A Holistic, Innovative Framework for the Design, Development and Orchestration of 5G-ready Applications and Network Services over Sliced Programmable Infrastructure

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Simply put, **MATILDA bridges the gap** between the **digital systems** that enable enhanced **cloud-native services** and the **networking layer** that forms the foundation for providing **networking services** to the different cloud-native applications. MATILDA does so by providing the tool set needed to advance and speed up the **evolution of the cloud paradigm** into the **5G ecosystem**. This set of tools that is being implemented within MATILDA will significantly contribute to bridge the gap between the **5G vertical applications** and the underlying network services, which would normally run on different domains. To do so, MATILDA adopts **a holistic approach** for tackling the **overall lifecycle** of **application's design**, **development**, **deployment** and **orchestration** in a **5G environment**.

MATILDA, now in the second year of operation, is developing its first version of **5G vertical application orchestrator** (VAO). The VAO will orchestrate **5G vertical applications** (5G vApps) on top of **application-aware** network slices powered by the **Network and Computing Slice Development Platform** (NCSDP) that will host the necessary Virtual Network Functions (VNFs). The MATILDA VAO and integration platform follows the **service-mesh-oriented** approach. The NCSDP includes an OSS/BSS system, an NFV Orchestrator (NFVO) and a resource manager handling the set of deployed Wide Area and Virtual Infrastructure Managers (WIMs and VIMs). The design and implementation are based on a service and functional separation concept that reflects the domains of the different interacting key building blocks of the 5G ecosystem, as shown in Fig. 1 below.

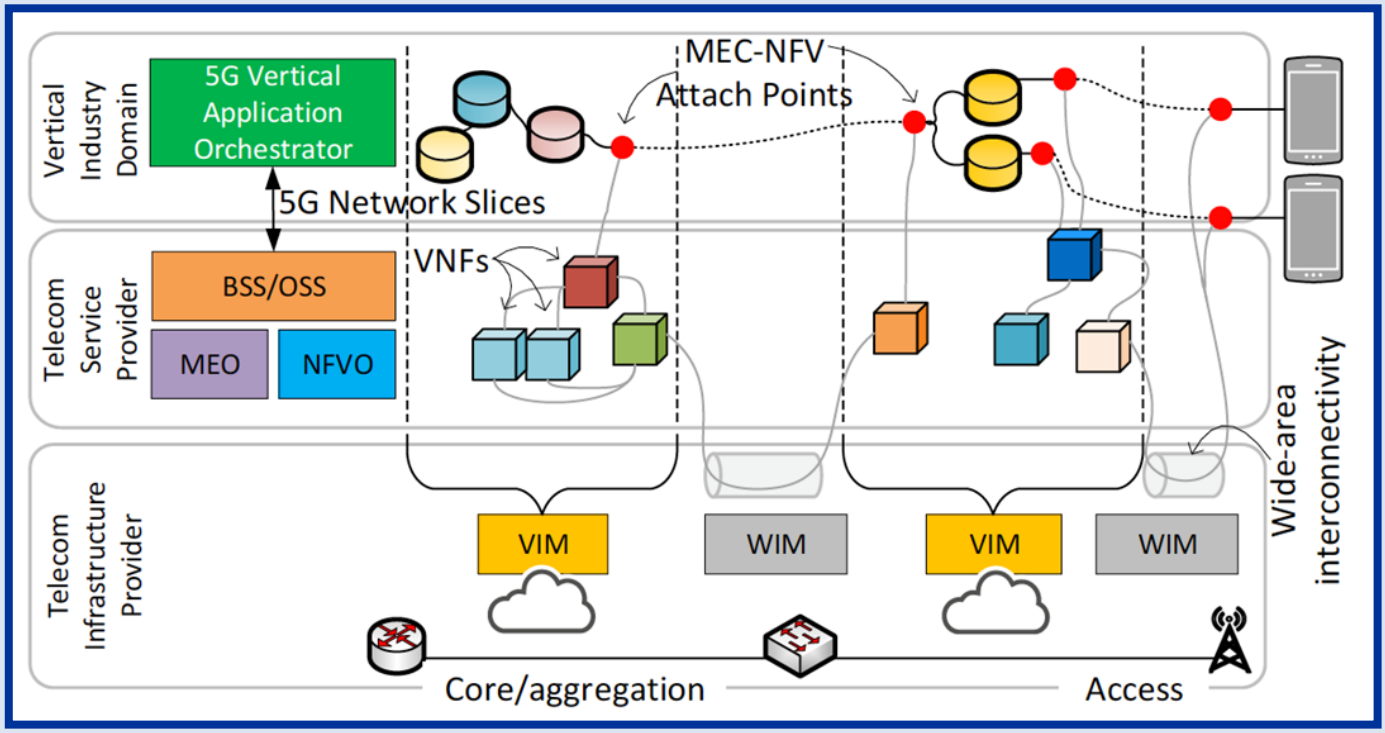

Fig. 1. MATILDA VAO and OSS/BSS building blocks and their interaction.

By utilizing the above-shown deployment architecture, the 5G vApps are orchestrated following a **separation of concerns paradigm**, whereby the **tenant spaces** of the each vApp and the **NFV/Mobile Edge services** are kept in their respective datacenters, so that each orchestrator has its own isolated resources, quotas, external networks, etc., as presented in Fig. 2.

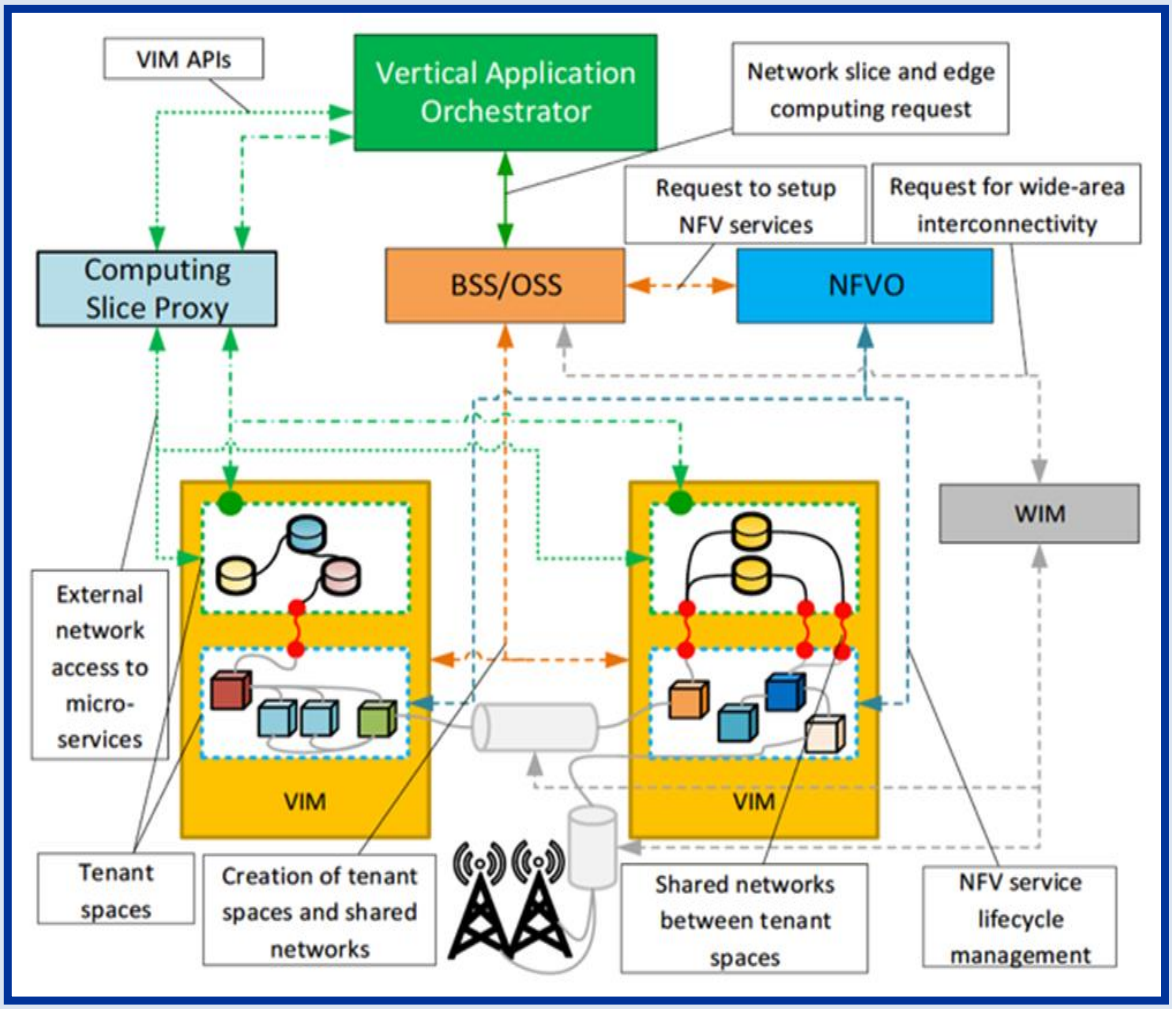

Fig. 2. Separation of management functionalities.

To realize the MATILDA VAO, the following components have been designed and presently under their respective development phases:

- the **deployment and execution manager** that supports the production of optimal deployment plans, as well as the management of the overall execution of the application;
- a set of **data monitoring mechanisms** which collect feeds from network and application-level metrics;
- a **data fusion, real-time profiling and analytics toolkit**, which produces advanced insights through machine learning mechanisms and provides real-time profiling of the deployed components, application graphs and VNFs;
- **service discovery mechanisms** for supporting registration and consumption of application-oriented services following a service-mesh-approach;
- a **context awareness engine** that provides inference over the acquired data and support of runtime policies' enforcement and application;
- **tools supporting interaction** among the vertical application orchestrator and the 5G programmable infrastructure management mechanisms.

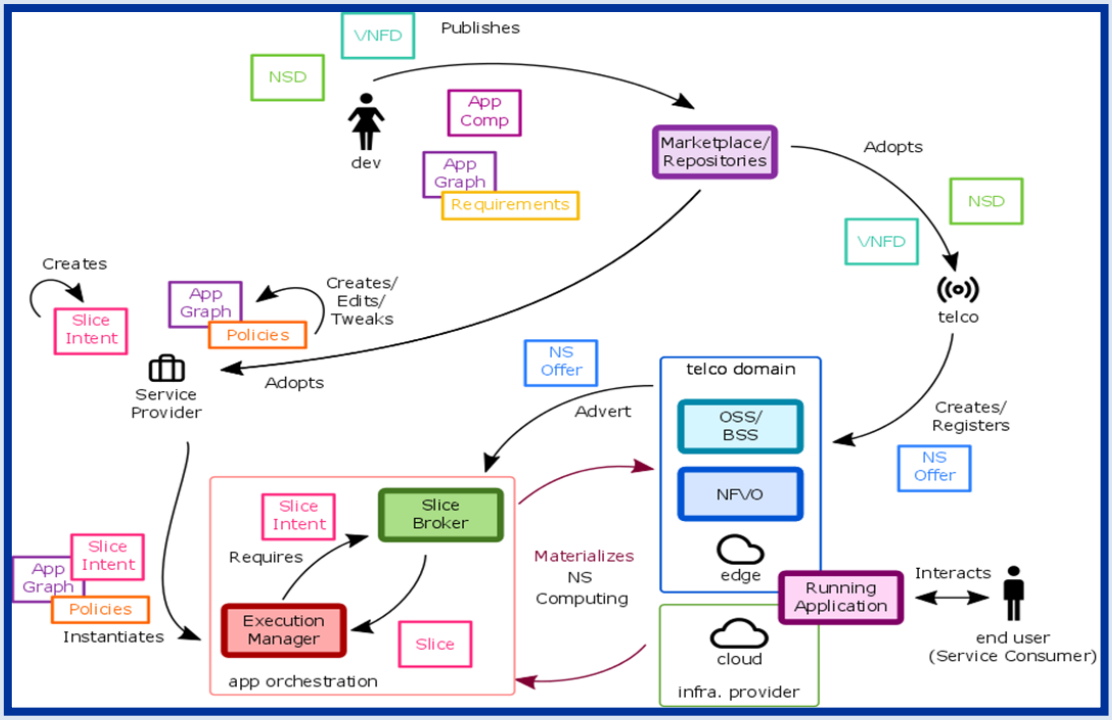

Fig. 3. Stakeholders' interaction workflow.

The diagram in Fig. 3 shows the **workflow of interactions** among the different stakeholders for the **orchestration and lifecycle management of a 5G application** created using the MATILDA framework and its metamodels. **MATILDA also encourages new business and wide collaboration**, by providing a Marketplace, where not only the created applications and components can be published, but also VNFs and Network Services (NSs).

Service Providers are able to adopt the developed 5G-ready applications (published to the Marketplace or created internally) and specify policies and configuration options for their optimal deployment and operation over the programmable infrastructure. Based on the provided application descriptor, service providers are able to design operational policies and formulate a slice intent. These operational policies describe how the application components should adapt their execution mode in runtime. On the other hand, the slice intent includes a set of constraints that have to be fulfilled during the placement of the application and a set of envisaged network functionalities that have to be provided. This information is used by the VAO to request the creation of an appropriate application-aware network slice from the Telecommunication Infrastructure Provider via the OSS/BSS.

The produced materialized slice will then reflect the agreed set of supported requirements needed to orchestrate both the underlying network services that will power the 5G vApp from the Telco domain and the application components that will be instantiated on the Cloud Infrastructure Provider environment. The instantiation of the materialized slice will give birth to a running 5G vertical application which end users will interact with in consuming its services.

MATILDA has identified and defined five different demonstrators, which are mapped to five corresponding vertical applications. These vertical applications shall be demonstrated on top the MATILDA's architectural layers and functional components. These identified demonstrators have a set of networking and operational KPIs, which is presented below.

- **High Resolution Media on Demand Vertical with Smart Retail Venues' Integration**: combining the functionalities of two systems, to provide 5G Personal Assistance in Crowded Events (5GPACE). The new framework can offer end-users Immersive Media Services combined with Machine Learning-based personal retail recommendations.
  - ***Network KPIs***: Device Density (~32 per small cell, ~50 per WiFi Hot Spot), Mobility (static users/low (0÷3 m/s)), Availability & Reliability (>99%), User Data Rate (~10 Mbps/user, depending on quality), End-to-end Latency (Max 1 s), Access Interoperability (must be available), Edge Computing (must be available), Storage at the Edge (must be available), Computing Acceleration at the Edge (must be available), Network Slicing Capability (must be available).
  - ***Operational KPIs***: 5GPACE App Deployment Time (~90 min), 5GPACE App On-Boarding Time (~15 min), Resource Usage Monitoring (must be available), 5GPACE App Component Scalability (must be available), Scaling Time (~20 s), Availability & Reliability (>99%), 5GPACE App Repository (must be available), Locality Awareness (must be available), Hardware Video Acceleration Management (must be available), Multi-site Management (must be available).

- **Testing 4.0 - Distributed System Testing**: based on FastWAN, an experimental communication technology that was developed as a solution for the enablement of geographically separated real-time industrial test benches.
  - ***Network KPIs***: Flexible Bandwidth Allocation (up to 10 Mbps/node (FastWAN Unit)), Low Delay/Latency (inside Germany – ~50 ms in-node latency; inside Europe – ~100 ms in-node latency; Worldwide – ~200 ms in-node latency), Interoperability with Various Access Networks (WLAN, LTE, Ethernet).
  - ***Operational KPIs***: High Availability (99.99% of operational time), Resource Usage Monitoring (must be available), Component Scalability (must be available), Deployment Time (~90 min), On-Boarding Time (~15 min), Locality Awareness (must be available), Multi-Site Management (must be available).

- **5G Emergency Infrastructure with SLA Enforcement (5GPPRD)**: a 5G system for Public Protection and Disaster Relief (PPDR). It extends the capabilities of a real time intervention monitoring and critical infrastructure protection product suite (iMON), combined with a suite for performance monitoring engines and advanced Operation, Administration and Management (OAM) functionalities to support SLAs (qMON).
  - ***Network KPIs***: Availability & Reliability (>99.999%), Network Slicing Capability (must be available), End-to-end Latency for Interactive Applications (<20 ms), End-to-end Latency for Mission-Critical Applications (<1 ms), Bandwidth (~20 Mbps/user), Jitter (<1 ms), Packet Loss (<0.01%).
  - ***Operational KPIs***: iMON Dashboard Components On-Boarding Time (~15 min), iMON Dashboard Component Deployment Time (~2 min), iMON Dashboard Application Graph Deployment Time (~5 min), Resource Usage Monitoring (must be available), iMON Dashboard Component Scalability (must be available), Scaling Time (~30 s), Availability & Reliability (>99.99%).

- **Industry 4.0 Smart Factory – Inter and Intra-Enterprise Integration**: focusing on a logistic application, which offers customers the possibility to track, change and prioritize their orders.
  - ***Network KPIs***: Device Density (~100 per LAN/WiFi Hot Spot), Bandwidth (up to ~10 Mbps/user, depending on quality), Availability & Reliability (WLAN, LTE, Ethernet), Delay/Latency (distance calculation scenario: the system is expecting a response after 100 ms; pattern matching scenario: the system is expecting a response after 250 ms), Access Interoperability (must be available), Security & Privacy (must be available).
  - ***Operational KPIs***: Deployment Time (~90 min), Availability & Reliability (>99%), Resource Usage Monitoring (must be available), Component Scalability (must be available), Locality Awareness (must be available), Multi-Site Management (must be available).

- **Smart City Intelligent Lighting System**: deployed in Alba Iulia, a small- to middle-size city in Romania with about 70,000 inhabitants, in order to provide an easy replicable solution with fast time to market, automated maintenance and a modular approach enabled by 5G application graphs that will assure better monetization of the intelligent city lighting solution.
  - ***Network KPIs***: Availability (>99.99%), Total Slice Bandwidth (~100 Mbps), End-to-End Latency (<300 ms), Jitter (~100 ms), Packet Loss (<0.1%).
  - ***Operational KPIs***: Device Status (100 Smart Light sensors), Service Availability (>99.99%), Device Bandwidth Capacity (~0.1 Mbps).

These above-described demonstrators shall be mapped onto different testbeds that are built the facilities of a selected number of the MATILDA consortium members.

The **five demonstrators** will be mapped over **three different testbeds**:

I. The **University of Bristol's testbed in Bristol, UK**: the facilities of the University of Bristol consist of an extensive environment of LTE radio, Wi-Fi and mmWave devices integrated and interconnected by fibre backhaul, and provides OpenStack on High Performance Computing nodes running within its premises.

II. The **CNIT-S2N (Smart and Secure Networks National Lab) testbed in Genoa, Italy**: the facilities of the CNIT-S2N lab are based on a Cloud infrastructure, which is able to control computing resources at the bare-metal level and to autonomously instantiate virtual infrastructure managers or software components in automated fashion. It also features a software defined networking-enabled environment for offering connectivity among computing and networking components, radio devices and user equipment. Similar testbeds are also being deployed in the respective facilities of Ubitech and Cosmote in Greece.

III. The **Orange Romania Smart City testbed in Alba Iulia, Romania**: the Orange Romania testbed offers a unique integration of LTE/5G Lighting Sensors, radio access and VNFs hosted in the Orange Regional Datacentre, along with a Cloud middleware IoT platform.

MATILDA has been thriving pretty progressively. Expected contributions from the different consortium members are gluing well towards a successful completion of the project.

A number of deliverables have been produced, which are listed along with those in the final stages of realization, to be released before the second technical review meeting that will take place in Ljubljana, Slovenia, in September 2019:

1. D1.1 – MATILDA Framework Reference Architecture
   Nature: Report, Dissemination Level: Public, Status: Approved
2. D1.2 – Chainable Application Components & 5G-ready Application Graph Metamodel
   Nature: Other, Dissemination Level: Public, Status: Approved
3. D1.3 – VNF/PNF & VNF Forwarding Graph Metamodel
   Nature: Other, Dissemination Level: Public, Status: Approved
4. D1.4 – Network-aware Application Graph Metamodel
   Nature: Other, Dissemination Level: Public, Status: Approved
5. D1.5 – Deployment and Runtime Policy Metamodel
   Nature: Other, Dissemination Level: Public, Status: Approved
6. D1.6 – Supported Verticals, Use Cases and Acceptance Criteria
   Nature: Report, Dissemination Level: Public, Status: Revision submitted (revision requested by reviewers)
7. D2.1 – 5G-Ready Applications and Network Services Development Environment and Marketplace – First Release
   Nature: Other, Dissemination Level: Confidential, Status: Approved
8. D2.2 – 5G-Ready Applications and Network Services Development Environment and Marketplace
   Nature: Other, Dissemination Level: Public, Status: Pending
9. D3.1 – Intelligent Orchestration Mechanisms – First Release
   Nature: Other, Dissemination Level: Confidential, Status: Approved
10. D3.2 – Intelligent Orchestration Mechanisms
    Nature: Other, Dissemination Level: Public, Status: Pending
11. D4.1 – Network and Computing Slice – First Release
    Nature: Other, Dissemination Level: Confidential, Status: Approved
12. D4.2 – Network and Computing Slice
    Nature: Other, Dissemination Level: Public, Status: Pending
13. D5.1 – Technical Integration Points and Testing Plan
    Nature: Report, Dissemination Level: Confidential, Status: Approved
14. D5.2 – MATILDA Integrated Framework – First Release
    Nature: Other, Dissemination Level: Confidential, Status: Submitted
15. D5.3 – MATILDA Integrated Framework
    Nature: Other, Dissemination Level: Confidential, Status: Pending
16. D6.1 – Evaluation Framework and Demonstrators Planning
    Nature: Report, Dissemination Level: Public, Status: Approved
17. D6.2 – Emergency Infrastructure with SLA Enforcement Implementation Report – First demonstration phase
    Nature: Demonstrator, Dissemination Level: Confidential, Status: Pending

18. D6.3 – High Resolution Media on Demand Implementation Report – First demonstration phase
    Nature: Demonstrator, Dissemination Level: Confidential, Status: Pending
19. D6.4 – Smart City Intelligent Lighting System Implementation Report – First demonstration phase
    Nature: Demonstrator, Dissemination Level: Confidential, Status: Pending
20. D6.5 – Industry 4.0 Smart Factory Implementation Report – First demonstration phase
    Nature: Demonstrator, Dissemination Level: Confidential, Status: Pending
21. D6.6 – Automobile Electrical Systems Remote Control Implementation Report – First demonstration phase
    Nature: Demonstrator, Dissemination Level: Confidential, Status: Pending
22. D6.7 – Validation Results, Performance Evaluation and Adoption Guidelines – First demonstration and evaluation phase
    Nature: Report, Dissemination Level: Public, Status: Pending
23. D7.1 – Communication Roadmap
    Nature: Report, Dissemination Level: Confidential, Status: Approved
24. D7.2 – 5G-PPP Interaction, Dissemination, Clustering & Standardisation Activities Report – Halfway
    Nature: Report, Dissemination Level: Public, Status: Approved
25. D7.3 – Communication Activities Report – Halfway
    Nature: Report, Dissemination Level: Public, Status: Approved
26. D7.4 – Market Analysis, Business Plan, Sustainability Model & Innovation Management
    Nature: Report, Dissemination Level: Confidential, Status: Approved
27. D7.8 – Market Analysis, Business Plan, Sustainability Model & Innovation Management - Final
    Nature: Report, Dissemination Level: Confidential, Status: Pending (early draft version requested by reviewers)
28. D7.9 – Data Management Plan
    Nature: ORDP - Open Research Data Pilot, Dissemination Level: Confidential, Status: Approved
29. D8.1 – Project Management Handbook
    Nature: Report, Dissemination Level: Confidential, Status: Approved
30. D9.1 – POPD-Requirement No.1
    Nature: Ethics, Dissemination Level: Confidential, Status: Approved

While most of the deliverables have been already accepted by the European Commission (EC) during the previous reviews, some have been not yet evaluated by the Project Reviewers and are thus still pending approval. However, **the set of deliverables** that have been or will be released before the MATILDA's second technical review meeting coming up in September 2019 **will reach the nontrivial number of 30**!

PIRAEUS PLENARY MEETING

MATILDA had its **fifth plenary meeting in Piraeus, Athens, on 9-11 April 2019**.

The plenary meeting was hosted on the premises of the University of Piraeus. We had three days of comprehensive and extensive discussion regarding the progress of MATILDA with respect to the different phases and stages of development, which the different work packages and their respective tasks are in. During the meeting, the work package leaders and their contributing consortium partners provided appropriate and detailed answers to all the questions asked and clarifications sought.

After this plenary meeting, another one will be organised soon. The forthcoming plenary meeting will take place sometimes possibly before the next technical review meeting, which is scheduled for September 2019. Accordingly, we will expect the meeting also to be very intensive and of comprehensive nature, with detailed discussions concerning all the different aspects of the project. In particular, the meeting shall be focused on the updates regarding the status of all the ongoing developments within the project and the status of the planned demonstrators. We anticipate to have useful and productive discussions throughout the plenary sessions during the meeting.