December 2023

DESIRE6G: One Year of Pioneering Innovation in 6G Networks

It has been a fruitful year for DESIRE6G, funded under the Horizon Europe - Smart Networks and Services JU initiative. This three-year journey, which began in January 2023, has set out to shape the system architecture for future mobile networks, laying the foundation for what we anticipate in the 6G era.

A Vision for 6G: Meeting Extreme Performance Demands

While 5G networks are being rolled out worldwide, DESIRE6G has its sights set firmly on the future. The world is already envisioning a more advanced network, a sixth-generation or 6G, expected to debut in the early 2030s. This cutting-edge network aims to support a range of new applications with extreme performance requirements, from zero power consumption to extreme low latency and ultra-high reliability. But here is the challenge: 6G must be simpler and more autonomous than its predecessor, 5G.

Building the Foundations for 6G: What DESIRE6G will Deliver

DESIRE6G aims to develop a Zero-Touch Control Platform, integrating native AI, to support eXtreme URLLC (ultra-reliable low-latency communication) applications and a programmable data plane. Key elements include:

- **E2E Data Plane Programmability:** A fully programmable RAN, transport, and core forwarding plane allows flexible, customized packet processing operations and protocol support. Multi-tenancy extends deep slicing to user planes, enabling slice-specific software stacks and hardware acceleration.
- **Multi-agent-based Network Control:** A hybrid centralized management and orchestration architecture, driven by Multi-Agent Systems (MAS), pushes automated decisions to the infrastructure, supporting fast, coordinated decision-making across network domains.
- **Serverless Computing and Function as a Service:** A pure cloud-native approach with dynamic migration of functions and state persistency ensures flexibility and scalability.

- **Multi-function Hardware Acceleration:** A generic hardware acceleration layer unifies application and network functions on heterogeneous systems, optimizing resource utilization.
- **Distributed Ledger Technology:** Leveraging DLT ensures dynamic federation and security, addressing challenges in dynamic environments.
- **Pervasive Monitoring:** A monitoring system with end-to-end observability and sub-millisecond granularity feeds AI algorithms for predictive maintenance and performance optimization.
- **Edge Intelligence:** Supporting edge intelligence at the application level through distributed, energy-efficient model training and inference algorithms.

Technical Work Packages: On Year In

WP2: Requirements and Architecture Design

WP2 is the foundation upon which the DESIRE6G architecture is built. This work package defines use cases, requirements, and sets the stage for our innovative architecture.

- Key achievements:

The first deliverable of WP2, D2.1 "Definition of Use Cases, Service Requirements and KPIs/KVIs", has been released end of December 2023. This deliverable has conducted as a starting point a review of the identified 6G use cases in different industry initiatives such as NGMN, the Next G Alliance and ITU-T. Based on that survey a set of reference use cases to be used for deriving the DESIRE6G architecture have been selected and defined, including two main demo use cases (an AR/VR use case for survey operations and an E2E Digital Twin system for robotics applications). A set of KPIs have been defined for those use cases which will be used for driving the design architecture of the DESIRE6G system that is already ongoing. A first design of the architecture has already been produced and presented in the 6G-PDN Workshop at ACM MOBIHOC 2023.

- Challenges & Solutions:

A challenge when dealing with innovative use cases for the definition of a new mobile communication system is reaching a consensus on the most representative use cases and KPIs to be met by the new system design. 6G is still at an early stage of definition in the different industry initiatives driving its development. As such there is not a clear consensus on the differential requirements to be met by the new system and the distinction between what could be considered an advanced 5G system and a future 6G design is still blurred. The project is confident anyway that the selected use cases will showcase the

technical innovations of the DESIRE6G project and the role that these can play in the design of 6G, once its distinctive requirements are finally agreed across the telecommunications industry and detailed.

- Upcoming goals:

As an important upcoming milestone, the project will release the functional architecture definition in mid 2024. Also during 2024, and as the architecture matures, the relevant techno-economic studies to be conducted in task 2.3 for the support of the required services by the DESIRE6G system will be defined.

WP3: Intelligent and Secure Management, Orchestration, and Control

WP3 dives into the development of our orchestration layer, multi-agent platform, and essential security components.

- **Key achievements:** The initial report of DESIRE6G's intelligent and secure management orchestration and control platform (D3.1) was released end of November 2023. In this deliverable, we capture the most important aspects of our work regarding the high-level orchestration layer of the DESIRE6G platform, along with the MAS and essential security components. Specifically, we decouple the fine-grained service orchestration placement from the SMO, bringing this functionality to the DESIRE6G sites (closer to where the service is being instantiated). This is achieved through the delegation of traditional SMO functionality to a thin layer on top of the VIM, leaving the SMO out of the critical path, handling more high-level orchestration decisions.

  We introduce efficient federation functionality to the SMO, leveraging DLT-based approaches.

  We optimize Intent-based service management through an efficient translation mechanism.

  We introduce a secure Multi-Agent System (MAS) to minimize response time. Control algorithms are executed as close as possible to the data sources, significantly reducing control loop latencies for service adaptation.

  We enable the use of AI/ML techniques, to address demanding 6G requirements. We explore how the edge resources are effectively used and we employ ML-based approaches to address problems on orchestration and lifecycle management of network services.

- **Challenges and solutions:** The integration of individual components that collectively optimize an end-to-end network service presents a unique challenge, both in terms of orchestrating the needed functionality, as well as in terms of optimizing the component coordination and input/output data. To this end, the SMO architecture provisions an efficient data exchange mechanism, providing visibility of only the required data to each individual component. Moving past bloated and

complicated orchestration software stacks, we introduce a highly efficient micro-service-based architecture that manages the instantiation and co-ordination of services across the D6G computing continuum..

- **Upcoming goals:** The first software release, including the basic implementation of the SMO and the API interfaces with the rest of the DESIRE6G components will be available at the end of March 2024 as part of MS3.2. Aspects related to the integration of the telemetry infrastructure will explored and clarified. We are targeting to have presentations regarding the D6G SMO architecture in relevant conferences.

WP4: Unified Programmable Data Plane Layer

WP4 provides the programmable data plane components essential to the DESIRE6G architecture.

- **Key achievements:** Our first deliverable, D4.1, describes the proposed packet processing and forwarding platform of DESIRE6G, including the pervasive monitoring architecture to be adopted for infrastructure and service monitoring. The document describes the main workflows for network service deployment and runtime operation/optimization.

  The initial design of the Infrastructure Management Layer (IML) shows how it acts a local NFVO and VIM that manages both traditional computational resources, softwarized network function and hardware-accelerated data plane resources (ASICs, DPUs, smartNICs, FPGAs), in a single DESIRE6G site.

  We identified the main infrastructure network functions that will ensure the deployment of network services implemented across multiple DESIRE6G sites in an end-to-end fashion. Together with the business logic related data plane functions, we identified 11 distinct network functions that are suitable candidates for hardware acceleration. These specific applications are mainly geared towards leveraging Intel Tofino switches for enhanced performance. Our focus encompasses a broad range of applications, such as the development of solutions for efficiently offloading high-traffic network segments, implementing hardware acceleration in data plane operations, and establishing sophisticated telemetry functionalities tailored for the MAS framework. This initiative marks a significant step in optimizing network efficiency and throughput, potentially revolutionizing how network traffic is managed and processed.

  We have presented the SOL framework, an innovative system designed to augment neural network workloads with maximum efficiency and minimal computational overhead. This ground-breaking framework is poised to significantly streamline the optimization and compilation processes for

diverse neural network models within the DESIRE6G architecture. Its implementation is expected to offer substantial improvements in processing speed and efficiency. In the execution phase, the IML will be the primary component responsible for running these neural network models, ensuring that the application performance is optimized in real-time. This approach represents a major advancement in the field of application acceleration, offering new possibilities in the realm of network management and data processing within the DESIRE6G framework.

- **Challenges and solutions:** IML will manage the local resources of a DESIRE6G site including hardware accelerated data plane resources like an Intel Tofino ASIC. These resources were not designed for multitenant usage. In DESIRE6G, IML adds multitenancy support for P4 programmable data planes by aggregating multiple P4 programs. We started the development of an access control proxy to isolate the access to different control plane entities to data plane resources.

  To ensure strict latency or throughput KPIs, runtime load optimization and the hybrid usage of CPU-based and hardware accelerated data plane network function instances are required. We work on methods that do the offloading with state migration seamlessly, similarly to the cloud-native approach in the world of microservices.

  Ensuring the desired throughput share and latency requirements among a large number of users using various network services (slices) needs a scalable and lightweight hierarchical quality of service framework - including route selection and rerouting, and traffic management. Traffic management needs to be programmable and flexible, so that it can ensure performance isolation between large number of slices and users in the data plane. This method also needs to be reconfigured in run-time according to the demands. In DESIRE6G, we work on a programmable traffic management solution that can ensure the traffic isolation at different levels.

  The main innovations on the service monitoring is the adoption of P4-INT, which enables the passive monitoring of the flow with the possibility to enhance the metadata transmitted. The main challenge here is reducing the potential traffic overhead. For this, a number of P4-INT solutions have been identified and designed.
- **Upcoming goals:** The first software releases, including IML and the main network functions needed for the operation, will be released at the end of March 2024 as part of MS4.2. Aspects related to the integration of pervasive monitoring will be clarified. We are targeting to have booths and presentations to EuCNC24 and other relevant conferences.

WP5: Integration, Validation, and Demonstration

WP5 is where we validate use cases, test project technologies, and showcase their capabilities.

- **Key achievements:** The work package started in July 2023 with a comprehensive survey of all the experimental facilities provided within the project. Conceptually, the experimental infrastructure is conceived as a decentralized interconnected sandbox, where it is possible to deploy and test preliminary components and their inter-working starting from early releases. Local testbeds available by different partners are joined together to form a federated testbed with enhanced capabilities in terms of software and/or hardware equipment. They will converge with future integration in two main integrated testbeds, the 5TONIC testbed and the ARNO testbed, that will deploy the two main use cases for final demos: the Digital Twin use case and the Drone Augmented Reality use case. The WP has also gone through the deployment of additional use cases mapping them to proof-concept with a KPI analysis and demo execution plans. Finally, we have identified and collected the most important datasets for the components requiring AI engines. All this work will be consolidated in our deliverable 5.1 that will be released in January 2024.
- **Challenges and solutions:** The main challenges are related to the experimental deployments used for the test of each component, the measurement collection and the feedback to the technical WPs to realize an effective continuous integration. DESIRE6G has joined the SNS Working Group on Testing Measurement and Validation (TMV), aiming at aligning to the best practices of validation methods, while provide definitions and experimental execution workflows of the specific use cases and scenarios covered by the project, with special focus on data plane programmability and real time AI-assisted joint re-optimization of radio, network and IT segments.
- **Upcoming goals:** The WP is coordinating a plan for the second year related to preliminary demonstration of the DESIRE6G solution, aiming at showing key component functionalities beyond the state of the art. We are targeting to have booths and experimental demonstrations oat OFC24, EuCNC24 and other relevant conferences.

Deliverables and Publications: Driving 6G Knowledge Forward

So far, DESIRE6G has already contributed to the progress of 6G research by disseminating its first results in different ways:

- 6 Project Deliverables, 3 of which are of technical nature (D3.1: Initial report on the intelligent and secure management, orchestration, and control; D4.1: Initial report on the DESIRE6G unified programmable data plane layer; and D2.1: Definition of Use Cases, Service Requirements and KPIs/KVIs).

- 17 publications (accepted or published/presented) in Peer-Reviewed Journals or Conferences
- Participation in conferences: EuCNC, ICTON, ONDM, MobiHoc, NetSoft.
- Organization of 2 workshops: "6G-PDN" (collocated with Mobihoc 2023), and "Future deterministic programmable networks for 6G" (EuCNC 2023).
- Lead organization roles in IEEE NetSoft 2023.
- Contributions to the 6G SNS, including editing the ongoing white paper on 6G Sustainability of the Vision WG.
- 2 demos showcasing early prototypes accepted in OFC 2024.
- 4 contributions to standards (IETF, O-RAN and 3GPP), including two accepted ones.

DESIRE6G has actively worked to enhance awareness of the project's objectives and broaden the reach of its research within the general public:

- 2 press releases and 3 pieces of news.
- 1 contribution to the Annual 6G SNS Journal.
- Participation in events addressing the general public, such a public science fair for children.
- 4 project presentations as part of SNS JU community and Steering Board.

All dissemination and communication materials are available at: https://desire6g.eu/dissemination

What Lies Ahead: Building the 6G Future

Over the next two years, DESIRE6G will continue its journey to shape the future of mobile communication. The project's ultimate goal is to reach a Technology Readiness Level (TRL) of 3 to 4, showcasing tangible proofs of concept for the potential of 6G networks through two representative 6G use cases: virtual / extended reality and digital twin industrial applications. These real-world demonstrations will provide tangible evidence of the potential our proposed architecture to enable next generation smart networks.

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