1 - M14): Statistical characterization of the distance to the closest visible BS (taking into account the presence of blocking objects). Impact on the achievable rate.
- Activity 4 (M1 – M14): Development of a predictor of NLOS/LOS regions based on a finite number of measurements and the statistical characterization of the blocking objects.

Expected results

- Publications: 3 papers in conferences and/or journals.
- TFGs / TFMs

Interactions with other tasks

The results could be useful for the following tasks:

- Task 3.2.
- Task 6.1.
- Task 4.3.

Task 3.2: Techniques for blocking mitigation in mmWave networks

Main objectives of the task

- Objective 1: To evaluate the impact of relaying for coverage enhancement in mmWave networks from a statistical point of view.
- Objective 2: To evaluate the impact of transmitting from multiple BSs (i.e. macrodiversity) for the reduction of shadow/NLOS regions.

Concrete activities to be performed and temporal planning

- Activity 1 (M1 – M6): Derivation of the probability of blockage for N links taking into account the statistical dependence of the blocking elements of each link for different models of blocking elements.
- Activity 2 (M10 – M18): For cell deployments with multiple relays, optimization of the position of the relays to minimize the average probability of communication failure, using the expressions obtained in the previous activity.
- Activity 3 (M16 – M22): For scenarios with multiple BSs, evaluation of the impact of interference, but taking into account the benefits of having some interferences being blocked.
- Activity 4 (M16 – M24): For scenarios with multiple BSs, study the case where the users can communicate with several visible BSs, that is in LOS, considering that blocking elements may obstruct the communication links. Evaluation of the performance increase due to cooperation among BSs in comparison with the case where the users only can communicate with one visible BS only.

Expected results

- Publications: 2 papers in conferences and/or journals.
- TFGs / TFMs

Interactions with other tasks

The results could be useful for the following tasks:

- Task 4.3.

Task 3.3: Coverage boosting through hybrid cooperation in heterogeneous communication networks

Main objectives of the task

- Objective 1: To develop strategies to provide ubiquitous service at a higher layer even when the load of the cellular system is extremely high or the channel conditions are very harsh.
- Objective 2: To fulfil diversified service requirements in network slicing strategies to alleviate the complex resource management in softwarized networks.

Concrete activities to be performed and temporal planning

- Activity 1 (M22 – M24): To review recent literature on deep learning applied to coverage boosting.

- Activity 2 (M25 – M27): To address heterogeneous scenarios where multiple radio access technologies (multi-RAT) coexist
- Activity 3 (M28 – M31): To design a new set of MAB algorithms intended to work in non-stationary and more realistic environments.
- Activity 4 (M32 – M36): To use deep contextual MAB as a way to predict QoE for every type of available RAT and improve handoff decisions.

Expected results

- Publications: 2 papers in conferences and/or journals.
- TFGs / TFMs

Task 4.1: Channel model for the near-field propagation conditions

Main objectives of the task

- Objective 1: Study the propagation channel models in the near-field of the antenna arrays (spherical wave vs. plane wave propagation), including polarization effects.
- Objective 2: Derive bandwidth limit for non-frequency selective channels in near-field propagating conditions.
- Objective 3: Study the implications in terms of channel acquisition/reporting.

Concrete activities to be performed and temporal planning

- Activity 1 (M1 – M3): Review of recent literature on channel models and near-field propagation and generate a realistic channel simulator.
- Activity 2 (M3 – M8): Study of the following aspects in mmWave and THz bands: i) the pathloss and multipath channel models when line-of-sight (LOS) and non-line-of-sight (NLOS) propagation components are present; ii) the dependence of the channel selectivity in time and in frequency as a function of the distance between transmitter and receiver, and as a function of the Doppler spread in the scenario.
- Activity 3 (M6 – M9): Generate a channel simulator that will be used in several tasks of the project.

Expected results

- Publications: 1 paper in conferences and/or journals.
- TFGs / TFMs

Interactions with other tasks

The results will be useful for the following tasks:

- Task 4.2
- Task 4.3
- Task 6.1
- Task 6.2

Task 4.2: Cell-free implementation of LIS/ELAAs in wireless systems

Main objectives of the task

- Objective 1: Study how the properties of ELAAs can be exploited in cellular systems, where near field propagating conditions are found. Include the penalties associated with polarization mismatch.
- Objective 2: Study antenna correlation and coherence bandwidth properties depending on the distance and devise appropriate codebooks for channel reporting.
- Objective 3: Study multiuser scheduling techniques for the downlink.

Concrete activities to be performed and temporal planning

- Activity 1 (M9 – M10): Review of recent literature on ELAAs.
- Activity 2 (M10 – M17): Derive analytic and semi-analytic models for the channel properties in ELAAs. Elaborate codebooks for channel reporting based on AI (e.g. autoencoders) that exploit the channel properties, and propose methods to use them in a predictive way for pilot overhead reduction and/or channel error estimation reduction in FDD systems, where the lack of channel reciprocity requires feedback of the DL CSI from the receivers to the BS. The CSI available at the BS is gained from DL probing, where the training sequences are reused among the BS antennas, motivated by the scarcity of available pilot sequences in FDD systems. While partial CSI leads to severe degradation of standard multiuser precoding techniques, the recently proposed bilinear equalizer/precoder method for massive MIMO systems in combination with rate-splitting shows very promising results. Study tradeoffs.
- Activity 3 (M18 – M25): Exploit the large capacity of multiuser transmission in ELAAs by devising user grouping techniques based on algebraic or AI methods. Check its performance in realistic scenario configurations.

Expected results

- Publications: 2 papers in conferences and/or journals.
- TFGs / TFMs

Interactions with other tasks

The results will be useful for the following tasks:

- Task 4.3

Task 4.3: IRS versus active antennas and conventional relays

Main objectives of the task

- Objective 1: Devise methods to increase the spectral efficiency by artificially transforming the propagation channel properties using IRS.
- Objective 2: Define protocols for IRS channel acquisition.
- Objective 3: Exploit the use of IRS in receive spatial modulation techniques in mmWave or THz channels.

Concrete activities to be performed and temporal planning

- Activity 1 (M23 – M24): Review of recent literature on IRS usage, exploitation and misconceptions.
- Activity 2 (M25 – M36): Study the capacity enhancement in single user links where IRS devices are present. Include the situations of near-field/far-field and antenna polarization mismatch. Define channel acquisition techniques for IRS in selective and flat fading channels and evaluate the overhead associated with the use of pilots. Study techniques for pilot overhead reduction based on predictive channel estimation. Use of AI methods to further reduce pilot overhead with low penalty. Study the impact in capacity due to imperfect channel estimation.
- Activity 3 (M25 – M36): Use one or several IRS to enhance the rank of the MIMO channel between transmitter and receiver. Elucidate the most appropriate configurations (number of antennas, relative position of transmitter, receiver and IRS, etc), and exploit them to increase the spectral efficiency of receive spatial modulation techniques, using several transmit precoding techniques. Evaluate the performance loss associated with channel estimation errors at the transmitter side. Check its performance in realistic scenario configurations.

Expected results

- Publications: 2 papers in conferences and/or journals.
- TFGs / TFMs

Interactions with other tasks

The results will be useful for the following tasks:

- Task 5.1

Task 5.1: Spatial modulation

Main objectives of the task

- Objective 1: To develop new modulation techniques inspired by spatial modulation.
- Objective 2: To apply the previous techniques using RISs integrated at the transmitter.

Concrete activities to be performed and temporal planning

- Activity 1 (M9 - M15): Analysis of the state of the art on spatial modulation techniques and index modulation schemes.
- Activity 2 (M12 - M20): Application of the spatial modulation techniques for transmitters based on RISs. Combination of the previous schemes with frequency modulation.
- Activity 3 (M18 - M22): Extension of the previous schemes to multi-user systems and incorporation of channel estimation.
- Activity 4 (M22 - M26): Numerical evaluation of the proposed schemes.

Expected results

- Publications: 1 paper in a conference and/or journal.
- TFGs / TFMs

Interactions with other tasks

The results could be useful for the following tasks:

- Task 4.2.

Task 5.2: Wireless power transfer for efficient energy transmission and reuse in mMTC networks

Main objectives of the task

- Objective 1: The analysis of integrated wireless information and energy transmission schemes in combination with energy harvesting from the interference.
- Objective 2: The design transmission strategies that address the requirements of both human type communications and machine type communications: high data rates and large battery lifetimes, respectively.

Concrete activities to be performed and temporal planning

- Activity 1 (M6 - M12): For cellular networks where sensors coexist with conventional human terminals (UTs), and are served by multi-antenna BS, characterization of the statistics of the energy collected by the sensors and the UTs data rate.
- Activity 2 (M12 – M18): Based on the results from the previous activity, derivation of strategies that maximize the sum rate while ensuring a sufficient amount of energy.

Expected results

- Publications: 1 paper in a conference.
- TFGs / TFMs

Interactions with other tasks

The results could be useful for the following tasks:

- Task 5.3.

Task 5.3: Energy-efficient multiple access strategies in multiuser/MTC communications

Main objectives of the task

- Objective 1: To cover the growing range of QoS requirements for dense deployments of MTC devices.
- Objective 2: To control traffic congestion and avoid packet collisions.
- Objective 3: To reduce the energy consumption of devices and the network latency.

Concrete activities to be performed and temporal planning

- Activity 1 (M22 – M24): To review recent literature on deep learning applied to managing a massive number of MTC devices in a contention-based multiple access.
- Activity 2 (M25 – M30): To explore the use of the spatial domain provided by the availability of multiple antennas at the BS. Exploit hierarchical codebook-based beamforming to redistribute the overload under high terminal activity regime and reduce contention.
- Activity 3 (M31 – M36): To develop new DQL algorithms that use prediction of the number of active users and other network parameters to enhance the performance in terms of throughput, latency and energy consumption.

Expected results

- Publications: 2 papers in conferences and/or journals.
- TFGs / TFMs

Task 6.1: Multipath-assisted localization

Main objectives of the task

- Objective 1: Use of sparsity and resolvability in time and angle for 6-dimensional positioning.

Concrete activities to be performed and temporal planning

- Activity 1 (M3 – M6): Selection of mmWave channel simulator for realistic indoor and outdoor scenarios.
- Activity 2 (M6 - M12): Development of AOA, AOD and delays estimators for each LOS/NLOS path (multidimensional channel) based on tensor decomposition where dominant singular values are associated to dominant signal paths.
- Activity 3 (M6 - M12): Development of AOA, AOD and delays estimators for each LOS/NLOS path (multidimensional channel) based on compressed sensing method based on channel sparsity both in angular and time domain.
- Activity 4 (M13 - M19): Evaluation of the performance of the estimators of receiver and scatter points positions.
- Activity 5 (M20 - M24): Development of orientation estimation algorithms.

Expected results

- Publications: 1 paper in conferences and/or journals.
- TFGs / TFMs

Interactions with other tasks

The results could be useful for the following tasks:

- Task 3.1.

Task 6.2: Location-aided communication

Main objectives of the task

- Objective 1: Sensing propagation environment.
- Objective 2: Use of highly precise positioning in mobility management.

Concrete activities to be performed and temporal planning

- Activity 1 (M7 - M24): Phase shifter design with deep learning for optimize positioning accuracy in RIS aided mmWave where LOS is obstructed.
- Activity 2 (M7 - M12): Analyze how location can be used for communication purposes by enhancing efficiency and radio network management.
- Activity 3 (M13 - M24): Develop sensing techniques in spatial domain will enable to define radio environment maps with sensor density information.
- Activity 4 (M16 - M32): Propose tracking algorithms for predicting UT positioning by fusion of multiple hybrid sensors in order to improve radio resource management in mobility.

Expected results

- Publications: 1 paper in conferences and/or journals.
- TFGs / TFMs

Interactions with other tasks

The results could be useful for the following tasks:

- Task 5.3.

4. DESCRIPTION THE PLANNED ORGANIZATION

○ ***Meetings***

Although in the project proposal, bi-monthly meetings were foreseen, finally, and for the sake of usefulness of the meetings, this will be divided into 2 groups with a different organization:

- Adhoc frequent technical meetings (every month) will be organized among researchers working in the same task and also between researchers working in tasks that can cooperate.

- Plenary meetings with all the researchers will be organized every 6 months to share the global state of the project, the state of the publications, the identification of risks and potential research lines, as well as results of interest.

○ ***Newsletters***

A newsletter will be produced every year to publish it through the project webpage and send it to the interested companies.

○ ***Webpage***

The webpage of the project is the following one:

https://spcom.upc.edu/en/projects/radio-technologies-for-ubiquitous-communications-in-the-evolution-from-5g-to-6g