DESIRE6G

Meeting extreme KPIs through Deep Programmability in 6G AI-Native Systems.

OVERVIEW

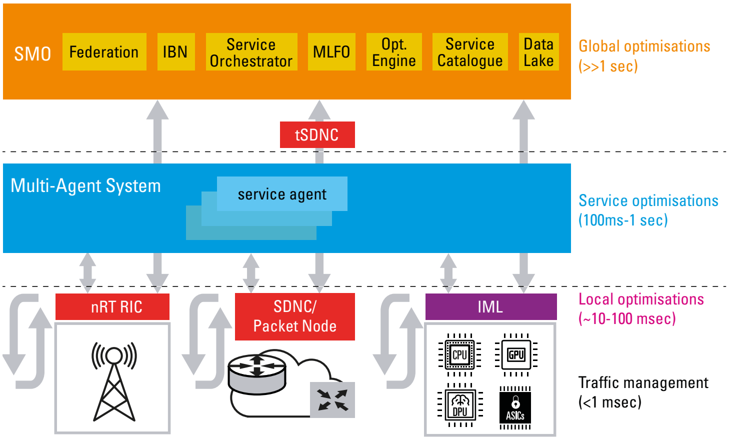
5G was set out to support various use case (UC) groups: enhanced Mobile Broadband (eMBB), massive Machine-Type Communications (mMTC), and Ultra-Reliable Low latency Communications (URLLC). While it laid the technical foundation for all three, eMBB emerged as the main commercial success. In DESIRE6G, we envision a 6G system that meets IMT-2030 requirements, without adding excessive complexity or overhead. By leveraging network programmability, we aim to support a wide range of UCs cost-effectively. Our research focuses on pushing the boundaries of a unified, flexible system for diverse UCs.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Programmability starts with a standard API where verticals can express service requirements in a simple, efficient way. The system's layers must then collaborate to meet these requirements using available resources. While this can be complex, defining clear responsibilities for each layer makes this feasible.

DESIRE6G employs several control loops at different timescales: i) real-time traffic management at packet level, ii) cloud-native user plane with local optimisation capabilities, iii) AI-driven, distributed service optimisation and iv) intelligent Service Management and Orchestration (SMO).

DESIRE6G multi-timescale control loops



INNOVATION

Aligned with the Open RAN principles, the SMO layer acts as a cross-domain management framework. It introduces intent-based service management, translating high-level business intents into actionable service templates. The SMO manages AI pipelines via the ML Function Orchestrator (MLFO) and handles non-real-time service lifecycle optimisation via the Optimisation Engine. Distributed ledger technology enables secure federation across administrative domains.

Operating across the RAN, core, and transport, SMO ensures cross-domain coordination via a microservices architecture enhancing modularity, scalability, and security. A Multi-Agent System (MAS) in the service optimisation layer collects telemetry and drives decisions to maintain service assurance. MAS employs AI, with distributed agents analysing service requirements, topology, and network domain properties to detect issues and propose reconfiguration solutions. To address vulnerabilities inherent in distributed systems, MAS integrates secure communication protocols and remote attestation mechanisms.

The programmable user plane features its own optimisation loops while the Infrastructure Management Layer (IML) abstracts physical resource management, optimising function deployment, scaling and network function aggregation/disaggregation. Flexible traffic management further enhances multi-service handling with intelligent packet colouring and dropping. Real-time programmable network telemetry ensures accurate data collection for informed decision-making.

USE CASES/ SCENARIOS

The proposed innovations are validated through experiments in laboratory environments, and larger field evaluations using the ARNO[1] testbed in Italy and the 5TONIC[2] testbed in Spain. DESIRE6G focuses on two key 6G UCs: Augmented Reality (AR) and Digital Twins (DT) in industrial settings.

The AR UC features a camera-equipped drone and an operator wearing an AR headset for real-time inspection. Edge processing enables object detection and data augmentation, allowing operators to dynamically control the drone's movements and focus. It showcases the network's ability to deliver high-bandwidth, and low latency communication for real-time AR applications, ensuring a smooth user experience while mitigating issues like cyber sickness.

The DT UC involves a robotic dog transmitting sensor data to update its virtual model while receiving navigation commands, requiring ultra-low latency and high reliability. Most of the End-to-End (E2E) latency budget is used for processing sensor data, leaving milliseconds for communication. DESIRE6G's in-network acceleration, multi-level optimisation, and E2E data plane programmability ensure Key Performance Indicators (KPI) compliance. Both UCs benefit from optimised resource and energy management.

RESULTS

At this stage, key results include architectural and design documents along with early demos, presented at events and disseminated through conferences, journals, and talks[3].

The AR demo uses a YOLO-based object detection framework on NVIDIA Jetson ORIN, paired with a video camera for data capture and a VR headset for visualisation. It runs in a multi-tech setup, including the RAN and a programmable packet-optical edge network. Near real-time service (re)optimisation via the MAS, consistently maintains latency below 25 ms[4] using in-band telemetry from the programmable data plane.

For the DT UC, DESIRE6G ensures reliable, low latency communication between the robot and its digital twin at the edge. Initial results[4] highlight the platform's ability to orchestrate and deploy programmable network functions and application workloads while effectively managing traffic during congestion scenarios. Traffic management policies dynamically prioritise critical robot control flows, minimising latency spikes. The system outperforms state-of-the-art solutions by maintaining latency within acceptable limits even under heavy network loads, ensuring compliance with key operational KPIs.

1.http://arnotestbed.santannapisa.it

2. https://www.5tonic.org

3.https://zenodo.org/communities/desire6g/records

4.D5.2 Report on Evaluation Results and Initial Proof-of-Concept Demonstrations. Project Deliverable, 2025.

Deep Programmability and Secure Distributed Intelligence for Real-Time E2E 6G Networks

DESIRE6G

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