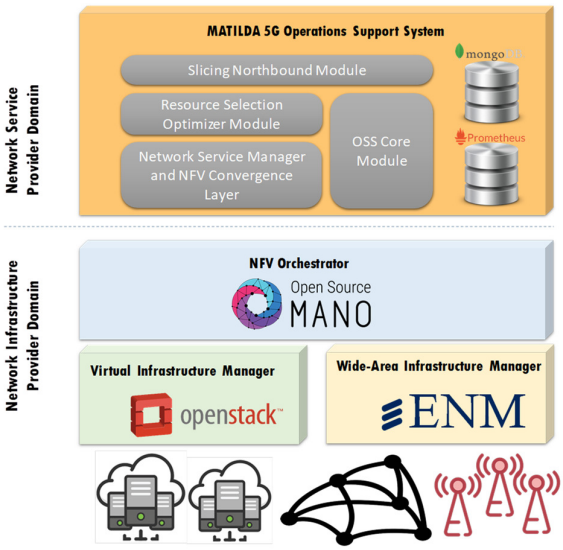


Fig. 1. Main building blocks composing the MATILDA 5G Telecom and Infrastructure Platforms.

I. THE COMPLETED MATILDA TESTBED

The goal of the MATILDA Project is to deliver a holistic and innovative 5G framework to undertake the design, development and orchestration of 5G-ready vertical applications (vApps) and 5G network services over programmable infrastructures. To this goal, a telecom layer platform has been designed to realize the autonomic management of the lifecycle of 5G network slices and edge computing resources. In accordance with 3GPP, the main stakeholders actively involved in this environment are three: the vertical industry owing the vApp, the telecom service provider delivering 5G services, and the telecom infrastructure provider offering computing and communication facilities.

Fig. 1 depicts the main functional blocks composing the telecom layer platform. The *Operations Support System* (OSS) is in charge of managing all functions and operations required for the placement of a vApp over a network slice, as well as maintaining the information on all the data regarding the deployed vApp, network services, available resources, and so on. The *NFV Orchestrator* (NFVO) is responsible for the lifecycle management of the network services, both those composing the base 4/5G services and the ones provided to slices. The *Wide-area Infrastructure Manager* (WIM) is devoted to manage and monitor the wide-area communication resources, to create overlay networks for vApps and base telecommunication services, as well as to provide information on the resources available in the distributed 5G infrastructure. Finally, the *Virtual Infrastructure Manager* (VIM – one instance per each distributed computing facility), abstracts and exposes computing, storage, and networking capabilities of datacenters within the 5G infrastructure. Vertical industries can autonomically manage the lifecycle of their application graphs by means of Vertical Application Orchestrators (VAOs). The VAO interacts with the OSS via a specific metamodel, called slice intent, which represents all requirements that should be satisfied during the creation of a slice. The VAO and OSS include most of the innovations developed within the project. In the OSS, among other functionalities, the *NFV Convergence Layer* (NFVCL) module provides a level of abstraction for the flexible and high-level management of the complete lifecycle orchestration of network services, Virtual Network Functions (VNFs) and Physical Network Functions (PNFs) instantiated in the 5G infrastructure.

A. Testbed Deployment

For the final demonstrations of the MATILDA Project, the testbed has been deployed as shown in Fig. 2. A wide-area network interconnects three VIMs and two e/gNodeB PNFs. VIMs 1 and 3 are supposed to be "edge" VIMs, in the sense that they are placed geographically closer to the e/gNodeBs, while VIM 2 is placed in the "core" of the Telecom infrastructure.

On top of this infrastructure, the NFVO instantiates a Public Land Mobile Network (PLMN) as base network service. The PLMN in Fig. 2 is composed of a number of network services, whose VNFs are highlighted with the light blue color. One service, in the core VIM 2, includes a single monolithic VNF implementing the EPC functionalities. This VNF has two main network interfaces, one towards the 4/5G network and one towards the public Internet. On each edge VIM, an additional network service is created for managing and configuring an eNB PNF and for providing S1 bypass capabilities. The S1 bypass has two main network interfaces, one towards the wide-area network to interconnect with the EPC

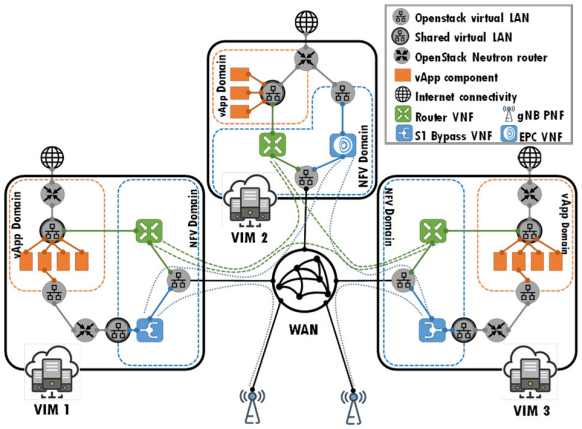


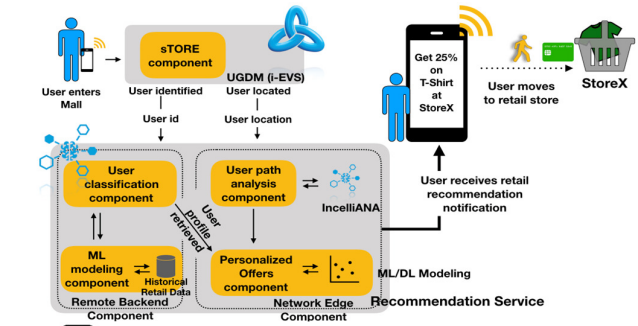
Fig. 2. Testbed deployment for the evaluation, including a base network service and a network slice, produced by the MATILDA Telecom Layer Platform.

and the eNBs, and one towards a virtual layer-2 network internal to the VIM.

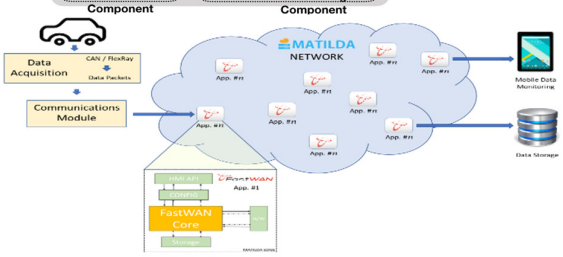
An OpenStack project is fully dedicated to the vApp and directly controlled by the VAO via a connection to the public Internet. Different vApps in the same VIM will be assigned to different and isolated OpenStack projects, highlighted with a sketched orange box in the figure. vApp components might be placed on edge VIMs close to the attach point network, if they have particular performance requirements, or in other VIMs, like the ones in the infrastructure core. In that case, a further Network Service (whose VNFs are colored in green in Fig. 2) should be created and deployed to provide connectivity among the vApp components in the different VIMs.

II. MATILDA USE CASES AND DEMONSTRATORS

High Resolution Media on Demand Vertical with Smart Retail Venues' Integration (5GPACE), offering high valued services to consumers participating in a crowded event. 5GPACE consists of two main parts, providing user management services, geo-localization functionalities, high-quality video sharing and processing capabilities, as well as smart retail recommendations for the users.

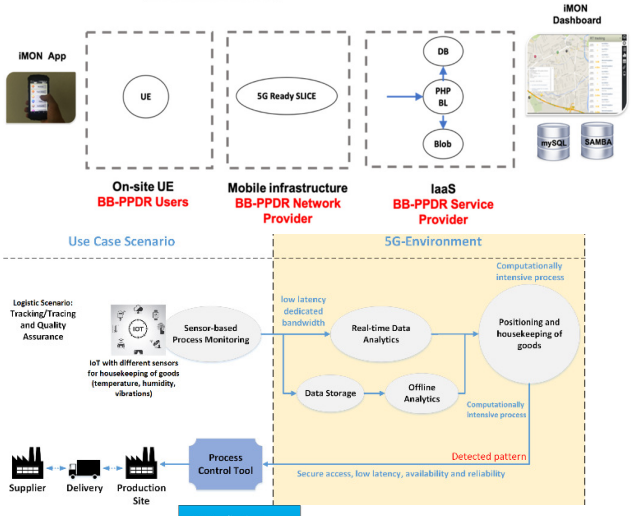


Testing 4.0 - Distributed System Testing, demonstrating the data acquisition and remote testing of Mobile System Under Test (SUT) units using the FastWAN solution by ExxpertSystems over a 5G network.



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 to support SLAs (qMON).

Industry 4.0 Smart Factory – Inter and Intra-Enterprise Integration, focusing on a logistic scenario, which offers customers the possibility to track, change and prioritize their orders, and on a production scenario, featuring both pattern detection for quality assurance and real-time distance calculation in a Human-Robot Collaborative (HRC) environment.



Smart City Intelligent Lighting System, implementing an end-to-end operational service framework for the Smart City Intelligent Lighting solution starting from design and development to end to end orchestration over a 5G infrastructure assuring the end-to-end management, control and orchestration of the slice.