6-SENSES

6G communication and SENsing for determiniStic wirEless networkS (6-SENSES)

Document DP

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

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Abstract:

This document describes, at the beginning of the 6-SENSES 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: 6G, communication and sensing, deterministic wireless networks, time-sensitive networks, massive MIMO, AI/ML/RL, intelligent reflective surfaces, smart factory, intelligent transport networks, smart health

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References

[ETSI GR RIS 001] V1.1.1 (2023-04) Reconfigurable Intelligent Surfaces (RIS); Use Cases, Deployment Scenarios and Requirements

[3GPP TS 22.368 v17] 0.0 (2022-03) 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Service requirements for Machine-Type Communications (MTC); Stage 1

[3GPP TR 22.837] 3rd Generation Partnership Project; Technical Specification Group TSG SA; Feasibility Study on Integrated Sensing and Communication (Release 19)

List of abbreviations & symbols

AGV	Automated Guided Vehicles
AI	Artificial Intelligence
AOA	Angle Of Arrival
AOD	Angle Of Departure
BS	Base Station
MIMO	Multiple Input Multiple Output
mMIMO	Massive MIMO
mTRP	Multiple Transmission Reception Points
MTC	Machine Type Communications
NLOS	Non-Line of Sight
LOS	Line Of Sight
QoS	Quality of Service
RAT	Radio Access Technology
RIS	Reconfigurable Intelligent Surface

1. INTRODUCTION

The objective of this document is to describe at the beginning of the 6-SENSES project the following issues:

- Identify potential use cases and scenarios of interest for each technical task of the project.
- Identify the key performance indicators to be considered in each task.
- Provide a concrete description of the activities to be performed for each task. This includes:
  - Objectives.
  - Description of the activities and temporal planning.
  - Expected results.
  - Interactions with other tasks.
- Describe the planned organization of the project:
  - Meetings.
  - Newsletters.
  - Webpage.

2. SCENARIOS AND KEY PERFORMANCE INDICATORS

2.1. Scenarios and use cases

This subsection enumerates some scenarios and use cases of interest for each technical task.

Task 3.1: mMIMO and RIS strategies for high-data-rate homogeneous coverage

- Indoor scenarios, for which line-of-sight (LOS) transmission cannot be guaranteed in some areas, such as corridors, corners, and stairs [ETSI GR RIS 001].
- Outdoor scenarios, for which mobile terminals and UEs at the edge of the cell or in the shadow area may suffer serious propagation loss, including path loss and shadow fading caused by obstacles such as buildings or trees. The RIS may be mounted on a stationary or non-stationary structure, such as a train or a vehicle [ETSI GR RIS 001].

Task 3.2: Configurable slice-aware mTRP management techniques for ubiquitous connectivity and guaranteed QoS under mixed traffic.

- Slice networks for serving traffic with heterogeneous service requirements such as capacity-limited services, ultra-reliable low-latency services, and time-sensitive services.
- Integration of Time-Sensitive-Networks in 5G-6G systems to enable time-sensitive networking over the air.

Task 3.3: Radio access for massive connections in overloaded environments

- Monitoring the environment with a mass of sensors [3GPP TS 22.368 v17].
- Metering devices monitored and controlled by a centralized entity [3GPP TS 22.368 v17].

Task 4.1: High-accuracy positioning and wireless sensing

- Terminal location for anticipating network needs
- Public safety search and rescue [3GPP TR 22.837].
- Sensing the traffic flow and the crowd density in tourist spots [3GPP TR 22.837].

Task 4.2: Wireless sensing and communication coexistence

- Object and intruder detection for smart homes, on a highway, on railways, in factories, in predefined secure areas around critical infrastructure, etc. [3GPP TR 22.837].
- Collision avoidance and trajectory tracking of vehicles, AGVs, etc. [3GPP TR 22.837].
- Automotive maneuvering and navigation [3GPP TR 22.837].

Task 4.3: Full integration and co-design of wireless sensing and communication

- Same as in 4.2.

Task 5.1: Mobility-aware dynamic multi-connectivity

- Multi-cell dense urban environment.

Task 5.2: Edge computing service continuity

- Same as 5.2.

Task 6.1: Smart factory

- AGV communication, detection, and tracking in factories [3GPP TR 22.837].

Task 6.2: Intelligent transport networks

- Automotive manoeuvring and navigation [3GPP TR 22.837].

Task 6.3: Smart health

- Contactless health status detection [3GPP TR 22.837].
- Health and sports monitoring [3GPP TR 22.837].

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 project task.

Task 3.1: mMIMO and RIS strategies for high-data-rate homogeneous coverage

- Blockage probability
- MIMO channel rank
- SNIR
- Bit error rate
- Throughput

Task 3.2: Configurable slice-aware mTRP management techniques for ubiquitous connectivity and guaranteed QoS under mixed traffic

- Latency
- Reliability
- Spectral efficiency
- Energy consumption

Task 3.3: Radio access for massive connections in overloaded environments

- Throughput
- Latency
- Packet Loss Rate
- Error rate

Task 4.1: High-accuracy positioning and wireless sensing

- Sensing Range
- Localization error

Task 4.2: Wireless sensing and communication coexistence

- Sensing Range
- Localization error
- Angular accuracy
- Velocity error
- Detection rate and false alarm rate
- Spectral efficiency
- Bit error probability
- Pilot overhead

Task 4.3: Full integration and co-design of wireless sensing and communication

- Sensing Range.
- Localization error.
- Angular accuracy.
- Velocity error.
- Detection rate and false alarm rate.
- Spectral efficiency.
- Bit error probability.
- Pilot overheads.

Task 5.1: Mobility-aware dynamic multi-connectivity

- Radio link problems (RLP) rate.
- Handover failures (HOF) rate.
- Ping-pong (PP) event rate.
- Service interruption rate.
- Signalling overhead.

Task 5.2: Edge computing service continuity

- Same as 5.1, but also applied to computing services.

Task 6.1: Smart factory

- Energy consumption
- QoS communications measurements: latency, reliability, throughput, energy consumption.
- Position and velocity accuracy.
- Prediction accuracy for key outcomes such as collisions or intruders.

Task 6.2: Intelligent transport networks

- Position and velocity accuracy.
- Velocity accuracy.
- Prediction accuracy for key outcomes such as collisions or intruders.

Task 6.3: Smart health

- Accuracy of the physiological measurements through contactless methods.
- Prediction accuracy of acute events.

3. DESCRIPTION OF TECHNICAL TASKS AND PLANNED ACTIVITIES

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

Task 3.1: mMIMO and Reconfigurable Intelligent Surface (RIS) strategies for high-data-rate homogeneous coverage

Main objectives of the task

- Objective 1: Explore the benefits of near-field propagation in high-frequency RIS-assisted systems to improve performance and spatial diversity
- Objective 2: Develop and evaluate efficient receiver and precoding strategies to enhance coverage and throughput in multiuser mmWave scenarios with RIS

Concrete activities to be performed and temporal planning

- Activity 1 (M1 – M3): Identification of channel models accounting for near-field propagation with extremely large antenna arrays and RIS setups.
- Activity 2 (M4-M9): Evaluate detection strategies in near-field RIS scenarios to identify optimal receiver designs.
- Activity 3 (M4-M9): Design robust multiuser precoding strategies addressing limitations in LOS scenarios to ensure homogenous coverage for RIS-aided systems.
- Activity 4 (M10-M13): Optimize RIS phase configuration, considering perfect and imperfect channel estimation.

Interactions with other tasks

The results could be useful for the following tasks:

- Task 3.2.
- Task 3.3.
- Task 4.1

Task 3.2: Configurable slice-aware mTRP management techniques for ubiquitous connectivity and guaranteed QoS under mixed traffic.

Main objectives of the task

- Objective 1: Develop dynamic radio resource management strategies to support heterogeneous service requirements in network slicing scenarios.
- Objective 2: Improve efficiency and QoS compliance for time-sensitive and capacity-limited traffic through adaptive frame and resource allocation.

Concrete activities to be performed and temporal planning

- Activity 1 (M4 – M12): Design a convex optimization-based scheme for power and subchannel allocation with dynamic admission control across multiple service slices for
- Activity 2 (M13 – M21): Propose novel radio frame structures for improving time-sensitive and non-time-sensitive traffic integration in deterministic networks.
- Activity 3 (M13 – M21): Investigate reinforcement learning algorithms for dynamic resource allocation in wireless networks serving different types of traffic.

Interactions with other tasks

The results could be useful for the following tasks:

- Task 6.1.

Task 3.3: Radio access for massive connections

Main objectives of the task

- Objective 1: Investigate advanced access and transmission architectures for overloaded wireless environments.
- Objective 2: Develop intelligent multiuser detectors in dense and overloaded wireless environments.

Concrete activities to be performed and temporal planning

- Activity 1 (M7-M9): Explore and evaluate random access, multicast/broadcast, and cell-free architectures for scalable connectivity in machine-type communications.
- Activity 2 (M10-M15): Investigate Successive Interference Cancellation (SIC) approaches for non-orthogonal access in dense environments.
- Activity 3 (M16-M21): Investigate robust RIS optimization for performance optimization in the presence of channel estimation errors.

Task 4.1: High-accuracy positioning and wireless sensing

Main objectives of the task

- Objective 1: To design enhanced high-accuracy sensing techniques that exploit RIS-aided systems' near-field effects.
- Objective 2: Evaluate the impact on the performance of the number of the RIS.

Concrete activities to be performed and temporal planning

- Activity 1 (M1 – M3): Review recent positioning and wireless sensing literature.
- Activity 2 (M4 – M12): Investigate spectral power density estimators that take advantage of the fact that the wavefront curvature reflected by an extended RIS depends on both the angle and the distance of the source.
- Activity 3 (M4 – M12): Investigate high-accuracy positioning techniques in RIS-aided systems based on the Cramer-Rao minimization
- Activity 4 (M13-M21) Investigate high-accuracy positioning techniques in RIS-aided systems using machine learning techniques.

Interactions with other tasks

The results will be useful for the following tasks:

- Task 4.2

Task 4.2: Wireless sensing and communication coexistence

Main objectives of the task

- Objective 1: Study suitable waveforms for the coexistence of wireless sensing and communication services
- Objective 2: Design and evaluate radio resource allocation strategies for sensing and communication.

Concrete activities to be performed and temporal planning

- Activity 1 (M4 – M6): Review of recent literature on the most suitable waveforms for the coexistence of sensing and communication services.
- Activity 2 (M7 – M21): Development of methods for assigning resources to sensing and communications. These allocation strategies must adapt quickly to the varying conditions for communications (changes of traffic, QoS demands, number of users, etc.) and sensing (changes in the scenario, including changes of positions of targeted objects) while fulfilling quality and accuracy requirements.

Interactions with other tasks

The results will be useful for the following tasks:

- Task 4.3
- Task 6.2

Task 4.3: Full integration and co-design of wireless sensing and communication

Main objectives of the task

- Objective 1: Study suitable waveforms for the full integration of wireless sensing and communication services
- Objective 2: Evaluate the advantages/disadvantages of coexistence and full integration of sensing and communications.

Concrete activities to be performed and temporal planning

- Activity 1 (M7 – M9): Review the literature related to delay-Doppler multicarrier (DDMC) modulations that multiplex the information symbols in the delay-Doppler domain

- Activity 2 (M10 – M21): Re-visit the resource allocation techniques developed in task 4.2 in the case that the same symbols are employed for both sensing and communication and compare them.
- Activity 3 (M10 – M21): Evaluate the usefulness of introducing RIS-based schemes to send communication signals transmitted through extremely narrow spatial beams.

Interactions with other tasks

The results will be useful for the following tasks:
- Task 6.2

Task 5.1: Mobility-aware dynamic multi-connectivity

Main objectives of the task

- Objective 1: Review mobility scenarios for communication and positioning purposes and the most recent literature on handover protocols designed
- Objective 2: Improve existing protocols for reducing QoS outage communication/positioning services under mobility conditions

Concrete activities to be performed and temporal planning

- Activity 1 (M18 – M21): Review critical mobility scenarios for communication and positioning purposes and analyze the state-of-the-art protocols designed to keep the interruption time of services at a minimum.
- Activity 2 (M22 - M29): Study the potential of introducing prediction tools for improving current state-of-the-art of current protocols.
- Activity (M30-36): Evaluate the impact of RIS-assisted MIMO networks in reducing the outages of communication/positioning services.

Interactions with other tasks

The results could be useful for the following tasks:
- Task 5.2.
- Task 6.2

Task 5.2: Edge computing service continuity

Main objectives of the task

- Objective 1: Review mobility scenarios for communication, positioning, and computing resources.
- Objective 2: Develop proactive methods for mobility management of communication, positioning, and computing resources.

Concrete activities to be performed and temporal planning

- Activity 1 (M21 – M23): Review critical mobility scenarios for communication and positioning purposes and analyze the state-of-the-art protocols for reduced service disruption.
- Activity 2 (M24 – M36): Design an effective service migration strategy for optimally contemplating where, when, and how many MEC servers to launch, using mobility prediction estimates (as developed in T5.1) and backhaul status knowledge.

Task 6.1: Smart factory

Main objectives of the task

- Objective 1: Simulate a complex industrial scenario.
- Objective 2: Investigate how other techniques developed within the project can improve location accuracy and preserve QoS in industrial networks with slices for different types of traffic.

Concrete activities to be performed and temporal planning

- Activity 1 (M13 – M15): Conduct an in-depth review of 5G-based positioning techniques for Industry 4.0 and examine the potential of mmWave, massive MIMO, and RIS technologies for industrial scenarios.
- Activity 2 (M15 – M21): To set up a 3D simulator of an industrial scenario.
- Activity 3 (M22 – M36): Evaluate the slice-aware management techniques for guaranteed QoS under mixed traffic in the simulated industrial environment.
- Activity 4 (M22 – M36): Develop and validate mechanisms for improving positioning accuracy in challenging industrial environments where obstructions and multipath propagation are common.

Task 6.2: Intelligent transport networks

Main objectives of the task

- Objective 1: Identify technical scenarios where the precision of the position estimation of the vehicle governs the trade-off between security and mobility.
- Objective 2: Investigate how the techniques developed in other work packages can improve reliability and accuracy, as well as mobility efficiency in transport networks.

Concrete activities to be performed and temporal planning

- Activity 1 (M13 – M15): Conduct an in-depth review of 5G-based positioning techniques for Industry 4.0 and examine the potential of mmWave, massive MIMO, and RIS technologies for intelligent transport scenarios.
- Activity 2 (M15 – M21): To set up a simulator of a railway scenario.
- Activity 3 (M22 – M36): Evaluate the techniques developed in tasks 4.2 and 4.3 in the simulated scenario.

Task 6.3: Smart Health

Main objectives of the task

- Objective 1: Propose wireless sensing techniques for positioning, movement, and estimating health parameters.
- Objective 2: Develop AI based data processing techniques for event prediction and decision-making that will help to identify risk patterns and detect acute events.

Concrete activities to be performed and temporal planning

- Activity 1 (M13 – M18): Conduct a measurement campaign to build a database with relevant radar and physiological signals.
- Activity 2 (M19 – M36): Study how integrating wireless signal sensing and communication will provide high-accuracy localization, allowing the detection of movements and falls and/or the estimation of health parameters (e.g., breathing and heart rate).
- Activity 3 (M13 – M18): Develop deep learning models using electronic medical records to anticipate the care needs of patients with elevated risk.

4. DESCRIPTION OF THE PLANNED ORGANIZATION

Meetings

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

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

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

Newsletters
A newsletter will be produced annually and published on the project webpage, as well as sent to interested companies.

Webpage
The webpage of the project is the following:

https://spcom.upc.edu/en/projects/6-senses