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MATILDA

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

DELIVERABLE D1.6

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Table of Contents

Table of Acronyms

Acronym	Definition
AAA	Definition of the acronym AAA
BBB	Definition of the acronym BBB
API	Application Programming Interface
BL	Business Logic
BLOB	Binary Large Objects Storage
BSS	Business Support System
CPS	Cyber Physical System
CRM	Customer Relationship Management
EPC	Enhanced packet Core
FDD	Frequency Division Duplex
GPU	Graphics Processing Unit
GDPR	General Data Production Regulation
HPN	High Performance Network
HRC	Human Robot Collaboration
HSS	Home Subscriber Server
i-EVS	italtel-Enhanced Video System
iMON	intervention MONitoring
IMS	IP Multimedia Subsystem
IoT	Internet of Things
LoRa	Long Range
LTE	Long Term Evolution
MEC	Multi-access Edge Computing
NaaS	Network as a Service
NFV	Network Function Virtualization
NFVO	Network Function Virtualization Orchestrator

Acronym	Definition
NIC	Network Interface Card
NR	New Radio
NS	Network Service
OEM	Original Equipment Manufacturer
OPC	Object linking and embedding for Process Control
OSM	Open Source Mano
PDN	Packet Data Network
P-GW, PGW	Packet data network Gateway
PNF	Physical Network Function
PPDR	Public Protection and Disaster Relief
qMON	quality MONitoring
RAN	Radio Access Network
RFID	Radio-Frequency IDentification
S-GW, SGW	Serving Gateway
SLA	Service Level Agreement
SLS	Service Level Specification
SDN	Software Defined Networking
SR-IOV	Single Root – I/O Virtualization and sharing
TDD	Time Division Duplex
ToR	Top of Rack
UGDM	User Group Database Manager
vEPC	virtualized Enhanced Packet Core
vHSS	virtual Home Subscriber Server
VIM	Virtualization Infrastructure Manager
vMME	virtual Mobility Manager Entity
vPGW	virtual Packet data network GateWay
vSGW	virtual Serving GateWay

Acronym	Definition
VNF	Virtual Network Function
VNFM	Virtual Network Function Manager
VNO	Virtual Network Operator
VTU	Virtual Transcoding Unit
WAN	Wide Area Network
WWAN	Wireless Wide Area Network

1 Executive Summary

This deliverable provides information about the three testbeds and the five demonstrators that will be developed by the MATILDA project. The testbeds will be set-up and operated by CNIT (UBITECH and COSM will realize an equivalent testbed in both of their premises for development and testing purposes), UNIVBRIS and ORO; they will be used by the consortium to deploy and run MATILDA demonstrators. Specifically, for each testbed, the document describes available Radio Access Network resources, Software Defined Networking controllers and Network Function Virtualization orchestrators, and discusses how they can be used by each demonstrator.

The five demonstrators cover a wide spectrum of vertical applications, ranging from advanced media services to public safety and industrial applications; moreover, a Smart City scenario is also addressed.

The first demonstrator combines the functionalities of two systems, independently developed by MATILDA partners INC and ITL, 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. The second demonstrator, by EXXPERT, focuses on distributed system testing and is based on FastWAN, an experimental communication technology that was developed as a solution for the enablement of geographically separated real-time industrial test benches. The third demonstrator (5GPPRD) is a 5G system for Public Protection and Disaster Relief (5GPPDR). It extends the capabilities of the iMon and qMon product suites developed by ININ. The fourth demonstrator, by BIBA, is related to the Industry 4.0 – Smart Factory context, and focuses on a logistic application, which offers customers the possibility to track, change and prioritize their orders. The fifth demonstrator, by ORO, will highlight how Alba Iulia, a small to middle size city in Romania with about 70,000 inhabitants, is moving forward as a smart city by adopting the latest Information and Communication Technologies.

The five demonstrators have already been presented in previous deliverables. This document provides additional information for each demonstrator, related to the following aspects. At first, the business scenario of interest for each demonstrator is specified, and its relevance in the 5G ecosystem is discussed. The definition of each demonstrator as a 5G-ready application, according to the MATILDA framework, is then provided. In particular, the innovative contribution of MATILDA to the realization of each demonstrator is highlighted. The resources needed by each demonstrator are also defined and discussed. Finally, implementation, deployment and demonstration plans for each demonstrator are defined.

2 Introduction

The advent of 5G networks is predicted as a leading factor in the fourth industrial revolution impacting multiple vertical sectors and changing the way services are developed. Nevertheless, the necessary integration between the digital systems that enable those services and the network layer remains undefined and represents a big challenge.

MATILDA aims to fill this gap, providing the tools to foster and speed up the extension/evolution of the cloud paradigm into the 5G ecosystem, intrinsically bridging the vertical application and the network service domains. MATILDA comes up with a novel and holistic approach for tackling the overall lifecycle of applications' design, development, deployment and orchestration in a 5G environment.

A set of novel concepts are introduced, including the design and development of 5G-ready applications -based on cloud-native/microservice development principles- the separation of concerns among the orchestration of the developed applications and the required network services that support them, as well as the specification and management of network slices that are application-aware and can lead to optimal application execution.

MATILDA follows a top-down approach where application design and development leads to the instantiation of application aware-network slices, over which vertical industries' applications can be optimally served. Different stakeholders are engaged in this process, with clear separation of concerns among them.

Still, MATILDA's main target is the Telecom Provider, including Virtual Network Operators (VNOs), Network as a Service (NaaS) companies and small players with innovative, telecom-centric, business models. MATILDA aims to help them to satisfy their vertical customers' needs, by creating a fruitful environment where network-intensive services can be easily prototyped and quickly deployed into production.

The framework allows software developers to create applications following a simple and conventional microservices-based approach, where each component can be independently orchestratable. Based on the conceptualization of metamodels (application component and graph metamodels), they can formally declare information and requirements -in the form of descriptors- that can be exploited during the deployment and operation over a programmable infrastructure.

Such information and requirements may regard capabilities, envisaged functionalities and soft or hard constraints that have to be fulfilled and may be associated with an application component or virtual link interconnecting two components within an application graph. The produced application is considered as 5G-ready application.

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 Virtual Network Functions (VNF) and Network Services (NS) (in the form of enhanced descriptors).

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 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 Vertical Application Orchestrator to request the creation of an appropriate application-aware network slice from the Telecommunication Infrastructure Provider.

While the instantiation and management of the application-aware network slice (including the set of network functions) is realised by the Network and Computing Slice Deployment Platform (managed by the telecommunications infrastructure provider), the deployment and runtime management of an application is realised by the vertical application orchestrator (managed by the service provider), following a service-mesh-oriented approach.

This recently introduced approach is adopted as a software management layer for controlling and monitoring internal traffic in microservices-based applications. It consists of a data plane and a control plane. The data plane consists of a set of intelligent proxies deployed alongside the application software components supporting the provision of support/backing services (e.g. service discovery, load balancing, health checking, telemetry). The control plane manages the set of intelligent proxies based on distributed management techniques and provides policy and configuration guidance for all the running support/backing services. Policies definition for the activation and management of the set of required support/backing services is realised based on a policies' editor, while policies' enforcement is realised through a rule-based management system. Advanced monitoring and analysis techniques are also applied for extracting insights that can be proven useful for service providers.

In order to instantiate and manage the application-aware network configuration during the overall lifecycle of the 5G-ready application, Telecommunication Infrastructure Providers rely on the concept of network slice to fulfil the vertical application needs. A network slice is a logical infrastructure partitioning allocated resources and optimized topology with appropriate isolation, to serve a particular purpose of an application graph.

The Network and Computing Slice Deployment Platform includes an OSS/BSS system, a NFVO and a resource manager to manage the set of deployed WIMs and VIMs. Based on the interpretation of the provided slice intent, the required network management mechanisms are activated and dynamically orchestrated.

The Telecommunication Infrastructure Provider is responsible to realise the instantiation of the slice over the programmable infrastructure. The reserved resources for this slice combine both network and compute resources. A Telecommunication Infrastructure Provider may deliver all these resources based on its own infrastructure or come into an agreement with a Cloud Infrastructure Provider and acquire access to additional compute resources (e.g. in the edge of the network).

These actions are realized in an agnostic way to application service providers. However, through a set of open APIs, requests for adaptation of the slice configuration may be provided by the Vertical Applications Orchestrator to the Network and Computing Slice Deployment Platform.

The materialization of the network slice requires the instantiation of network services (NSs) that are composed of virtual network functions (VNFs) chains. These NSs and VNFs can imported into the telecommunications infrastructure provider's catalogue from the MATILDA marketplace.

A summary of the described overall lifecycle of an application created with the MATILDA Framework is represented in Figure 2.1 below, highlighting the interaction among the different stakeholders and the usage of the metamodels.

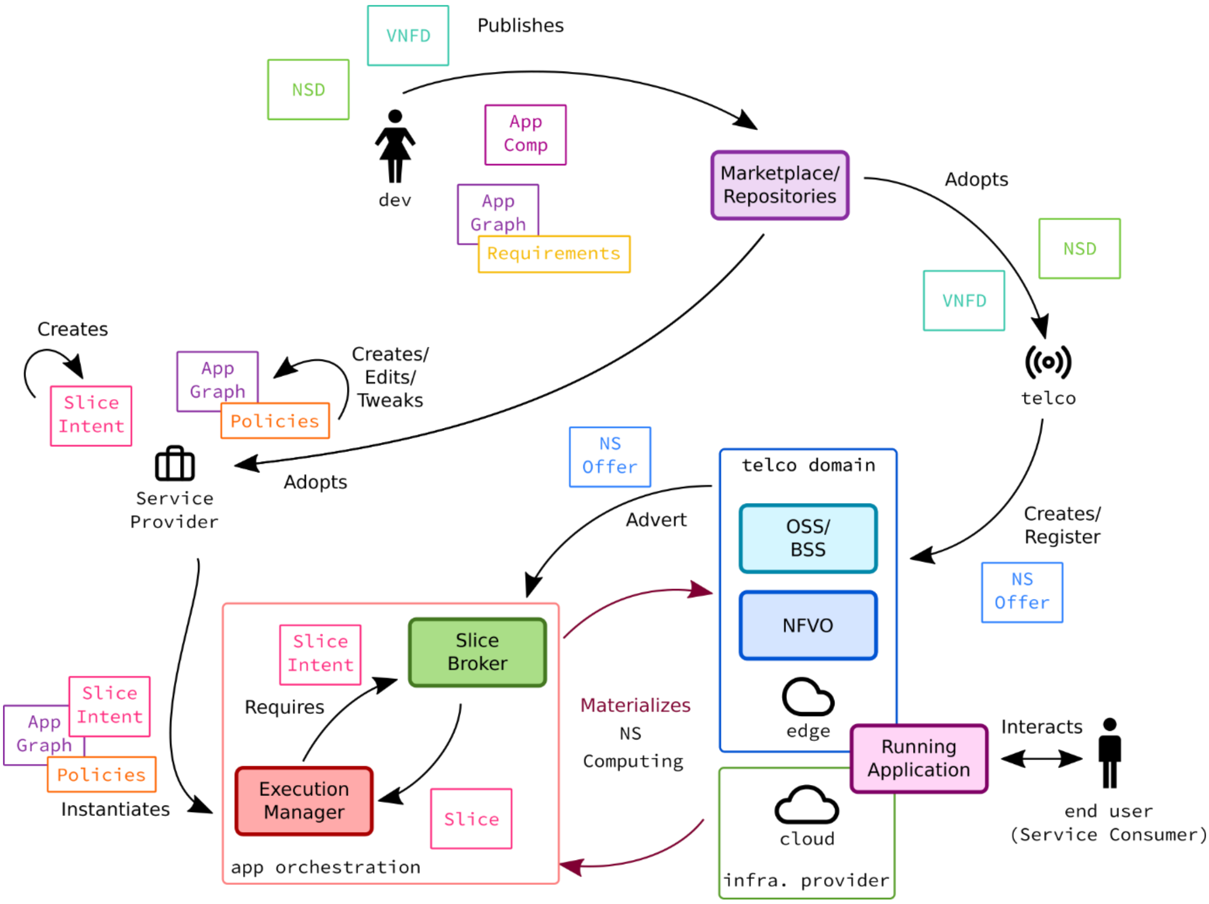

Figure 2.1: MATILDA workflow highlighting the different stakeholders and metamodels.

The MATILDA reference architecture is divided in three distinct layers; namely, the 5G-ready Applications Layer, the Applications' Orchestration Layer and the Network and Computing Slice Management Layer. Separation of concerns per layer is a basic principle adhered towards the design of the overall architecture. The Applications Layer is oriented to software developers, the 5G-ready Application Orchestration Layer is oriented to service providers and the 5G Infrastructure Slicing and Management Layer is oriented to telecommunications infrastructure providers.

The 5G-ready Applications Layer takes into account the design and development of 5G-ready applications per industry vertical, along with the specification of the associated networking requirements. The associated networking requirements per vertical industry are tightly bound together with their respective 5G-ready applications' graph, which defines the business functions, as well as the service qualities of the individual application.

The Applications' Orchestration Layer supports the dynamic on-the-fly deployment and adaptation of the 5G-ready applications to their service requirements, by using a set of optimisation schemes and intelligent algorithms to provide the needed resources across the available multi-site programmable infrastructure.

The Programmable 5G Infrastructure Slicing and Management Layer is responsible for setting up and managing the 5G-ready application deployment and operation over an application-aware network slice. Network slice instantiation and management, network services and mechanisms activation and orchestration as well as monitoring streams management, are realized. Such actions are triggered based on requests provided by the Applications' Orchestration Layer through the specification of Open APIs.

As an Innovation Action, a major goal of MATILDA is to prove the effectiveness of its proposed mechanisms and architectural choices, in a set of 5G-ready demonstration test beds based on real vertical-industry use cases.

MATILDA demonstrators address a broad portfolio of verticals with different characteristics and application requirements. The goal is not to demonstrate the benefits of 5G per se in diversified application fields, but rather to show the impact of the MATILDA architecture and mechanisms on the entire lifecycle of the 5G-ready applications, in terms of easing and smoothing the development, deployment and operations phases; likewise, the goal of integrating cloud-native applications in a much more dynamic NFV and MEC environment will be demonstrated.

Five vertical applications in different domains will be demonstrated on top of the MATILDA architectural layers and components.

The first demonstrator combines the functionalities of two systems, independently developed by MATILDA partners INC and ITL, 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. The second demonstrator, by EXPERT, focuses on distributed system testing and is based on FastWAN, an experimental communication technology that was developed as a solution for the enablement of geographically separated real-time industrial test benches. The third demonstrator (5GPPRD) is a 5G system for Public Protection and Disaster Relief (5GPPDR). It extends the capabilities of the iMon and QMon product suites developed by ININ. The fourth demonstrator, by BIBA, is related to the Industry 4.0 – Smart Factory context, and focuses on a logistic application, which offers customers the possibility to track, change and prioritize their orders. The fifth demonstrator, by ORO, will highlight how Alba Iulia, a small to middle size city in Romania with about 70,000 inhabitants, is moving forward as a smart city by adopting the latest Information and Communication Technologies.

The five demonstrators have already been presented in previous deliverables. This document provides additional information for each demonstrator, related to the following aspects. At first, the business scenario of interest for each demonstrator is specified, and its relevance in the 5G ecosystem is discussed. The definition of each demonstrator as a 5G-ready application, according to the MATILDA framework, is then provided. In particular, the innovative contribution of MATILDA to the realization of each demonstrator is highlighted. The resources needed by each demonstrator are defined and discussed. Finally, implementation, deployment and demonstration plans for each demonstrator are defined.

The five demonstrators will be mapped over three different test beds:

- UNIVBRIS testbed, integrating an extensive environment of LTE radio, WiFi and mmWave devices, interconnected by fibre backhaul, and providing OpenStack on High Performance Computing nodes in Bristol, UK;

- The CNIT-S3ITI testbed in Genoa, Italy, based on WiFi and LTE radio devices, emulated Enhanced Packet Core, a MEC platform (OpenVolcano) and a cloud infrastructure stemming from a FIWARE Lab node, in a controlled laboratory environment. Equivalent testbeds will also be deployed by UBITECH and COSM in their premises.
- The Orange Romania Smart City testbed in Alba Iulia, Romania, integrating LTE/5G Lighting Sensors, radio access and VNFs hosted in the Orange Regional Datacentre, and a Cloud middleware IoT platform.

Specifically, for each testbed, this document describes available Radio Access Network resources, Software Defined Networking controllers and Network Function Virtualization orchestrators, and discusses how they can be used by each demonstrator.

3 Performance Evaluation Methodology

In MATILDA, performance evaluation regards the assessment of the mechanisms of the MATILDA framework and platform, as well as the appraisal of the Key Performance Indicators (KPIs) of the set of MATILDA Demonstrators. In the current section, a short description of the overall performance evaluation methodology to be followed in the project is provided. This overall methodology is going to constitute the basis for the specification and documentation of the evaluation framework, the validation methodology and the set of scenarios that will run during each demonstrator, including the evaluation indicators and the overall time plan in WP6 and specifically in D6.1.

With regard to the MATILDA framework and platform, a set of deployment and orchestration mechanisms are under development, related to the Vertical Applications Orchestrator and the Network and Computing Slice Deployment Platform. Such mechanisms are going to be tested and evaluated in terms of stability, efficiency and scalability. The objective is to identify capacity constraints per mechanism and come up with suggestions regarding the optimal usage of the provided orchestration mechanisms. Issues related to network slice creation and management, runtime policies enforcement, deployment time per application graph or network service, failures management, etc., are going to be examined. It should be also noted that the evaluation of the MATILDA platform is going to include usability aspects taking into account the developed user interface and the way it facilitates software developers and service providers to realise their activities more effectively. For instance, self-reported efficiency increase during development and validation of 5G-ready applications and network services, as well as self-reported decrease in time required to develop and validate 5G-ready applications and network services are going to be provided.

As regards the MATILDA Demonstrators, a set of operational and business-oriented KPIs and their associated acceptance criteria are going to be evaluated. These KPIs regard main operational and societal 5G KPIs along with those associated with the business logic of the application provided per Demonstrator. Depending on the requirements of each Demonstrator and the exploitation of 5G technologies per network part, evaluation of the most relevant 5G KPIs is going to take place. An identification of these KPIs is realised in this document, while the exact plan and testing activities for their evaluation is going to be detailed in D6.1.

An iterative cycle of performance evaluation activities is going to be realised. Given the release of individual mechanisms per WP (WP2, WP3, WP4) at M15 and M24 and the integrated

MATILDA platform (WP5) at M18 and M24, testing and evaluation activities are going to take place, leading to a set of results, as well as feedback for improvements. Specifically, the first demonstration phase is going to be finalised at M21 leading to valuable feedback towards WP2-WP5 for improving identified inefficiencies in the final release of the overall development and orchestration mechanisms. The second demonstration phase is going to lead to production of continuous evaluation results that -in parallel with the adopted continuous development and integration approach- can lead to various improvements in the MATILDA platform. It should be noted that such activities are envisaged to be realised towards the end of the lifetime of the project.

4 MATILDA Testbeds' Description

The MATILDA testbeds deployed by UNIVBRIS, ORO and CNIT aim to provide a managed infrastructure for the deployment and execution of industrial, vertical 5G-ready applications. In this context, the testbeds will provide significant infrastructural resources: (*i*) network resources, (*ii*) storage space and (*iii*) compute resources, to meet the needs of the different industry vertical use cases to be implemented and evaluated in the project.

This section describes the physical infrastructures of the three MATILDA testbeds and summarizes the equipment and technologies in use.

- The UNIVBRIS testbed is a multi-site network connected through a 10-km fibre. It provides high performance equipment controlled by a rich software stack composed by: (*i*) two different NFV orchestration and management solutions (OSM and NOKIA CloudBand), (*ii*) cloud/edge computing solutions (Openstack Pike and Nokia MEC), and (*iii*) a NetOS SDN controller.
- The ORO Smart City testbed integrates LoRA/LTE-M Lighting Sensors, radio access and VNFs hosted in the Orange Regional Datacenter and a Cloud middleware IoT platform. The physical architecture of the ORO testbed is composed by four main components: (*i*) RAN part (LoRA/LTE-M/ Nb-IoT, 4G), (*ii*) IoT Aggregator platform, (*iii*) IoT Middleware part, and (*iv*) Connectivity system.
- The CNIT testbed is a 4G/5G radio access network and edge/cloud computing testbed. It consists of a set of high-performance pieces of equipment and several computing and networking technologies used nowadays. The testbed is based on a multi-node OpenStack architecture (OpenStack Queens).

4.1 UNIVBRIS Testbed

In order to explore and validate the deployment of 5G in an architecture that combines existing technologies and innovations, UNIVBRIS has deployed a rich testbed comprised of several networking and computing technologies, interconnecting a significant area in the Bristol city centre, as shown in Figure 4.1. This testbed aims to provide a managed platform for the development and testing of new solutions delivering reliable and high-capacity services to several applications and vertical sectors.

The University of Bristol's 5G testbed is a multi-site network connected through a 10-km fibre with several active switching nodes that are depicted in Figure 4.2. The core network is located at the High-Performance Network (HPN) laboratory at the University of Bristol and an extra edge computing node is available in another central location, known as Watershed. As shown in Figure 4.1, the access technologies are located in two different areas in the city centre: Millennium Square for outdoor coverage and “We The Curious” science museum for indoor coverage.

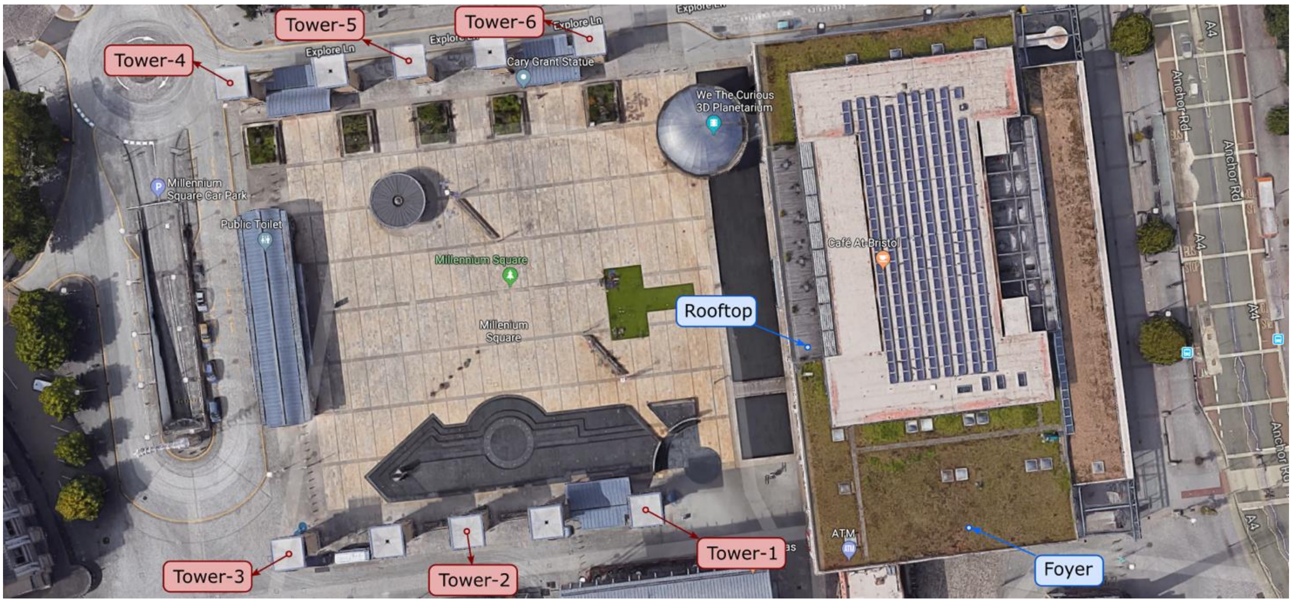

Figure 4.1: Distribution of the testbed access technologies.

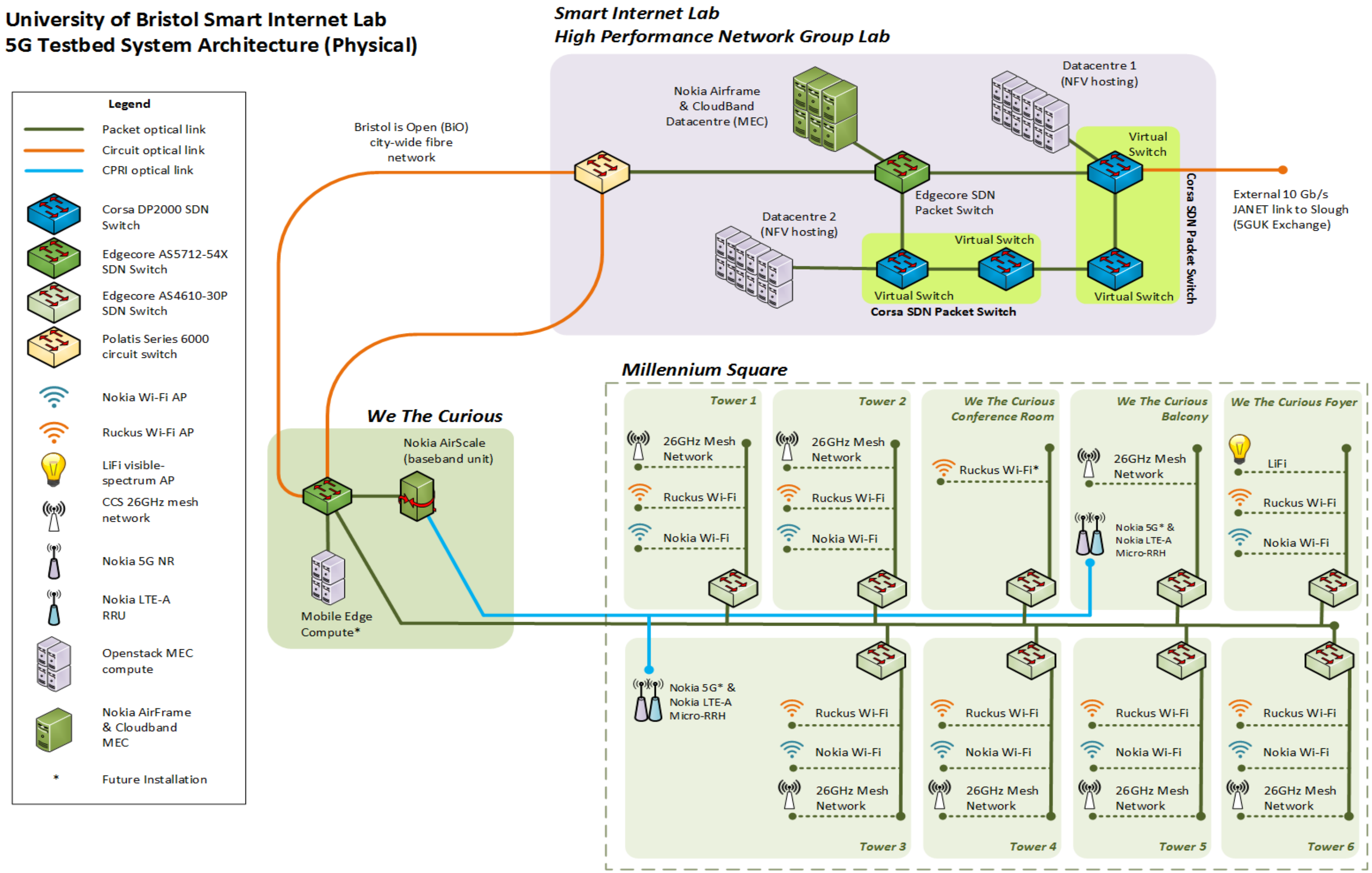

Figure 4.2: University of Bristol testbed top level system architecture.

A summary of the testbed constituent equipment and capabilities is:

- Multi-vendor software-defined networking (SDN) enabled packet switched network
  - Corsa switch (Corsa DP2100)
  - Edgecore switch (Edgecore AS4610 series & AS5712-54X)
- SDN enabled optical (Fibre) switched network
  - Polatis Series 6000 Optical- Circuit Switch
- Multi-vendor Wi-Fi
  - SDN enabled Ruckus Wi-Fi (T710 and R720)
  - Nokia Wi-Fi (AC400)
- Nokia 4G and 5G NR
  - 4G EPC & LTE-A (Dual FDD licensed bands for 1800MHz and 2600MHz; with 15MHz of T&D licence in 2600MHz band)
  - 5G Core & 5G NR Massive MIMO (TDD band 42 at 3.5GHz; with 20MHz T&D licence) – The hardware responsible for the 5G connectivity is already installed in the testbed, preliminary operation for the full system is expected after June 2019 (non-standalone operation, 3GPP option 3 networking - http://www.3gpp.org/release-15), according to the software availability plan of the vendor.
- Self-organising multipoint-to-multipoint wireless mesh network
  - CCS MetNet a 26GHz with 112MHz T&D licence providing 1.2Gbps throughput
- LiFi Access point
  - pureLiFi LiFi access points supporting a nominal rate of 43Mbps
- Cloud and NFV hosting
  - Nokia Multi-access Edge Computing (MEC)
  - Datacentre for Application/VNF hosting, built upon
    - 11x Dell PowerEdge T630 compute servers 700+ vCPU cores, 1TB+ RAM and 100TB of HDD storage.
- Advanced fibre optics FPGA convergence of all network technologies enabling considerable flexibility, scalability and programmability of the front/back-haul, to provide experimentation with -
  - Elastic Bandwidth-Variable Transponders
  - Programmable Optical White-box
  - Bandwidth-Variable Wavelength Selective Switches (BV-WSS)

The available equipment is controlled using a rich software stack (showed in Figure 4.3) that is composed by:

- two different NFV orchestration and management solutions:
  - Open Source MANO release THREE (opensource)
  - NOKIA CloudBand (proprietary, providing network slicing and virtualisation in rapid service creation)

- two cloud/edge computing solutions:
  - Openstack Pike (opensource)
  - Nokia MEC (proprietary)
- one SDN controller responsible for providing connectivity:
  - NetOS (proprietary, based on the Open Daylight opensource).

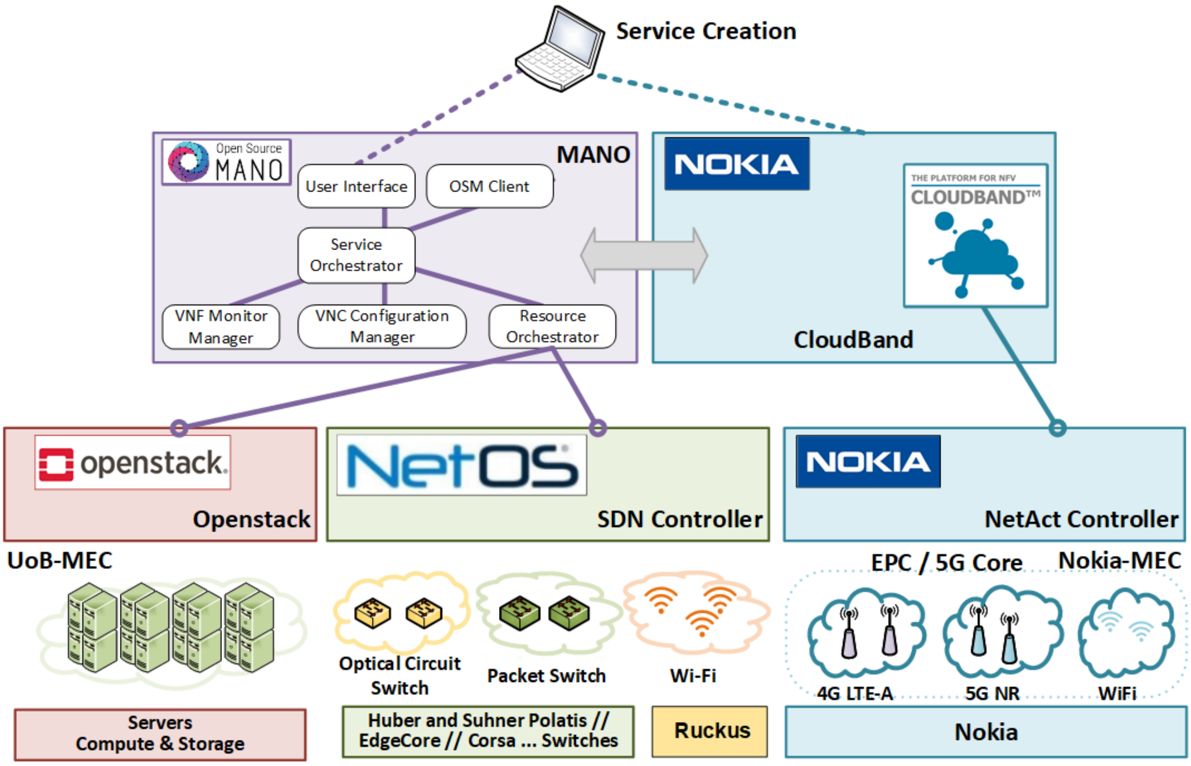

Figure 4.3: Software used for management and orchestration of the testbed resources.

Within the MATILDA project, the aforementioned structure will be used to support different vertical demonstrators, such as entertainment, finance, manufacturing and automotive testing.

The diverse range of access technologies interconnected sharing the same underlying system will be used by the MATILDA framework to provide connectivity for the demonstrators, showcasing seamless integration between heterogeneous network components, an important concept in 5G. Additionally, the alternative and innovative technologies available, such as pureLiFi for fixed access, can be used to demonstrate the principle of access-agnosticism, also important for the 5G vision.

The state-of-the-art radio access technologies deployed in Millennium Square will deliver high-bandwidth, high-bitrate and high-reliability connections to the user equipment, therefore enabling the usage of the network-intensive distributed applications developed by MATILDA demonstrators. In particular, the availability of LTE-Advanced (LTE-A) and future installations of 5G access points (Nokia 5G NR) will be especially important in MATILDA to demonstrate applications that require mobility while keeping user experience continuity.

The SDN capabilities expressed by the NetOS controller will facilitate network slicing through optical, electrical and radio technologies via on-demand SSID creation, demonstrating another key concept in the 5G architecture that will be explored by MATILDA to provide a multi-tenant environment, where the multiple demonstrators, or even final users, can coexist independently with different connectivity specifications.

The high performance and edge computing capabilities will power resource-intensive applications developed by MATILDA demonstrators. In these applications, hardware acceleration and GPU-processing will be used to deliver enhanced performance and enable low-latency/real-time user interaction.

Finally, the University of Bristol 5G testbed will deliver an automated and programmable environment that will be used by the MATILDA southbound interface to create fully integrated orchestration for both application components and network services.

4.2 ORO Testbed

Orange Romania Smart City testbed (Figure 4.4) integrates LoRA/LTE-M Lighting Sensors, radio access and VNFs hosted in the Orange Regional Datacenter and a Cloud middleware IoT platform.

The ORO testbed solution architecture for the Smart City MATILDA use case testing and validation will be deployed as a small-scale network which will combine several network components with the aim to create a logical infrastructure with appropriate isolation, dedicated resources and topology to sustain Smart City applications' vertical functionality. The testbed platform will provide infrastructure resources (network resources, storage space, compute resources) spanning from the radio access to transport and core network offering programmable network resources capabilities to:

- perform multi-site management of the allocated resources per network slice
- support the lifecycle management of the network
- manage interfaces towards OSS/BSS systems
- handle VNF graphs
- administration of monitoring and management mechanisms

The testbed network will incorporate all network elements that are expected to be included in the final Smart City commercial solution such as RAN type components, OS components (e.g., vEPC) and the IoT platform that will be interconnected with the rest of MATILDA platform blocks.

The physical architecture for the ORO testbed is composed by four main components:

1. RAN part (LoRA/LTE-M/ Nb-IoT, 4G)
2. IoT Aggregator platform
3. IoT Middleware part
4. Connectivity system

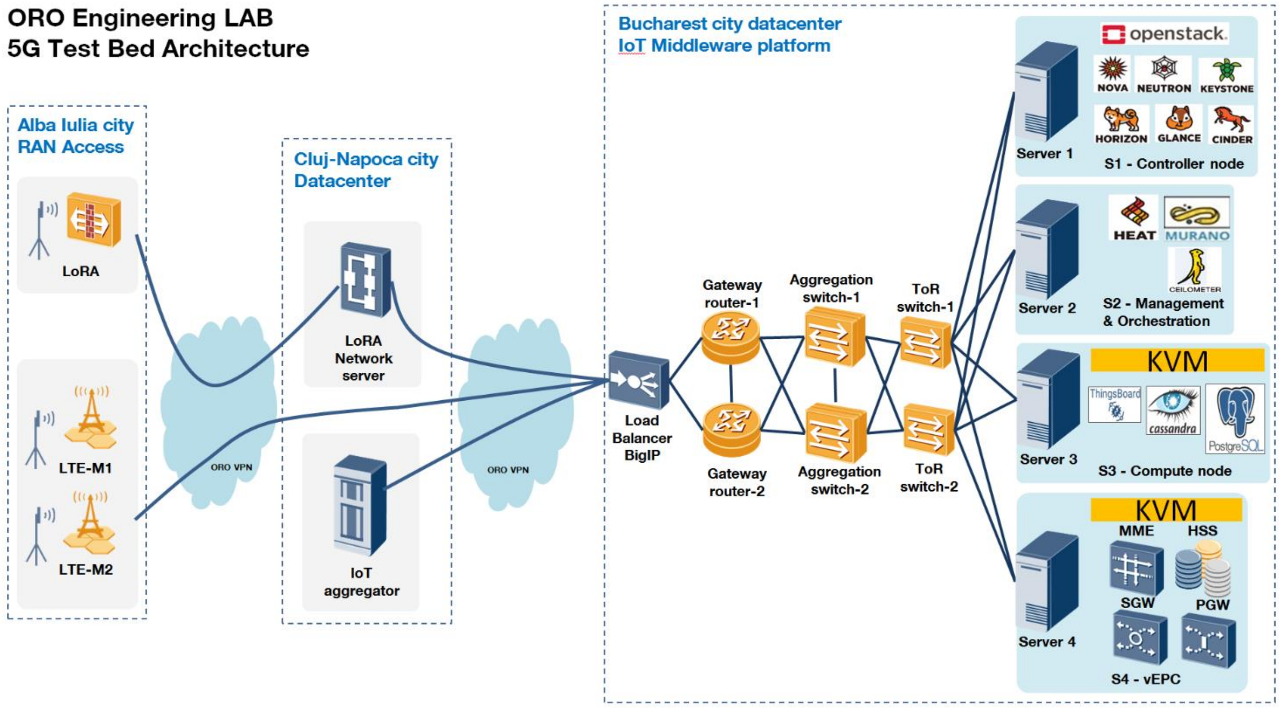

Figure 4.4: ORO testbed system architecture.

- RAN part (LoRA/LTE-M/ Nb-IoT, 4G)
  - LoRA/LTE-M smart lighting sensors
  - LoRA Gateway platform
  - LoRA Network server
  - connectivity Interfaces (public and private) to collect data, send commands or notifications from/to smart lighting sensors
- IoT Aggregator platform
  - Load balancer BigIP – Cisco F5 Load-Balancer BigIP
  - IoT aggregator platform (VM running on dedicated server)
- IoT Middleware platform
  - 3 servers hosting IoT platform, NFVO, VNFM, VIM, SDN controllers, and Tacker module functionalities with the following individual capabilities:
    - 2 processors, 12-core/processor @ 2.4 GHz
    - 128 GB RAM
    - 2 TB Hard Disk
    - 2 Network adapters 1Gbps
  - 1 server hosting vEPC (vMME; vS/P-GW; vHSS) with the following individual capabilities:
    - 2 processors, 12-core/processor @ 2.3 GHz
    - 512 GB RAM
    - 2.4 TB Hard Disk
    - 2 Network adapters 1Gbps

- Server 1 – OpenStack controller node containing VIM (Nova – Neutron – Keystone – Glance) and OSS/BSS (Horizon)
- Server 2 - Management & Orchestration node containing VNFO (Heat), VNFM (Murano – Ceilometer) and Tacker module (Tacker) with addressing role to the orchestration module
- Server 3 - computing node using KVM virtualization capacity to instantiate several virtual machines for all Smart City application components, having the role of processing and storage of the information provided by Smart City sensors and actuators:
    - VM1 - hosting open source IoT platform for components functionalities management (Thingsboard.IO)
    - VM2 - hosting open source relational SQL database (PostreSQL)
    - VM3 - hosting non-relational open source database for Smart City solution data storage (Cassandra NoSQL)
    - VM4 - hosting IoT Gateways responsible for processing of data received by IoT platform
    - VM5 – hosting monitoring platform with ticketing capabilities being responsible for client identification, device identification, health status for servers and database (storage/load)
    - VM6 - a billing platform in charge of traffic evaluation and monetization functions
- Server4 - compute node using KVM virtualization capacity hosting virtual EPC

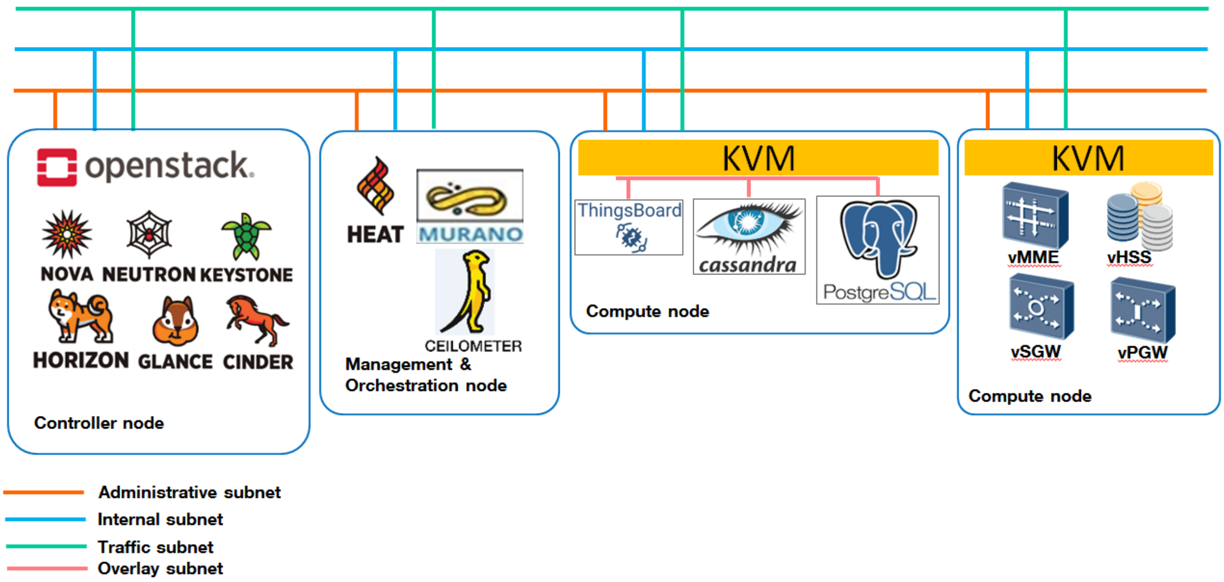

Figure 4.5: ORO testbed IoT middleware connectivity system.

- Connectivity system composed by 4 connectivity layers (Figure 4.5):
  - physical layer:
    - 2 routers (acting as gateways for demarcation between WAN networks and Core infrastructure)
    - 2 aggregation switches (for future planned expansions)
    - 2 ToR switches used for servers' connectivity
  - underlay network layer - based on VLAN and created during the infrastructure provisioning
  - overlay networks - containing tunneling mechanisms (VXLAN /MPLSoUDP) used for tenants' traffic isolation
  - administrative subnet used for remote management access to all nodes of the infrastructure

4.3 CNIT Testbed

The integration testbed deployed by CNIT, UBITECH and COSM aims to provide a managed infrastructure for the deployment and execution of industrial, vertical 5G-ready applications. In this context, the physical infrastructure of the testbed is the same for the three partners, in order to best meet the requirements of the industry vertical use cases to be implemented and evaluated in the project. For the sake of simplicity, we describe the physical architecture of the CNIT testbed, as shown in Figure 4.6.

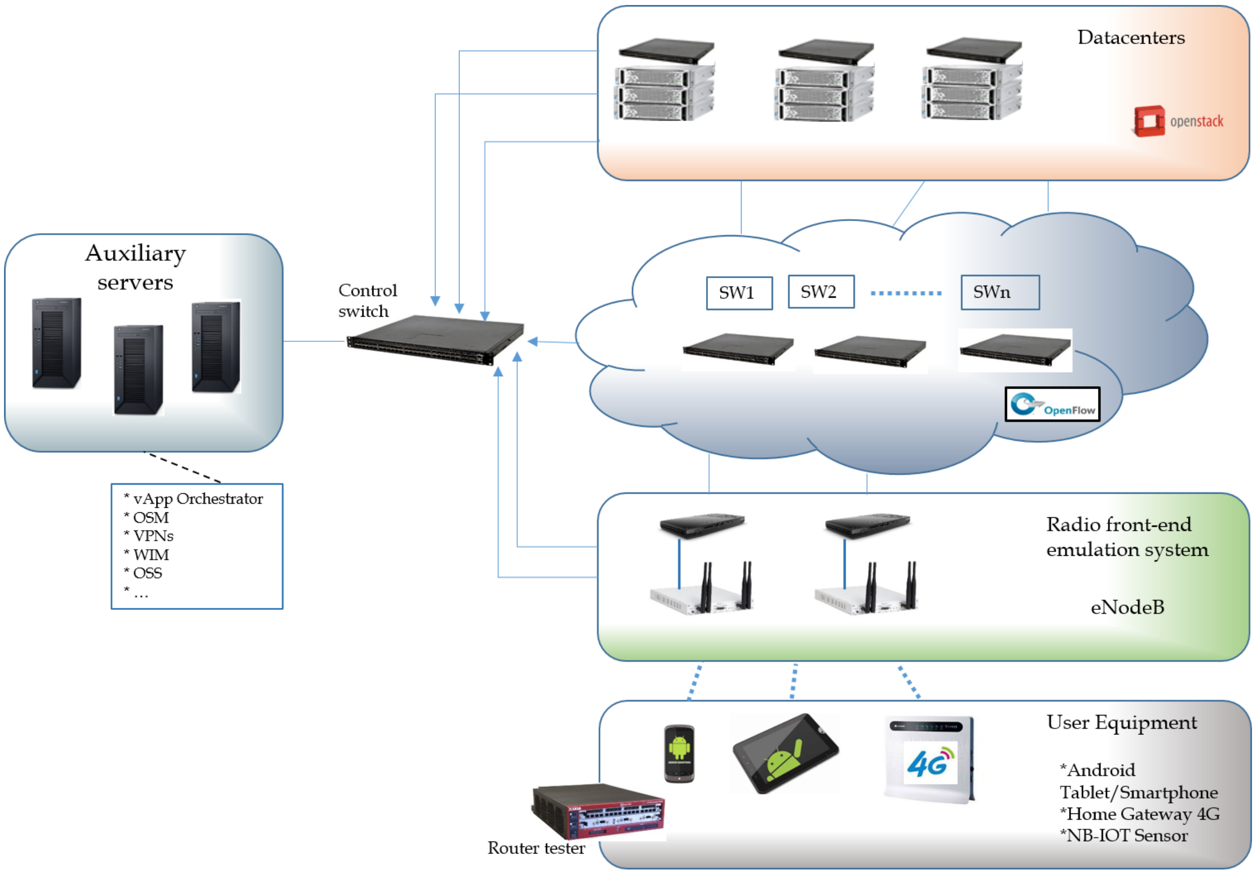

Figure 4.6: CNIT testbed physical architecture.

The testbed consists of a set of high-performance equipment and several computing and networking technologies used nowadays. The equipment used in the testbed is detailed below:

- A set of servers for the compute nodes
  - 6x blade servers Intel KP-S2600KPR (3x Xeon E5-2630v4 Q1'16/3x E5-2660v4 Q1'16, 2.2/2.0Ghz, 20/28 cores, 64/128GB RAM)
- An optional set of compute nodes available on request for the needs of vertical applications
  - 2x servers (2x Xeon E5-2643 v3 Q3'14, 3.4 GHz, 12 cores, 64GB RAM)
  - 1x server HP EDL560 Gen8 (4x Xeon E5-4610 v2 Q1'14, 2.3GHz, 32 cores, 128GB RAM)
  - 1x Supermicro server (2x Xeon E5-2630v2 Q3'13, 2.6GHz, 12 cores, 32GB RAM)
- A set of servers for the network nodes. One of these servers will be used to host the OpenStack controllers
  - 3x server HPE DL360 Gen9 (1x Xeon E5-2620 v4 Q1'16, 2.1GHz, 8 cores, 64GB RAM) (these servers will be probably upgraded to double the number of cores and the RAM)
- A set of servers used for auxiliary purposes, including storage
  - 3x Supermicro server (2x Xeon X5650 Q1'10/Xeon X5640 Q1'10, 12/8 cores, 2.66GHz, 48GB)
- Network adapters for server connectivity
  - 6/12x Intel X710, dual port, 10 GbE
  - 3x Intel x520, dual port, 10 GbE
  - 2x Mellanox ConnectX-2, dual port, 10 GbE
  - 2x Mellanox ConnectX-3, dual port, 40 GbE
- High performance Ethernet switches with OpenFlow and SDN support.
  - 1x Pica8 Pronto 3920 48 Port 10 GE with 4 Port 40 GE
  - 2x Pica8 Pronto 3290 48GE with 4 Port 10 GE
- 1x Mellanox SX6036 36 Port 40 GE, with 10GbE adapters (this switch will be used within the 3 datacenters depicted in Figure 4.6).
- A radio front-end emulation system
  - 2x Intel NUC i7-32 GB
  - 2x NI USRP B210 board
- 4G User Equipment
  - 2x SODAQ SARA-N211 NB-IoT
  - 2x FRITZ!Box 6820 LTE modem
  - 1x Samsung Galaxy Tab A T285
  - 1x Samsung Galaxy S5 (dual sim)

With this configuration, the testbed provides 268 physical cores, and with the acquisition of new storage disks the maximum available storage capacity of the testbed is around 30 TB (RAID protected).

Regarding the connectivity in the testbed (Figure 4.6), there are two different speed link connections:

- 1 Gbps for the control network, eNodeB links and 4G HGs.
- 10/40 Gbps for the datacenter network.

In order to guarantee a full integration of the testbed it is essential to highlight some of its relevant characteristics and requirements:

- Multi-node OpenStack architecture with a separate controller node. The OpenStack version used in the testbed is Queens with administration access.
- OpenStack compatibility with Open Source NFV Management and Orchestration (MANO) release THREE
- OpenStack Networking with the support of (*i*) Single Root I/O Virtualization and Sharing (SR-IOV) mechanism with VLAN, and (*ii*) Virtual Extensible LAN (VxLAN) technology.
- VNFs compatibility guaranteed among themselves, with the UBITECH/COSM testbed, with the three testbeds deployed in the project, and with the partners use case applications.
- Network termination points compatible with the testbeds' mobile network deployments.
- Network slice attach points towards vertical industries.

This CNIT, UBITECH and COSM integration testbed, within the MATILDA project, will provide a significant environment for supporting the different vertical applications that will be illustrated and validated upon it.

Connectivity Resources

In the context of MATILDA, complementarily to the live testbed deployments, an LTE/EPC/IMS testbed (at COSMOTE premises) can be used (as initial testing/integration environment), complemented with a Cloud (Openstack-based) setup. The setup is based on a lightweight 4G EPC/IMS – Evolved Packet Core/IP Multimedia Subsystem provided by ATHONET, where the two core network components (EPC and IMS) comprise two Virtual Machines (VMs) hosted on a PowerEdge Dell R630 server (32GB RAM, 600GB HD, QP1G NIC (10Gbps)). The setup is presented in Figure 4.7:

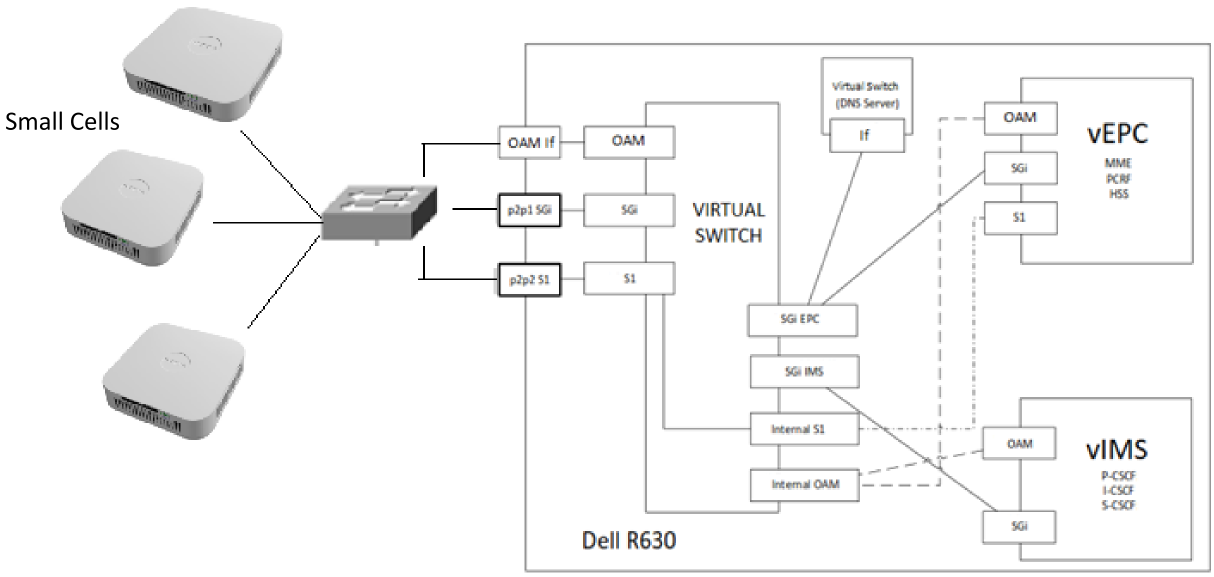

Figure 4.7: COSMOTE LTE/EPC/IMS Testbed Deployment.

The test EPC/IMS deployment constitutes a small scale, real mobile network, allowing one to perform all standardized 4G EPC/IMS functions; e.g. user/USIM/QoS profiles/APNs definition, Network and Service Access Control/network parameters' configuration, traffic monitoring etc., and is upgradable to 5G 3GPP releases. The solution exposes a REST API interface, to allow the execution of a number of functions through external software (JSON or XML based communication), thus providing an automated and configurable environment to be used by the MATILDA southbound interface, which can be easily extended with 5G concepts.

The deployment is complemented by a number of small cells connected to the EPC; namely, a number of "Flexi Zone Multiband Indoor Pico BTS" (FZ MBI) provided by NOKIA. These small cells provide all LTE macro cell functionalities, being a fully compliant 3GPP solution, and support standard network interfaces to other network elements, such as S1 and X2 in LTE. The small cells air interface supports 5 (only FDD), 10, 15, or 20 MHz LTE carriers with 2x2 MIMO, as well as a Wi-Fi interface at 2.4GHz and 5GHz, thus delivering a Heterogeneous network solution.

Compute and Storage Resources

Complementarily, a cloud setup based on OpenStack Pike (Ubuntu Server 16.04 LTS) can be made available to provide compute and storage resources.

5 Demonstrator 1: High Resolution Media on Demand Vertical, with Smart Retail Venues' integration

5.1 Business Scenario

The High Resolution Media on Demand Vertical, with Smart Retail Venues' integration Demonstration builds on top of the High Resolution Media on Demand (ITL) and Banking on the Cloud (INC) use cases and relevant software solutions. As described in Section 5.4, this is enabled through providing concrete integration points, by utilizing the service mesh approach of the MATILDA framework.

This paired demonstration involves a user that is moving around a crowded venue, such as a shopping mall or an open-air market area, sharing high quality media contents with his/her peers (Figure 5.1), while making purchases around the brick and mortar shops that are part of this venue.

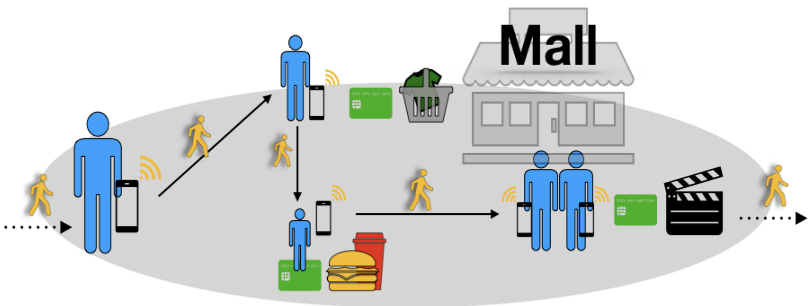

Figure 5.1: A user journey inside a shopping mall area. Users receive and share high quality media content and personalized recommendations while moving around the shops.

The user, through his/her mobile device, can discover personalized recommendations and offers, based on his/her exact current location, and his/her preference to consume certain types of products or services (possibly in sequences or bundles). Such data-driven retail recommendations come in the form of a *"Move to next shop that offers an A% discount just for you"* visual aid on the user's mobile screen, and are created by applying advanced machine learning methods on the user's purchase history and mobility data, in user-perceived real-time.

It should be noted that the calculation of such retail recommendations is done via the Incelligent's software platform and is delivered to the end user by the i-EVS application and edge platform of Italtel. Due to the service-mesh nature of the MATILDA framework, both functionalities can be developed in parallel and independently and offered either separately or as services that are part of the MATILDA application graph.

The two main components of this overall framework have already been described in detail in Deliverable D1.1 [1]. The respective application graphs are described in the next two subsections, along with a brief explanation of their functionalities. Moreover, the interaction points between the two systems are also introduced and briefly discussed.

5.2 Vertical Application Reference Structure

5.2.1 i-EVS System

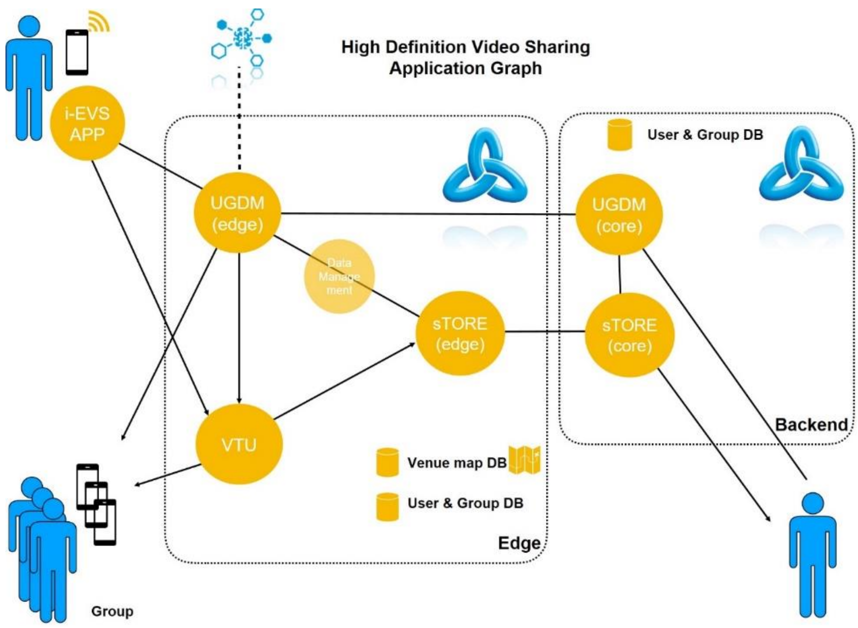

Figure 5.2: i-EVS application graph.

Figure 5.2 shows the Application Graph of the i-EVS system. i-EVS gives the possibility of sharing High Definition (HD) video content, anywhere, at any time and via any device, with the chance of (perceived) real-time interaction with the system and among the users.

It consists of two components, the i-EVS Cloud Application and the i-EVS App. The Cloud Application provides video processing and data storage functionalities. It also manages the information related to the users (organized in groups) accessing i-EVS services, by storing and keeping the related data updated in the i-EVS User and Group Database.

The App can be downloaded by the users onto their devices; it offers the possibility to register to i-EVS, and create groups of users who can access the provided services. The App provides geo-localization and image processing services. The main features of the i-EVS Cloud Application and App, as well as their interactions, are summarized in the next paragraphs.

The i-EVS Cloud Application

The i-EVS Cloud Application consists of three Components, namely the Video Transcoding Unit (VTU), the User and Group Database Manager (UGDM) and the sTORE component.

The VTU can provide three main functionalities, i.e. i) Video/ Audio transcoding; ii) Media streaming, and iii) Video/ Audio file upload/download. The VTU can convert audio and video streams from one format to another. The source stream can originate from a file within the local storage system, or as a packetized network stream. The requested transcoding service can be mono-directional, as in video streaming, or bi-directional, like in videoconferencing.

The UGDM component, conversely, handles and stores all the information about CE participants, which have registered to i-EVS. It provides Operation and Maintenance (O&M) functionalities, and manages the local storage system where audio/video data are stored (sTORE). UGDM collects and monitors relevant information about CE participants and groups, storing it into an ad hoc database, the User and Group Database. Any user connecting to the network during a CE can download the i-EVS App, and register to the system. Registered users are permanently identified by a randomly generated key that remains unchanged for the entire duration of the event, combined with user name and/or nickname.

The i-EVS App

i-EVS offers a web-based interface, accessible from any browser. However, to improve User Experience, a specific i-EVS App has been developed. Through the App, users can register to i-EVS, as described above, create groups and access services. A shared local storage area is assigned to each group, where all the users of the group can read or write media contents privately. The simplest services accessible through the App include video file exchange and video chatting. In addition, geo-location functions and QR code readers can be provided, combined with augmented-reality-based applications.

Finally, the i-EVS system includes a back-end component, which can be used for long term storage of contents, and maintaining user management data after the duration of specific events.

5.2.2 Smart Recommendation System

In Figure 5.3, the applications graph components with respect to both Backend and Edge functionalities are described. Data management components are necessary in both cases. Interesting to note that the modelling methods employed take into account information from large datasets including diverse data that involve user specific, spatial and temporal data:

- Client profile (i.e. demographics, registration data, corresponding market segments, etc.)
- Time-related data (such as time of year, day, time of day, sales period, mean time spent in specific areas, etc.)
- Area/ venue-related data (e.g. mapping of open area/venue, paths & areas of interest, mapping of stores within the area)

- Current/ previous offers and campaign data (modelled based on parameters such as type of store/offer, monetary value, time of year/event).

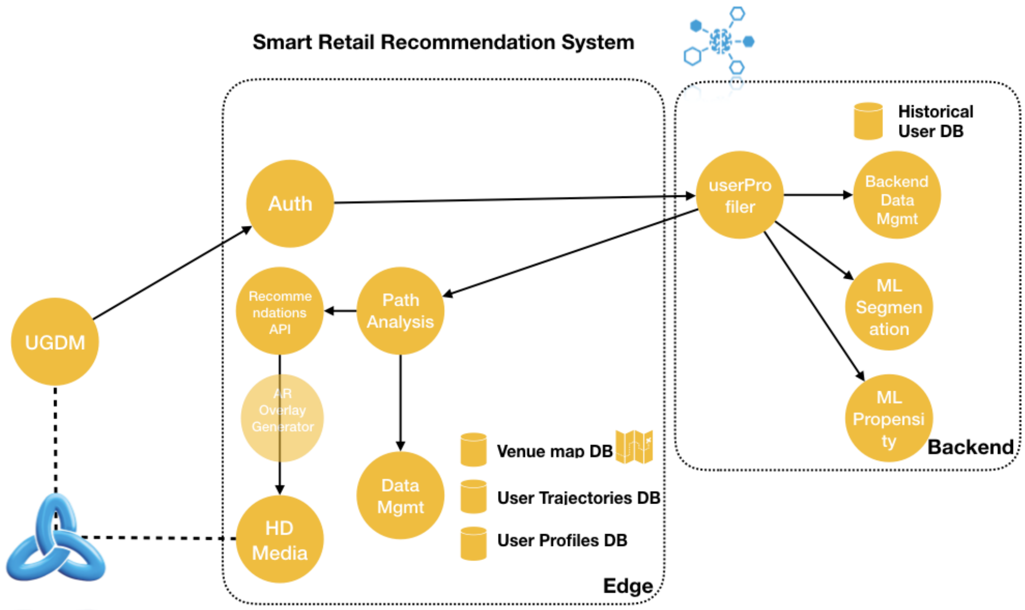

Figure 5.3: Incelligent recommendation system Application graph.

At the Backend, the "user profiler" component utilizes results from machine learning components that offer advanced user segmentation and prediction of user propensity to buy for profiling purposes. The component mechanisms include a series of advanced ML methods, incorporating various aspects of the Customer Relationship Management (CRM) modelling. In particular, models trained at the central premises use open source and proprietary software for both supervised and unsupervised techniques. Various data analysis methodologies are employed and tested -supervised and unsupervised, separately or combined- for clustering, dimensionality reduction, classification and regression. The user profiler component updates the ML components at the edge.

At the edge, basic user profile data, segmentation and location analytics for the extraction of highly probable paths and mobility patterns, along with the area map representation of the shop placement and type together with the corresponding offers, are employed for user movement prediction (Path Analysis). These mobility patterns can be regularly updated based on new mobility patterns or with respect to specific events (e.g., concerts). Lastly, the recommendation API delivers the retail recommendation offer based on the probability and size of transaction, given specific nearby offers and the advanced user profile assigned by the headquarters.

5.2.3 Joint Scenario workflow

An indicative action and corresponding work- and data- flow for the paired demonstration is depicted in Figure 5.4. This representation follows how the network application interprets and reacts to the way a user moves inside the mall and engages in its retail stores.

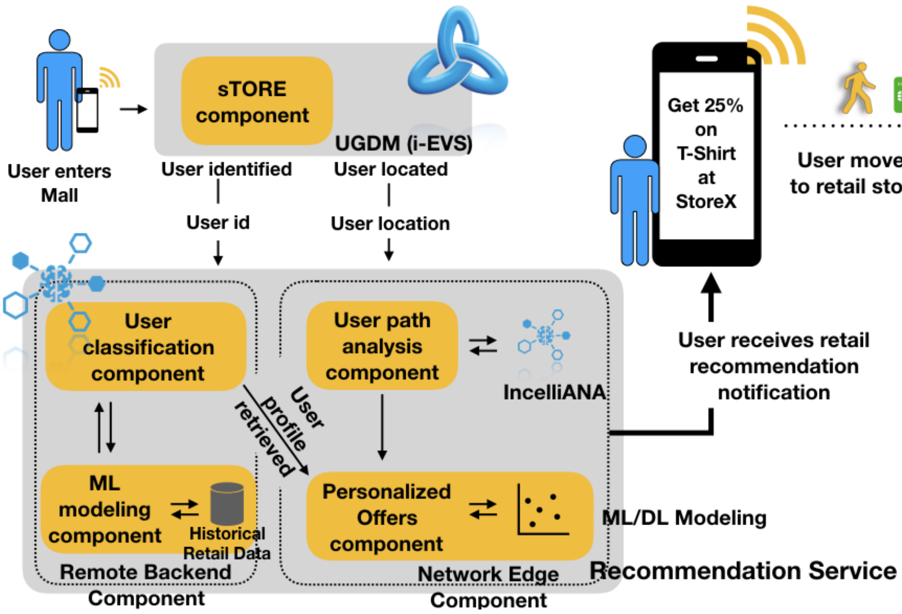

Figure 5.4: The work and data flow of the system. A user gets identified, associated with a user profile at the backend component, and receives a personalized/localized offer on screen by the edge recommendation service component.

The user must be identified as a single entity across i-EVS and the Incelligent edge recommendation component. Both components are physically located at the network edge (i.e. at the mall) running as VNFs or virtualized containers on an OpenStack edge cloud. The deployment is depicted in Figure 5.5.

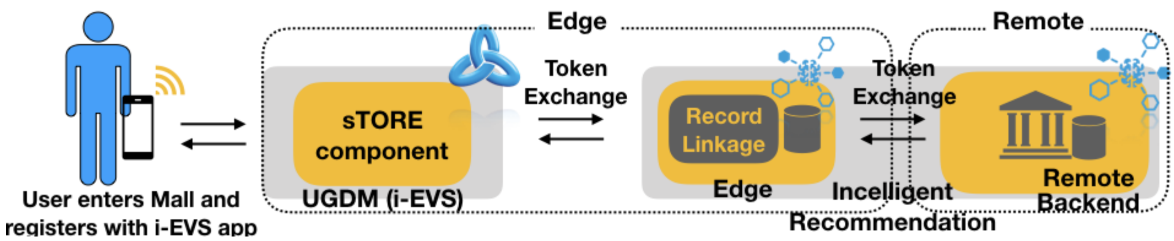

Figure 5.5: User identification across the recommendation service edge and backend components.

A simple scenario always starts with the user registering his/herself to the i-EVS User and Group Database Manager (UGDM), which is a Component of the i-EVS Cloud Application. The recommendation service component includes a database of previous interactions between consumers and retailers. This database can either be located at the network edge, or at the backend, in the recommendation service providers premises, depending on (mostly privacy conserving) SLAs. This data store contains a combination of historical data, i.e., past purchases made by the considered user.

To bridge the data flow between the two services, the i-EVS user securely identifies his/herself with the edge recommendation component, which acts as a broker to the recommendation service provider. This can happen via a password or fingerprint authentication mechanism on the mobile device. The token returned by a successful identification is stored together with the i-EVS user key, demographics data and location data in the recommendation service database. This data exchange is performed between the two services (i-EVS and recommendation) that live in separate Virtual Machines/containers and expose interfaces according to the microservice/service mesh paradigm.

Once a user's identity is successfully resolved (as per the previous subsection) his/her behaviour must be modelled. Taking into account the particular demographic data and purchase history, the user is clustered inside a microsegment of the consumer base with specific characteristics and propensities to consume. This modelling task involves advanced machine learning and deep learning methods that (i) are computationally intensive, thus they must be performed where adequate computing power (CPU- and GPU-based) is available, and (ii) are used as the starting point for a specific offer recommendation, thus they can be run asynchronously with no detrimental effect on the user's QoE. Hence, the user profiling functionality can be offloaded to the backend component. The user model, expressed in terms of consumption behavioural patterns, is produced at the remote backend service component; hence, the backend component must expose such a user model to the edge component through a RESTful API with a semi-structured (i.e. JSON) payload. Both service components reside in virtual or container images that are orchestrated externally in terms of availability, service discovery and monitoring.

Once a retail recommendation for a specific user has been originated by the INC system, it is sent back to i-EVS. The retail recommendation can be complemented with media contents, which are already resident in the VTU component of i-EVS or are included in the data sent from the smart recommendation system to i-EVS. A process running in the VTU components finalizes the media message with retail recommendations and transmits it to the end-user device.

5.2.4 Joint Network Slice Intent Metamodel

The paired demonstration scenario will be deployed at the same time in the demonstration testbeds. Hence, it makes sense to produce a joint Network Slice Intent Metamodel which captures the network and compute requirements for the scenario to run smoothly.

Table 5.1 provides an example of a Network Slice Intent Metamodel, as defined in MATILDA Deliverable D1.4, for a possible implementation of the proposed framework for immersive services.

Table 5.1: Network Slice Intent Metamodel.

Element	Level 1	Level 2	Level 3	Level 4	Example
ServiceMeshIdentifier					<ServiceMeshID.ServiceMeshIhInstance> e.g. SM.01.01
Constraints	ComponentHosting Constraints	ResourceConstraint			X vCPU X RAM X Storage
		LocationConstraint			Access/Core
	GraphLinkConstraints	GraphLinkQoS Constraint	Delay		100 ms
			Jitter		100 ms
			PacketLoss		0.001%
			Throughput		X Gbps
	AccessConstraints	AccessConstraint	AccessQualityProfile	QCI	
				ResourceType	
				Priority	
				PacketDelayBudget	100 ms
				PacketErrorLossRate	
				UE Type	
LogicalFunctions	VPN	VPN Configuration			Allow/Deny

5.3 *Relevance of MATILDA Framework*

The framework proposed by MATILDA can significantly facilitate the creation and deployment of the combined Italtel – Incelligent system for immersive and personalized services during CEs. In particular, the MATILDA proposal contributes on two main aspects, i.e., *i)* the creation and management of a MATILDA Network Slice, which includes all the network and IT resources required to provide the offered service, and *ii)* the straightforward integration of the two inter-operating systems into a unique framework through the micro-service approach ("Service Mesh").

The combined Italtel and Incelligent systems require a large and heterogeneous set of compute and network resources. For instance, to provide an effective and sustainable solution in production deployment both from the financial and energy-efficient point of view, they both need the support of Hardware (in particular, Graphical Processing Units) to perform the most compute-intensive task at the network edge. In addition, besides RAN connectivity, they also need interconnecting the software components running at the network edge with the backend components in the core network.

MATILDA can greatly simplify the allocation of such resources, typically required by a vertical Service Provider of a Telecom Operator, through the Slice-Intent and Slice Metamodels and the underlying “request/response” negotiation mechanism (described in MATILDA Deliverable D1.4). Moreover, MATILDA also provides built-in means that enable enforce deployment and runtime policies, as well as system monitoring capabilities.

MATILDA can greatly simplify the interworking process between the i-EVS and the Incelligent system. We recall that the two systems must continuously exchange data related to user authentication, geo-localization, etc. Instead of developing a proprietary interaction mechanism between the two systems, the underlying MATILDA “Service Mesh”–based and orchestrator approach can be used. Interworking between the software components constituting the overall 5G-ready Application is formally described in the 5G-ready Application Graph Metamodel. The Service Mesh approach can then facilitate data exchange, abstracting from network topology issues and the specific deployment environment of the 5G-ready application.

5.4 Requested Testbed Resources

The descriptions given above allow to summarize the main infrastructural elements needed to deploy the proposed system.

Compute and Storage Resources

The i-EVS VNF and the recommendation service edge component run as software appliances on the edge virtualized infrastructure, which must hence provide adequate local compute and storage resources, as envisioned by MEC. For video processing functions, GPUs must be available. Such GPU resources can also be used by the edge recommendation service component. The virtualized infrastructure manager is OpenStack. The system can interoperate with different ETSI MANO Open Source orchestrators, such as Open Source Mano. Additionally, remote resources (i.e. not included in the local MEC infrastructure), to store media content produced by the users also beyond the CE duration and to run the backend recommendation service, can be potentially required.

Connectivity

Wireless local connectivity must be provided to the users to access the provided services. Moreover, connectivity of the local blocks to the remote storage and compute resources is needed. To provide high quality, immersive video services, anywhere and with any device, two features play a fundamental role from the local connectivity point of view, i.e., bandwidth and latency, both on the user plane and on the control plane.

The 5G architecture will provide significant advances related to such parameters. 5G networks will enable eMBB (enhanced Mobile Broad Band) types of services, and will operate in scenarios with high user device densities (more than 10,000 per km^2) and low latency.

The 5G network will start operations from 2020. Thus, other scenarios must be considered. One solution consists in using a WiFi access network. A second option is the use of Small Cells. In this case, the present 4G mobile network architecture can be used.

5.5 KPI Description and Acceptance Criteria

The main network KPIs for this demonstrator are the ones that typically characterize a Crowded Event, as represented in Table 5.2 below. In Table 5.3, conversely, we report a list of meaningful operational KPIs, which focus on the capabilities that the Matilda Framework should make available to handle the overall lifecycle of the 5GPACE App.

Table 5.2: Network KPIs for Demonstrator 1.

KPI	Description	Acceptance Criteria/ Threshold
Device Density	The application expects a big number of connected devices	~32 per Small Cell ~50 per WIFI Hot Spot
Mobility	End-User mobility	Static users/low (0-3m/s)
Availability	Network availability	>99%
Reliability	Network reliability	>99%
User Data Rate	As a video application, high data rates per user are required.	~10 Mbps/user, depending on quality
End-to-end Latency	For real-time video sharing, small delays are required	Maximum 1 s
Access Interoperability	Interoperability with various access technologies (4G/5G/WAN)	Must be available
Edge Computing	Edge computing capabilities for network offloading	Must be available
Storage at the Edge	Storage capabilities to save multimedia contents at the network edge	Must be available
Computing acceleration at the edge	High resolution video processing requires HW acceleration	Must be available
Network Slicing Capability	Network Slice Management	Must be available

Table 5.3: Operational KPIs for Demonstrator 1.

KPI	Description	Acceptance Criteria/ Threshold
5GPACE App deployment time	Time to on-board and deploy for the first time the 5GPACE App	~90 minutes
5GPACE App on-boarding time	Time required of the App developer to on-board the 5GPACE App	~15 minutes
Resource Usage Monitoring	Compute/storage/networking resource usage monitoring	Must be available

5GPACE App component scalability	Specific components of the 5GPACE App must be able to scale horizontally	Must be available
Scaling time	Time required to start/stop a component once a pre-defined parameter crosses the corresponding threshold	~ 20s
Availability	Service availability	High >99%
Reliability	Service reliability	High 99%
5GPACE App repository	Repository for the on-boarded App	Must be available
Locality Awareness	The 5GPACE App requires locality awareness	Must be available
HW video acceleration management	Management of HW acceleration resources in the infrastructure	Must be available
Multi-site management	The 5GPACE App can be composed of components instantiated in different sites	Must be available

To correctly dimension the needed network, compute and storage resources to achieve the given KPIs, ad hoc modelling tools have been developed and are available for i-EVS. Such tools can express the amount of IT resources as a function of the total number of attendees, and few Quality of Experience related parameters.

5.6 Privacy and Security Compliance

Demonstrator 1 is designed to support a number of end-users who are citizens and consumers of retail products. Furthermore, their interaction with the 5G ready application is taking place through their mobile devices (User Equipment). It involves *i*) the gathering of private and sensitive data which include demographic, location and consumption data points, and *ii*) the processing of such data to provide purchase recommendations. To this extent, it is recognized that user privacy must be absolutely respected according to trade ethics and privacy regulations, especially with respect to the General Data Protection Regulation [2], which is enforced in the EU area since May 25th, 2018.

To this end, a list of the measures that are taken during the design, development and deployment of the 5GPACE application follows below, organized by requirement. It should be noted that the testbed on which the application will be deployed is a controlled environment and that in production the requirements will be further reinforced.

5.6.1 Obtaining Consent

Before registering to use the application, the users agree to a set of terms of consent which are clear and describe exactly how their data will be stored and processed. The first screen of the application states this clearly. The users can withdraw their consent through the Settings screen in the app.

5.6.2 Timely Breach Notification

In case of a security breach, the users are notified via their email accounts within 72 hours since the breach acknowledgment.

5.6.3 Right to Data Access

The users can request their data profile in an electronic copy at any time including which predictive models were trained using their data profiles.

5.6.4 Right to Be Forgotten

The users can request the total erasure of their personal data at any time, once models are trained.

5.6.5 Data Portability

The users can request that the original data they provided to the application are returned to be used in another setting. This does not include predictive models trained using their personal data. It is explicitly mentioned that, once models are trained, the trained model does not include any of their original data.

5.6.6 Privacy by Design

The 5GPACE application employs secure protocols within its internal components. Furthermore, personal data are anonymized through data transmission between microservices, the edge and the backend.

6 Demonstrator 2: Testing 4.0 - Distributed System Testing

6.1 Business Scenario

It is expected that 5G will not only be an evolution of mobile broadband networks, but rather it will enable new unique network and service capabilities. These include not only enhanced user experience continuity in challenging situations such as high mobility (e.g. in trains), very dense or sparsely populated areas, and journeys covered by heterogeneous technologies, but it will also be a key enabler for the Internet of Things and the next generation of remote testing by providing a platform to connect a massive number of sensors, industrial devices, control and monitoring equipment, etc., with stringent energy and transmission constraints, as well as high reliability, high QoS, global coverage and very low latency.

With this in mind, it is interesting to consider that, to a great extent, all major industries throughout Europe and the world require a form of distributed communication of Industrial Bus Signals between machines and/or software that fulfils the following necessities:

- **High Quality of Service**
- **Real-time**
- **Guaranteed Data Delivery with High Data Volume Capabilities (Reliability)**
- **Interoperability (Plug & Play)**
- **Modularity & Scalability**

Presently, compliance with these communication necessities can only be assured in an isolated scenario, i.e., with a dedicated physically connected local network infrastructure, and not between geographically separated locations using Wireless Wide Area Networks (WWAN) communication technologies.

Furthermore, today's systems, especially in the Automotive Industry, are made up of complex integrated systems with several components being developed at geographically distributed locations. Integration and functional testing of these highly coupled systems involve a great deal of logistics, high amount of personnel, and most importantly a lot of time and high costs.

FastWAN is an experimental communication technology that was developed as a solution for the enablement of geographically separated real time industrial test benches. FastWAN presently provides the following features:

- Support and provision of virtual extensions over the Internet for a variety of industry BUS Standards such as AFDX, ARINC 429, Digital, Analog, etc.
- Assurance of time and quality delivery for all signal data with efficient data acquisition and packing
- Deterministic and reliable reconstruction of signals at destination by using accurate GPS signal time stamping, configurable fixed delays, and jitter compensation
- Integration of fast standard data "container" transmission services such as Ethernet UDP
- Assurance of reliable data transmission integrity by way of failure detection (detection of lost or incorrectly ordered packets), as well as recovery mechanisms (packet re-ordering and re-transmission)
- Efficient bandwidth usage with customized proprietary packing methods based on signal priorities and destination requirements
- Comprehensive system control and monitoring GUI to monitor the data logistics network and virtual connection statistics

Within the automotive Industry, FastWAN, based on the MATILDA 5G Framework, can enable a superior interconnected integration and functional testing of these end product systems over WWAN infrastructures. This will further improve the reduction in system development life cycle times and costs in an environment where system complexity, competition and certification requirements are dramatically increasing. More particularly, only by means of 5G technology and the MATILDA architecture, is it possible to achieve greater quality of service whilst dramatically increasing flexibility. This flexibility refers to the fact that test campaign strategies can be revolutionized by eliminating geographical constraints. This 5G FastWAN solution will allow test campaigns responsible to interconnect a much greater number of devices, over a more diverse range of interface means (e.g. UMTS, WLAN, LAN, etc.), whilst being much less restricted by geographical location. This can be achieved while maintaining, for the entire time, the demanding requirements of the closed loop system and equipment tests; namely, QoS, latency and flexibility. In summary, the four main goals for this demonstration are as follows:

- Unifying the interfaces to Industrial Bus Signal Protocols
- Providing interoperability with various Access Networks (Ethernet, LTE, WLAN, etc.)
- Reducing / compressing the amount of Industrial Bus Data sent over the network
- Increasing the QoS, Speed and Integrity of the Network

6.2 Vertical Application Reference Structure

ExxpertSystems will adopt the role of telecommunication equipment vendor (converting industrial Bus Protocol Signals into Internet Packets and vice versa) by providing a Physical Network Function (PNF); namely, the ExxpertSystems FastWAN solution.

Usually, the development of test systems for the Automobile Industry is done internally by the same company that wants to use it. So, it is common that the roles of 5G Application Developer, Service Consumer and Service Provider are played by the same stakeholder: the final consumer itself.

The general Network Requirements are as follows:

- Flexible Bandwidth Allocation
- Low Delay/Latency
- High Availability
- Interoperability with Various Access Networks (WAN, LTE, 5G, etc.)
- Security & Privacy
- Dynamic QoS Provisioning
- Network Programmability
- Network Monitoring

These are quantified in the Application Graph of Fig. 6.1.

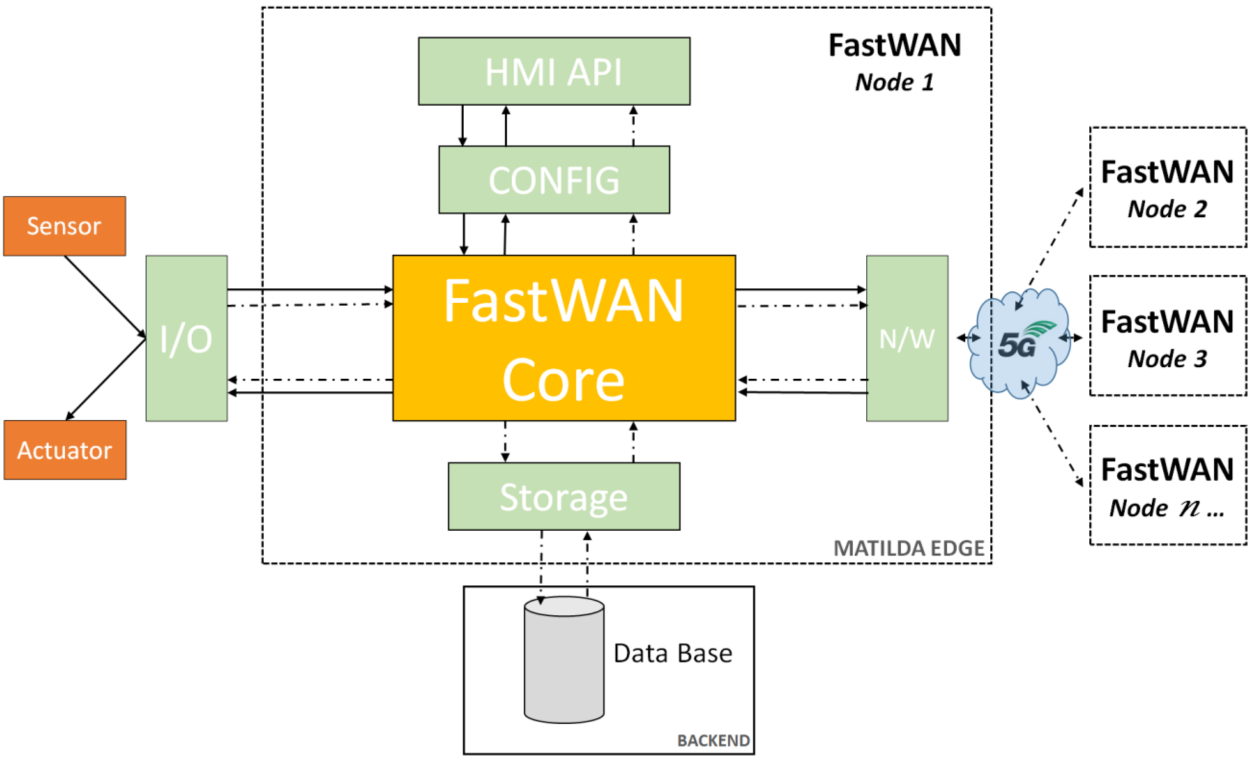

Figure 6.1: Application Graph of the FastWAN demonstrator.

The high-level architecture for the FastWAN demonstrator is depicted in Fig. 6.2.

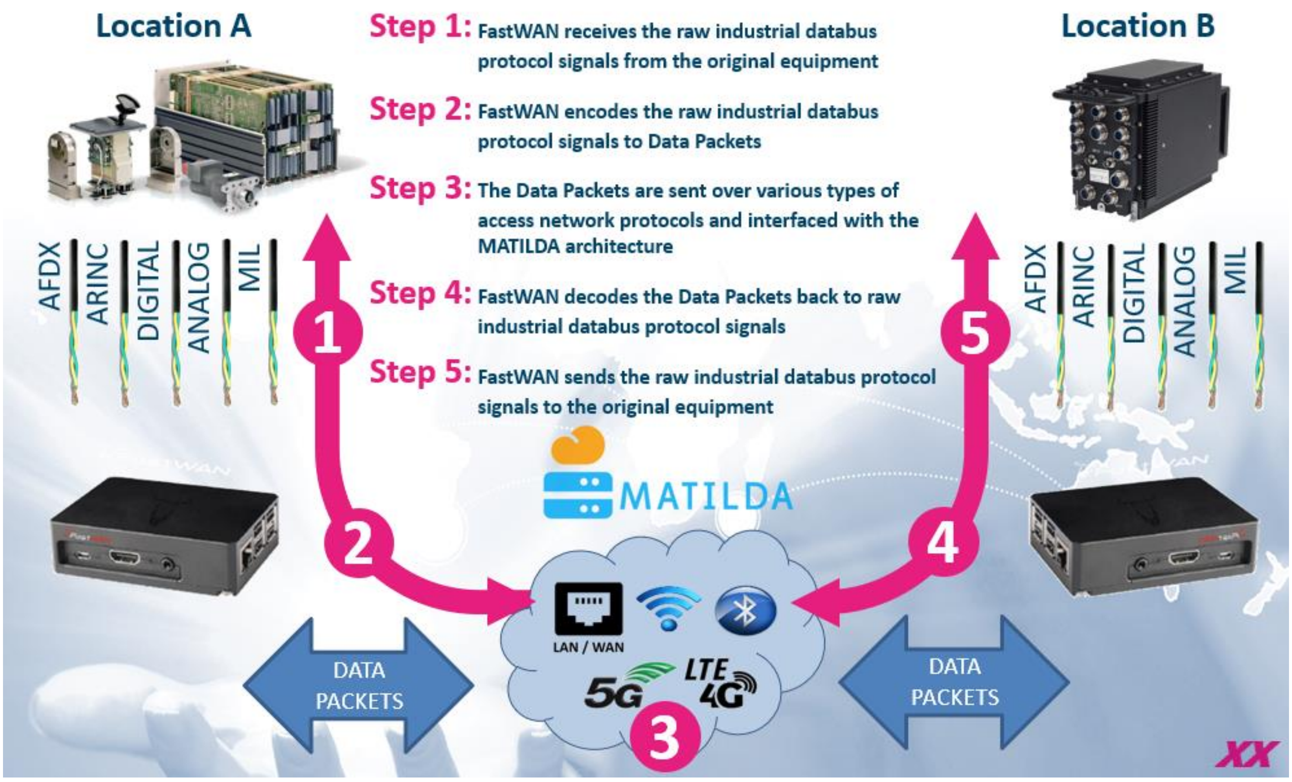

Figure 6.2: Physical Component Architechture of the FastWAN Demonstrator.

The FastWAN solution is a software/hardware solution that interfaces with the MATILDA 5G Network. The FastWAN solution provides an Access interface that is in charge of:

- Interfacing with Systems / Equipment Under Test by way of unified Industrial Bus Signal Protocol interfaces
- Reducing / compressing the amount of Industrial Bus Data sent over the network
- Interfacing with the MATILDA 5G Network over various Access Networks (Ethernet, LTE, WLAN, etc.)

The data will be sent over a common Internet Infrastructure provided by a Telecommunications Network Provider. This solution will be provided to engineers responsible for the creation of the tests/testing systems, who can then develop their own 5G Application on its basis.

6.2.1 Joint Network Slice Intent Metamodel

The FastWAN slice intent metamodel proposal aims to represent all the requirements that should be satisfied by the telco provider during the creation of the network slice that will facilitate the deployment of the application.

Table 6.1 provides an example of a network slice intent metamodel for a possible implementation of the proposed framework.

Table 6.1: Network Slice Intent Metamodel.

Element	Level 1	Level 2	Level 3	Level 4	Example
Constraints	ComponentHosting Constraints	ResourceConstraint			4 CPU 8 GB RAM 40 GB Disk
		LocationConstraint			Access/Core
	GraphLinkConstraints	GraphLinkQoS Constraint	Delay		100 ms
			Jitter		< 1 ms
			PacketLoss		< 0.01%
			Throughput		50 Mbps
LogicalFunctions	Firewall	FirewallConfiguration			Allow / deny rules

6.3 Relevance of MATILDA Framework

In order for the FastWAN solution to extend its potential use cases by increasing QoS, performance and flexibility, the integration into the MATILDA Framework is crucial, owing to the MATILDA intelligent orchestration platform that is able to support end-to-end applications and services provision over a programmable network, compute and storage infrastructure. In other words, the MATILDA Framework enables network slices as end-to-end (E2E) logical networks running on a common underlying (physical or virtual) network, mutually isolated, with independent control and management, and which can be created on demand. This ensures the optimal efficiency of the network for highly critical and performance dependent use cases.

6.4 Requested Testbed Resources

The following types of connectivity shall be provided by the test beds:

- LTE - for high-speed wireless communication that increases the mobility and geographical freedom of the FastWAN Use Cases
- WLAN - to enable the wireless interconnection of FastWAN nodes to the MATILDA Infrastructure
- Ethernet – to enable the highest speed interconnection of the FastWAN nodes over the MATILDA infrastructure.

6.5 KPI Description and Acceptance Criteria

Table 6.2: Network KPIs for Demonstrator 2.

KPI	Description	Acceptance Criteria/ Threshold
`Flexible Bandwidth Allocation`	Flexible bandwidth allocation is needed between geographically distributed systems / sub-systems under test to ensure the integrity and required performance of distributed functional and integration testing.	Flexible network that supports data rates up to: 10 Mbit/s (Mbps) per Node (FastWAN Unit).

Low Delay/Latency	Low Delay is required between geographically distributed systems / sub-systems under test to ensure the integrity and required performance of functional and integration testing.	• Inside Germany - Approximately 50 ms Latency in node • Inside Europe - Approximately 100 ms Latency in node • Worldwide - Approximately 200 ms Latency in node
Interoperability with Various Access Networks (WLAN, LTE, Ethernet)	The infrastructure/services for deploying FastWAN Test Systems shall be supported seamlessly over various Access Networks.	WLAN LTE Ethernet

Table 6.3: Operational KPIs for Demonstrator 2.

KPI	Description	Acceptance Criteria/ Threshold
High Availability	The test systems interconnection infrastructure/services shall be always available.	99.99% of operational time
Resource Usage Monitoring	To allow preparation of dynamic scaling the monitoring of the current resource usage is needed	Must be available
Component scalability	Dynamic scaling is needed to fulfill actual user communication requests	Must be available
Deployment time	Time needed for first installation and onboarding	~90 minutes
Onboarding time	Time needed for update and onboarding during development	~15 minutes
Locality Awareness	Locality awareness needed for optimized scalability and communication	Must be available
Multi-site management	Functionality at its core is implemented as a distributed application	Must be available

7 Demonstrator 3: 5G Emergency Infrastructure with SLA Enforcement

7.1 Business Scenario

The 5G Emergency Infrastructure and Services Orchestration with Service Level Agreement (SLA) Enforcement demonstration is based on the implementation of a 5G-enabled emergency response pilot provided with the iMON product suite for real time intervention monitoring and critical infrastructure protection, extended with performance monitoring engines and advanced Operation, Administration and Management (OAM) capabilities of the qMON solution for supporting SLA.

Main goals are the following:

- Extending capabilities of the iMON (intervention MONitoring) solution to support high availability and scalability of the system in extreme conditions (natural and man-made disasters) based on distributed IaaS deployments of the iMON components.
- Novel provisioning technologies for distributed applications in cloud-based and virtualized 5G environments for public safety.
- Automatization of setup, deployment and scaling of the PPDR services and 5G network slices for the public safety use.
- Active and passive monitoring and QoS/QoE measurement and diagnostics for cloud-based and virtualized 5G environments.
- SLA/SLS enforcement and continuous 5G system/services monitoring based on the MATILDA orchestrated qMON product suite.
- VNF/PNF (MANO enabled) as part of the application graph to enable end-to-end service and network monitoring in 5G.

More details are available in the Deliverable D1.1 [1].

7.2 Vertical Application Reference Structure

The high-level architecture showing the iMON-based PPDR demonstrator is shown in Fig. 7.1. More on the iMON-based PPDR solution is available in the Deliverable D1.1.

The MATILDA-based iMON solution encompasses four main architectural blocks:

- Broadband Public Protection and Relief (BB-PPDR) Head Quarters using iMON Dashboard for real-time monitoring and management of field units (e.g. first responders),
- Broadband BBDR Emergency Mobile Nodes that represent units in the field using iMON smart phone applications that provide data to BB-PPDR HQ,
- MATILDA 5G Network Slice which provides reliable communication over the dedicated link realized on top of the 5G communications infrastructure,
- MATILDA 5G-ready Application Orchestrator that provides intelligent 5G orchestration mechanisms to dynamically orchestrate iMON application components.

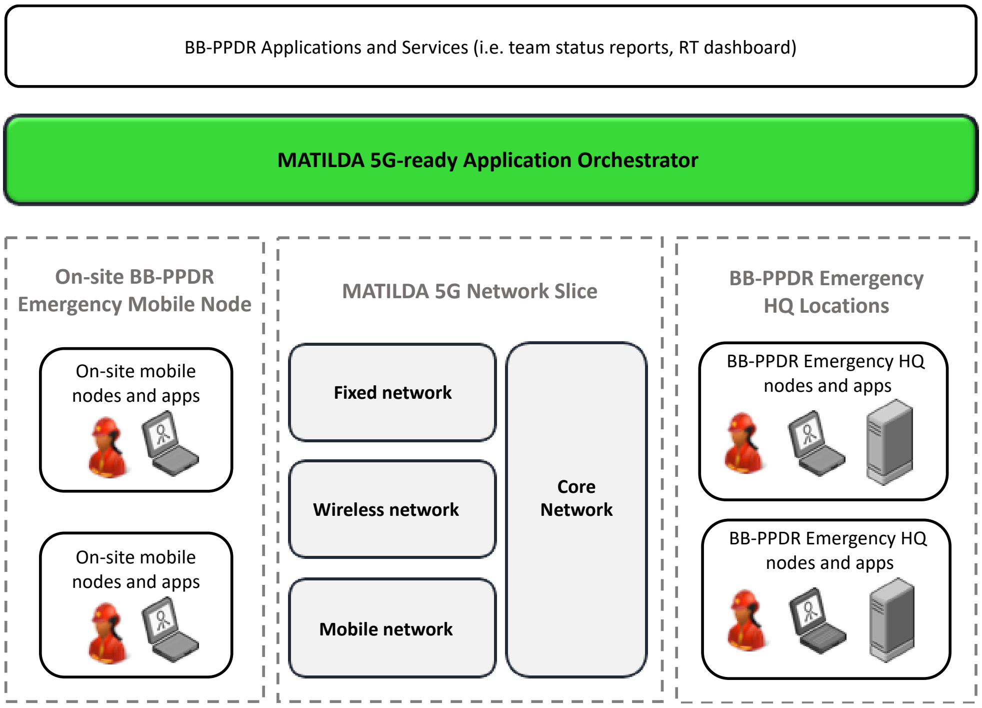

Figure 7.1: High-level architecture of the iMON-based PPDR Solution.

7.2.1 Application Graph

The application components' placement in the architecture of a distributed iMON-based PPDR application is described with the application graph and is shown in Figure 7.2 below.

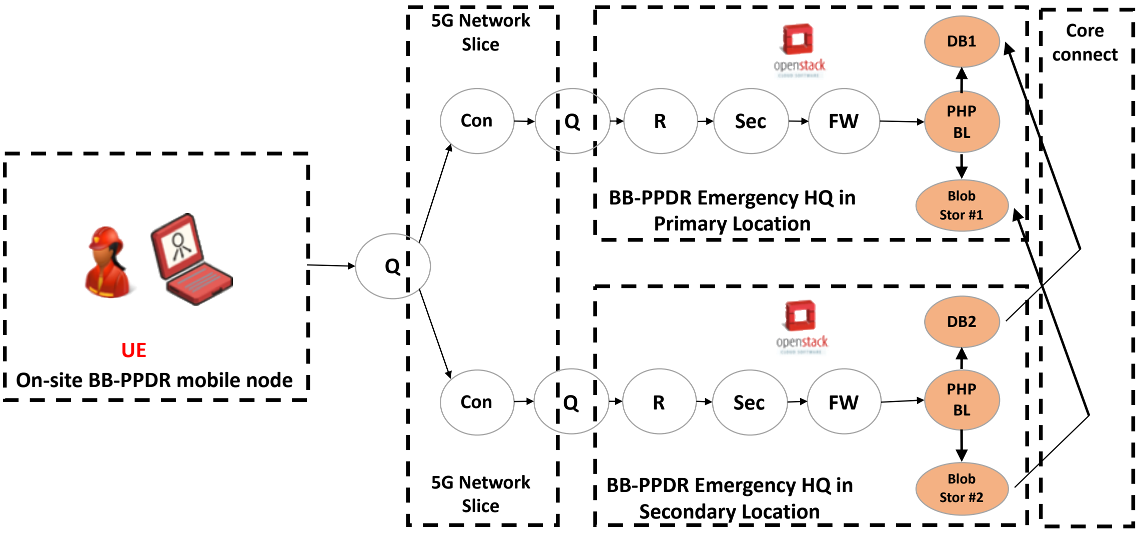

Figure 7.2: Application graph of a PPDR demonstration.

The graph shows application components (orange) and NFV-based components (grey). The distributed iMON application is deployed in two separated data centres. In each of the data centres, all application components are provisioned with the means to provide full redundancy in case of catastrophic accident that can cause one data centre to be shut down. To be able to achieve that, the full sync must be realized between DB and BLOB components in each data centre.

The roles and short descriptions are provided in the following paragraphs.

Application components:

- DB (Database)
  - Provides database system to maintain data of the registered users (e.g. smartphone application of a first responder in the field), alarms, events and reports along with the metadata that accompany them.
  - Offers chainable interface to PHP BL component.
  - Vertically scalable.
  - Example: MySQL service.
  - Requirements: 2x CPU, 2GB RAM, 20G DISK.
- PHP BL (PHP Business Logic)
  - Provides the business logic in the shape of a tactical dashboard, displaying field operatives with location, various alarms and events, and also providing detail reports with multimedia metadata.
  - Dependent on the DB and BLOB component in order to achieve stateless behaviour regarding the PHP sessions and storage of multimedia files.
  - Requires chainable interface to DB and BLOB component.
  - Horizontally scalable.
  - Example: Apache Web Server hosting proprietary PHP-based page.
  - Requirements: 2x CPU, 2GB RAM, 10G DISK.
- BLOB (Binary Large Objects Storage)
  - Provides single shared storage for multimedia files and PHP related data to all PHP BL components in a service graph and is needed to achieve stateless operation of a PHP-based business logic. Furthermore, it also provides the file sync service between two BLOB components.
  - Offers chainable interface to PHP BL component.
  - Vertically scalable.
  - Example: SAMBA service.
  - Requirements: 2x CPU, 2GB RAM, 40G DISK.

NFV-based components:

- FW (Firewall)
  - Provides network firewall functions such as port filtering and forwarding, IP-based access rules, etc.
  - Example: Open HTTPS ports for each new instance of a PHP BL instance.
- Sec (Security)
  - Provides network security functions such as encryption, tunnelling or VPN.
  - Example: VPN-based end user connection requires VPN termination service.

- R (Router)
    - Provides network routing functions that enables dynamic path selection, network load balancing, etc.
    - Example: Policy-based routing.
- Q (QoS Monitoring)
    - qMON-based active network monitoring providing measurement data to the MATILDA platform.
    - Example: Based on the monitoring data sent by qMON agents the best path in terms of QoS parameters can be selected.
- Con (Connectivity)
    - Represents dedicated links over the 5G network infrastructure (e.g., 5G Network Slice).

Graph links

Graph links are divided into core and access links. Core links are used for connecting application components between themselves while access links represent graph links through which user requests come in.

In the PPDR demonstration, there are two core links:

- PHP-BL – DB,
- PHP-BL – BLOB.

All other links are access links which can be described with the network slice intent metamodel that is shown in Table 7.1 below.

Table 7.1: Network Slice Intent Metamodel – Example for PPDR demonstration for interactive applications.

Element	Level 1	Level 2	Level 3	Level 4	Example
ServiceMeshIdentifier					5G PPDR (Mission Critical Data)
Constraints	ComponentHosting Constraints	ResourceConstraint			4 CPU 8 GB RAM 40 GB Disk
		LocationConstraint			EU-WEST/EU-EAST
	GraphLinkConstraints	GraphLinkQoS Constraint	Delay		5 ms
			Jitter		< 1 ms
			PacketLoss		< 0.01%
			Throughput		20 Mbps
	AccessConstraints	AccessConstraint	AccessQualityProfile	QCI (5QC)	70
				ResourceType	Non GBR/eMBB
				Priority	5.5
				PacketDelayBudget	10 ms
				PacketErrorLossRate	0.000001
				UE Type	eMBB
LogicalFunctions	Firewalling	FirewallConfiguration			Allow/deny rules
	VPN	VPNConfiguration			VPN policy

7.3 Relevance of MATILDA Framework

The MATILDA reference architecture, with three distinct and divided layers (the 5G-ready Applications Layer, the Applications' Orchestration Layer and the Network and Computing Slice Management Layer) is fully aligned with the next generation emergency response ecosystem, where, due to the roles of the PPDR organizations, strict separation between PPDR software developers, PPDR service providers and PPDR telecommunication infrastructure providers is foreseen. The "5G emergency infrastructure with SLA enforcement" use case, where strict QoS guarantees, high availability and reliability requirements need to be natively supported, will highly benefit from the provided MATILDA framework, where the PPDR application business functions and network and compute requirements are bound to the 5G-ready applications' graph; the latter will, with the support of the Applications' Orchestration Layer, enable fast deployment and dynamic adaptation to daily predictable and unpredictable extreme situations of the PPDR operational environment.

7.4 Requested Testbed Resources

For the application components' deployment, the following testbed resources are required:

- Compute
  - 6x CPU (up to 24x CPU to be available for the scaling scenarios)
  - 8 GB RAM (up to 16GB RAM to be available for the scaling scenarios)
- Storage
  - Up to 100 GB hard disk

For the NFV-based components additional resources are required:

- Compute
  - 8x CPU
  - 8 GB RAM

Moreover, the 5G-ready communication infrastructure should be available for use with the PPDR demonstration. This includes a capability to establish a dedicated virtual link over the mobile network infrastructure.

7.5 KPI Description and Acceptance Criteria

The emergency infrastructure industry requires the setup and deployment of mission critical services on the commercial mobile infrastructure for public safety use (5G PPDR network slice), belonging therefore to the Ultra Reliable Low Latency Communications (URLLC) and Enhanced Mobile Broadband (EMBB) service categories.

We will consider the following KPIs and thresholds for the demonstrator acceptance criteria, described in Table 7.2 below.

Table 7.2: Network KPIs for Demonstrator 3.

KPI	Description	Acceptance Criteria/ Threshold
`Availability`	Network availability	>99,999 %
`Reliability`	Network reliability	>99,999 %
`Network Slicing Capability`	Network Slice Management	Must be available
`End-to-end Latency for interactive applications`	Connected devices should be able to communicate without significant delay/ latency. Example application: ▪ Real-time queries in transactional databases	< 20 ms
`End-to-end Latency for mission critical applications`	Connected devices should be able to communicate without significant delay/ latency. Example application: ▪ Remote control of drones and robots	< 1 ms
`Bandwidth`	High bandwidth required for: ▪ Data intensive applications for PPDR use ▪ Ultra HD video streaming from disaster site (land and aerial based)	~20 Mbps/user
`Jitter`	Time-critical communications should be stable and reliable. Timing variation must be minimal	< 1ms
`Packet Loss`	Reliability and high availability of the services in extreme conditions is essential for emergency systems. Therefore, packet loss should be made as small as possible	< 0.01%

Table 7.3: Operational KPIs for Demonstrator 3.

KPI	Description	Acceptance Criteria/ Threshold
`iMON Dashboard components on-boarding time`	Time required for the App developer to on-board the iMON Dashboard components	~15 minutes
`iMON Dashboard component deployment time`	Time needed to deploy an individual component of the application graph	~2 minutes
`iMON Dashboard application graph deployment time`	Time to deploy the iMON Dashboard application graph	~5 minutes

Resource Usage Monitoring	Compute/storage/networking resource usage monitoring	Must be available
iMON Dashboard component scalability	PHP BL components of the iMON dashboard must support horizontal scaling	Must be available
Scaling time	Time required to trigger the scaling after a certain threshold was reached	~ 30s
Availability	Service availability	High >99,99%
Reliability	Service reliability	High 99,99%

8 Demonstrator 4: Industry 4.0 Smart Factory – Inter and Intra-Enterprise Integration

8.1 *Business Scenario*

The aim of the fourth industrial revolution, which is fuelled by cyber-physical-systems (CPS) and Internet-of-Things (IoT) technology, is to realize highly efficient, connected and flexible Factories-of-the-Future. Within this vision, future collaborative business settings are characterised, among others, through the improvement of the ways in which data in manufacturing processes are processed and integrated into the entire manufacturing supply chain. Two main trends in manufacturing are driving this transformation and will influence the future competitiveness:

- the increasing role of services in manufacturing
- the growing importance of global value chains

It is estimated that by 2025 manufacturers will get more profit from services than from products [3]. This is a consequence of a trend called "servitization of manufacturing", indicating a shift from solely selling produced goods to providing added value services together with either connected (smart) or non-connected goods. The growing importance of global value chains is a second trend that drives the demand for truly connected manufacturing eco-systems.

The implementation of a reliable communication layer capable of dealing with an increase of several orders of magnitude in the number of assets, volume, variety, type of information and reaction times in future manufacturing systems is still a challenging issue. 5G promises to be a key enabler for communication concerns within Factories of the Future. It will not only deliver an evolution of mobile broadband networks; it will provide the unified communication platform needed to disrupt with new business models and to overcome the shortcomings of current communication technologies.

This use case addresses scenarios in and in-between manufacturing facilities. The first part of this use case addresses inter-enterprise integration. Main challenges are caused from multiple stakeholders (OEMs, suppliers, logistics service providers), all of which running different technologies and management solutions, which have to be smoothly interconnected. Collaborative manufacturing production will be addressed (e.g. tracking, process/product co-designing, task planning), which relies on process data from suppliers of raw material, from production/assembly, as well as from logistics service providers. The second part of this use case addresses intra-enterprise integration. An assembly chain scenario will be considered, where interconnection provides for the different machinery collaborative working on manufacturing goods. MATILDA will be exploited towards deploying and orchestrating network-aware applications that will reflect both scenarios of this use case. Required performance, security, reliability and real-time communication characteristics will be facilitated by 5G access and MATILDA enabling architecture through the proper integration of VNFs and application components. MATILDA multi-site management will be an enabler for the first scenario while monitoring, analytics and optimization will drive complex decision making in both scenarios. BIBA smart factory infrastructure facilities will be exploited in this use case, while the applications will be implemented mainly by UBITECH and validated over the Bristol Is Open provided infrastructure.

8.2 Vertical Application Reference Structure

For a better understanding, the following section is divided in two parts, one part for each use case scenario.

8.2.1 Logistics

In the logistics scenario a transport shall be tracked, starting from a supplier and moving to a production facility. In addition, the goods loaded on a transporter shall be monitored in real-time, as in this scenario the goods are very fragile and need sensitive handling. For this purpose, temperature, humidity and vibrations are transmitted in real-time to give the client a possibility to monitor the client's goods all over the time of transport. For tracking, the goods are scanned first at the supplier (start), second at the transportation and third at the final destination at the production facility (end). This will be done by tagging the goods with RFID labels.

For the application, the first step is to scan the goods at the supplier on a fixed location to get the information on which goods have to be transported. The second step is scanning the goods at the transportation. From here, the transportation phase begins. Information like positioning via GPS and the housekeeping of the goods (humidity, temperature, vibration) shall be monitored and sent directly to a client. Next to the monitoring, the data shall be collected for further analysis to optimize the transportation phase. The final step is scanning the goods at the production facility. With doing so, the scenario ends as the goods reach their final destination. In Figure 8.1, the application graph for this use case scenario is shown.

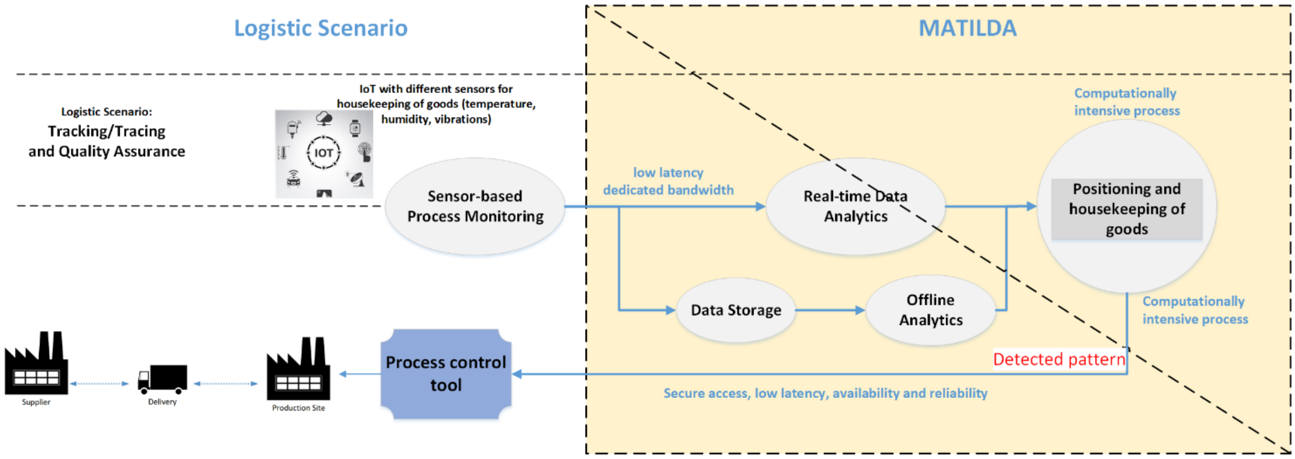

Figure 8.1: Application graph of the inter-enterprise Integration (Logistics scenario).

8.2.2 Production

The application for this use-case consists of two scenarios.

Pattern Detection for Quality Assurance

In production facilities, quality assurance is a mandatory phase to prevent mistakes, defects in products and therefore take right decisions towards process adjustment, delivery time, etc. The assembly process of mass customized automotive parts (e.g. steering wheel, car door, rear light, etc.), is still requiring human eyes to check the quality and standard of the finished product. Within MATILDA, BIBA is trying to evaluate the integration of 5G with a production assembly system, in which the quality (correctness) of assembled parts will be monitored by the use of image processing. For example, if a rear light assembly station where different types of parts coexist (described in D1.1 as the so-called “variant tree”), it is very difficult for the human eye to find any discrepancy in the quality of the expected product. Hence, camera-based monitoring systems can be used to find any kind of discrepancies in an efficient manner. The efficiency in this scenario is in terms of time of response and pattern detection. Once some defect or mistakes (wrong colour of rear light) is found in the actual stage of the product assembly, an alarm, triggered by the process control system in the production facility, is raised for the particular assembly station.

This scenario will help in optimizing the conventional methods of quality assurance for various products and will also help in cutting down the cost of human resources for a manufacturing plant that manually check the quality and standard of products.

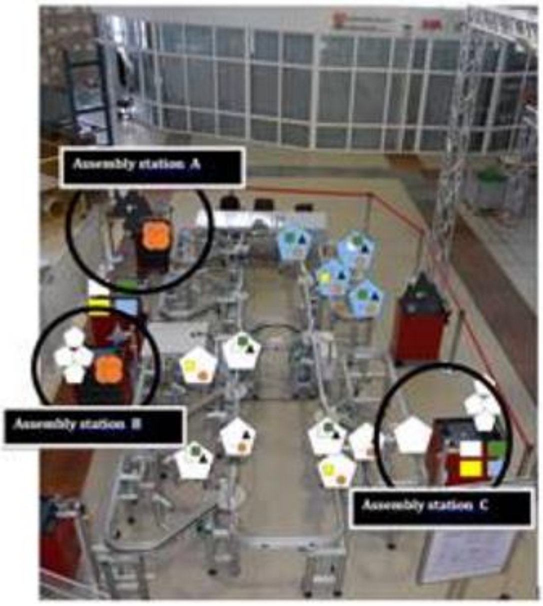

Figure 8.1: Infrastructure for assembly/production scenario.

Real-Time Distance Calculation in Human-Robot Collaborative (HRC) Production Environment

Due to the fact that within some safety critical collaborative applications safety fences will be eliminated, any collisions between robots and workers must be avoided. For this purpose, a predefined safety distance between worker and heavy payload robots has to be ensured in order to avoid dangerous hazards. The use of cameras can be considered as an interesting approach. However, image processing requires high performance computing to deal with constraints related to accuracy, response time and real-time process control. The goal of this use case is to evaluate the benefits and limits of 5G within safety-critical applications such as Human-Robot Collaboration. The contribution of MATILDA within this scenario consists of detecting the humans (workers) close to the operated robot and providing the shortest distance between workers and robot in real-time. Based on this information, the PLC (controller), will control the speed (stop/reduce/full speed) of the robot.

Figure 8.2: Infrastructure for HRC scenario.

The application graph for the proposed smart factory use-case is shown in Figure 8.3 below.

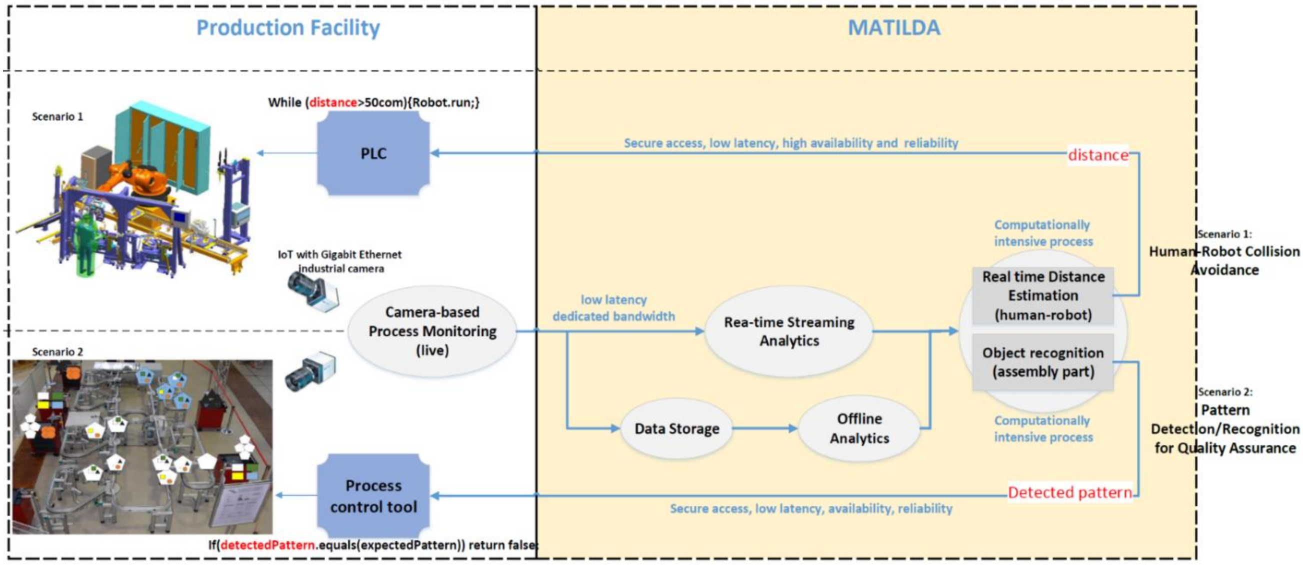

Figure 8.3: Application graph of the smart factory use-case.

Both scenarios are using cameras for live streaming of the state of the environment.

For the HRC scenario, Gigabit Ethernet industrial cameras will be placed in different locations in order to ensure a coverage of the whole environment where the robot arms can operate. In addition to the live streaming, a data exchange concept (OPC, Web service, …) will be prepared in order to enable the communication of the collision avoidance service with the PLC. The output of the service (distance in cm) will be the basis for the decision making of the robot controller.

For the second scenario, four cameras will be placed close to the assembly stations (one camera for each station) in order to provide live streaming of the assembled parts. The process will be reconfigured so that a part has to wait at the end of the station until the control system gets the response from the pattern detection service and takes a decision (alarm: redirection of the assembled part/no alarm: assembled part continues the rest of the process). In collaboration with UBITECH, a detailed concept for the connection and data gathering of/from the cameras will be worked out.

8.2.3 Joint Network Slice Intent Metamodel

The Industry 4.0 Smart Factory slice intent metamodel proposal aims to represent all the requirements that should be satisfied by the telco provider during network slice creation that will facilitate the deployment of the application.

Table 8.1: Network Slice Intent Metamodel for Demonstrator 4.

provides an example of a network slice intent metamodel for a possible implementation of the proposed framework for services.

Table 8.1: Network Slice Intent Metamodel for Demonstrator 4.

Element	Level 1	Level 2	Level 3	Level 4	Example
Constraints	ComponentHosting Constraints	ResourceConstraint			4 CPU 8 GB RAM 40 GB Disk
		LocationConstraint			Edge&Core
	GraphLinkConstraints	GraphLinkQoS Constraint	Delay		200 ms
			Jitter		< 1 ms
			PacketLoss		< 0.01%
			Throughput		20 Mbps
	AccessConstraints	AccessConstraint	AccessQualityProfile	QCI (5QC)	
				ResourceType	eMBB
				Priority	5
				PacketDelayBudget	200 ms
				PacketErrorLossRate	< 0.01%
				UE Type	eMBB
LogicalFunctions	Firewall	FirewallConfiguration			Allow/deny rules
	VPN	VPNConfiguration			VPN policy

8.3 Relevance of MATILDA Framework

The proposed MATILDA framework will improve the capabilities of both use cases by using an intelligent orchestration platform.

One of the most advantages is the guaranteed reliable and highly available interconnection of distributed manufacturing facilities. Moreover, by offering real-time information from and to production processes better access to remote process control and process monitoring is enabled. By using the MATILDA framework, this will not only increase the Quality of Service (QoS), but also the performance and flexibility in the use case scenarios. Mobility is a key feature for logistics; with MATILDA supporting seamlessly the connection of various Access Networks, the scenario can be served by different access networks depending on their location and availability. This will simplify the interoperability, meaning the data exchange among heterogeneous devices and interfaces. Furthermore, MATILDA will support secure and private end-to-end services, which is highly relevant in business scenarios where transferred data between interconnected manufacturing facilities are necessary.

8.4 Requested Testbed Resources

The following resources shall be provided by the testbed to run the use case scenarios:

- VPN connection between BIBA IT Infrastructure and UNIVBRIS
- Cloud service
- LTE
- WiFi

8.5 KPI Description and Acceptance Criteria

The main KPIs for both demonstrators are listed in Tables 8.2 and 8.3 below and are divided in network KPIs and operational KPIs.

Table 8.2: Network KPIs for Demonstrator 4.

KPI	Description	Acceptance Criteria/ Threshold
Device Density	The application expects a big number of connected sensors, actuators, machines	~100 per LAN/ WIFI Hot Spot
Bandwidth	Due to device density and data traffic between production processes high bandwidth per application is required.	Up to ~10 Mbps/user, depending on quality
Availability & Reliability	The test systems interconnection infrastructure/services shall be always available.	WLAN LTE Ethernet
Delay/ Latency	The MATILDA framework shall be able to support the decision making in these applications by ensuring low latency	Scenario distance calculation: the system is expecting a response after 100 ms Scenario pattern matching: the system is expecting a response after 250 ms
Access Interoperability	The MATILDA framework shall be interoperable with various access networks, e.g. LTE, WiFi, ZigBee	Must be available
Security & Privacy	The MATILDA Framework has to provide services ensuring the security/privacy requirements.	Must be available

Table 8.3: Operational KPIs for Demonstrator 4.

KPI	Description	Acceptance Criteria/ Threshold
Deployment time	Time needed for first installation and onboarding	~90 minutes
Availability	The test systems interconnection infrastructure/services shall be always available.	> 99 %
Reliability	Service reliability	99 %

Resource Usage Monitoring	Monitoring of the current resource usage is needed to allow preparation of dynamic scaling	Must be available
Component scalability	Dynamic scaling is needed to fulfill actual user communication requests	Must be available
Locality Awareness	Locality awareness is required for optimized scalability and communication	Must be available
Multi-site management	Functionality at its core is implemented as a distributed application	Must be available

9 Demonstrator 5: Smart City Intelligent Lighting System

9.1 Business Scenario

Orange developed the first smart city in Romania in a small to medium size city called Alba Iulia, where it provides a suite of smart solutions to its inhabitants thus improving the quality of their day-to-day lives. One of the key solutions delivered in Alba Iulia refers to Smart Lightning, the use case selected to be demonstrated within MATILDA. Today, the Smart Lighting solution is enabled by LoRaWAN connectivity, which assures the connectivity from the lighting sensors installed on poles to the application server used for command, control and maintenance. Considering the solution that we have in place today, there are several key steps followed for the deployment:

1. Deploy the needed physical or virtual infrastructure with the necessary configuration in terms of memory, CPU power, etc.
2. Deployment/installation of the application on the physical/virtual infrastructure
3. IP configuration in order to assure connectivity from the pole sensors to the application server
4. Radio optimization for LoRaWAN (or any other radio network used) in order to be sure the radio layer can support the amount of signaling
5. Installation of lighting sensors on the poles
6. Functional testing and acceptance of solution (including any fine-tuning needed)

Each of the six steps involves extensive human resources and a time of deployment around two or three months. Last but not least, the in-life management of the solution is also time consuming. The in-life management refers to:

1. Monitoring in order to assure that the solution is working as expected
2. Repairing in case of faults related to connectivity, physical/virtual infrastructure, etc.
3. Upgrades (e.g. adding more lighting poles)
4. Deprovisioning

Considering the appetite of Service Consumers towards Smart City (it is estimated to reach 8.1 billion Euros in 2025 [4]) the model used for deployment and in-life management has to be further optimized in order to be able to automate most of the human tasks. In this respect, 5G technology will be used as an enabler for automation, thus granting:

1. An easy replicable solution with fast time to market
2. Automated maintenance (except for the case in which a pole sensor is broken, where human intervention is needed)
3. A modular approach enabled by 5G application graphs that will assure better monetization of the solution.

9.2 Relevance of MATILDA Framework

Building on the 5G ecosystem, the MATILDA framework defines the end-to-end architecture and provides the technological capabilities that shall drive the deployment and in-life management of the Smart Lighting solution towards automation. The 5G state of the art for creating network-aware applications and application-aware networks stands in the center of the MATILDA framework and is augmented by the existence of a marketplace. The purpose of the marketplace is to offer a GUI to the different stakeholders to the (already) developed 5G-ready application components, applications, virtual network functions and L7VFs for open-source or commercial purposes, reuse and extension. In other words, by means of the marketplace GUI, a Service provider can deploy a Smart City Solution in an automated way without requiring, for example, any human intervention from the Infrastructure Provider.

This is achievable since, within MATILDA, cloud-native application components are developed to be hosted on the cloud infrastructure. A separation approach will be used between the business logic part of a component and the network layer specific functionalities. The communication between them is realized through a dedicated proxy sidecar attached to each component. The Smart City MATILDA 5G-ready application will be developed as a Service Mesh to exploit the 5G cutting edge technologies. A service mesh is a dedicated infrastructure layer for handling service-to-service communication. It is responsible for the reliable delivery of requests through the complex topology of services that comprise a modern, cloud-native application. In practice, the service mesh is typically implemented as an array of lightweight network proxies that are deployed alongside application code, without the application needing to be aware [1]. Within MATILDA, the Service Mesh provides the bidirectional link between application and infrastructure/network, which builds the ecosystem for application aware networks and network aware applications.

Each component in the Service Mesh will be described by a set of complex type elements. These elements are [5]: Distribution (exposes the information regarding the final image/container and components' location), Exposed Interface (contains the interface typology and interface identifier needed to assure the connection between components), Configuration (set of component variables used during instantiation), Volume (capability of the Hypervisors [6] to provide storage to virtual machines via volumes), Minimum Execution Requirements (to be met by the hosting environment for the proper execution – VCPU, RAM, Storage), Exposed Metric (the metrics that will be reported by the proxy sidecar), Required Interface (contains the information regarding the graph link) and Capability (encapsulates runtime capabilities of the components). The components are logically interconnected through a graph link forming in this way the application graph. Each component has at least one graph link according with the design of the application. The graph link is a logical link deployed with the associated network and compute constraints [7].

In order to describe the evolution of the smart city use case, we need to introduce the stakeholders that will play specific roles in the utilization of MATILDA 5G ecosystem. Four main entities will be involved: the Service Consumer, the Service Provider, the Application Developer and the Infrastructure Provider.

The **Service Consumer,** as part of smart city vertical industry ecosystem, is the first and the last actor in the overall process chain having the first role as consultant, providing the application specific requirements during the deployment phase and the final stage role as consumer of the application offered by the Service Provider. The **Service Provider** is responsible for the creation of the application graph in line with the requirements provided by the Service Consumer and is also responsible for instantiation of the 5G-ready application created over the sliced programmable infrastructure in order to be delivered to the end-user. The **Application Developer** is responsible for the development of two functionalities, according to the MATILDA proposal. The first component is the Marketplace application store where the smart city applications will be stored to be downloaded by the Service Provider. The Application Developer is also in charge of producing the smart city application components suited for an operational application graph composition. The application components design should be aware of the end-to-end application functionality requirements, the chaining and interoperability characteristics and the dependencies needed to form the logical application graph. The **Infrastructure Provider** assures the infrastructure resources, network, storage and compute during smart city application graph instantiation. This role can be associated to several actors depending on the nature of requested resources. For example, the Telecom Infrastructure Provider will assure a programmable 5G network infrastructure, a radio/fixed access layer, a transport and a core network, while the Cloud Infrastructure Provider will be responsible to provide operating cloud/edge capability with compute and storage programmable resources.

One way to introduce the deployment and in-life management for the smart lighting use case is to consider the following role mapping: Service Consumer represented by the operator of the public lighting service and by the city manager's team, Service Provider and Infrastructure Provider represented by the telecom infrastructure provider operating both 5G and cloud infrastructure and Application Developer represented by the entity developing the smart lighting related enterprise applications that will be monetized by the Service Provider.

The target for both Service Consumer and Service Provider is to obtain a cloud-native, context-aware and cost-efficient smart lighting enterprise application framework able to perform several tasks. This allows in fact providing a highly replicable solution with fast time to market and without requiring excessive human intervention.

Before presenting the deployment and in-life management, it is important to understand the main application functionalities of the Smart Lighting solution:

4. The **IoT Middleware** with the capability to retrieve, process and store in a secure way the real-time datasets coming from the 5G connected actuators/controllers, and potentially mix them with other datasets that are not accessible in real-time through sensors or actuators.
5. The **Lighting Service Management** function will be responsible for integrating the 5G connected actuators/controllers and remotely control every single city lighting pole in real-time and in a secure way, in order to adjust the lighting intensity and efficiently manage energy consumption. Another enterprise application (**Lighting Energy Management**) will allow real-time and history-based energy consumption measurements per pole or branch of poles.

6. The **Lighting Service Availability** will allow the Service Consumer to be able to proactively spot the malfunctions, energy loss or energy theft attempts on the public lighting network, by generating intervention tickets in real-time per pole or branch of poles. Part of the smart lighting enterprise applications' framework can be also an application responsible for the management of the 5G connected street lighting poles (**Lighting Device Management**) that will assure they are always running the last validated firmware, will facilitate maintenance planning and operations management and will check that 5G connectivity is up and running.

The main steps in order to deploy and maintain the Smart Lighting solution within MATILDA are depicted below.

1. The Service Consumer will select a Service Provider that will deliver the 5G connected actuators/controllers to be installed by the Service Consumer, one per each public lighting pole and poles aggregation node from the selected area. As in our case the Service Provider is also the Infrastructure Provider, we will have a seamless procedure for 5G actuators/controllers authentication and authorization.
2. The Service Consumer will go to the MATILDA Marketplace indicated by the Service Provider and download, from the smart city services catalogue, the full 5G-ready smart lighting enterprise applications framework, including the following functionalities: IoT Middleware, Lighting Service Management, Lighting Energy Management, Lighting Service Availability and Lighting Device Management.
3. The Service Provider will use the right smart city metamodel to generate the Service Consumer specific enterprise application graph that will help instantiating the cloud-native enterprise applications (Infrastructure Provider cloud resources) set over the end-to-end sliced programmable infrastructure (Infrastructure Provider 5G resources).
4. Once the graph is up and running over the Infrastructure Provider 5G telecom and cloud resources, the smart lighting enterprise applications framework will go into a dynamic operation mode facilitated by the 5G programmable infrastructure. The Service Consumers will benefit from all the capabilities enabled by MATILDA certified applications.
5. The functional testing of the solution should be fully automated, meaning that, once the solution is live, a set of test scenarios should be run automatically and provide a test report in order to assure the correct functionality as per the acceptance criteria.

It can be observed that the deployment and the in-life management of the solution within the MATILDA framework are achieved by leveraging the key concepts enabled by MATILDA: cloud-native applications deployed within the marketplace and exposed programmable infrastructure using the slicing concept [8]. In-life management is also facilitated by these key concepts as the network continuously adapts to any application changes and vice versa.

MATILDA is building the end-to-end framework leveraging 5G ecosystem that will finally enable a highly automated deployment and in-life management of the next generation smart cities.

9.3 Vertical Application Reference Structure

The Smart City application assures individual remote management of streetlight lamps, being specially designed and optimized for LoRaWAN and LTE-M networks to perform autonomous operation based on predefined schedules and light level sensors. It provides an efficient bandwidth with minimal communication requirements for under/overpower smart monitoring, voltage monitoring and daytime/nighttime consumption mismatches being reported in real-time to the central server. It also provides map visualization of managed devices (maps, grid, power supply cabinet, etc.), lights switching (ON/OFF) and dimming (per single light), compatibility with different lighting sensors, real time lighting sensors monitoring. As mentioned in the previous subsection, the Smart City application architecture (Figure 9.1) is composed of three main application functionalities: **Lighting Service Management** deployed through the IoT aggregator flash component and the Dashboard component, **IoT Middleware** deployed through the IoT Aggregator component and the Storage component and **Lighting Service Availability** deployed through the Monitoring component.

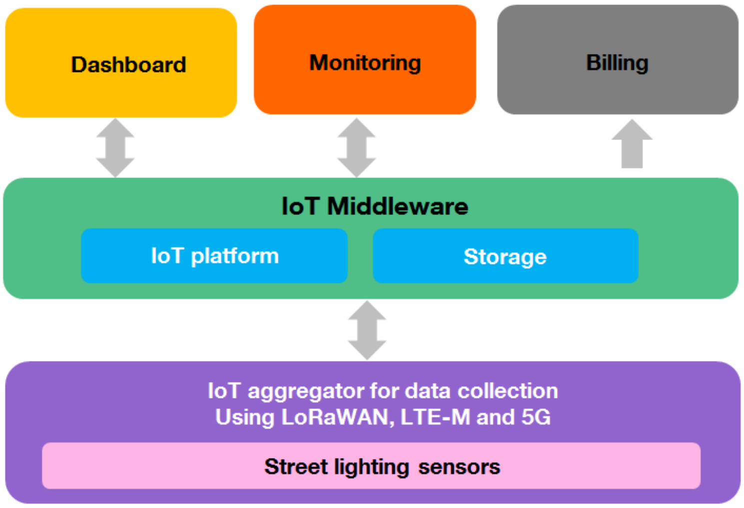

Figure 9.1: Smart City application architecture.

The **lighting controllers** are hardware parts based on LoRaWAN, LTE-M and 5G technology in the future, which are installed on lighting poles assuring the capability of remotely controlling them. The **IoT aggregator** component assures secure connection over access networks with lighting controllers and sends the raw data to IoT platform. The **dashboard** component gives administrators the potential to remotely control and access lighting sensors data but also to set a schedule on groups of lamps. The alert and ticketing system (**Monitoring** component) provides administrators a way to inform in no time the repair team and also keep track of every service required by all of the poles.

9.3.1 Application Graph

The Smart Lighting system is a fixed solution with a predefined operating schedule (the mobility scenario and the interconnection with other access networks as 2G/3G is not applicable). It would be transparent to network access factors due to seamless functionality planned to be deployed over LoRaWAN, LTE-M, 5G. According to MATILDA metamodel requirements each application should be translated into application graph format together with interconnecting links. The Smart City application graph is depicted in Figure 9.2.

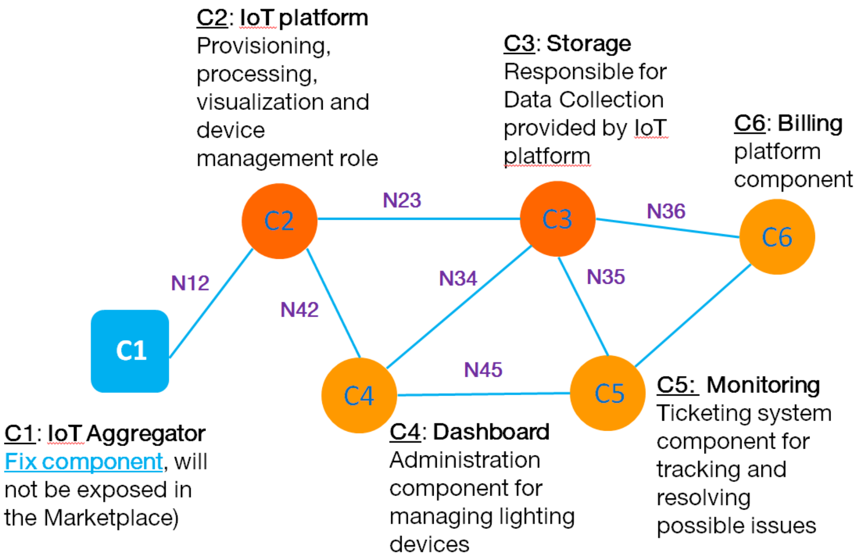

Figure 9.2: Smart City application graph.

Component C1: fixed component not exposed in Marketplace composed of IOT aggregator which assures secured connection with lighting sensors.

Component C2: IoT component providing provisioning, processing, visualization and lighting sensor management role.

Component C3: storage component responsible for data collection provided by the IoT platform.

Component C4: dashboard component with administrative role, assures the management of lighting devices.

Component C5 acts as a monitoring platform with ticketing capabilities being responsible for client identification, device identification, health status for servers and database. (storage/load).

Component C6 is a billing platform in charge with traffic evaluation and monetization functions.

Application components are bound together through four main logical graph links:

1. **N12** graph link assures the connectivity between fixed component C1 (IoT Aggregator) and component C2 (IoT Middleware/IoT Platform).
2. **N23** graph link assures the connectivity between IoT Platform component and Storage component
3. **N34** graph link assures the connectivity between Storage component and Dashboard component
4. **N35** graph link assures the connectivity between Storage component and Monitoring component
5. **N36** graph link assures the connectivity between Storage component and Billing component
6. **N42** graph link assures the connectivity between Dashboard component and IoT platform component
7. **N45** graph link assures the connectivity between Dashboard component and Monitoring component.

9.3.2 Application Component Descriptors

1. **Component C1** – ComponentIdentifier: IoT Aggregator Flash
   Distribution:
   - Image Descriptor: IoTAggregator
   - Repository Descriptor:

   ExposedInterface:
   1. InterfaceIdentifier: C1N12 interface
      InterfaceType: ACCESS
      Port: TBD
      TransmissionProtocol: TCP/UDP

   RequiredInterface:
   1. GraphLinkIdentifier: C1C2N12 connection
      ComponentIdentifier: IoTMiddleware
      InterfaceIdentifier: C2N12 interface

   Configuration: to be decided
   Volume: 50GB
   MinimumExecutionRequirements:
   - VCPUs: minimum
   - RAM: minimum 2048 MB
   - Storage: 50 MB
   - HypervisorType: if is a preference.

2. **Component C2** – ComponentIdentifier: IoTPlatform
   Distribution:
   - Image Descriptor: IoTPlatform
   - Repository Descriptor: URL 2

   ExposedInterface:
   1. InterfaceIdentifier: C2N12 interface
      InterfaceType: ACCESS
      Port: to be decided
      TransmissionProtocol: TCP/UDP
   2. InterfaceIdentifier: C2N23 interface
      InterfaceType: CORE
      Port: to be decided
      TransmissionProtocol: TCP/UDP
   3. InterfaceIdentifier: C2N42 interface
      InterfaceType: CORE
      Port: to be decided
      TransmissionProtocol: TCP/UDP

   RequiredInterface:
   1. GraphLinkIdentifier: C2C1N12 connection
      ComponentIdentifier: IoT Aggregator Flash
      InterfaceIdentifier: C1N12 interface
   2. GraphLinkIdentifier: C2C3N23 connection
      ComponentIdentifier: Storage
      InterfaceIdentifier: C3N23 interface

3. GraphLinkIdentifier: C2C4N42 connection
   ComponentIdentifier: Dashboard
   InterfaceIdentifier: C4N42 interface

Configuration:
Volume:
MinimumExecutionRequirements:
VCPUs: 10
RAM: 16384 MB
Storage: 61440 MB
HypervisorType: if is a preference
Capability:
Scaling: Both.

3. **Component C3** – ComponentIdentifier: Storage

Distribution:
Image Descriptor: Storage
Repository Descriptor: URL3
ExposedInterface:

1. InterfaceIdentifier: C3N23 interface
   InterfaceType: CORE
   Port: to be decided
   TransmissionProtocol: TCP/UDP
2. InterfaceIdentifier: C3N34 interface
   InterfaceType: CORE
   Port: to be decided
   TransmissionProtocol: TCP/UDP
3. InterfaceIdentifier: C3N35 interface
   InterfaceType: CORE
   Port: to be decided
   TransmissionProtocol: TCP/UDP
4. InterfaceIdentifier: C3N36 interface
   InterfaceType: CORE
   Port: to be decided
   TransmissionProtocol: TCP/UDP

RequiredInterface:

1. GraphLinkIdentifier: C3C2N23 connection
   ComponentIdentifier: IoTPlatform
   InterfaceIdentifier: C2N23 interface
2. GraphLinkIdentifier: C3C4N34 connection
   ComponentIdentifier: Dashboard
   InterfaceIdentifier: C4N34 interface
3. GraphLinkIdentifier: C3C5N35 connection
   ComponentIdentifier: Monitoring
   InterfaceIdentifier: C5N35 interface

4. GraphLinkIdentifier: C3C6N36 connection
   ComponentIdentifier: Billing
   InterfaceIdentifier: C6N36 interface

Configuration:
Volume:
MinimumExecutionRequirements:
   VCPUs:2
   RAM: 4096 MB
   Storage: 20480 MB
   HypervisorType: if is a preference
ExposedMetric:
   MetricIdentifier: to be decided
   MeasurementUnit: to be decided
Capability:
   Scaling: Both.

4. **Component C4** – ComponentIdentifier: Dashboard

Distribution:
   Image Descriptor: Dashboard
   Repository Descriptor: URL4
ExposedInterface:
1. InterfaceIdentifier: C4N42 interface
   InterfaceType: CORE
   Port: to be decided
   TransmissionProtocol: TCP/UDP
2. InterfaceIdentifier: C4N34 interface
   InterfaceType: CORE
   Port: to be decided
   TransmissionProtocol: TCP/UDP
3. InterfaceIdentifier: C4N45 interface
   InterfaceType: CORE
   Port: to be decided
   TransmissionProtocol: TCP/UDP

RequiredInterface:
1. GraphLinkIdentifier: C4C2N42 connection
   ComponentIdentifier: IoTPlatform
   InterfaceIdentifier: C2N42 interface
2. GraphLinkIdentifier: C4C3N34 connection
   ComponentIdentifier: Storage
   InterfaceIdentifier: C3N34 interface
3. GraphLinkIdentifier: C4C5N45 connection
   ComponentIdentifier: Monitoring
   InterfaceIdentifier: C5N45 interface

Configuration:
Volume:
MinimumExecutionRequirements:
VCPUs: 2
RAM: 4096
Storage:20480
HypervisorType:if is a preference
Capability:
Scaling: Both.

5. **Component C5** – ComponentIdentifier: Monitoring
Distribution:
Image Descriptor: Monitoring
Repository Descriptor: URL5
ExposedInterface:
1. InterfaceIdentifier: C5N35 interface
InterfaceType: CORE
Port: to be decided
TransmissionProtocol: TCP/UDP
2. InterfaceIdentifier: C5N45 interface
InterfaceType: CORE
Port: to be decided
TransmissionProtocol: TCP/UDP
RequiredInterface:
1. GraphLinkIdentifier: C5C3N35 connection
ComponentIdentifier: Storage
InterfaceIdentifier: C3N35 interface
2. GraphLinkIdentifier: C5C4N45 connection
ComponentIdentifier: Dashboard
InterfaceIdentifier: C4N45 interface
Configuration:
Volume:
MinimumExecutionRequirements:
VCPUs: 4
RAM: 8192MB
Storage: 51200
HypervisorType: if is a preference.

6. **Component C6** – ComponentIdentifier: Billing
   Distribution:
   Image Descriptor: Billing
   Repository Descriptor: URL6
   ExposedInterface:
   1. InterfaceIdentifier: C6N36 interface
      InterfaceType: CORE
      Port: to be decided
      TransmissionProtocol: TCP/UDP

   RequiredInterface:
   1. GraphLinkIdentifier: C6C3N36 connection
      ComponentIdentifier: Storage
      InterfaceIdentifier: C3N36 interface

   Configuration:
   Volume:
   MinimumExecutionRequirements:
   VCPUs: 4
   RAM: 8192MB
   Storage: 51200
   HypervisorType: if is a preference.

9.3.3 Network Slice Intent Metamodel

The Smart City slice intent metamodel (Fig. 9.1) proposal aims to represent all the requirements that should be satisfied by the telco provider during network slice creation that will facilitate the deployment of the application. The scope of the metamodel proposed is to facilitate the request of a vertical service provider to the telco.

Table 9.1: Smart City Slice Intent.

Element	Level 1	Level 2	Level 3	Level 4	Example
Constraints	ComponentHosting Constraints	ResourceConstraint			18 vCPU 32 GB RAM 150 GB Storage
		LocationConstraint			Edge&Core
	GraphLinkConstraints	GraphLinkQoS Constraint	Latency		< 500 ms
			Jitter		100 ms
			PacketLoss		< 1%
			Throughput		150 Mbps
	AccessConstraints	AccessConstraint	AccessQualityProfile	QCI	70
				ResourceType	eMTC
				Priority	5
				PacketDelayBudget	500 ms
				PacketErrorLossRate	< 1%
				UE Type	LTE-M
LogicalFunctions	Firewalling	FirewallConfiguration			Allow/Deny
	VPN	VPN Configuration			VPN policy
	vEPC				vHSS, vMME, vS/PGW

9.4 Requested Testbed Resources

Compute and Storage Resources

- 3 servers/computing blocks with the following individual capabilities:
  - 2 processors, 12-core/processor @ 2.4 GHz
  - 128 GB RAM
  - 2 TB hard disk
- 1 servers/computing blocks (vEPC host) with the following individual capabilities:
  - 2 processors, 12-core/processor @ 2.3 GHz
  - 512 GB RAM
  - 2.4 TB hard disk

Connectivity

- 2 Ethernet Network adapters 1Gbps interface for each server/computing blocks
- VPN connection between Alba Iulia – Cluj Datacenter – Bucharest Datacenter

9.5 KPI Description and Acceptance criteria

Table 9.1: Network KPIs for Demonstrator 5.

KPI	Description	Acceptance Criteria/ Threshold
Availability	Calculated as network down time/total time, reflects in percentage the availability/stability performance of Smart City demo platform	> 99.99%

Table 9.2: Operational KPIs for Demonstrator 5.

KPI	Description	Acceptance Criteria/ Threshold
Device status	Evaluates the number of smart light sensors deployed on testbed platform.	100 Smart Light sensors
Service Availability	Calculated as service down time/total time, reflects in percentage the availability/stability performance of Smart City service	>99.99%
Device bandwidth capacity	Evaluates the transfer capacity volume of information collected from sensors to IoT platform.	~0.1 Mbps
Total slice bandwidth	Evaluates the transfer capacity volume of aggregated information from sensors to IoT platform. Calculated as (device number) x (bandwidth/device) (helpful for VNFs system parametrization)	~ 100Mbps
End-to-end Latency	Measures packet round trip time from IoT platform to device sensor.	< 300 msec
Jitter	Evaluates packet delay variation in latency between IoT platform and device sensor.	~100 msec
Packet Loss	Shows the percentage of packets lost during transfer between sensors and IoT platform. The Smart Lighting service is not critical, therefore retransmission is being allowed, without affecting end-to-end application functionality.	< 0.1%

10 Conclusions

This deliverable provides information about the three testbeds and the five demonstrators that will be developed by the MATILDA Project. The testbeds will be provided by CNIT (UBITECH and COSM will provide an equivalent testbed in their premises for development and testing purposes), UNIVBRIS and ORO; they will be used by the Consortium to deploy and run MATILDA demonstrators. For each testbed, the document has described available Radio Access Network resources, Software Defined Networking controllers and Network Function Virtualization orchestrators, and discussed how they can be used by each demonstrator.

The five demonstrators have already been presented in previous deliverables. This document has provided additional information for each demonstrator, related to:

i) the business scenario of interest for each demonstrator, and its relevance in the 5G ecosystem;

ii) the definition of each demonstrator as a 5G-ready application, according to the MATILDA framework;

iii) the innovative contribution of MATILDA to the realization of each demonstrator;

iv) the resources needed by each demonstrator;

v) implementation, deployment and demonstration plans for each demonstrator.

References

[1] D1.1 – MATILDA Framework and Reference Architecture [online] Available: http://www.matilda-5g.eu/index.php/outcomes

[2] Data protection Rules for the protection of personal data inside and outside the EU. http://ec.europa.eu/justice/data-protection/reform/index_en.htm

[3] The European 5G Annual Journal 2016 [online] Available: https://bscw.5g-ppp.eu/pub/bscw.cgi/d117642/Euro%205G%20Annual%20Journal%202016.pdf

[4] SMART report on the impact of 5G on EU industry: "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe", ISBN 978-92-79-58270-7, October 2016. [online] Available: http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17802

[5] D1.2 – MATILDA Chainable Application Component & 5G-Ready Application Graph Metamodel Architecture [online] Available: http://www.matilda-5g.eu/index.php/outcomes

[6] RFC 7666 [online] Available: https://tools.ietf.org/html/rfc7666SMART report on the impact of 5G on EU industry: "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe", ISBN 978-92-79-58270-7, October 2016. [online] Available: http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17802

[7] COMM2018 [online] Available: https://www.comms.ro/openconf/author/paper.php

[8] Description of Network Slicing Concept January 2016 [online] Available: https://www.ngmn.org/fileadmin/user_upload/160113_Network_Slicing_v1_0.pdf