VertIcal demos over Common large scale field Trials fOr Rail, energy and media Industries

D2.2 Preliminary individual site facility planning

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Executive Summary

The advanced vertical use case (UC) verification proposed by 5G-VICTORI is carried out in an integrated 5G-platform that exploits existing ICT-17 infrastructures, i.e. 5G-VINNI (Patras, Greece), 5GENESIS (Berlin, Germany) and 5G-EVE (France/Romania), and the 5GUK testbed (Bristol, UK). The large-scale trials carried out in the project require upgrades in those infrastructures to support Transportation, Energy, Media, Factories of the Future and cross-vertical UCs over an integrated 5G platform.

This deliverable is the second technical deliverable and falls in the framework of Task 2.2 “Individual site facility planning and experimentation plan per facility”. It relies on the set of requirements and initial architecture blueprint for each of the sites – work that was carried out as part of Task 2.1 and led to the release of deliverable D2.1 [1] – and presents a high-level overview of the extensions planned for each of the sites. It also defines per site the timeline and progress of the associated upgrades of the required infrastructures.

A more detailed analysis of the upgrades and components exploited by the project will be part of deliverable, D2.3 entitled “Final individual site facility planning”, which will concentrate on the refined planning, and a detailed technical definition of the subsystems and their interconnection comprising any enhancements required per site.

The outcomes of this task will feed Task 2.3, where the 5G-VICTORI end-to-end (E2E) reference architecture will be defined, including technical definition of the subsystems and description of their interconnection towards the implementation of the upgraded 5G sites.

This deliverable provides input to the upcoming project activities within Work Package 2 (**WP2**), deliverable D2.3 “Final individual site facility planning”, and deliverable D2.4 “5G-VICTORI end-to-end reference architecture”, as well as activities of **WP3** “Vertical Services to be demonstrated“, and **WP4** “Trials of Coexisting Vertical Services, validation and KPI evaluation”.

1 Introduction

The aim of digital technologies in the framework of the Fourth Industrial Revolution is to influence a large variety of sectors, with emphasis on verticals to the ICT industries such as Transportation, Energy, Media, and Factories of the Future. Some examples of this influence are the offering of connected goods, collaborative and automated processes within and across sectors, optimized processes related to energy or other resource consumption, optimized transportation and logistics, new and improved services concerning safety and security, user experience, etc.

5G platforms can play an instrumental role in bringing together technology players, vendors, operators and verticals orchestrating their interaction to target new business models and opportunities for the ICT and vertical industries, and to also enable cross-vertical collaborations and synergies to offer further enhancements in value propositions.

There is a clear need in Europe to deploy 5G solutions for vertical industries. One of the first steps is the development of future proof 5G infrastructures to address a wide range of vertical applications adopting a flexible architecture. These infrastructures would offer converged services across heterogeneous technology domains deploying unified software control. At this stage, verticals face the problem that they can only practically verify their use cases (UCs) in small scales in commercially relevant environments before investing in large-scale deployments.

5G-PPP ICT-17 projects triggered the development of 5G ICT infrastructures to become available to verticals to test their applications. ICT-17 projects are only able to provide small-scale testbed infrastructures that are not suitable to accommodate the integration of verticals in operational environments. There is a need to feature these infrastructures with suitable extensions to enable the integration of verticals and to allow a small-scale testing environment for vertical commercially relevant infrastructures.

However, large-scale trials are not the main target of the ICT-17 facilities. Nevertheless, the work being currently going on in these facilities is an important step key to enable the execution of 5G trials. In this context, 5G-VICTORI aims at conducting large-scale trials for advanced UC verification in commercially relevant 5G environments for *Transportation*, *Energy*, *Media* and *Factories of the Future* as well as some specific UCs involving cross-vertical interaction

Deliverable D2.1 [1] defined and described the proposed UCs and their specific requirements, as they are dictated by the associated vertical industries, including also the development of a methodology that can be followed for the analysis of the UCs. The specific UCs under consideration include: "Enhanced Mobile broadband under high-speed mobility", Vertical: Transportation – Rail, "Digital Mobility", Cross-Vertical – Transportation and Media, "Critical services for railway systems", Vertical: Rail, "Smart Energy Metering", Cross-Vertical: Energy and Rail, "Digitization of Power Plants", Vertical: Smart Factory, and "CDN services in dense, static and mobile environments", Vertical: Media.

Following the UC descriptions, D2.1 provided a definition of relevant Key Performance Indicators (KPIs) relating both to the delivered services as well as to the required underlying network performance. It also includes a description of the various 5G-VICTORI facilities that represent the sites where the various UCs will be hosted, indicating the relevant architectural approaches and technology solutions.

The deliverable at hand builds upon the set of requirements defined in D2.1 and the initial architecture blueprint for each of the sites, presenting a high-level overview of the extensions planned for each of the sites. To that end, it turns the site facility requirements definition per facility cluster (5G-VINNI [2], 5GENESIS [3], 5G-EVE [4] and the 5GUK testbed [5]) into an initial planning on how the facility shall look like. Each individual facility in 5G-VICTORI is described from a 5G network perspective and the required extensions to support integration of the verticals in the facilities are also discussed. Finally, the deliverable defines per site the timeline and progress of the upgrades of the required infrastructures.

1.1 Objectives

This deliverable builds on top of D2.1 “Use case and requirements definition” to refine requirements and the architecture blueprint for each of the sites: Berlin, Bristol, France/Romania and Bristol.

Based on this information, the timeline and progress of the different upgrades to be carried out are defined per site. This description serves as the basis for deliverable D2.3, where the 5G-VICTORI end-to-end (E2E) reference architecture will be defined, including the technical definition of the subsystems and their interconnection in support of the enhanced sites.

1.2 Approach and Methodology

For the preliminary definition per site, the UCs reported in deliverable D2.1 haven been reviewed. Some of the planned site visits have been already conducted to enable a detailed architecture planning of the relevant sites. Unfortunately, some other site visits could not be organized due to the early COVID-19 lockdown that was imposed for some of the premises. These site visits will take place later in time, when circumstances allow for this.

The analysis starts with a description of the site location(s) and the respective architecture blueprint. Based on this, we plan the locations within the site where the additional required components have to be placed to support the site-specific UCs. These decisions are based on the observations of the site visit and agreements between the vertical partners and the owner of the site.

The output of the relevant “Activity planning” process per site results in a proposed timeline regarding the UC implementation for each of the sites. This includes equipment purchase, installation and testing, and it is the responsibility of the individual sites to manage and carry out the relevant process, e.g. certain sites decided to conduct lab testing first, before moving the equipment to the final site.

1.3 Purpose of the document

This is the second technical deliverable of 5G-VICTORI, and it is the first deliverable report of Task 2.2 " Individual site facility planning and experimentation plan per facility", which belongs to Work Package 2 (WP2) entitled " Description – Use cases/ Specifications".

The purpose of this deliverable is to meet the following WP2 objectives:

- Preliminary definition per site to fulfill the requirements of the UCs to be run in the different sites.
- Initial timeline of the planned work.
- High-level description of the components and subsystems that will be part of the sites’ upgrades.

Table 1-1: Dependencies with previous 5G-VICTORI Documents

id	Document Title	Relevance
D2.1 [1]	5G VICTORI Use case and requirements definition and reference architecture for vertical services	This document presents the 5G-VICTORI UCs and their specific requirements (UC requirements, network performance requirements and functional requirements), as they are dictated by the associated vertical industries.

1.4 Document Structure

This deliverable comprises four main sections, which follow a similar structure content-wise: facility description, the components and the activity planning for the implementation of the UCs:

Section 2 refers to the Berlin Cluster Facility.

Section 3 refers to the Bristol Cluster Facility.

Section 4 refers to the France/Romania Cluster Facility.

Section 5 refers to the Patras Cluster Facility.

Section 6 concludes the deliverable and, finally, Section 8 presents the Appendix with some additional information.

2 Berlin Cluster Facility Planning

The Berlin cluster exploits the Berlin Platform, which is a 5G infrastructure currently being built-up in the context of the ICT-17 5GENESIS Project [3]. This platform will be extended in the framework of 5G-VICTORI for the support of vertical industries in operational environments. It will offer certain capabilities to execute the verticals' UCs proposed by 5G-VICTORI, as described in deliverable D2.1 [1].

The Berlin Platform targets ultra-dense areas covered by various network deployments. In 5G-VICTORI this infrastructure spans towards the Deutsche Bahn premises (railway stations) in the Berlin area. The specific 5G infrastructure deployed at these vertical premises will involve an edge deployment that will be connected with the 5G Radio Access Network (RAN) over state-of-the-art transport network.

The KPIs for the various UCs foreseen for the Berlin Platform will be assessed when running the UCs over the different sites that comprise the Berlin facility, from both the network infrastructure and the application (service) perspective. The target network KPIs are User Density, Reliability, Service Creation Time, and Data Rate.

This section presents first the initial site facility implementation in Section 2.1. The overall hardware (HW) and software (SW) components of the infrastructure, the planning and the timeline for the extension of the ICT-17 infrastructure are also included in Section 2.1. An overview of the upgrades needed in the ICT-17 infrastructure to become a suitable platform to run the 5G-VICTORI UCs are described in Section 2.2. Finally, in section 2.3 an initial risk assessment is included given the emergency situation faced in this first quarter of 2020.

2.1 Site Facility Implementation

The Berlin Platform built-up in 5GENESIS includes the Fraunhofer FOKUS site in West Berlin, the IHP site in Frankfurt (Oder), and the Humboldt University site in the center of Berlin [6]. A flagship activity to be performed within the 5GENESIS Berlin Platform is the installation of a 5G edge deployment leveraging 5G access technologies in order to provide 5G access to the visitors of the "Festival of Lights" event, which is held in Berlin every October.

5G-VICTORI proposes the extension of the ICT-17 5GENESIS infrastructure with the provision of 5G equipment and enhancements to the existing components to accommodate the 5G-VICTORI UCs. These UCs are related to the deployment of a 5G infrastructure in a railway-related venue. The Berlin Cluster will run three UCs at the Berlin Central Station (*Berlin Hauptbahnhof*), which have been described in deliverable D2.1 [1]:

- UC # 1.2: Transportation, Digital/Future Mobility.
- UC # 1.3: Transportation, Rail Critical Services.
- UC # 3: CDN services in dense, static and mobile environments.

The required equipment to support the above-mentioned UCs involves SW and HW components. For the extension of the Berlin facility, there are components that are common for all three UCs, while other components are only relevant for specific UCs. For an initial experimentation of the respective UCs, the equipment can be built and tested in the lab or in office environments.

Figure 2-1 shows the local area of the Berlin cluster, where some of the key sites that comprise the Berlin facility are highlighted. These are:

- The **Fraunhofer FOKUS** site hosts all management components of the Berlin site and represents the central control point for the interconnection of additional sites. It provides centralized compute and storage capabilities and integrates around the FOKUS Open5GCore legacy 4G radio technologies, as well as 5G NR Stand-Alone (SA) equipment and non-3GPP access technologies such as Wi-Fi and satellite links for interconnecting remote sites. The management capabilities of the Fraunhofer FOKUS site allow as well to push selected network management functionality or a fully-fledged 5G core network to completely self-contained or interconnected remote sites, such as the Berlin Central Station, coping with potentially disruptive or bandwidth-limited inter-site connections.

Figure 2-1: Local area of the Berlin Cluster

- **Berlin Central Station, *Berlin Hauptbahnhof***, or **Berlin Hbf** throughout this document. It is one of the main railway stations in Germany. Around 1800 trains call at the station per day and the daily number of passengers is approximately 350000. The station consists of several independent operating points. The most relevant platforms for the project are platforms 11 to 14, which are located above-ground and are used for regional and intercity services. This station is the target site for the execution of the trials.
- **Berlin Jungfernheide station**, operated by Deutsche Bahn, represents an alternative site for running the UCs in case of restrictions to access Berlin Central Station.
- ***Betriebsbahnhof Rummelsburg*** is a depot operated by Deutsche Bahn, for the storage and maintenance of passenger train sets used for long-distance traffic. It represents an alternative site for the execution of UC # 1.2.
- **Deutsche Bahn's Advanced Train Lab and Living Lab near Annaberg-Buchholz**, is a large-scale testing facility for infrastructure and onboard systems that can be placed on an ICE train, and it features the first Deutsche Bahn's digital interlocking. In this site the first integration tests could be performed and, at the same time, the first in Europe.

5G-VICTORI will extend the Fraunhofer FOKUS facility to at least one of the three aforementioned train stations to execute the field trials. The decision of which train station will be provisioned for field trials, depend on security and safety constrains imposed to the deployment of the 5G test infrastructure at each facility, as well as equipment and installation costs for the provisioning. All of the latter are currently under further evaluation and will be clarified as soon as the team is allowed to access the Deutsche Bahn infrastructures and meet the responsible people in charge of the stations' department, rolling stock personnel together with the technicians and IT people. This decision will be taken over the summer break and the definite sites for running the UCs will be specified in deliverable D2.3.

2.1.1 Berlin Hauptbahnhof Facility Description

Berlin Hbf is one of the major stations in Germany (Figure 2-2). The station is special as it has two layers of main line tracks, one layer connects west-east while the other connects north-south bound trains. This can be seen in Figure 2-3.

For the interest of 5G-VICTORI, the tracks on the upper floor (Figure 2-3 a) are more relevant, as the regional train from *Jungfernheide* uses these and it is normally scheduled for Platform 11. The interior of Berlin Hbf as well as the placement of Platform 11 can be seen on Figure 2-4.

Figure 2-2: Berlin Hauptbahnhof

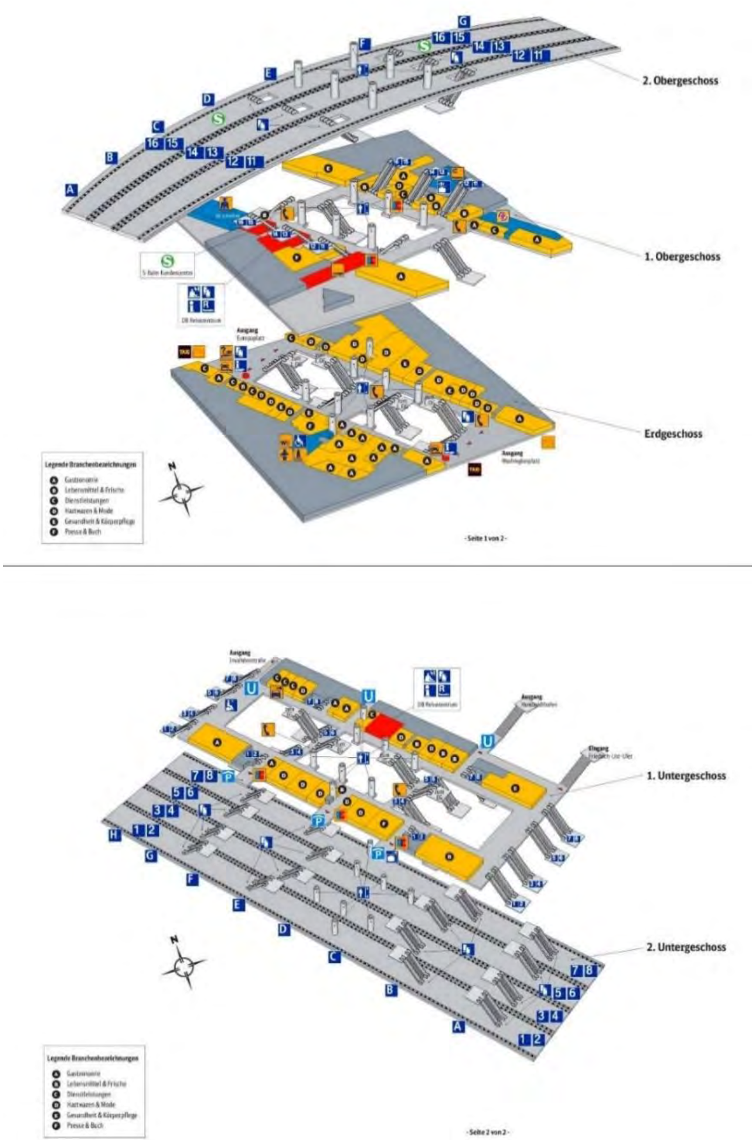


Figure 2-3: Floorplan of Berlin Hbf, a) upper floors (W/E), b) lower floors (N/S)

Figure 2-4: Interior of Berlin Hbf (view on track 11 - with ICE train)

Figure 2-5: Berlin Hbf Track 11/12 - direction West

For the support of the Berlin Cluster UCs, the 5G radio network nodes' deployment should provide sufficient coverage footprint over the platform area of the station, presented in Figure 2-5. As far as the deployment of the 5G radio equipment is concerned, a clear line of sight between the antennas on-board the train and the Remote Radio Heads (RRHs) is desirable, a placement in one of the rooms of the bow is not possible as this would require the signal to go through the roof construction, which could lead to a loss of signal strength.

Due to this, a placement of the RRH right at the platform is most feasible. As the position should be a protected area, which also does not raise too much attention by the customers, we aim for using already existing structures. In Figure 2-5 a view standing right at Platform 11 can be seen. As the platform and the tracks are used for normal railway operation the placement right above the track is impossible as this could lead to safety issues. Due to this, a placement of the RRH at the signal bridges of the platform seems to be the best solution.

On the west side of the platform a T-shaped signal bridge exists (Figure 2-6), which could be equipped with the RRHs as well as some smaller management devices. From there a cable can be installed, connecting to an office location in one of the bows where the servers will be located.

The same can be done for the east side, as there is also a signal bridge in place (Figure 2-7).

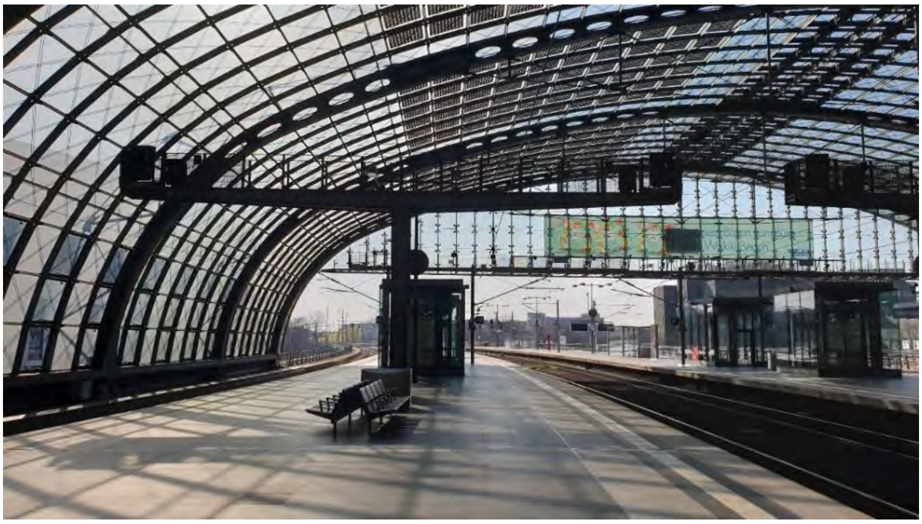


Figure 2-6: Berlin Hbf Track 11/12 - direction West

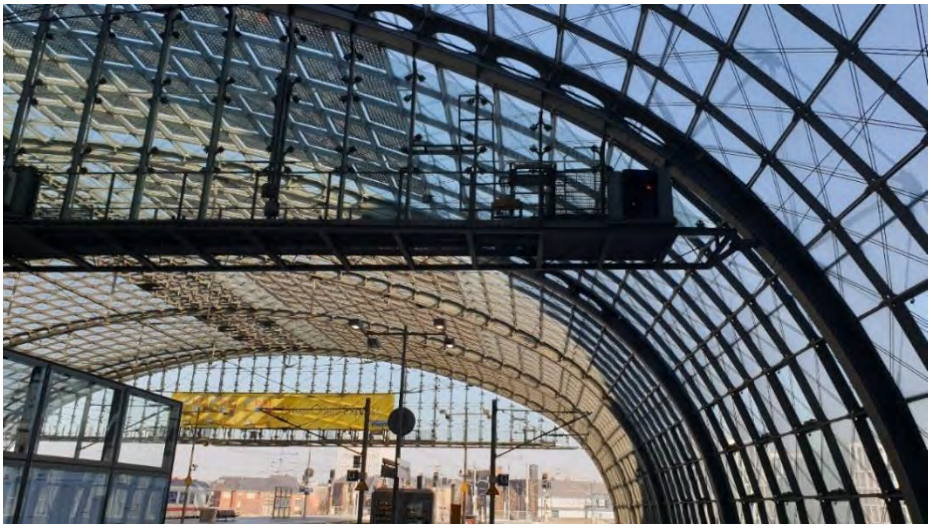


Figure 2-7: Berlin Hbf Track 11/12 - direction East

2.1.2 Annaberg-Buchholz Test Field

The Annaberg-Buchholz Digital Test Field bundles competencies in research, development, testing, and evaluation in order to develop new products and implement new technologies in the railway industry in a simple and flexible way. The new Digital Test Field of DB Netz AG and DB Erzgebirgsbahn is a test environment consisting of a test track and test vehicles with the aim of testing operational processes. It reduces operating and maintenance costs, sustainably increases competitive advantages and ensures more capacity and punctuality in rail transport.

The Digital Test Field is a 25 km long railway track between Annaberg and Schwarzenberg in Saxony (see Figure 2-8). As there are only a few tourist trains on this route and no regular operation takes place, it provides the unique opportunity to test both software and HW solutions for the operation of vehicles and infrastructure under various operating conditions.

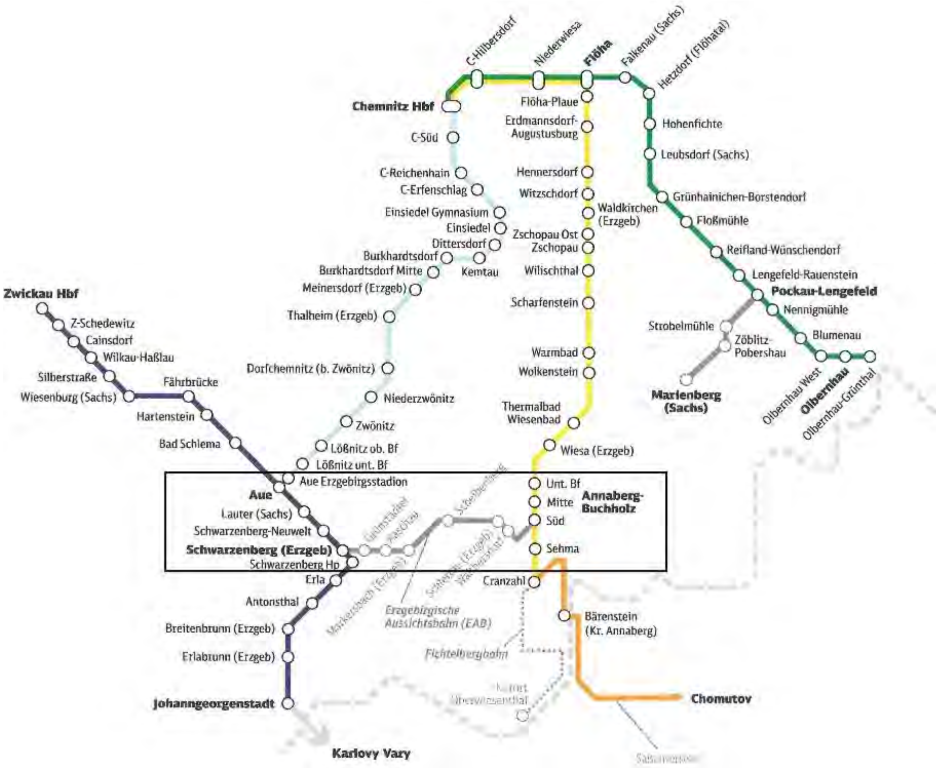


Figure 2-8: Area of the Digital Testfield

Testing novel technologies is often complicated due to the high occupancy rate in passenger traffic. Within the Digital Test Field, the advanced TrainLab is operated, being one of the Deutsche Bahn test vehicles in which innovative tests can be carried out. Multiple units of train wagons (605 series, also known as ICE-TD) are available for implementing the 5G-VICTORI innovations within a controlled and safe framework.

2.1.3 Alternate Site: Berlin Jungfernheide

Berlin *Jungfernheide* is a passenger station in the western part of Berlin, which consists of two platforms over ground and a metro station in the underground (Figure 2-9). For 5G-VICTORI only the tracks above ground are of interest and, from the two platforms, only the Platform 1/2 operates trains that are scheduled for the Berlin Central Station. On the other platform, only trains of the “Ringbahn” of “S-Bahn Berlin” operate.

Considering the 5G radio network nodes’ deployment, as the station is rather small and the platforms do not contain many facilities and housings, the most feasible location for placing the RRH can be seen on Figure 2-10. The displays of the passenger information systems are mounted to cross-like structure, which also contains speakers for announcements. For testing purpose, it would be most feasible to also attach the RRH to this structure, as it has a clear line-of-sight to the trains and provides a protected area from the passengers. Unlike the potential deployment at the Berlin Central Station, any installation in this station is prone to climate effects, such as rain.

2.1 Planning and Components

The 5G-VICTORI Berlin cluster aims at putting demo equipment at the station, in the platforms and on-board the train for the different UCs proposed. The on-board vertical services use several Network Slices over the same available 5G radio network nodes. This will allow the concurrent provision of the above-mentioned services with the required isolation and performance – given by a certain Service Level Agreement (SLA) – of each vertical service.

Figure 2-9: Overview of Berlin Jungfernheide

Figure 2-10: Berlin Jungfernheide Platform 3/4 and possibilities for placement of equipment

In order to comply with German spectrum regulation for the operation of these demonstrators, the owner/user of the facility to be eventually used – in this case Deutsche Bahn – will apply for a campus network license or test/experimental license from the *Bundesnetzagentur* (BNetzA) for spectrum in the 3700 - 3800 MHz band reserved for local / campus networks.

Office, Wayside and Onboard demo equipment descriptions are provided in the following subsections.

2.1.1 Common Components and Equipment

The *Berlin Hauptbahnhof* site includes the deployment of a 5G RAN, a 60 GHz wireless transport network, fixed transport network and compute and storage resources, which will be shared across UCs. Additionally, for the UCs that require on-board equipment, Wi-Fi access points and wired network connectivity devices will be deployed on the train.

Figure 2-11 shows a diagram of the equipment that will be used when executing the UCs. The common equipment is depicted in black. It mainly comprises commercial-off-the-shelf (COTS) equipment, the 5G access and backhaul components and the HW components that are currently being developed in the framework of the ICT-17 5GENESIS project.

In the sequel we present in more detail the common equipment, HW and SW components that will be made available to manage the infrastructure, to support the monitoring and analysis of the data and to evaluate the KPIs.

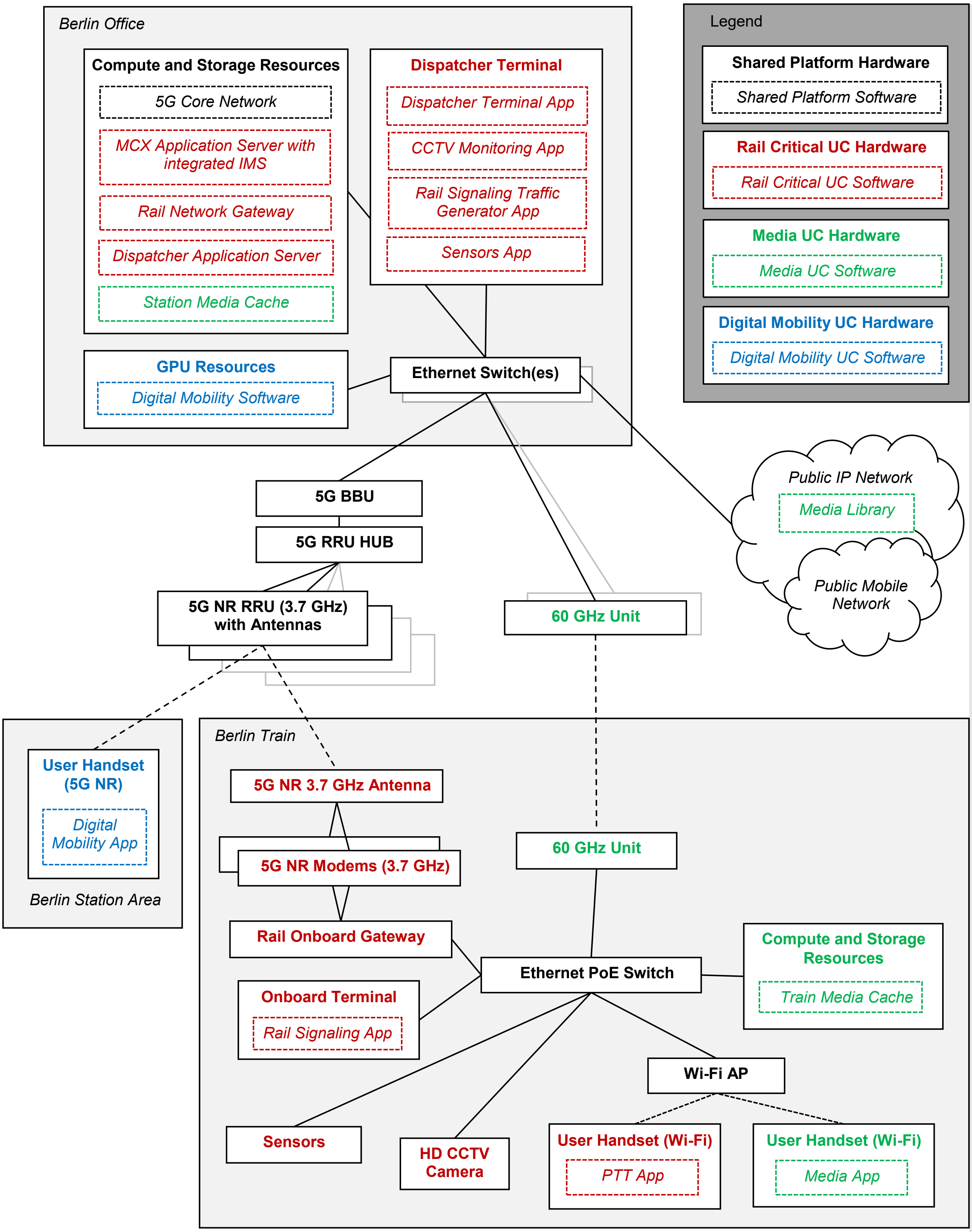


Figure 2-11: Berlin Cluster demo equipment and applications overview

2.1.1.1 5G Access and Transport Network

Regarding the RAN solutions, 5G NR (Stand Alone) will be used for providing access to the 5G-enabled UE devices, as well as for providing the feed (last mile) connection to Wi-Fi APs on board the train; the latter will be potentially used in unlicensed bands for 802.11 in 5 GHz and 2.4 GHz across all facility sites and UC sites.

At the *Berlin Hauptbahnhof* facility, the 5G access and 60 GHz backhaul equipment will be set up at the station and in the train(s). Figure 2-12 depicts a high-level sketch of the baseline 5G components that will provide connectivity at the platforms and train.

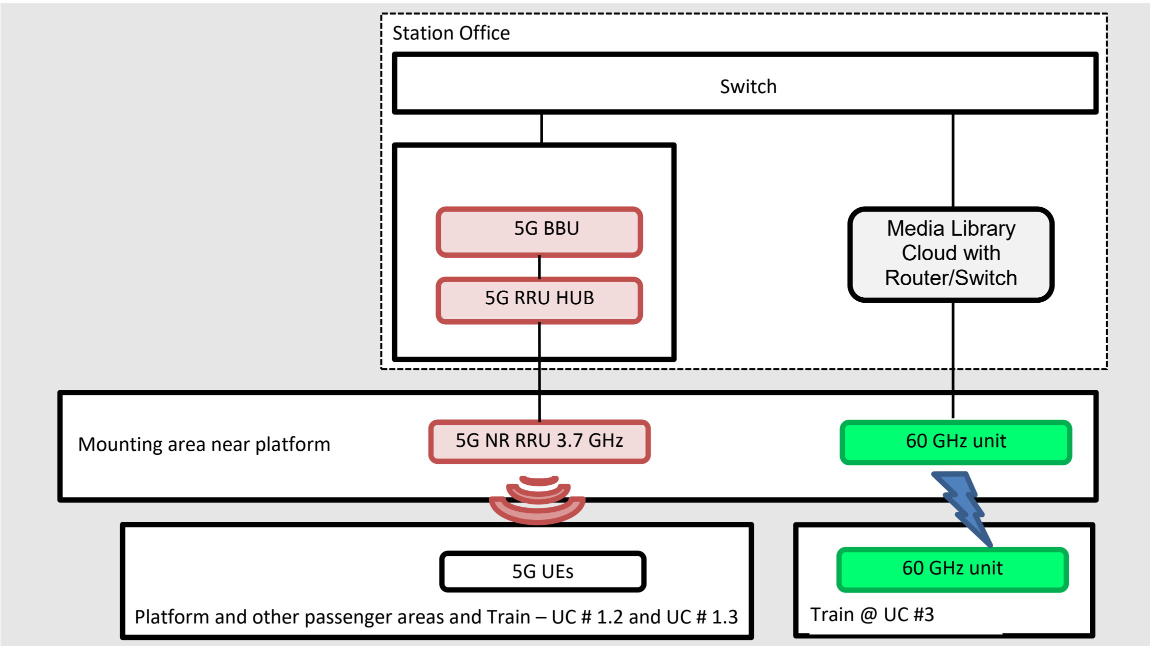


Figure 2-12: Berlin Hauptbahnhof 5G equipment at the office, mounting area and rolling stock

Two types of solutions will be installed at *Berlin Hauptbahnhof*, for the provisioning of FRMCS, the first being the 5G NR Stand Alone access equipment at 3.7 GHz, and a second being a millimeter wave (mmWave) 60 GHz solution. Both technologies will serve as last mile backhaul links from the mounting area on top of the platform to the train; the 5G link may also serve directly end-user devices.

- The 3.7 GHz Remote Radio Units (RRUs) RRUs are connected to the 5G network and serve the UCs Digital Mobility (UC # 1.2) and Rail Critical Services (UC # 1.3). These RRUs cover both the train and the platform areas to provide connectivity to pedestrians situated at the train(s) and at the platform(s). The RRUs will be connected to the necessary 5G NR Baseband Unit (BBU) and RRU Hub. The latter will be connected to a 5G Core Network.
- The 60 GHz unit at the mounting area is connected to a Media Library Cloud and serve the UC for CDN video cash updates (UC # 3). The 60 GHz unit at the mounting area provides wireless connectivity to the unit installed at the train. It is a fully integrated solution featuring in a small form factor both baseband and MAC parts together with the full 60 GHz transceiver. The 60 GHz link is separated from the 5G Network.

2.1.1.2 Interconnection between sites

The sites will be interconnected via a virtual private network link over the public Internet (DFN network at FOKUS' site and commercial Internet provider at the DB sites). Depending on the delay and throughput characteristics of this link, network components may be hosted at the FOKUS data center or at the edge deployment at the train stations. Both solutions are technically supported by the Berlin facility.

2.1.1.3 Cloud infrastructure and MANO services

The MANO Layer of the Berlin facility comprises three main components: NFV MANO, Network Management System (NMS), and Slice Manager.

The NFV MANO is realised via OSM and OpenStack. The VIM is provided by OpenStack.

The NMS is a platform-specific NMS with direct access to physical resources as well as configuration interfaces. In the Berlin platform, the NMS will provide the overview of the physical resources and an interface to manage them.

Cloud infrastructure will be deployed at the office area and will make use of shared compute and storage resources.

2.1.1.4 5G Core

The Open5GCore implementation is a 5G oriented implementation of the 3GPP core network stack (currently 3GPP Release 14 and 15, whilst Release 16 is planned in future releases).

Open5GCore runs on top of common hardware platforms and can be deployed with containers or virtual machines (VMs) on top of a large number of virtualization environments. The required hardware for a testbed setup highly depends on the expected capacity. Open5GCore scales from Raspberry PI to a complete rack of servers.

At the demo site, the Open5GCore 5G Core Network will be deployed in the office area on the shared compute and storage resources. Local deployment of the core network's user plane functions will enable lower latency and better throughput for data connections to support the locally deployed UC services.

2.1.1.5 Edge computing

References in the site descriptions to the Berlin Office assume a full edge deployment at Berlin Hauptbahnhof. However, the level at which edge computing is used relies on two key aspects of infrastructure that are yet to be assessed:

- The amount of physical compute, storage, and GPU resources that can be installed at Hauptbahnhof due to space or other site constraints and to whether they can support each of the UC applications
- The quality of the inter-site network connection between the FOKUS and Hauptbahnhof (for example in terms of throughput and latency) and whether it can support each of the UC applications

Table 2-1 outlines the potential options. A final decision of the deployment option will be taken once the infrastructure has been assessed.

Table 2-1: Options for edge deployment in the Berlin Cluster

	Conditions	Deployed at FOKUS	Deployed at Hauptbahnhof
Full edge	Compute resources at Hauptbahnhof support all UCs.		5GCN All UC applications
Partial edge	Compute resources at Hauptbahnhof only support some UCs. Inter-site connection only supports some UCs.	UC applications	5GCN UC applications
Minimal edge	Compute resources at Hauptbahnhof only support 5GCN. Inter-site connection supports all UCs.	All UC applications	5GCN
No edge	No compute resources at Hauptbahnhof.	5GCN All UC applications	

The virtualized components may be instantiated at any compute/data center location present at any of the Berlin facility sites.

2.1.1.6 Monitoring and analytics

The full-chain monitoring and analytics framework developed in the context of 5GENESIS [7] will be used in 5G-VICTORI to validate suitable functioning of the network components. This framework will oversee the collection and analysis the data “created” when using the 5G-VICTORI Berlin facility. This will also ensure a correct assessment of the KPIs.

2.1.1.7 KPI evaluation support

The Berlin facility will be able to create and adapt interfaces for the support of the aggregation of measurements to enable 5G KPI evaluation. The 5GENESIS KPI evaluation framework will be used for that purpose.

2.1.2 **UC # 1.2 - Transportation: Digital Mobility**

For this UC, passengers involved in the trial will arrive at the station by train with the front-end app pre-installed on their 5G UEs (or project partners with 5G UEs in case 5G UEs are not broadly available), as described in section 4.4.1 of deliverable D2.1 [1]. These passengers will walk around the station with the app, where the 3D twin will be rendered and overlayed on the smart phone’s live camera feed, and thereby help the passenger to orientate inside and around the station. The app will connect to the back-end running at the edge (located physically in a server room at the station), and download the station’s spatial digital twin (3D).

To address the requirements derived in deliverable D2.1, the network deployment will comprise the following components:

- Office equipment: Use of Urban Hawk’s (**UHA**’s) GPU cloud in part or as a whole. It consists of 4 Nvidia RTX 2080 and 4 Nvidia GTX 1080 GPUs, 2 Intel I9 CPUs with 2x16 GB RAM. Data storage wise the capacity is up to 2 TB on SSDs and up to 16 TB on HDDs.
- Wayside equipment: considers Edge computing from the future mobility demo’s point of view. The same back-end software piece is going to run at the Edge. Limited datasets, which are location relevant and with limited range, will be present in each Edge node. One GTX 2080 will be sufficient to serve the suggested number of demo passengers.
- Onboard equipment: this UC is not planned to involve any infrastructure on board of trains. The UC targets the passenger arrival at the station, where station guidance, real-time journey planning and re-planning (as you walk), and passenger following (mobility) will be the key features. Any on board communication from the passenger front-end devices will go straight to the cloud/back-end.

This UC is similar with regard to the implementation to that of happening in the Bristol cluster, which is described in section 3.1.3.3.

2.1.3 **UC # 1.3 - Transportation: Rail Critical Services**

The Rail Critical Services UC aims at showing that a selected number of typical railway services such as train to ground communication services for safety relevant system can be conveyed over a 5G cellular network at the same time, while keeping the characteristics needed for each service.

The required characteristics needed by each service will be reached regardless of other services and background traffic, i.e. not being disturbed by other services or background traffic, and not disturbing others.

The isolation between services over a 5G cellular network is done both by using different Network Slices, and by using different QoS indicators within each Network Slice. These parameters propagate to the backbone network slicing, securing E2E resources.

The execution of Rail Critical Services requires deployment of infrastructure, services and applications in Signalling, Fixed installation and Rolling Stock domain. The railway applications, i.e. application layer, provides railway-specific functionalities, which are reflected in Rail Critical Services UCs like:

- Train Control Signalling UC based on emulated train signalling like CBTC, ETCS or FRMCS by Rail Signaling Traffic Generator between the train and Berlin Office endpoints.
- Real-time High-Definition CCTV transmission from train to the Berlin Office, from a train-mounted HD camera.
- Mission-Critical (MC) Railway Telephony like emergency group communication, operational private and group communication between driver, other stuff, primary controller based on MCPTT service and MC Railway Data like sensor-based telematics between train and ground based on MCData service.
- Object Controller Signalling between an Interlocking and an Object Controller with its objects like Point Machine or a Signal.

The railway applications are deployed on-board and wayside on dedicated HW. The communication and complementary services used by the railway applications are provided by MCX and Dispatcher Application Servers upon IMS-based SIP core, i.e. service stratum. The service stratum and its components are deployed as VMs on common compute and storage HW resources. All railway services are provided via 5G utilising its 5G service-based architecture as transport stratum.

Figure 2-13 shows how the Berlin Cluster HW boxes needed for the Rail Critical Services are interconnected, both using Common HW and Rail Critical Services specific HW.

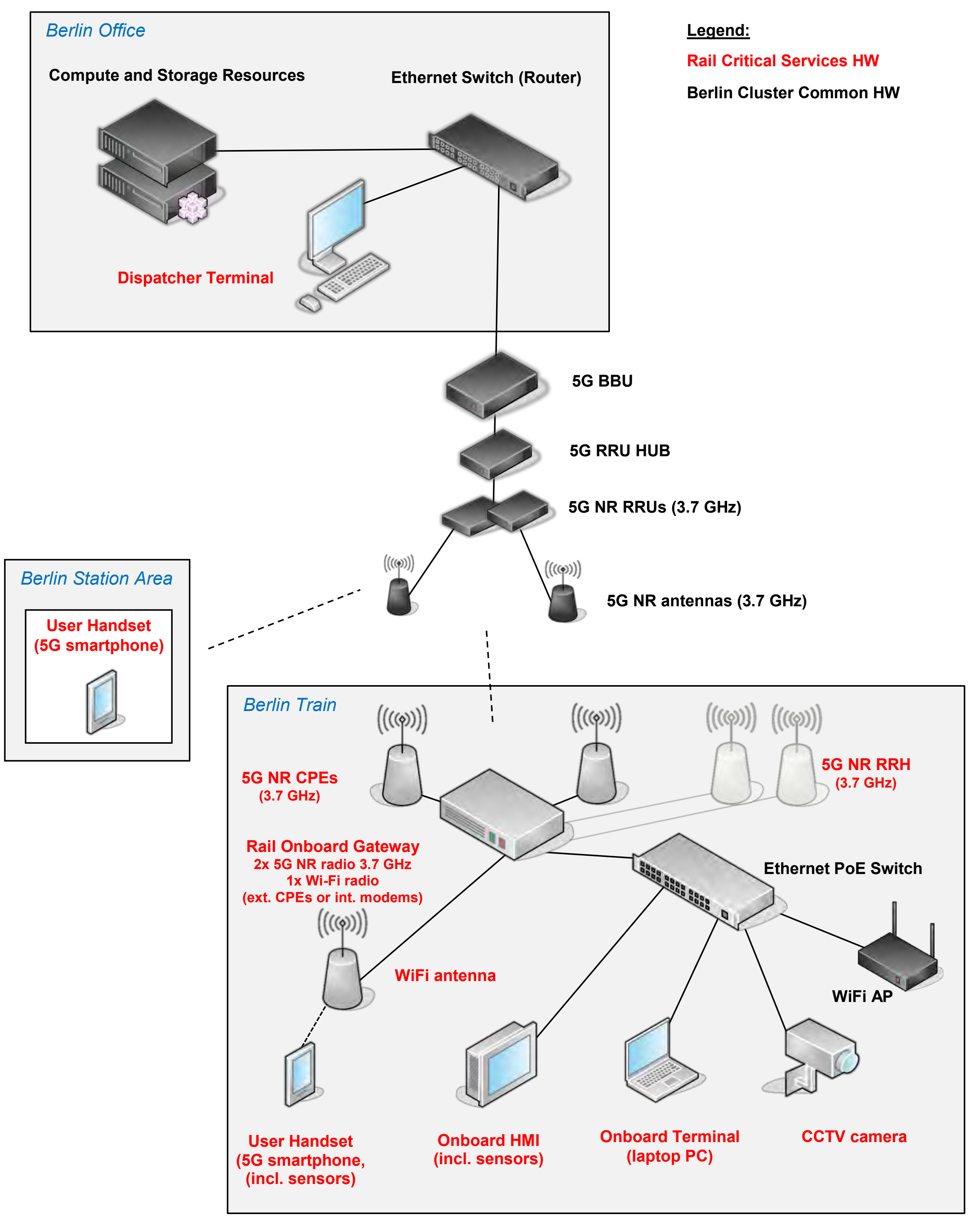


Figure 2-13: UC # 1.3 Rail Critical Services - Connection Diagram

Figure 2-14 shows all HW and SW for the Rail Critical Services needed in the Berlin Cluster. The SW are both Applications (APP) and VMs. The figure also shows project partner contributions, using the 5G-VICTORI project defined colors.

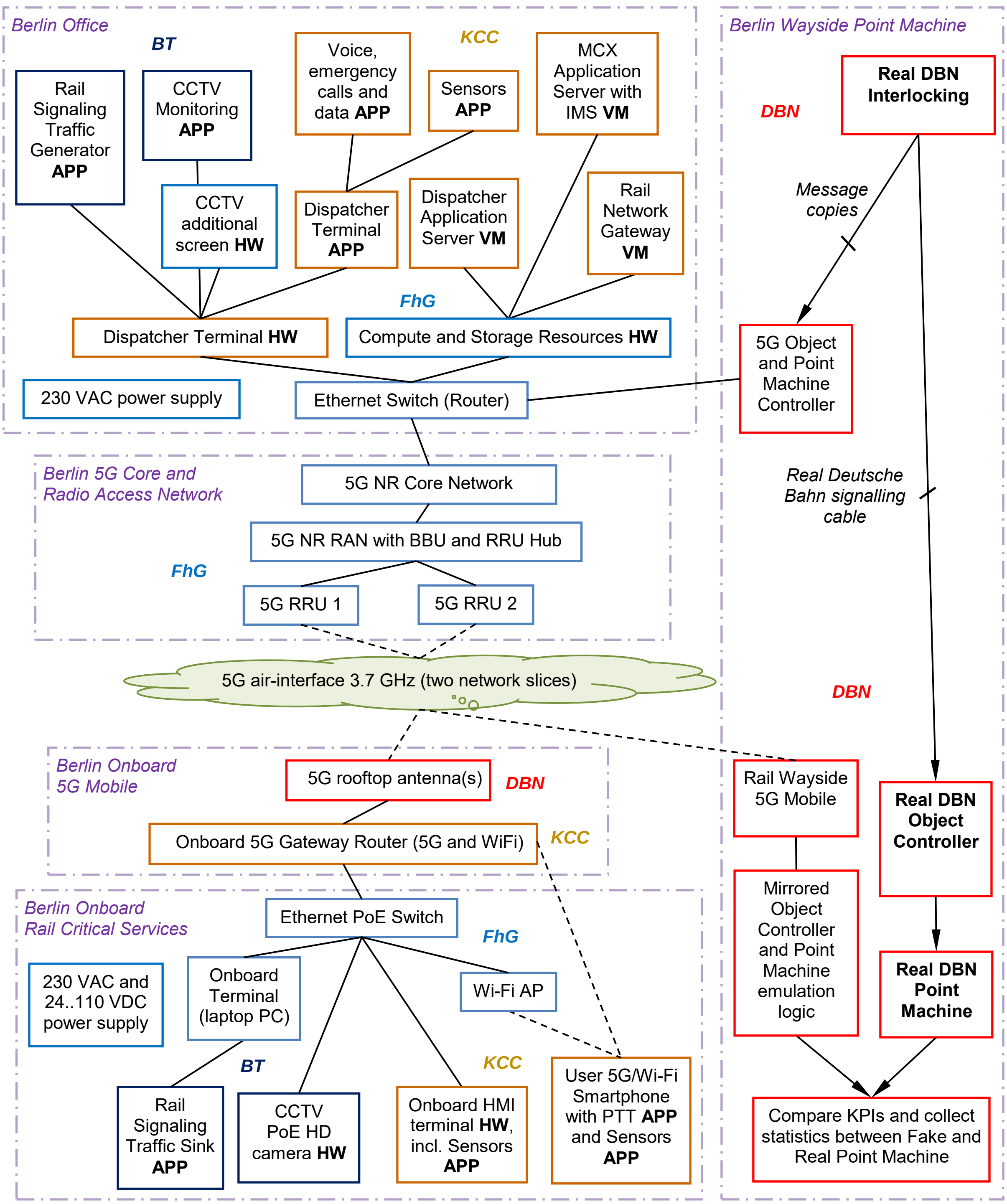


Figure 2-14: UC # 1.3 Rail Critical Services – HW and SW with Contribution Overview

2.1.3.1 Lab - Rail Critical Services Equipment

The equipment for Rail Critical Services is first put in a lab to make sure everything is working as intended. Then the equipment can be moved to a train. Therefore, the lab equipment will be the same, or similar as much as possible, to the train equipment.

If the radio equipment RF output power cannot be configured to a low safe level for lab purpose, RF cables with attenuators can be used instead of the real RF air-interface with antennas.

2.1.3.2 Office - Rail Critical Services Equipment

The Office equipment for Rail Critical Services is based on HW (**FhG** and **KCC**) with SW applications (**BT** and **KCC**), connected via a common Ethernet Switch (**FhG**) to the Berlin 5G Core and RAN.

The Berlin Office for Rail Critical Services will host Compute and Storage Resources HW, where all virtualised components of the transport stratum, the 5G Core Network (**FhG**) and of the service stratum, the MCX and Dispatcher Applications Server and the IMS-based SIP core (**KCC**), will run. The Compute and Storage Resources HW could be mounted in a transportable 19-inch rack, so that the node can be placed either at the Berlin Hbf station or at the Fraunhofer lab premises easily.

Furthermore, there is Dispatcher Terminal HW (**KCC**) in the Berlin Office (see Figure 2-15a), which is a specialized embedded PC with touch screen, gooseneck microphone, handset and loudspeakers (product targeted for railway controllers in railway operations control centers). The Dispatcher Terminal hosts a Dispatcher Terminal App (**KCC**), which offers railway critical voice, data, messaging, video communication and sensor-based asset management via Sensor App (**KCC**).

Besides that, the Dispatcher Terminal HW hosts third-party applications for High-Definition CCTV Monitoring (**BT**) and a Rail Signaling Traffic Generator (**BT**). The terminal will be connected to an external monitor (**FhG**) to improve the usability of the HD CCTV monitoring and allow seamless parallel operation of all apps hosted by the terminal.

The CCTV camera monitoring App in the Berlin Office is an application called “Companion” or “Camera Station”, from vendor Axis. The monitoring application shows streaming pictures from the camera. Stored event-based video clips can also be shown from the local SD memory in the camera, if configured to record video clips (**BT**).

The Rail Signaling Traffic Generator in the Berlin Office is an application from vendor Ixia, with target version IxChariot. The minimum license is for two users and 10 Performance End-points. From the console in the Office, communication paths with certain characteristic and protocols can be set up bi-directional between these pre-installed End-points (**BT**).

Further infrastructure required at the Berlin Office is an Ethernet switch or a router (**FhG**)[1]. Power supply for the Office equipment: 230 VAC, 50 Hz, 2000 Watt via a schuko socket (**DBN**).

Figure 2-15: a) Dispatcher Terminal, b) On-board Handheld Terminal

[1] If the Compute and Storage Resources HW (**FhG**) is accessed remotely, a stable broadband internet connection is needed in between (**DBN**)

2.1.3.3 Office – Berlin 5G Core and RAN

The Berlin 5G Core and RAN contains:

- 5G NR Core Network.
- 5G NR Radio Access Network with BBU, and RRU Hub.
- 5G RRU 1, RRU 2, and probably an RRU 3 (including antennas).

2.1.3.4 Wayside - Rail Critical Services specific 5G Network Equipment

The Wayside equipment is available at the Digital Test Field of **DBN**. For the test, the following equipment will be featured:

- Gateway device with 5G antenna and wired connection to the EULYNX Object Controller (**DBN**).
- Siemens EULYNX Object Controller (with interface for point machine) (**DBN**).
- Point machine hard-wired to the Object Controller (**DBN**).

2.1.3.5 Berlin Station Area

To be able to demonstrate group-based rail critical services, it is required to have three and more involved railway users, i.e. MCX clients, in the communication. That is why there is mobile handset running Rail Push-To-Talk (PTT) application required to participate in emergency and operational group communication in the Berlin Station area.

2.1.3.6 Berlin Onboard 5G Mobile

The Berlin Onboard 5G Mobile equipment, which consists of 5G train rooftop antennas for 3.7 GHz (**DBN**) and Onboard 5G Gateway Router (**KCC**), will be installed in the rolling stock under supervision of DB and in case of rooftop antenna specifically by authorized maintenance **DBN** staff.

The Onboard 5G Gateway Router provides communication services to all onboard applications via onboard Ethernet network and via onboard Wi-Fi network. The Gateway Router is using two external 5G (3.7 GHz) CPEs with external rooftop antennas or potentially, internal 5G miniPCIe radio module(s) and an internal Wi-Fi module connected to an indoor Wi-Fi antenna (**KCC**).

It can be assumed that the 5G and Wi-Fi radios have suitable RF filters for isolation to other onboard radios (also depending on how close these antennas are located to other existing antennas). Else additional filters might be needed.

Furthermore, it can be assumed that the rolling stock (**DBN**) is capable of providing 230 VAC, 50 Hz, 200 Watt power socket, else a power converter (**DBN**) is to be installed to convert from onboard voltage.

2.1.3.7 Onboard - Rail Critical Services Equipment

The Onboard equipment for Rail Critical Services, which shall be installed on a “demo train” under supervision of **DBN** or authorized personnel, is based on hardware (**KCC**) with software applications (**BT** and **KCC**), connected via a common Ethernet PoE Switch (**FhG**) to the Berlin Onboard 5G Mobile.

There is an Onboard Terminal, which is a laptop or a PC, hosting Rail Signaling Traffic Sink (**BT**) and which can be potentially used for KPI monitoring as well.

The High-Definition CCTV camera (**BT**), which is an indoor rail rigid camera version, is mounted in the train cab, inside the train front window. Parts of the camera view can be masked if needed (GDPR reasons). Recording of events can be done on a camera local SD card, if configured to do so.

The Onboard Human Machine Interface (HMI) is a fixed terminal or a tablet or a smartphone running onboard Rail PTT application (**KCC**), which allows the train driver to communicate via voice, data and messaging with controllers, other drivers and wayside staff.

The terminal contains several sensors such as accelerometer, gyroscope, magnetometer, GPS and barometer, which are used by the sensor-based asset management and alert trigger application. It is installed in the train cab. It is connected through onboard Ethernet switch and network, using communication services of the Onboard 5G Gateway Router.

The Onboard Handheld (Figure 2-15b) is a ruggedized smartphone (**KCC**) running onboard PTT application incl. sensor-based asset management and alert trigger application (**KCC**). It is equipped with physical emergency, alert and PTT buttons. It is connected via onboard Wi-Fi network and using communication services of Onboard 5G Gateway Router.

Further infrastructure required onboard in the rolling stock is an Ethernet PoE Switch, CAT-6 cabling, indoor Wi-Fi Access Point used to connect the onboard mobile handsets, plus power On/Off switch, grounding, circuit breakers, cabling, housing (**DBN**).

Onboard equipment could be mounted in a transportable 19-inch rack, so that it can be moved around between lab and rolling stock. Power supply needed for the train (**DBN**) is: 230 VAC, 50 Hz, 200 Watt via a standard schuko socket. If this is not available, a power converter (**DBN**) is needed to convert from what is available onboard.

2.1.4 UC # 3 - Media: CDN services

This section describes the components required for the setup of the media-related UC, i.e. UC # 3 “CDN services in dense environments”. No special equipment for the wayside is required for this UC. The block diagram including the HW and applications is shown in Figure 2-16.

2.1.4.1 Office – Media: CDN services

The “Media: CDN services” equipment in the Office is based on hardware (**IRT**) with applications (**IRT**), connected via an Ethernet Switch (**FhG**) to the Berlin 5G Core and Radio Access Network.

The office HW for Rail Critical Services consists of:

- Office Cache (**IRT**): stores the video streams in the office.
- Content Aggregator (**IRT**): merges the URLs of the video streams and video stream segments obtained in the aggregation process into a list and sends this list to the Prefetcher.
- Content Prefetcher (**IRT**): requests the videos from the list via the Media Cache.
- Content Archive of VoD service operator (**IRT**): the archive of the video streams.
- CDN of VoD service operator (**IRT**): CDN cloud service where the video streams are hosted.

2.1.4.2 Wayside – Media: CDN services

No “Media: CDN services”-specific equipment is planned

2.1.4.3 Onboard – Media: CDN services

The onboard “Media: CDN services” equipment is based on HW (**FhG**, **IRT**) with applications (**IRT**, **FhG**), connected via an Ethernet Switch (**FhG**) and 60 GHz units (**IHP**).

The onboard HW for “Media: CDN services” consists of:

- 60 GHz units (**IHP**).
- Ethernet Switch (**FhG**): connects the onboard equipment to the 5G gateway and antennas.
- Wi-Fi AP (**FhG**): end-users are connected to this Wi-Fi AP to consume video streams.
- Onboard Wi-Fi Media end-user devices) (**FhG**): Wi-Fi-capable end-users devices, e.g. Smartphones, Tablets or Laptops.
- Compute and Storage (onboard cache) (**IRT**): local cache onboard that stores video streams.
- Onboard Terminal (**IRT**): connected to the cache for debugging purposes.

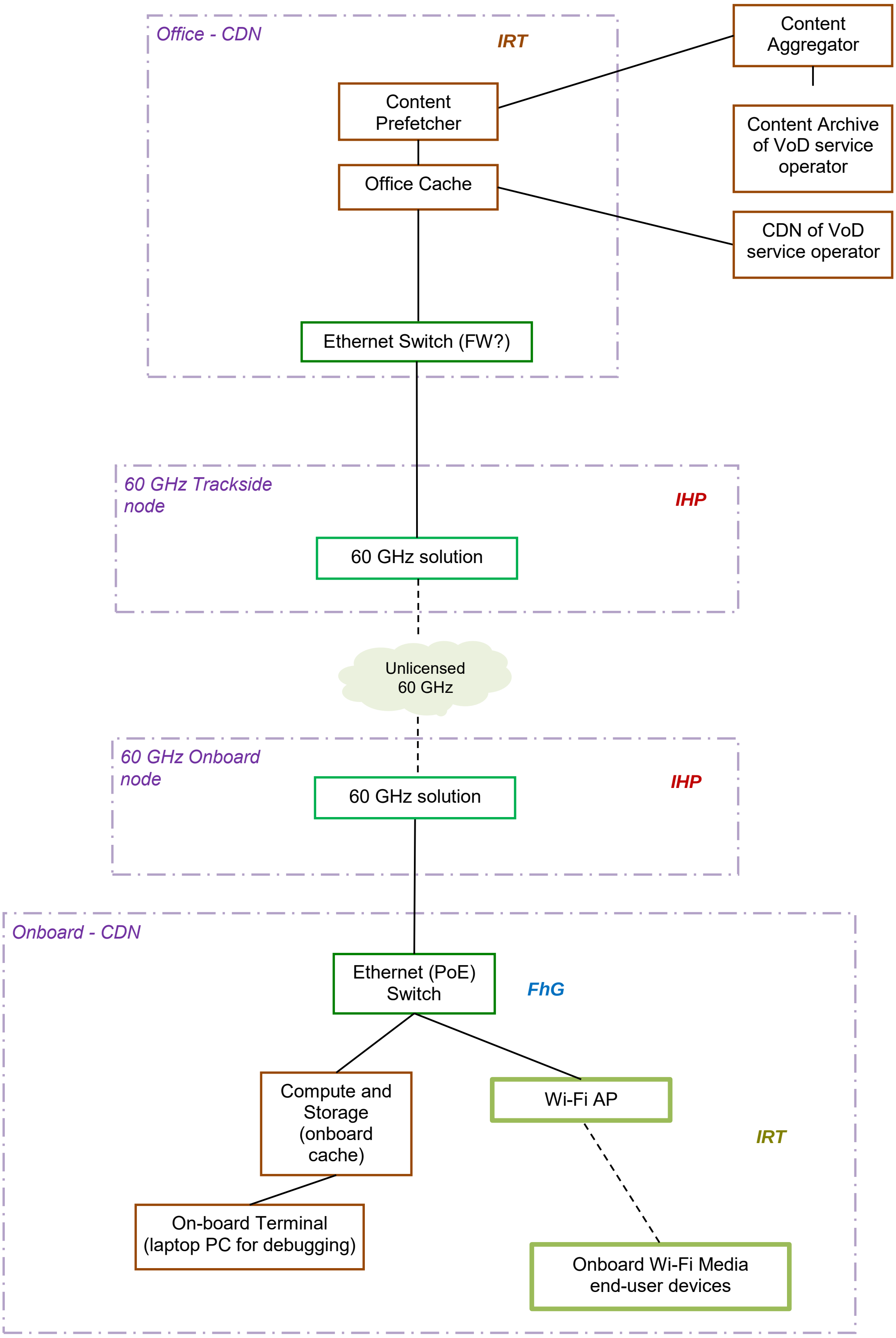


Figure 2-16: UC # 3 - HW and Applications Block Diagram

2.1.5 Activity planning

As explained in the previous sections, the activities in the Berlin cluster are linked to the current developments carried out in the 5GENESIS project. Some of the technologies, both HW and SW will be leveraged by 5G-VICTORI to support the UCs.

By the time this deliverable is submitted, due to the COVID-19 lockdown, it has not been possible to schedule a site visit to *Berlin Hauptbahnhof*. This visit is key to evaluate the environment and physical possibilities for the precise installation of the equipment at the station. This information will be detailed in deliverable D2.3, with due date end of November 2020.

Table 2-2 describes the Berlin Cluster roadmap for planning the facility and the availability of HW and SW components. The final planning of the facility will be provided in deliverable D2.3, and more detail on the specific components and tests will be given in the upcoming WP3 deliverables.

The roadmap for the Berlin facility planning and implementation is also captured as a Gantt chart in Figure 2-17.

Table 2-2: Berlin Cluster – Planning and Components

Activity	Start / Finish Quarter[2]	Dependencies to other Berlin partners
0. Initial high-level planning	M01–M12	Initial phase, **ALL**
1. Network Requirement capture a. UC network dimensioning b. Network coverage c. Network Mobility	M10–M15	Initial phase, Activity 2, **ALL**
2. Site Survey and report on the planning a. UC # 1.2 b. UC # 1.3 c. UC # 3	M12–M15	Activity 1 UC # 1.2 **DBN**, **UHA**, **FhG** UC # 1.3 **DBN**, **KCC**, **BT**, **FhG** UC # 3 **DBN**, **RBB**, **IRT**, **FhG**, **IHP**
3. Processing Requirement capture a. UC cloud/server dimensioning b. MEC requirements	M11–M15	Activity 1 **FhG**, **UHA**, **IRT**
4. Bill of Materials Listing a. HW/SW Equipment (additionally required to existing facilities infrastructure) b. Identifying the gaps between facilities & 5G-VICTORI test setups e.g. in terms of Capabilities Coverage, Spectrum licenses, hosting sites etc.	M12–M18	Activity 1, **ALL**
5. Design Review a. Compliance to UC requirement b. Identifying the gaps with exiting Test Network Capabilities and Coverage, e.g. identify the HW, SW, Spectrum licenses, hosting sites etc.… for the project	M12–M20	Activity 1, 2 **ALL**
6. Procurement process: Acquire parts and services for the install and commissioning of each test network slice per UC	M06–M20	Activity 4 **FhG**, **IHP**, **DBN**
7. Install and commission additional network entities	M12–M24	Activity 5 **FhG**, **IHP**, **DBN**
8. Configure and validate the network slices	M20–M24	Activity 5 **FhG**, **BT**, **IRT**, **UHA**
9. On-board network application a. 5G CN components	M20–M24	Activity 5

[2] There is an impact on the project due to social distancing across Europe.

b. MEC & analytics		FhG
10. Onboard each UC App to their appropriate network slices	M20–M24	Activities 5, 8 FhG, KCC, BT, UHA, RBB
11. Lab testing and initial validation of services per UC a. Component and functional tests b. Report on observed KPI	M20–M24	Activities 9, 10 **ALL**
12. Test and validation of the applications: a. Component and functional tests b. Report on observed KPIs	M24–M36	Activities 9, 10, 12 FhG, BT, IRT, UHA
13. Prepare for the experimentation for the Project Review and Official Deliveries	M24–M36	Activities 10, 11, 12 **ALL**

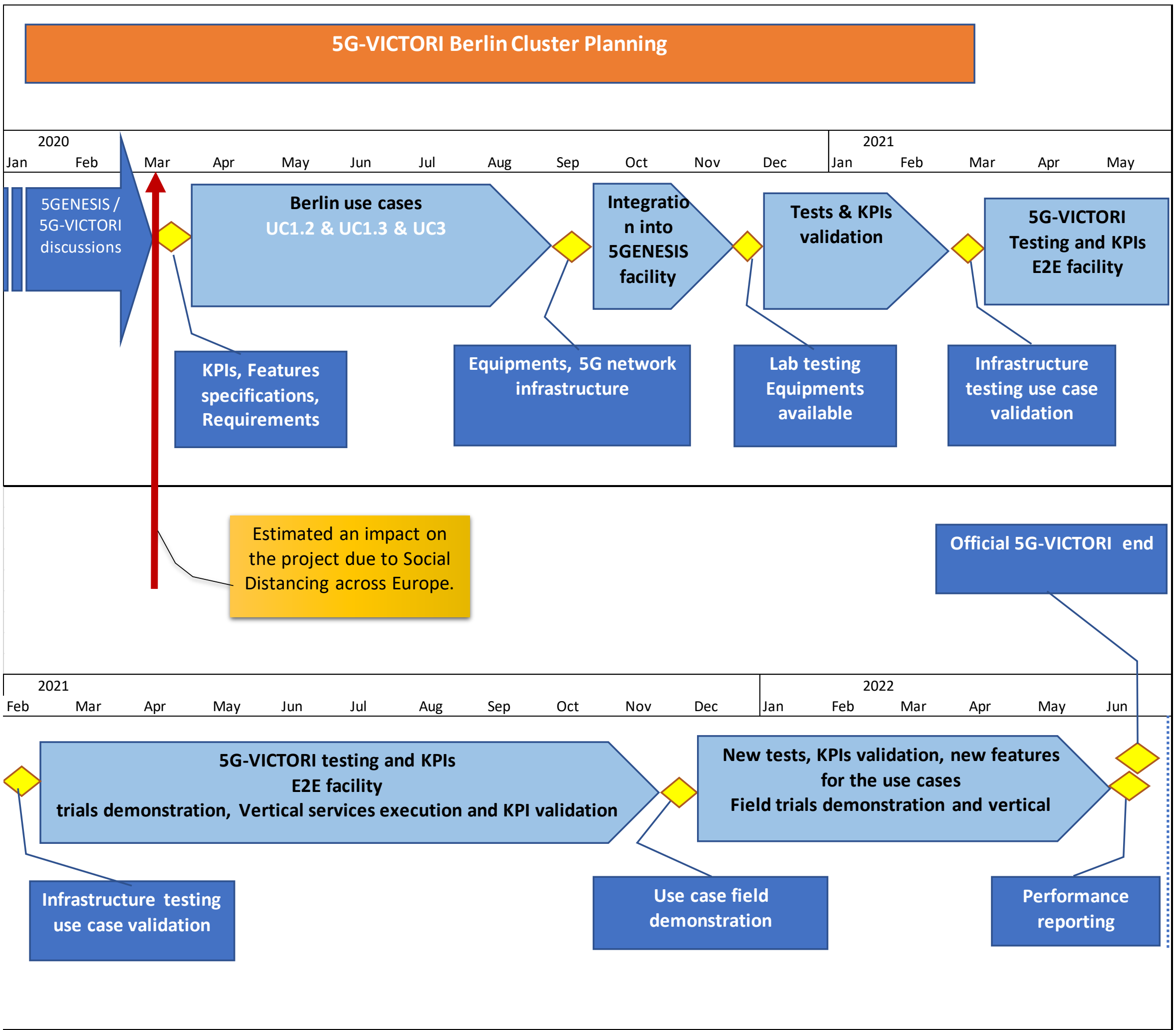


Figure 2-17: High-level planning of Berlin cluster UCs

2.2 Use Case Experimentation related to ICT-17/ICT-19 capabilities

5G-VICTORI will make use of the know-how and available existing assets to extend the impact of the 5GENESIS Berlin Platform towards the sites that are under consideration in 5G-VICTORI, i.e. the Berlin Central Station (*Berlin Hauptbahnhof*) as an additional remote deployment of the Berlin Platform, to support the three UCs (UC # 1.2, UC # 1.3, UC # 3) that will be running in Berlin.

The 5GENESIS Berlin Platform represents a multi-technology, multi-site E2E environment capable of the assessment of 5G services (eMBB and URLLC). It consists of a 5G Core (Open5GCore), diverse

RAN technologies (including 5G), both wired and wireline transport technologies and edge computing capabilities. All these features will be set up to support the 5G-VICTORI UCs that are part of the Berlin cluster. Moreover, the 5GENESIS Berlin Platform is setting up an experimentation framework [6] –in line to the work carried out in the ICT-17 5GENESIS project, which is endorsed by the Test, Measurement and KPIs Validation Working Group of the 5G-PPP. Among the capabilities the platform can offer to external (vertical) industries, we outline its ability to expose interfaces for control and monitoring, involving the required automation processes for experimentation, measurement and KPI computation, as well as to implement control and security aspects.

One of the key aspects of the 5GENESIS blueprint architecture is the ability to accommodate access to the facility and the definition and execution of experiments that vertical industries could trigger as part of the trials to be carried out in 5G-VICTORI. The precision of this definition is under discussion and will be captured in future deliverables (e.g. D2.3 for all Open issues currently under investigation are the following of the questions that are pending to be answered are:

- The way verticals can access the Berlin Platform to perform experiments, is something else needed in addition to a Portal or an “exposed” API?
- Monitoring tools availability for the evaluation of the service-associated KPIs, and the integration of these tools with the existing network-associated KPI evaluation tools.
- Which elements are needed to perform E2E evaluation, including QoS and QoE – as potential indicators for the “user” experience assessment.

Table 2-3 shows a detailed overview of the features the ICT-17 Berlin Platform and the ICT-19 experimentation facility make available for vertical industries to run their services.

2.3 Risk assessment

Field trials in crowded environments, e.g. a railway station, are subject to security and safety constraints imposed to the deployment of any 5G test infrastructure installation. The current COVID-19 lockdown situation in Germany and Europe has an impact on the integration and validation activities at the Berlin Hauptbahnhof facility. Deutsche Bahn currently forbids externals to visit the facility until September 2020. This may lead to a delay of 3-4 months for the integration and testing activities at Berlin Hauptbahnhof. Further delays are expected if the COVID-19 situation persists.

As indicated in section 2.1, alternative sites to Berlin Hauptbahnhof have been initially considered. Being the most crowded station in Berlin together with potential restrictions happening due to, e.g. COVID-19, the Berlin cluster has targeted the implementation of the UCs in these additional sites as a risk-mitigation measure in case this risk materializes.

Table 2-3: ICT-17 and ICT-19 capabilities and extensions for experimentation

Cluster	ICT-19 5G-VICTORI Berlin Cluster					
ICT-17	5GENESIS Berlin Cluster					
Use case	**UC # 1.2 Future Digital Mobility**	**UC # 1.3 Rail Critical Services**	**UC # 3 CDN services to the train**	**Facility capability**		**Details**
Use case Experimentation	The app will connect to the 5G Edge, where the back-end will run, and download the station's spatial digital twin (3D). At front-end (app) the 3D twin will be rendered and overlayed on the smart phone's live camera feed, and thereby help the passenger to orientate inside and around the station. Passengers will appoint travel goals through the app, where the back-end will build an optimal travel route, starting from the station,	MC Railway Telephony, like operational voice private and group communication with PTT emergency group communication MC Railway Data Service	Consumption of linear live content and the viewing of VoD content. VoD content will be preloaded via a 5G data shower to a content cache on the train, which acts as an edge server of the content providers CDN.	ICT-17	ICT-19	Tools/Components
Physical Infrastructure	Physical network elements and auxiliaries					
Hardware/PNF	Compute & Storage, mmWave equipment for backhaul	Compute & Storage, MCX/pre-FRMCS, Onboard Gateway, Dispatch terminal	Compute & Storage, 5G NR Baseband Hub, 5G NR RRH, APN Router, mmWave @track, onboard 5G gateway (CPE + mmWave node), Wi-Fi APs, onboard cache	x	x	extend computing capabilities towards Berlin Hbf, including the 5G equipment and the use case equipment
Transmission	IP/MPLS, VPNL3	IP/MPLS, VPNL3	IP/MPLS, VPNL3		x	connectivity of the sites, FhG-Berlin Hbf
Devices	5G UEs	CCTV, On-board radios are 5G UEs, CPEs or 5G radio modules	Ues inside DB Regio trains		x	
Spectrum	4G5G Licensed spectrum, unlicensed spectrum (V-Band)	4G5G Licensed spectrum	4G5G Licensed spectrum, unlicensed spectrum (V-Band)	x	x	
Cloud/Edge	back-end (GPU server)	Open5GCore	GPU for AR/VR, transcoding		x	
Virtualized Infrastructure	Cloud capabilities					
SDN/VIM				x		OpenStack, OSM vX
Monitoring	Infrastructure monitoring; VMs state monitoring	Infrastructure monitoring; VMs state monitoring	Infrastructure monitoring; VMs state monitoring	x		Prometheus
NFV/VNF	Virtualized functions					
4G/5G RAN	N/A	N/A	N/A	x		

4G/5G Core	5G SA Core Network	5G SA Core Network with IMS-based SIP	5G SA Core Network		x	Open5GCore
Use case App	Mobile App	MCX-Application Server	CDN Content Database		x	
MANO	Orchestration					
Resource Orchestration	OSM	OSM	OSM	x		OSM vX
Slice Orchestration	OSM	OSM	OSM	x		OSM vX
Service Orchestration	OSM	OSM	OSM	x		OSM vX
Catalogues	OSM	OSM	OSM	x		OSM vX
Inventory	OSM	OSM	OSM			OSM vX
Service performance	N/A	N/A	N/A			
Policy Framework	N/A	N/A	N/A			
Service Monitoring Analysis	Application monitoring					
Data Visualization	Service data visualization; Data collection, Dashboard	Service data visualization; Data collection, Dashboard	Service data visualization; Data collection, Dashboard	x	x	Grafana
KPIs	KPI service validation	KPI service validation	KPI service validation		x	
Interworking layer	5G-VICTORI cluster interworking					
Multi-site orchestrator	control and management framework for instantiation of vertical specific applications from the 5G-VICTORI repository; network service deployment; Inventories				x	
Multi-site inventory					x	
Orchestration broker					x	
Service Design	5G-VICTORI Design-time framework					

3 Bristol Cluster Facility Planning

The Bristol cluster facility will be configured to support the 5G-VICTORI Digital Mobility UCs (UC # 1.2) requirements and validation of its KPIs.

3.1 Site Facility Implementation

This document provides a detailed description of the various infrastructures involved in the Bristol Cluster facility, and a relevant pictorial representation is illustrated in Figure 3-1. The figure summarises equipment, services and connectivity between locations. This covers the following locations: Smart Internet Lab, MShed, Millennium Square (MSq), We The Curious (WTC), Watershed (WS), VR Lab and VIRTUS Data Centre in Slough, as well as nodes that have been operated in the framework of different projects in the city of Bath.

The Cloud Core Network is situated at the Smart Internet Lab at the University of Bristol supporting edge-computing, SDN switches and access nodes positioned at selected locations like WTC, MSq, MShed, and until recently Roman Baths where we demonstrated one of the Smart Tourism UCs.

3.1.1 Technologies

The University of Bristol contributes to the key SDN technologies for E2E 5G service delivery. The Smart Internet Lab researchers have created a multi-technology city-wide testbed that supports a fully integrated service orchestration through the various network components.

A dynamic and programmable system is provisioned with visibility across the network layers with SDN enabled applications and services. This network infrastructure is being used to demonstrate diverse technologies and support experimentation of a variety of 5G UCs. Figure 3-2 portrays some of the different technologies in the various network layers.

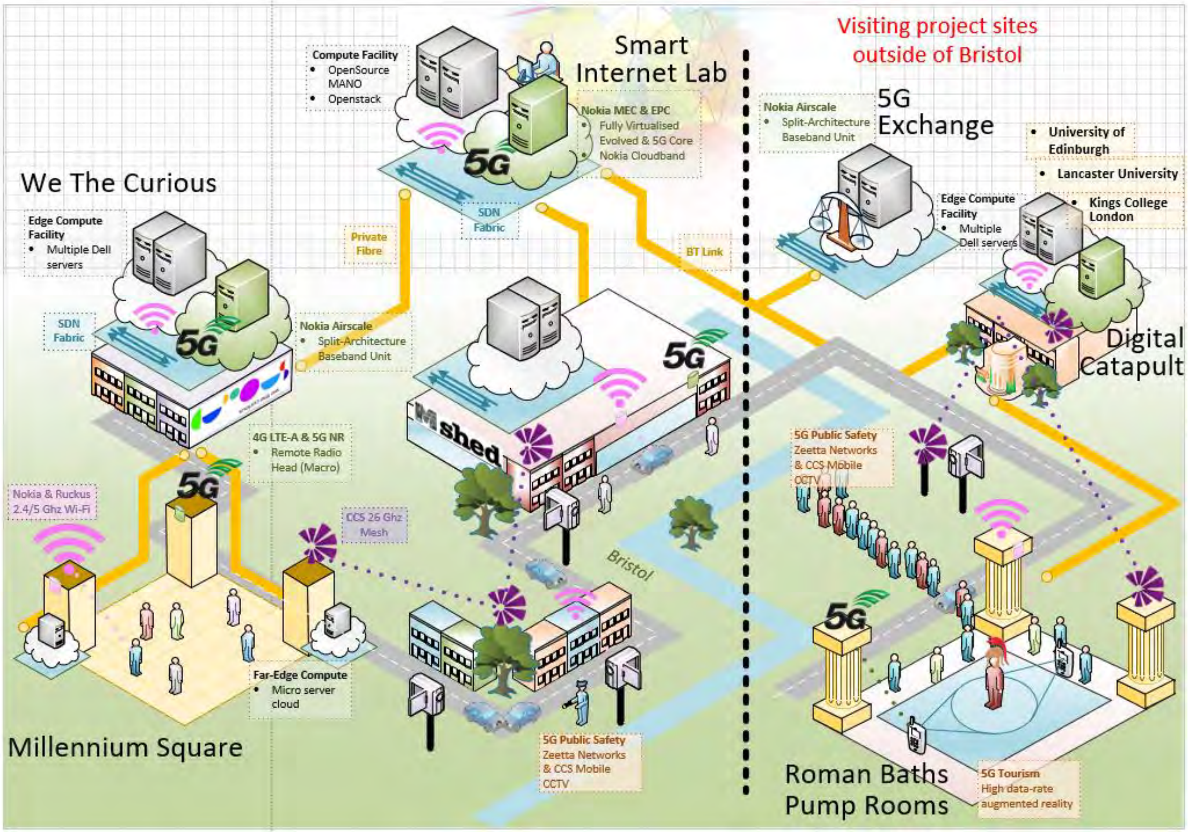


Figure 3-1: Overview of the Smart Internet Lab Network architecture

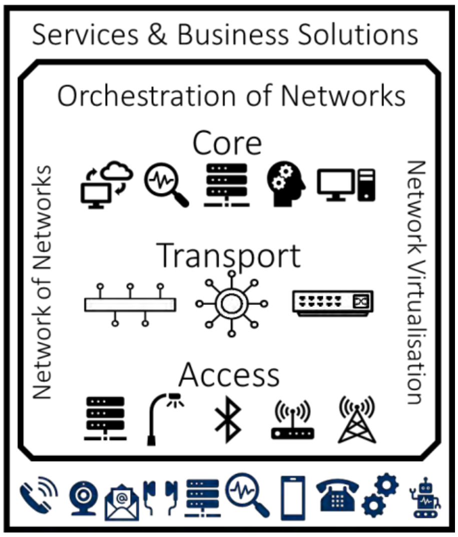


Figure 3-2: Network Components supporting Network of Networks delivering Services

Among the growing list of technologies that our infrastructure supports include:

- Multi-vendor SDN enabled packet switched network.
- SDN enabled optical (Fibre) switched network.
- Multi-vendor Wi-Fi.
- Multi-vendor 4G and 5G NR.
- Self-organising multipoint-to-multipoint wireless mesh network.
- LiFi Access point.
- 5G NR Massive MIMO radio as a stand-alone demonstrator for research and exhibition only under special arrangement.
- Open source NFV management and orchestration including the OSM.
- Nokia orchestration solutions for Cloud and NFV hosting.
- Inter-island network connectivity, slicing and service delivery.
- Advanced fibre optics using FPGA for converging network technologies.

It is noted that the 5G radio solution from Nokia is managed and controlled using Nokia's 5G Core NSA as Evolved EPC solution called MCN-18. This is a mini-Core network entity operating on a single airframe computing server. This solution is providing the Option 3.x 5G Core solution.

Among the orchestration solutions such as Open Source MANO, the test network is equipped with Nokia's CloudBand platform that delivers an integrated NFV environment including infrastructure (NFVI + VIM), management (VNFM) and orchestration (NFVO) engine that optimizes, automates and abstracts operational tasks for carrier network services. The three CloudBand products are- CBIS ver-18, CBAM 17.5 sp1 & CBND ver-18. The engineering solution for this platform are two years old and are no longer supported by Nokia without an upgrade. However, for research purpose the consortium partners are welcomed to investigate and develop solution on this platform considering no vendor support, while respecting the NDA in place with Nokia.

The MEC deployment at the UNIVBRIS test network is an implementation of the UC depending on the project requirements. As the test network is spread in a small geographical area the data path delay between the core network and the radio unit is insignificant. Hence enabling us to deploy the MEC application servers at the point of data breakout within the cloud network.

For the purpose of the 5G-VICTORI project this test network will move its satellite test network equipment from City of Bath to create a new node at a railway station such as Bristol Temple Meads train station as shown in Figure 3-3 where 5G-VICTORI's digital mobility UC can be demonstrated.

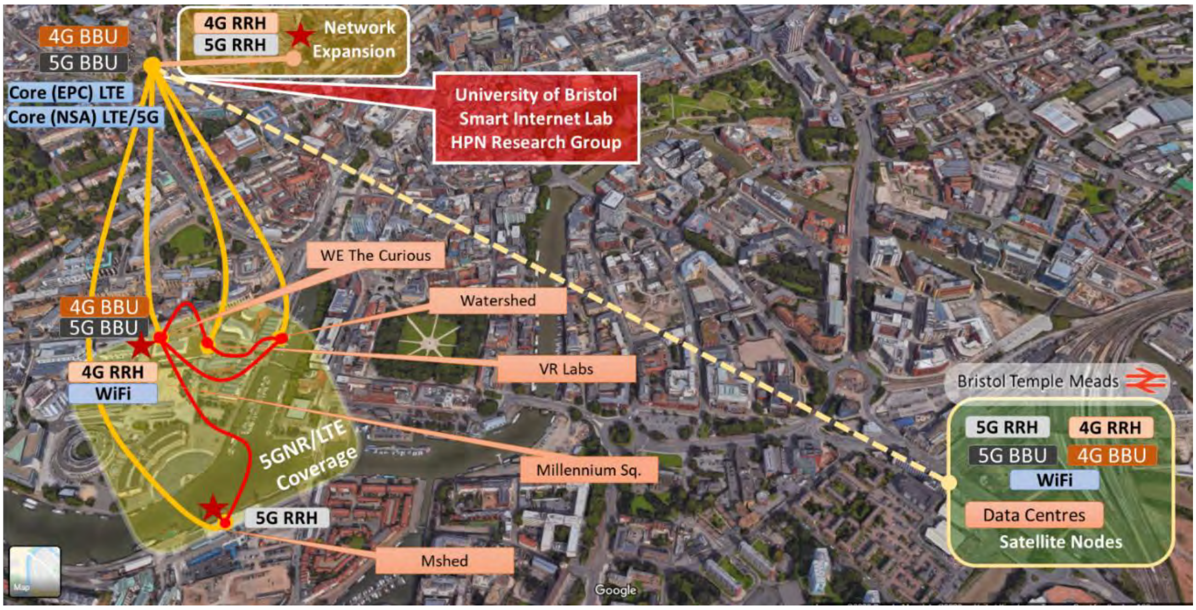


Figure 3-3: Map of the locations for University of Bristol 5G Test Network

This network is supported by dark fibre across the city centre and has several active nodes across the city.

i2CAT's E2E solution enables the on-demand deployment and life-cycle management of network slices, including radio and compute resources, together with the orchestration of services instantiated on top of such slices. To do so, several components are integrated, such as OpenStack for VIM, OSM for NFVO, OpenDayLight for SDN Controller and several wireless technologies for RAN access, which are managed by a custom RAN controller. In 5G-VICTORI, **i2CAT** will extend the 5GUK test network with additional Wi-Fi nodes, based on custom devices capable of offering wireless backhaul and access pop-up connectivity. In addition, this solution could integrate Amarisoft's 5GNR nodes and Accelleran's LTE Small Cells (if available), including the instantiation of 4G/5G cores, thus allowing the deployment of multi-RAT slices and services. The deployed RAN slices will be connected to the available edge resources and to the UNIVBRIS 5GUK test network through Ethernet links installed in all or some of the nodes (i.e. root nodes), applying L2 data forwarding based on per-slice VLAN tagging.

Digital Catapult (**DCAT**) will be supporting 5GUK test network with a pop-up 5G NR capable node, based on Amarisoft, which is providing in-fill in areas where **UNIVBRIS** does not have coverage. That could be at the Temple Meads station, which currently does not have 5GNR radio, connected back to UNIVBRIS 5G test network or edge infrastructure through an Ethernet link. This node uses a Software Defined Radio, capable to operate on any frequencies <6GHz, thus configurable to the corresponding spectrum license obtained for that location. It offers different configurations, currently using 40 MHz for 5GNR (max 50 MHz) and 20 MHz for LTE. As it is currently operating with low power radios, a max 20m range coverage in open space is the best practice.

In addition, Digital Catapult will be using its 5G Testbed in London, which already is interconnected to UNIVBRIS 5GUK test network, for developing and testing the 5G-VIOS platform.

3.1.2 Cell Capacity

The network cell capacity is proportional to the licensed spectrum bandwidth allocated to each radio technology. Within the 5GUK test network we have experienced the following throughput and latency during past projects using the licensed and unlicensed spectrums (seeTable 3-1).

Table 3-2 resumes the network cell capacity for pop-up network. Moreover, Table 3-3 resumes the usual capacities of i2CAT's Wi-Fi access and backhaul solution.

Table 3-1: Network cell capacity experienced in the 5GUK test network

Technology	5G NR	LTE	Wi-Fi
Single UE throughput (Mbps)	500	100	200 (noise limited)
Multi n x UE throughput (Mbps)	< 500 / n	< 100 / n	< 200 /n
Latency	5 ms expected[3]	30 ms expected[4]	3 ms to 200 ms variable

Table 3-2: Network cell capacity for pop-up network

Technology	5G NR	LTE
Single UE throughput (Mbps)	200 DL / 40 UL	100 DL (up to 600 with CA x3) / 30 UL
Multi n x UE throughput (Mbps)	< 200 / n	< 100 / n
Latency	5 ms expected	30 ms expected

Table 3-3: i2CAT's network cell capacity for pop-up network (usual values under low-interference conditions)

Technology	Wi-Fi Access (802.11ac, omni-antennas, variable bandwidth)	Wi-Fi Backhaul (802.11ac, directional antennas, 80 MHz)	Wi-Fi WiGig Backhaul (80211ad, wAP 60Gx3 AP, to be confirmed[5])
Single UE throughput (Mbps)	200 (80 MHz) 100 (40 MHz)	180 Mbps (~80 metres) 350 Mbps (~20 metres)	1 Gbps (+200 metres)
Multi n x UE throughput (Mbps)	< 200 /n (80 MHz) < 100 /n (40 MHz)	< 180 / n (~80 metres) < 350 / n (~20 metres)	< 1 Gbps / n
Latency	3 ms to 200 ms variable	1-3 ms per hop	< 1 ms per hop

3.1.3 UC # 1.2 (Digital Mobility) – Network dimensioning, coverage and user dimensioning

As described in deliverable D2.1, the main objective of the Digital Mobility UC is to develop a common framework for innovative mobility applications and services. In this UC, it will be demonstrated how the E2E 5GUK platform can be on the fly configured to provide Application 1 (Immersive media services to travelers arriving at Bristol), Application 2 (VR Live streaming application delivered at UNIVBRIS campus during a course), and Application 3 (Future Mobility). The network dimensioning, coverage area and user dimensioning of each application are described in detail in the respective subsections ofeach application.

3.1.3.1 Application 1

Application 1's Network dimensioning and coverage area:

The MATI's immersive 5G tour application 1 will provide to group of users arriving at Bristol a 360° synchronous tour guide at specific geolocations include Bristol Temple Meads, MSq and University of Bristol.

[3] We can expect 5 ms from a fully optimised network. However, for our experimental network this can be around 40 ms from device to device.

[4] We can expect 30 ms from a fully optimised network. However, for our experimental network this can be around 60 ms from device to device.

[5] I2CAT plans to integrate this technology in their solution during the execution of the project.

This application relies on two different services, the video streaming service and synchronization service. Moreover, the virtual tour will benefit from network slicing as synchronisation and 360° video quality are critical to the whole experience. For more details, please refer to D2.1.

Table 3-4 provides the required network parameters of Application 1 including user's size, bandwidth, and required resources. These parameters need to be compared with the network capabilities in the following deliverables such as D2.3. This will be a feedback to the application development to adjust their solutions.

Application1's Network Mobility and MEC:

The Bristol cluster MEC capabilities described in Section 3.1-Technologies will be used to provide content and synchronization services as close to the users as possible without network traffic traveling to the origin servers while the streaming server backend storing the videos and synchronization server state machine can be put in the backend. The synchronization edge service and video edge service will need to move with the passengers from location to location. Mobility will ensure that these services will run uninterruptedly while users move between networks and between edge nodes.

It is required to ensure uninterrupted playback and synchronization while users are moving between edge nodes. It is also needed to preserve the state of each edge node after initialization, so that the application can be up and running with minimal latency.

The mobility of the passengers from the train station (location1) to MSq (location 2) and then to the University of Bristol (location 3) is shown in Figure 3-4.

Table 3-4: Digital Mobility UC -Application 1's required network parameters

UC requirement	Range	Description
Network coverage	3 locations	Temple Meads, University of Bristol, MSq
Network User's size	From 10 to 20 users	Density of users per m^2: 2
Network Bitrate per Endpoint	Should be 1Gbps	N/A
Network Bandwidth per user	50 Mbps	Stream up to the maximum 50 Mbps bitrate of 360' videos to the users at the same time
Required Resources in Edge nodes	2 CPUs, 4 GB of RAM, 5 GB of Space	No GPU acceleration is needed
Required Resources in backend synchronisation server	2 CPUs, 8 GB of RAM, 5 GB of Space	No GPU acceleration is needed
Required Resources in backend video streaming server	4 CPUs, 8 GB of RAM, 100 GB of Space	No GPU acceleration is needed

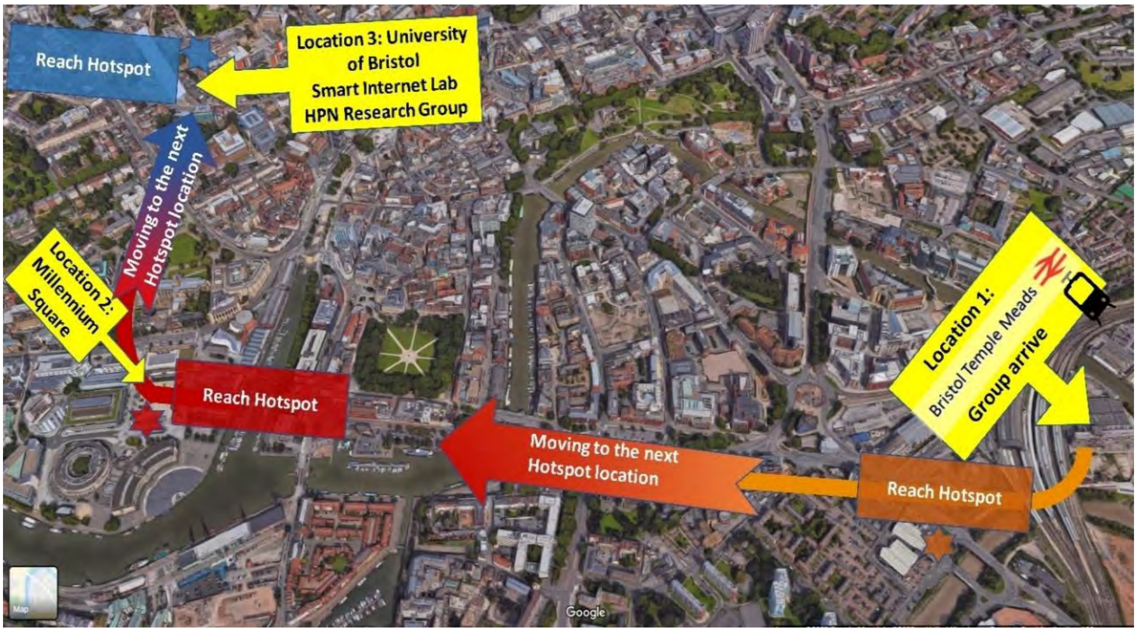


Figure 3-4: Application 1's route of travel

Application 1's user dimensioning

The 360 VR tour guide of the route between Bristol Temple Meads (location 1), MSq (location 2), and University of Bristol (location 3) will be provided to the group of up to 20 users carrying compliant 4G or 5G phones equipped with University of Bristol's 5G test network SIM cards.

3.1.3.2 Application 2

Application 2's Network dimensioning and coverage area:

The second application of Mativision's 5G UC, as introduced in D2.1 focuses on **a 360° VR Multicamera Live streaming**. There will be a **training course** hosted at the University of Bristol where the users taking part at the class can be located anywhere in Bristol with 5G coverage or Wi-Fi AP connected to the 5GUK test network.

For the training course, three 360° cameras will be set up in a **UNIVBRIS** classroom (by **MATI**) that will stream to the MATI HTML5 multicamera player. Each camera will send a high bandwidth stream (up to 50 Mbps) to the backend streaming server. The backend streaming server in turn will re encode the stream to multiple qualities and segment it to support HTTP live streaming. The application will benefit from network slicing as video streaming will be delivered through a network slice. More details were provided in D2.1.

Table 3-5 provides the required network parameters of ***App 2*** including user's size, bandwidth, and required resources. These parameters need to be compared with the network capabilities in the following deliverables such as D2.3. This will be a feedback to the application development to adjust their solutions.

Table 3-5: Application 2's Network dimensioning

UC requirement	Range	Description
Network coverage	2 locations	**A classroom** at the university of Bristol, users taking part in the class can be located **anywhere in Bristol with 5G coverage or Wi-Fi AP** connected to the 5GUK test network.
Network User's size	n	Max number of network users (n) depends on number of edge nodes and the bandwidth that network can provide Density of users per m^2: 2
Network Bitrate per Endpoint	n x bitrate of streams	n is the number of users. Min of Network Bitrate per Endpoint should be 1 Gbps.

		Bitrate of the stream can go up to 50Mbps.
Network Bandwidth per user	50 Mbps	
Required Resources in Edge nodes	2 CPUs, 4 GB of RAM, 5 GB of Space	No GPU acceleration is needed
Required Resources in backend origin video streaming server	8 CPUs, 16 GB of RAM, 50 GB of Space	No GPU acceleration is needed

Application 2's Network Mobility and MEC:

5G-NR's higher bandwidth can open up higher quality streams for more concurrent users. More users and better-quality videos will be supported by caching segments on the edge servers. In other words, we can support n number of more concurrent streams, where n is the number of edge servers, without stressing the core network. The edge servers are specialist network solution and apart from a defined compute resource requirement they also require special software licenses for their platform and implementation. The test network provides space, power and connectivity for such solution at different locations. In one example, we deployed eight servers with seven at the edge of the network and in another one server equipped with graphical cards at the edge of the network. For 5G-VICTORI the test network still needs to be designed and additional hardware to be allocated or acquired depending on the needs of the project.

Application 2's User Dimensioning:

The users taking part at the class can be located anywhere in Bristol with 5G coverage or Wi-Fi AP connected to the 5G infrastructure. Edge nodes are imperative for this UC as we need each user to reach the highest available bitrate. With streaming directly from the origin this limit is forced by the network. While the BH and FH of the test network in Bristol is based on 10 Gbps switched Ethernet connectivity, the wireless network technology in each location is limited by the available licensed spectrum bandwidth and the interference from other users of the unlicensed bands. The expected throughput is shown in Table 3-1 for different wireless technologies deployed at Bristol's test network. Figure 3-5 shows Application 2's user dimensioning along with the backend streaming server, the edge streaming service, and the 5GUK test network.

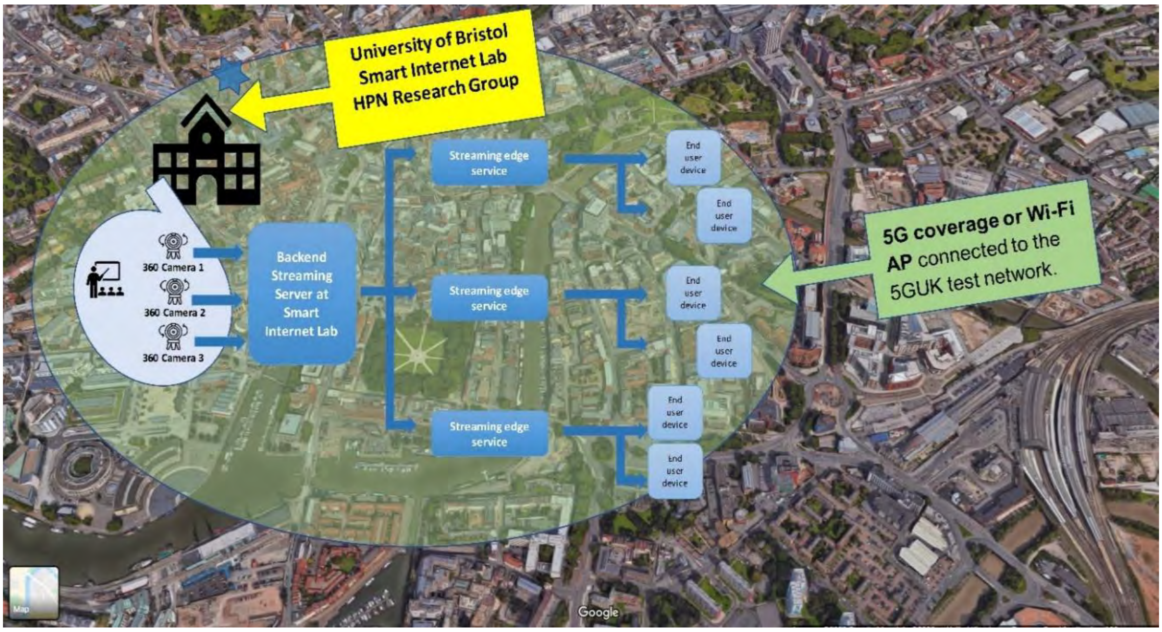


Figure 3-5: Application 2's user dimensioning along with the backend streaming server, the edge streaming service, and the 5GUK test network

3.1.3.3 Application 3

Application 3's Network dimensioning and coverage area:

As discussed in deliverable D2.1, section 3.2.1, in UHA's Future Mobility Application people will pass from the train station towards the city centre and their information including their location, their mobility and movement will be collected and analysed. Furthermore, the application will provide passengers with station guidance and multi-modal transport journey planning beyond the train station using AI techniques. In emergency situations it can create and manage network slices.

This application will have a front-end and a back-end technical element. The front-end is a smart phone app, the back-end is a data collection and analytics and route planning service. The Insurtech layer will operate from the back-end and sync with the insurers through an API.

Table 3-6 provides the required network parameters of Application 3 including user's size, bandwidth, and required resources. These parameters need to be compared with the network capabilities in the following deliverables such as deliverable D2.3. This will be a feedback to the application development to adjust their solutions.

Table 3-6 Application 3's Network dimensioning

UC requirement	Range	Description
Network coverage	2 locations	Train station and Bristol city centre (for example MSq)
Network User's size	From 1 to 20	Number of End devices per end point: Max 20 Density of users per m^2: 2
Network Bitrate per Endpoint (mbps)	From 100 to 200	Split/shared among all users concurrently
Network Bandwidth per user	Max: 100 Mbps	Bitrate required per end device: Max 100 Mbps Upload bandwidth of at least 10 Mbps and Download Bandwidth of at least 30 Mbps to maximum 100 Mbps are required for multiple concurrent users.
Required Resources in Edge nodes	(4-6-8) CPUs, 2xNvidia 1080 cards	UHA's current back-end contains 4x Nvidia 1080, and 4x Nvidia 2080 cards. The demo can be certainly realized with less than this. (2x Nvidia 1080 cards on the Edge and/or back-end are sufficient). As not all processing goes massively parallel, due to the nature of algorithms (for example entropy compression, etc.) 4-6-8 cores are sufficient.
Required Resources in backend server	(4-6-8) CPUs, 2xNvidia 1080 cards	

Application3's Network Mobility and MEC:

As planned in deliverable D2.1, passengers involved in the trial will arrive at the station by train with the front-end app pre-installed on their phones. The app will connect to the 5G Edge, and the 3D twin will be rendered and overlayed on the smart phone's live camera feed, and thereby help the passenger to orientate inside and around the station. Passengers will appoint travel goals through the app, where the back-end will build an optimal travel route, starting from the station using AI techniques

Some specific requirements of the Application both at the edge and at the backend are provided in the following.

Upload bandwidth of at least 10 Mbps and Download Bandwidth of at least 30 Mbps to 100 Mbps are required for multiple concurrent users. Where no 5G Edge is available, the mechanism will fall back to cloud, which will end up in increased latency and longer loading times. To mitigate also that the spatial resolution can be decreased dynamically.

Application 3's User Dimensioning:

Figure 3-6 shows Application 3's user dimensioning.

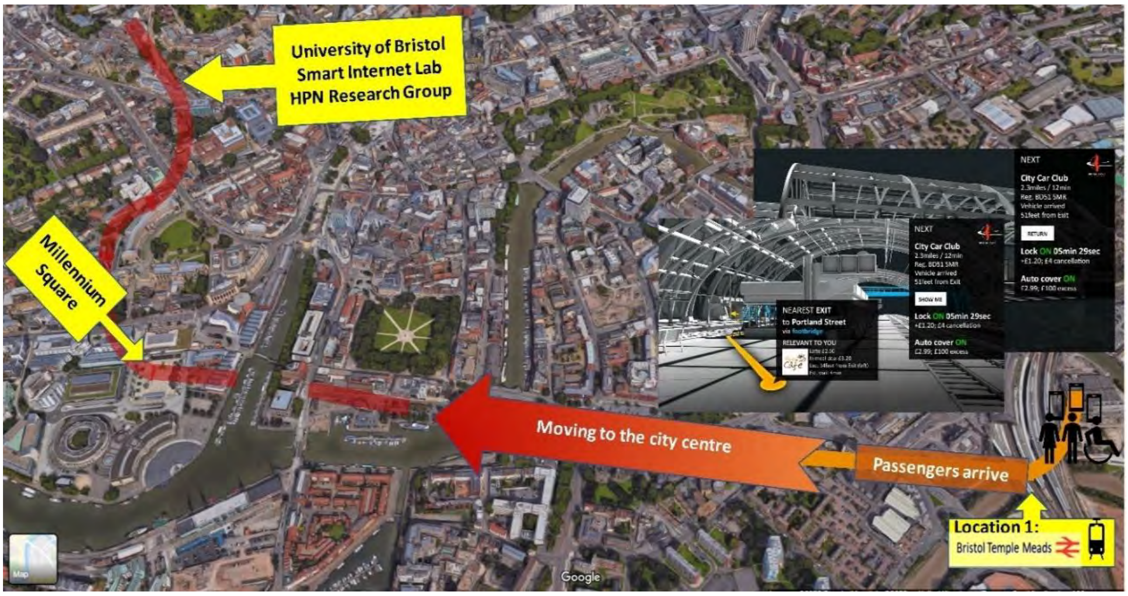


Figure 3-6: Application 3 (Future Mobility)'s user dimensioning

Once all the requirements for the user applications, network coverage space and mobility of the service and the comparison of the requirements is done with the network capabilities are fully defined; then the network slice will be ready to be designed. The network slices will be designed in the second iteration of the deliverable such as D2.3. The output of the network slice design will highlight:

- Network entities identified for re-deployment.
- Additional network entities for completion of the design.

3.2 Planning and Components

For planning we consider the following activities shown in Table 3-7, from the capture of network deployment requirement to the delivery of the experimentation in the test network in Bristol. The start/finish date of each activity is shown in Quarter format. Moreover, Beginning, Mid, and End mean the first, second and third month of each quarter of a year shown with Q1, Q2, Q3, and Q4. It is important to note that the provided Start/Finish Quarter may have two months tolerance. From Activity 6 onwards, Start/Finish is divided into two sections. The first section describes the planning of actual deployment and operation of intra-field trial and heralds the completion of the first phase of field trials, which focuses on Bristol cluster facility. In addition, the second section shows the inter-field trials. It should be noted that there is an impact on the project, mainly from Activity 3 onwards regarding the current lockdown situation due to COVID-19. We foresee potential delay specifically on Activities 3, 6 and 7 to 10. However, all the subsequent activities will be affected by this delay.

The roadmap for Bristol facility high level planning and implementation is presented in Table 3-7.

Table 3-7: Bristol Cluster – Planning and Components

Activity	Start / Finish Quarter[6]	Dependencies to other Bristol partners
1. Plan Activity	Beginning of Q2 2019 / End of Q1 2020	-
2. Requirement capture a. Use Case network dimensioning b. Network coverage c. Network Mobility	Beginning of Q2 2019 / End of Q1 2020	-

[6] There is an impact on the project due to social distancing across Europe.

3. Site Survey and report	End of Q1 2020 / Beginning of Q2 2020	Impact due to external partners
4. Network Slice Design for each use case a. App 1- Network Design b. App 2- Network Design c. App 3- Network Design	End of Q1 2020 / Mid of Q3 2020	**DCAT** (for 5G-VIOS) **I2CAT** **ZN**
5. Design Review a. Compliance to use case requirement b. Identifying the gaps with exiting Test Network Capabilities and Coverage e.g. identify the H/W, S/W, Spectrum licenses, hosting sites and etc., for the project	Beginning of Q2 2020 / Mid of Q4 2020	**i2CAT** (for identifying gaps btw UC requirements and capabilities of i2CAT HW and SW) **DCAT** **ZN**
6. Procurement process a. Acquire parts and services for the install and commissioning of each test network slice per use case	Mid of Q2 2020 / Beginning of Q4 2020	Digital Catapult (for 5GNR node) **I2CAT** (for custom Wi-Fi solution and edge computing server) **ZN**
7. Install and commission additional network entities	Beginning of Q2 2020 / Beginning of Q4 2020 / Beginning of Q1 2021 / Beginning of Q3 2021 /	**DCAT** (for 5GNR node) **i2CAT** (for installing SW components of i2CAT slicing solution) **ZN**
8. Configure and validate the network slices	End of Q3 2020 / End of Q4 2020 / End of Q2 2021 / End of Q3 2021 /	**DCAT** (for 5GNR node and 5G-VIOS) **i2CAT** (for configuring and validating the network slices created via i2CAT's SW) **ZN**
9. Onboard each use case application to their appropriate network slices	End of Q4 2020 / Mid of Q1 2021 End of Q3 2021 / Mid of Q4 2021	**DCAT** **I2CAT** **ZN** **MATI** **UHA**
10. Test and validate each Application a. Component and functional tests b. Report on observed KPI	Mid of Q1 2021 / End of Q2 2021 Mid of Q4 2021 / End of Q1 2022	**DCAT** **I2CAT** **ZN** **MATI** **UHA**
11. Prepare for the experimentation for the Project Review and Official Deliveries	End of Q2 2021 / Mid of Q3 2021 End of Q1 2022 / Mid of Q2 2022	**i2CAT** **DCAT** ZN **MATI** **UHA**

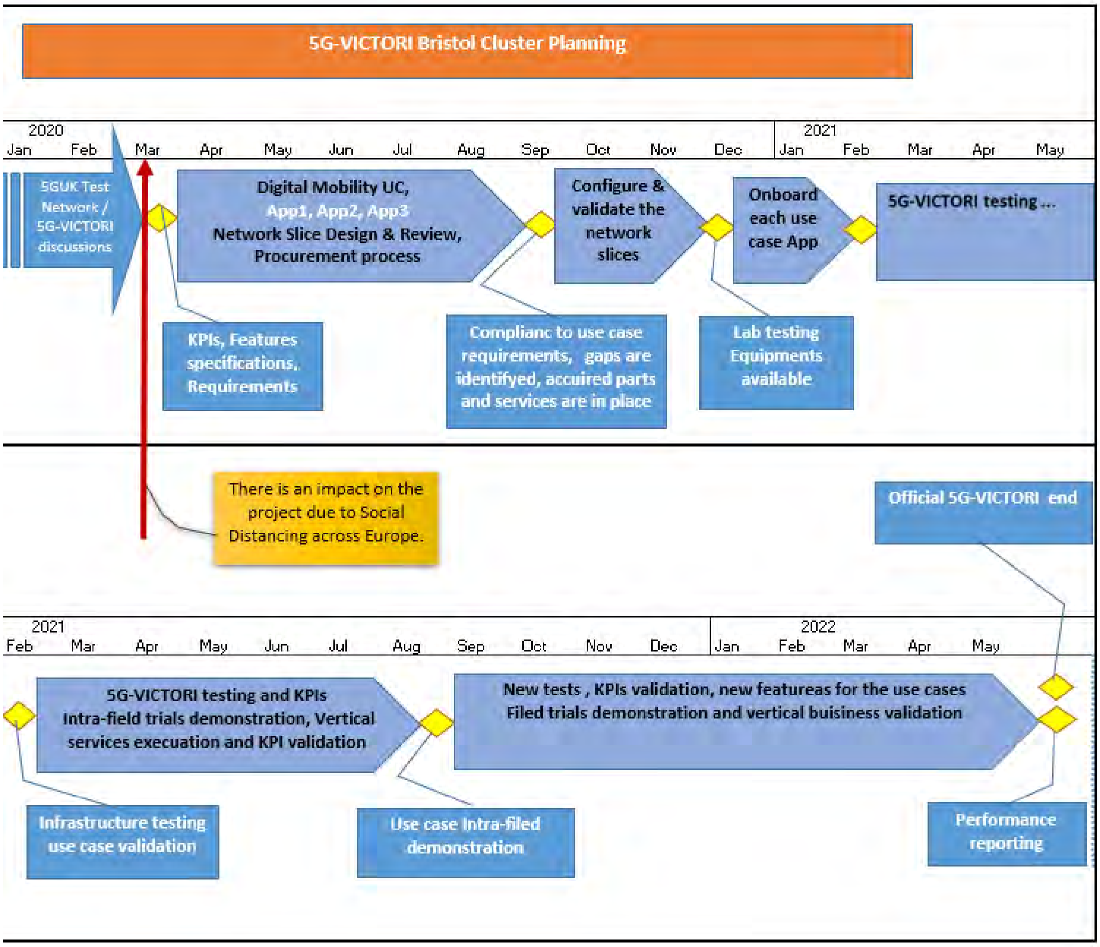


Figure 3-7: High-level planning of Bristol cluster's UC # 2

3.3 Use Case Experimentation related to ICT-17/ICT-19 capabilities

This chapter describes the initial Bristol cluster's Digital Mobility UC experimentation related to ICT-17/ICT-19 capabilities. These capabilities are aggregated in Table 3-8.

The first row of this table shows the experimentation requirements as well as the main objectives of the Bristol cluster's Digital Mobility UC applications 1, 2, and 3, respectively. The UC experimentation is divided into various categories including the physical network elements and auxiliaries as the **Physical Infrastructure,** the cloud capabilities as the **Virtualized Infrastructure, NFV/VNF, MANO, Monitoring & Analytics**, the **Interworking** layer to show the 5G-VIOS capabilities as a multi edge orchestrator and last but not least the **Service Design** framework for the use-cases**.** The second column of this table shows the **ICT-19 facility capability** according to each category and the **Details** column shows any specific tool/component related to Bristol cluster partners. It also provides specific tool/components according to each category.

In addition, the UNIVBRIS 5GUK testbed is capable of using the licensed and unlicensed bands for connectivity towards user devices as end points for the communication services, or for device-to-device connectivity as shown in Figure 3-8. It should be noted that, at the moment of writing this deliverable, the frequency licenses shown here were applicable in June of 2020.

For the transport Xhaul solution the test network is equipped with dual connectivity on most outdoor access points where the switches at the edge of the network can redirect the access points connectivity either via a fibre network or the wireless transport network operating in licensed or unlicensed band depending on its deployment.

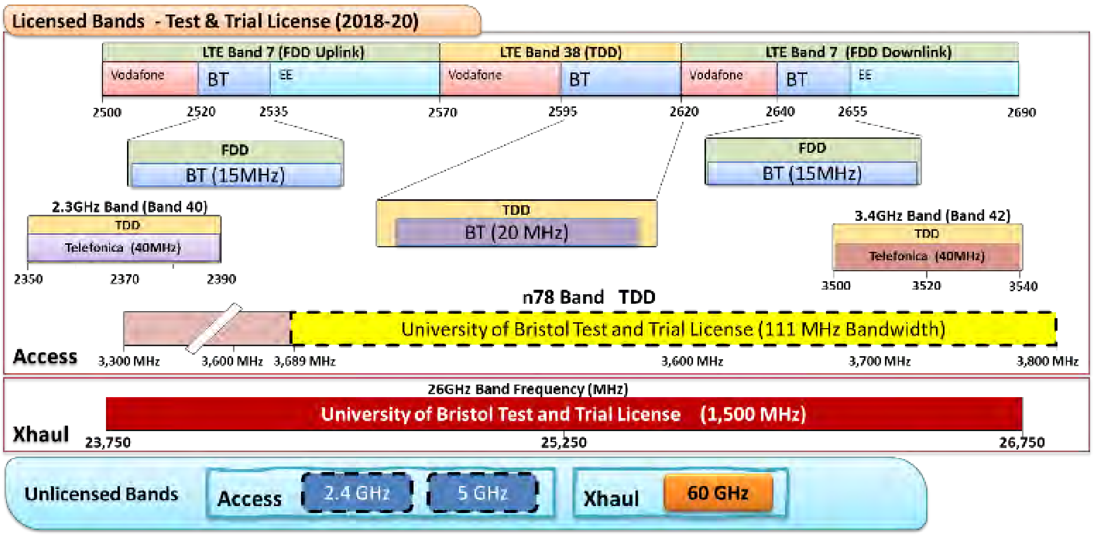


Figure 3-8: Radio and Access solutions (as of June 2020)

The access technologies in licensed bands operate in a similar way as indicated above. That is, they are used either for access to the end user device or for device-to -device connectivity as part of transport network. The technologies include LTE-A and 5G NR providing access to the UE devices as shown in Figure 3-8.

The unlicensed bands are used for Wi-Fi technology, i.e. 802.11 at 5 MHz and 2.4 GHz bands across all test network sites for open source solutions. These are the most convenient way to demonstrate the data break out at the edge of the network closest to the access point demonstrating the Multi-access edge computing (MEC), otherwise known as Mobile Edge Computing solutions.

As a matter of operation the appropriate regulatory applications will be made in time to obtain the necessary licensed spectrum; in case the licensed bands become unavailable (outside the control of the project) at the time of the demonstration the project will use the unlicensed bands to deliver the UC demonstration.

3.4 Risk assessment

It should be noted that there is an impact on the project, mainly from Activity 3 “Site Survey and report” onwards regarding the current lockdown situation due to COVID-19. We foresee potential delays specifically on:

- Activity 3, “Site Survey and report”.
- Activity 6, “Procurement process”.
- Activity 7 to 10 “Install and commission additional network entities”, “Configure and validate the network slices”, “Onboard each use case application to their appropriate network slices”, and “Test and validate each Application”.

All the subsequent activities will be affected by this delay.

It is important to mention that considering a railway station (such as the Temple Meads station indicated in section 3.1 as part of the demonstration in Bristol) also introduces a project risk. At this point in time in the project, we have initiated the dialogue with Network Rail and the GWR railway operator to obtain a hosting and data sharing agreement so that we could include a railway station such as Bristol Temple Meads.

Until we obtain the hosting agreement with a railway operator, this activity entails some level of risk. Meanwhile, our mitigation plan is to provide the mobility between MShed to MSq, which requires some network roll-out/expansion instead of the route between the Temple Meads railway station and MSq.

Table 3-8: Bristol cluster's Digital Mobility UC experimentation related to ICT-17/ICT-19 capabilities

ICT-19 5G-VICTORI Bristol Cluster- Digital Mobility UC						
	Application 1 (Immersive media services to travellers arriving at Bristol)	**Application 2 (VR Live streaming application delivered at UNIVBRIS campus during a course)**	**Application 3 (Future Mobility)**	**Facility capability**		**Details**
Use Case Experimentation	•Deploying and instantiating various services on MEC servers, Backhaul servers, and User equipment •Various APIs such as API to signal deploying of edge services, API to signal mobility and API to signal network slice creation are needed to be supported by the 5G-VIOS. •Handling the specific events by the Application, Edge Orchestrator, and 5G-VIOS in cases such as Mobility and Network Slicing should be supported. •Various KPIs are required to be provided at Edge and Backhaul servers. (Please refer to section 3.1.1 for detailed list of Application requirements)	•Interaction between the 360 camera, Backhaul server, and 5G-VIOS is required •Deploying and instantiating various services on MEC servers, Backhaul servers, and User equipment •Various APIS such as API to signal creation of edge services, API to signal mobility and API to signal network slice creation are needed to be supported by 5G-VIOS •Various are required to be provided at Edge and Backhaul servers. (Please refer to section 3.1.1 for detailed list of Application requirements)	•Interaction between the Edge server and Backhaul server is required •the 3D twin is needed to be rendered and overlayed on the smart phone's live camera feed. •Various resources such as CPU, MEM, and GPU are required both at the Edge and Backhaul servers. •Various KPIs are needed to be supported such as the amount of time it takes to download a spatial dataset, Digitisation accuracy, and Guidance App location and orientation accuracy	ICT-17	ICT -19	Tools/Components
Physical Infra	Physical network elements and auxiliaries					
Hardware/PNF	4G and 5G Infrastructure + Wi-Fi for indoor and outdoor				x	i2CAT's specifics: Wi-Fi 802.11ac (access and backhaul), Wi-Fi 60GHz (backhaul, TBC)
Transmission	HW: L2/L3 switching and routing capabilites, Rapide				x	i2CAT's specifics: L2 switching
Devices	HW: 4G/5G terminals with WIFI as handset or tablet				x	N/A
Cloud/Edge	HW: compute resources both exist in the cloud or in the edge				x	i2CAT's specifics: 1/2 compute nodes at the edge, ZN's specifics: 1 Compute Node in the Rapide
Virtualized Infrastructure	Cloud capabilities					

SDN	Nokia platform cloudband, ONOS, NetOS		x	i2CAT's specifics: ODL (RAN and backhaul)
VIM	Openstack, KVM images for both backhaul and edge services		x	N/A
Monitoring	Own developed platform / Nokia Netact / Prometheus / Nova / Zabbix / cAdvisor		x	i2CAT's specifics: Prometheus, ZN's specifics: Prometheus
NFV/VNF	Virtualized functions			
4G5G RAN	4G / 5G NSA		x	N/A
4G5G Core	5G NSA		x	N/A
Use case App	Use case business solution validation and experimentation		x	N/A
MANO	Orchestration			
Resource Orchestration	OSM, ZN's Network Resources orchestrator: Zeetta's Orchestrator		x	OSM RO
Slice Orchestration	OSM, i2CAT Slice Manager (Own developed platform), Zeetta's Orchestrator		x	OSM Slice Manager
Service Orchestration	OSM, Zeetta's Orchestrator		x	OSM Service Orchestration
Catalogues	OSM		x	N/A
Inventory	OSM, Zeetta's Orchestrator		x	N/A
Service testing	Profiling component		x	Own Profiling component (to be developed)
Monitoring & Analytics	Application and Network monitoring			
Data Visualization	Own developed platform / Nokia Netact / Prometheus / Grafana / Nova / Zabbix / cAdvisor		x	i2CAT's specifics: Prometheus / Grafana, ZN's specifics: Zeetta's GUI
KPIs	MATI Applications' specifics: Custom analytics package to be called directly from the application and services	N/A	x	Own developed platform to evaluate compute performances of Applications, ZN's specifcs: Kibana in Netos
Dashboard	MATI Application1's specifics: Streaming server dashboard / MATI Application2's specifics: Streaming server dashboard	N/A	x	Own developed platform, ZN's specifics: Kibana in Netos

Interworking layer	5G-VICTORI cluster interworking		
Multi-site orchestrator	Control and management framework for instantiation of vertical specific applications from the 5G-VICTORI repository; network service deployment; Profiling, Migration and Mobility management	x	5G-VIOS (to be developed)
Multi-site inventory		x	5G-VIOS - Repository (to be developed)
Profiling		x	5G-VIOS - Profiling (to be developed)
Mobility Management		x	5G-VIOS- Mobility Manager (to be developed)
Orchestration broker		x	5G-VIOS-Broker (to be developed)
Service Design	Use cases developed for evaluating the business solutions	x	N/A

4 France/Romania Cluster Facility Planning

The 5G-VICTORI France/Romania (FR/RO) cluster stems from the ICT-17 5G-EVE cluster located in the France, Paris and Nice facilities. This cluster supports the verticals' UCs proposed for transportation and energy, which will be demonstrated in Romania. These are:

- UC # 1.2: Transportation, a critical service application that addresses URLLC feature requirements and pop-up network on-demand creation capabilities.
- UC # 4.2: Low Voltage (LV) energy metering UC, addressing mMTC capabilities.

These UCs make use of OpenAirInterface (OAI) (5G software alliance), Mosaic-5G (first ecosystem of 5G R&D open source platforms ranging from the centralized network control to the mobile edge network deployment), Open Networking Automation Platform (ONAP) and capable virtualized infrastructure.

The 5G-EVE French cluster, depicted in Figure 4-1, is described in detail in D2.1 [1], where the network elements and components used for site facility deployment is included.

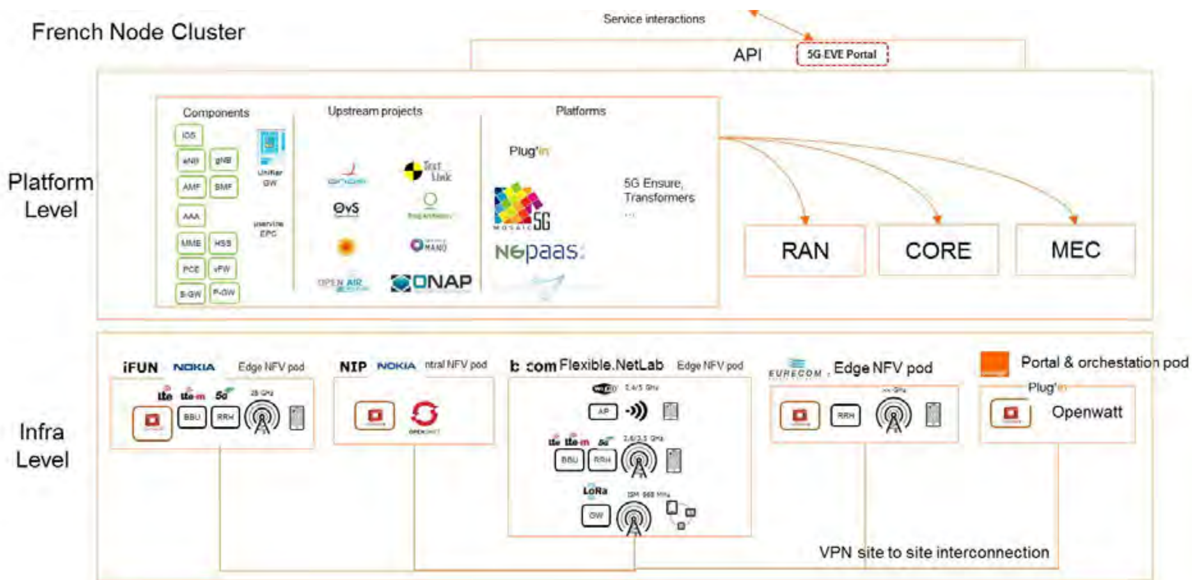


Figure 4-1: 5G-EVE French Node Cluster overview

The vertical's services demonstrated must be served by several 5G key concepts as network slicing capabilities, 5G RAN and Core implementations, service's resources allocation and isolation, network capacity to support simultaneous services and users.

The proposed UCs will be validated and demonstrated in Alba Iulia Municipality (**AIM**), using, from a technological perspective, open source SW components for RAN and core, management and orchestration tools available through the 5G-EVE cluster facility developments, including network elements and physical network devices, within an interconnection framework, as presented in Figure 4-2. These components comprise:

- Mosaic5g project, as a set of functions providing 5G connectivity from the UE level, 5G RAN and Core to the application.
- Management, monitoring and orchestration tools.
- Web Portal for service design.
- Inter-working layer for 5G-VICTORI framework orchestration.

- Physical infrastructure, already existing components or cluster facility extension to AIM.
- Sites preparation activities, for network element installation in AIM, civil works activities, power, cabinets, antenna installation.
- End-user device for UCs demonstration:
  - o 5G components, video cameras, compute nodes servers for analytics application (UC # 1.2).
  - o IoT device components (UC # 4.2).

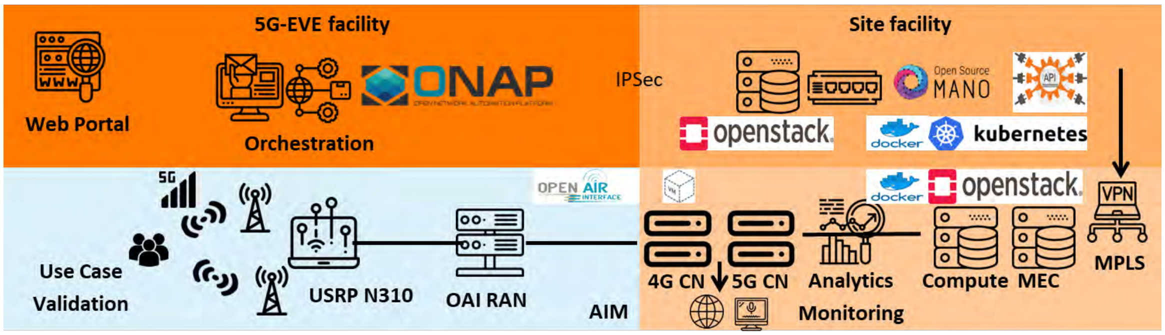


Figure 4-2: 5G-VICTORI Romanian facility cluster

4.1 Site Facility Implementation

The FR/RO cluster aims to demonstrate UC # 1.2 and UC # 4.2 described in the deliverable D2.1 [1]. This requires that the facility support several capabilities, namely network slices, eMBB/URLCC service-type communication, mobility, service and slice deployments and tools for monitoring.

The UCs experimentation and demonstration require implementation of the 5G testbed, infrastructure deployment including SW and HW components and E2E network and system integration. The site facility implementation consists of several layers, and includes: end users devices, specific UC SW applications, network components for physical infrastructure extended to AIM, virtualized infrastructure for 5G components on-boarding and service deployment, including components for service design, management and orchestration tools and capabilities of multi-site service orchestration.

The FR/RO cluster implementation will provide a 5G capable infrastructure for the UCs' demonstration, in line with the requirements and KPIs already described in deliverable D2.1.

The facility should provide the vertical's experimentation environment and it is technically supported by ICT-17/ICT-19 (5G-EVE/5G-VICTORI) platforms capabilities and features presented in section 4.3. Due to the fact that the site facility implementation is linked not only to the UCs' requirements but also to the geographical location for UCs experimentation; a preliminary site survey is needed to determine facility requirements such as:

- user device locations.
- radio site deployments, radio design and coverage.
- MEC facility implementation.
- Network connectivity capabilities.

The preliminary site surveys for the two UCs have identified the possible locations, for the experimentation and demonstration activities, based on location, address, geographic coordinates. These will be used to further refine equipment's installation, radio coverage and mobility aspects.

The preliminary locations identified for the UCs implementation, experimentation and demonstration are highlighted on the city map and are presented in next figures:

- Figure 4-3, covering locations in the N area of the city, including Public Bus Garage (STP), School and a College.
- Figure 4-4, covering locations N-E area of the city, including the City Hall, Schools and High schools.
- Figure 4-5, covering locations in W area of the city, including sever schools and high-schools.
- Figure 4-6, covering locations in city center, including museums.

The preliminary surveys provide, at this stage, several specific facility components, identified to fulfil the use cases requirements for validation and experimentation, and are described as:

1- OAI 5G RAN Platform

OAI implements several 3GPP RAN interfaces in [8] and is composed of the:

- Radio Cloud Centre (RCC), having the role of NG-RAN Central Unit.
- Radio Access Unit, multiple MAC-RLC mid-haul entities, having the role of NG-RAN Distributed Unit.
- Radio Remote Unit, equipment radio at the site level, processing elements, corresponding to a PNF.

5G RAN consists of the RU SW module, L1 software module, MAC-RLC software module, pre-decoder software module, PDCP-U and RRC-PDCP-C module.

2- The **Software Defined Radio** (SDR) unit is based on National Instruments ETTUS N310; a network SDR that provides reliability and fault-tolerance for deployment in large-scale and distributed wireless systems. The SDR used is the USRP N310, which features the following characteristics:
   - RF Capabilities 4 TX, 4 RX.
   - Filter banks.
   - Capable of operating from 10 MHz to 6 GHz carrier frequency.
   - Capable of operating up to 100 MHz bandwidth per channel.
   - Based Band Processing.
   - Synchronization.
   - Clock ref, PPS time ref, Trig/PPS out, GPSDO included.
   - Peripheral including:
     - SFPs+(1/10 Gbps).
     - RJ45.
     - USB.

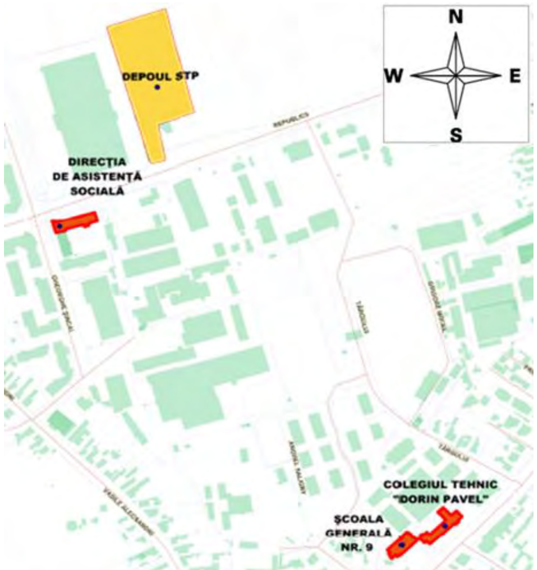


Figure 4-3: Preliminary location analysis 1

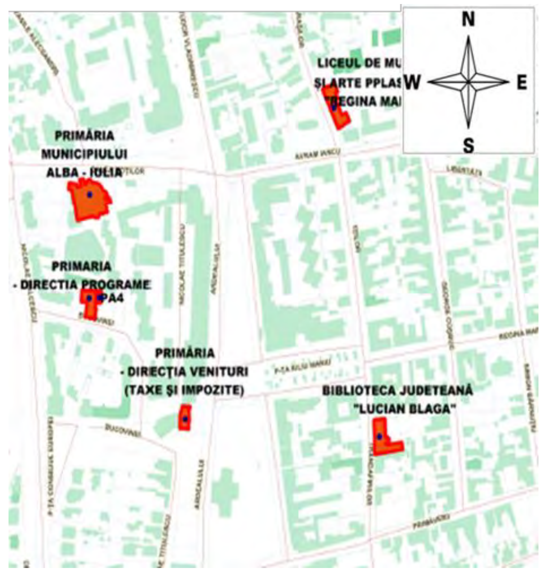


Figure 4-4: Preliminary location analysis 2

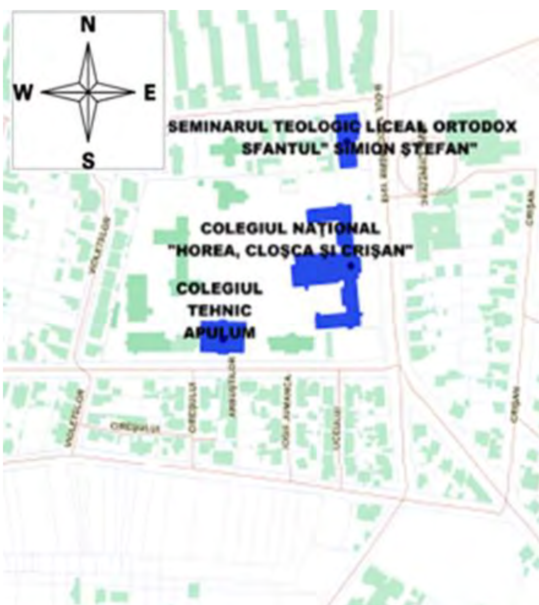


Figure 4-5: Preliminary location analysis 3

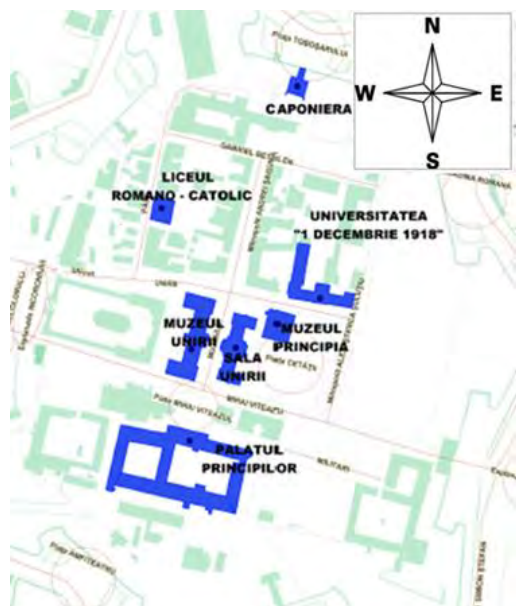


Figure 4-6: Preliminary location analysis 4

3- **OAI Core Network:** the OAI CN, the Mosaic5G E2E 5G ecosystem [9] described in Figure 4-7, integrating different 4G/5G service capabilities, such as:

- 3GPP vEPC implementation (HSS, MME, S-GW and P-GW).
- 5G Service-based Core Network architecture, as per the 5G-EVE cluster will be developed as an Open Core Network fully compliant with 3GPP 5G CN.
- 5G Core Network running in a virtualized infrastructure environment, using OpenStack-based implementation and Kubernetes.

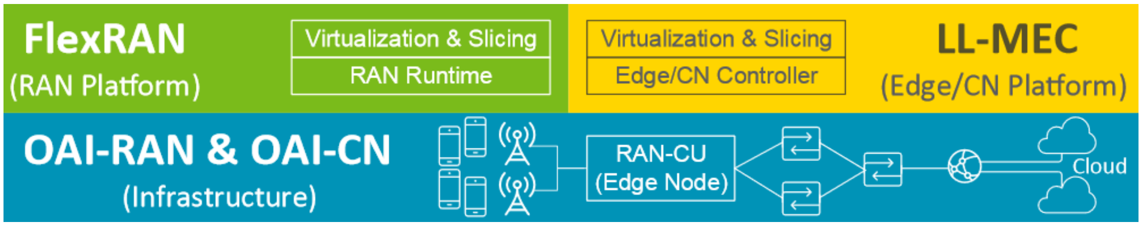


Figure 4-7: Mosaic5G Ecosystem

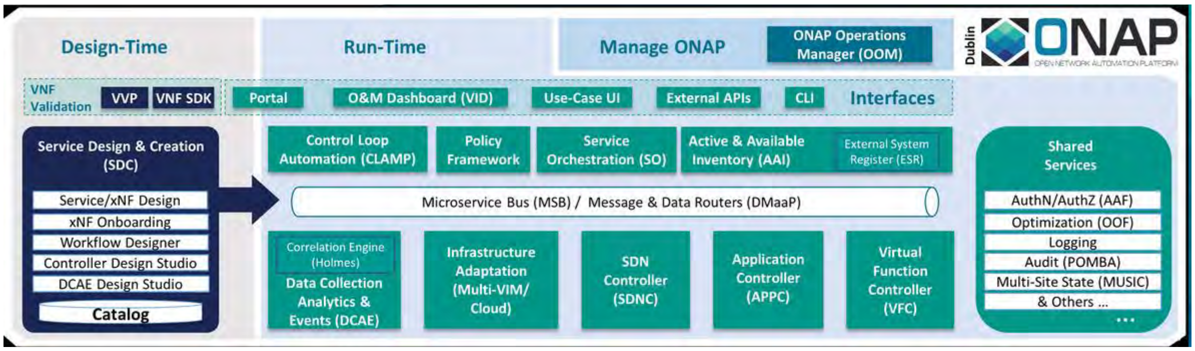


Figure 4-8: ONAP Platform architecture

Table 4-1: Computing infrastructure of the 5G-VICTORI FR/RO cluster

Computing/MEC server	ONAP deployment server
CPU: 48 cores (2.2 GHz) RAM: 96GB net: 4 * Ethernet 1GB local disk: 2 * 600GB(RAID 1) Operating System: Ubuntu 16.04;18.04	CPU: 112 cores (2.7 GHz) RAM: 1TB net: 8 * Ethernet 1Gb local disk: 4 * 600GB OS: Ubuntu 18.04

4- **Orchestration and management tool**: ONAP, the Open Network Automation Platform [10], platform architecture described in Figure 4-8, orchestration for design, creation, orchestration, monitoring, and life cycle management of VNFs. The ONAP will be integrated with Orange Openstack infrastructure for proper NFVs/VNFs onboarding and services instantiation

5- **Physical Infrastructure for virtualization:** MEC**,** compute, management and control nodes, described in Table 4-1, provides minimum servers characteristics, as an extension of existing network infrastructure in the 5G-EVE cluster:

- Layer 2 – Layer 3 and security network elements, already existing in testbed infrastructure:
    - Routers Cisco ASR920
    - Switches Cisco NX-OS
    - Firewalls Fortinet 1500D
    - IP/MPLS VPNs connectivity between 5G-VICTORI Bucharest facility-AIM infrastructure
        - will be implemented after equipment's install in Alba Iulia.
    - IPSec between 5G-VICTORI infrastructure and 5G-EVE French Cluster ONAP
        - will be provided later in the project.
- Other facility requirements:
    - Radio Antenna Kathrein (3.5 GHz 4-port panel antenna).
    - RRU installation on the site.
    - Radio site facility frequency bands for demonstration.

Eurecom (EUR) site facility – French Cluster planning

The **EUR** site facility will be based on the work carried out in the 5G-EVE French site in support of both indoor and outdoor 4G and 5G pre-validations prior to RO/Alba Iulia field trial. To this end, the EUR computing platform is based on a number of dense servers and white-box switches (Cumulus) and include eNB (outdoor 2x2 10 MHz, B28 or B13), eNB (indoor SISO RRUs, B38), gNB FR 1(4x50 MHz or 2x100 MHz, n78), gNB FR 2 (100 MHz, n261), 4G core (with NSA), CN Testers (DS), 2x 5G phones (n78 TIM config, n261 Verizon config), and several 4G phones. The cluster planning activities and preliminary UC execution timeline is described in Table 4-2.

In the first deployment phase, OpenShift/K8s will be used to deploy 4G/5G network on the computing platform shown in Figure 4-9 based on RedHat OS. It will make use of k8s pods as workers, Multus CNI for networking (control / user-plane separation, fronthaul/midhaul networking).

In the second deployment phase, the facility will be extended to support the below deployment on an Ubuntu-based OS shown in Figure 4-10.

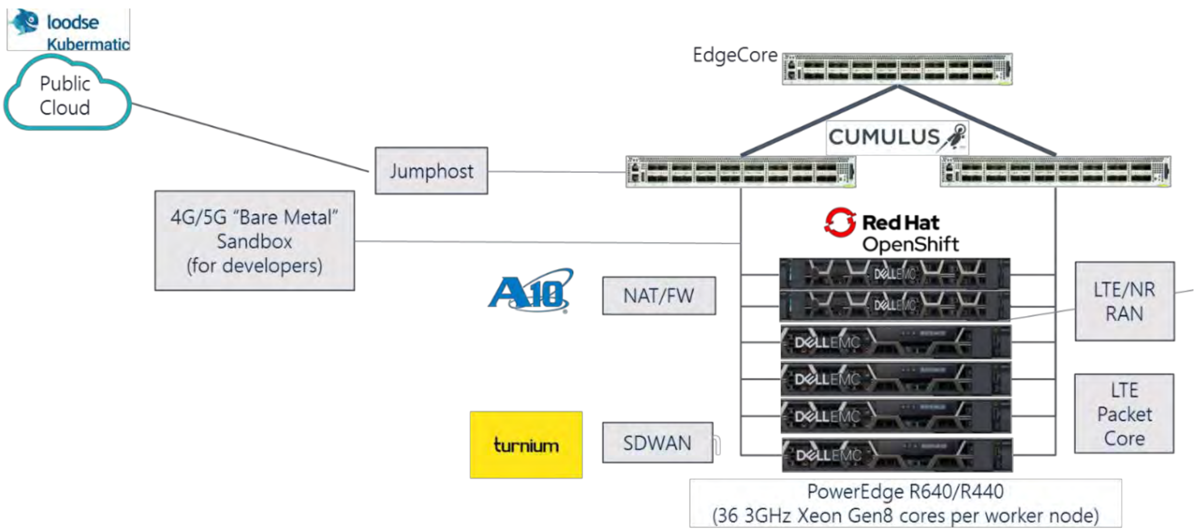


Figure 4-9: EUR 5G-EVE/5G-VICTORI computing platforms

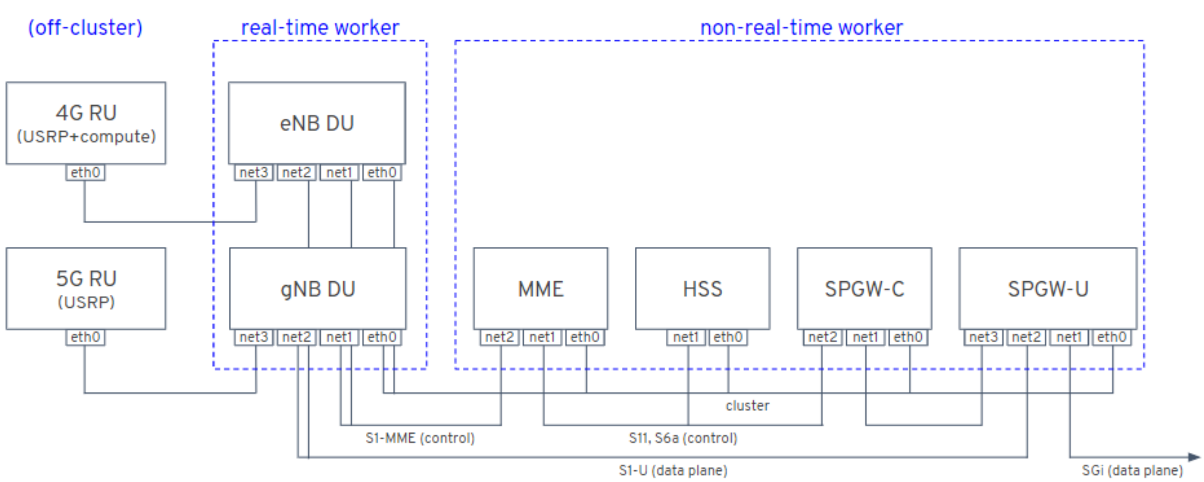


Figure 4-10: 5G-VICTORI 5G-EVE 4G/5G network platform

4.2 Planning and Components

Planning and components, supporting section 4.1 facility requirements and UC validation, start with software and HW components pre-validation at EUR facility, part of 5G-EVE in Sophia Antipolis (gNodeB software w/o mobility) of the 5G system. This will provide the 5G network infrastructure ready for initial UC demonstration in Q3 2021:

Table 4-2: FR/RO preliminary UCs execution timeline

	Facility Activities	Description	Resp.	Time plan
1	Infrastructure extension	Extend EUR/OFR infra to support UCs in Alba Iulia	EUR / Orange	Q2 2020
2	Devices	HW acquisition of end devices(meters, cameras)	AIM / ORO	End Q1 2020
3	Infrastructure deployment	Deploy infra with 2 nodes and computing capability in Bucharest & MEC in Alba	EUR / ORO	Q2-Q3 2020
4	Application development	Development of application for the use cases(digital mobility & energy)	AIM / UHA / ORO	Q2-Q3 2020
5	End device deployment	Deploy devices for the two UCs	AIM / ORO	Q3-Q4 2020
6	Pre-validation system	Pre-validation at EUR facility part of 5G-EVE in Sophia Antipolis (gNb w/o mobility)	EUR / Orange	Q4 2020
7	Integration of applications	Applications integration in Romanian infrastructure	UHA / ORO	Q4 2020 - Q1 2021
8	Integrate Romanian infrastructure with 5G-EVE facility	Integration in Romanian infrastructure of 5G-EVE facility gNB	EUR / ORO	Q1-Q3 2021
9	Initial demonstration	Initial UCs demonstrations at RO/Alba Iulia facility	AIM, ORO, Orange, EUR, UHA	Q3 2021

A roadmap for facility planning and implementation, is described in Table 4-3. It is created based on the assumption of pre-validation activities described in Table 4-2, also in line with the two use case requirements and KPIs validation, as detailed in deliverable D2.1, in terms of network services and dimensioning. A more detailed facility components list and planning will be provided in deliverable D2.3.

Table 4-3: Roadmap for FR/RO facility planning and implementation

Activity	Start / Finish Month	Dependencies
1. Network Requirement capture a. UC network dimensioning b. Radio Network coverage c. Network Mobility/Handover d. Orchestration and management e. Infrastructure deployment	M01 – M12	Initial phase
2. Processing Requirement capture a. UC cloud/server dimensioning b. MEC requirements c. Analytics application	M06 – M16	Activity (1)
3. First Site Survey and report /Initial planning a. UC # 1.2 b. UC # 4.2	M06 – M12	Activity (1) & (2)
4. Network service and slice design for each use case	M12 – M18	Activity (1) & (3)

a. UC # 1.2 b. UC # 4.2		
5. Bill of Materials a. Hardware: servers, radio, antennas b. Connectivity network elements c. Device d. Sites preparation	M01 – M12	Activity (1) & (2)
6. Procurement process a. Acquire network and user components for the installation and commissioning of each test use case	M01 – M12	Activity (1)
7. Compliance to UC requirement, Test Network Capabilities and Coverage a. identify the H/W, S/W b. Spectrum licenses, c. Host sites	M12 – M20	Activity (1) & (2) & (3)
8. Lab testing and initial validation of services per UC a. UC # 1.2 b. UC # 4.2	M20 – M24	Activity (7) & 10 - 13
9. Second Site Survey and report a. UC # 1.2 b. UC # 4.2	M24 – M28	Activity (8) & 10 - 13
10. Install, integrate and commission network entities	M12 – M24	Activity (7)
11. On-board network application a. 5G CN components b. MEC & analytics	M12 – M24	Activity (10)
12. Configure and validate the network services and slices, blueprints	M12 – M20	Activity (10)
13. On-board E2E UC application, deploy appropriate services and network slices	M16 – M28	Activity (10)
14. Test and validate applications a. Component and functional tests b. Report on observed KPI	M24 – M30	Activity (8) & (9)
15. Prepare for the experimentation for the final Project Review and Official Deliveries	M30 – M36	Activity (14)

The roadmap for Romanian facility planning and implementation is in line and agreed by 5G-EVE cluster related to 5G-VICTORI implementation in Romania and is presented in Figure 4-11.

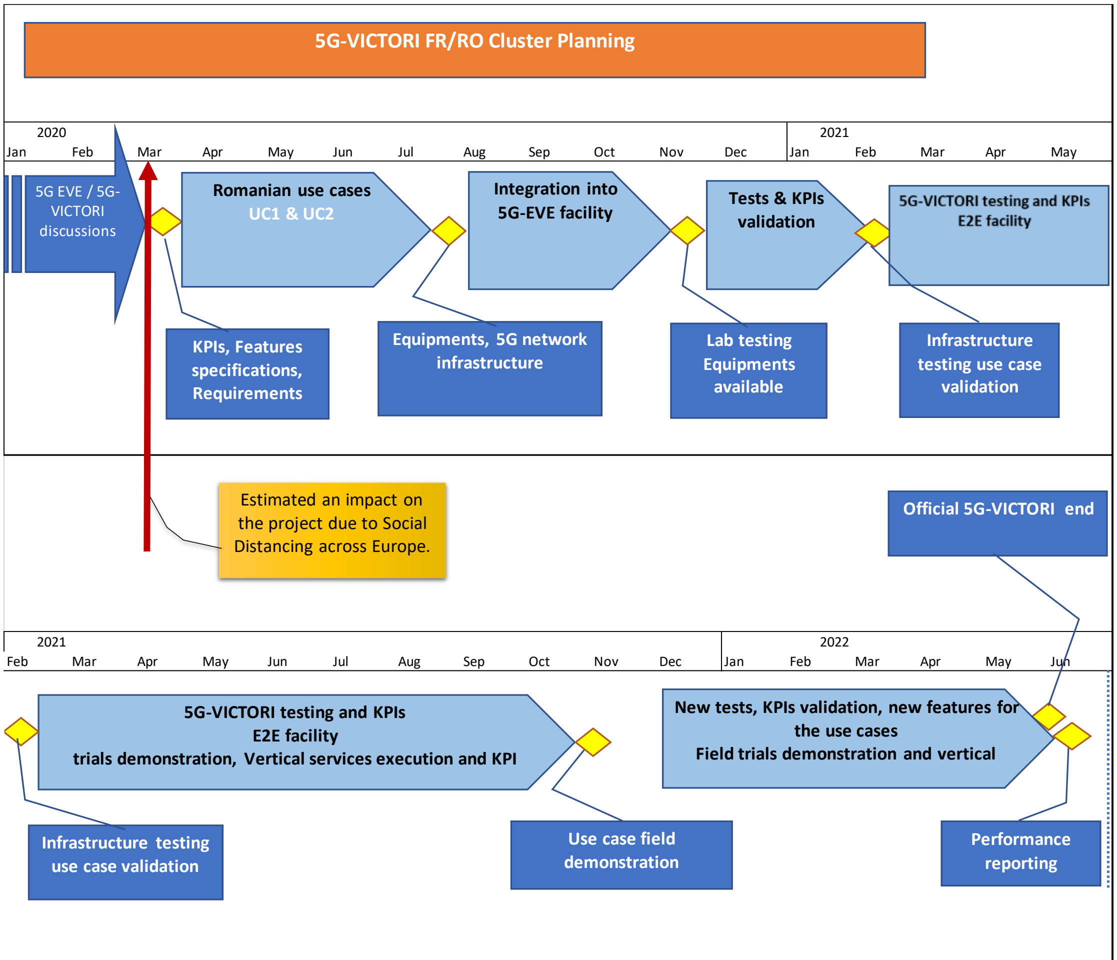


Figure 4-11: 5G-VICTORI/5G-EVE high-level planning

4.3 Use Case Experimentation related to ICT-17/ICT-19 capabilities

This section describes the initial UCs experimentation related to ICT-17/ICT-19 capabilities for demonstrations at the RO/Alba Iulia facility.

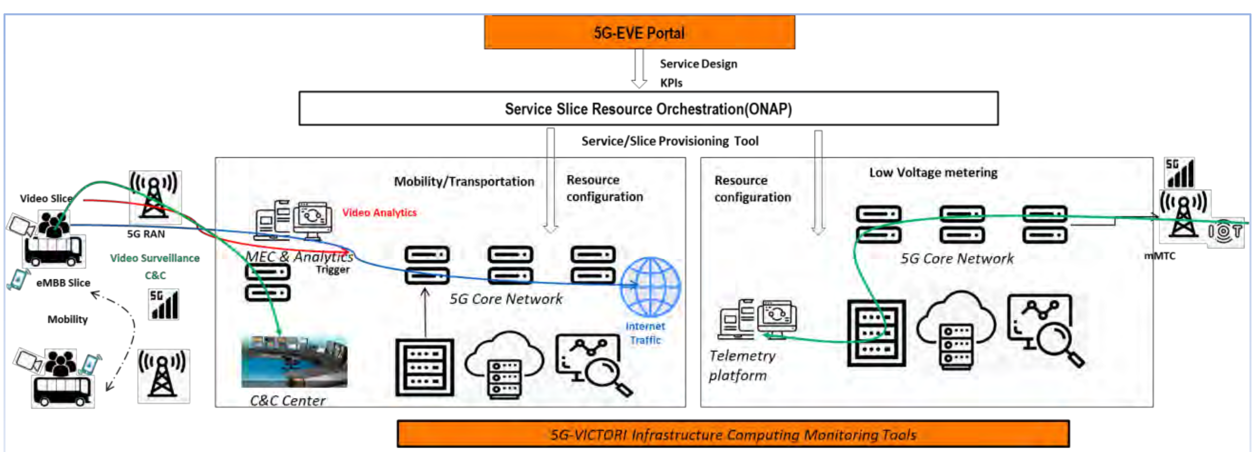


Figure 4-12: Romanian Cluster UC experimentation

The first scenario presented in the left side of Figure 4-12, foreseen from the perspective of experimentation related to ICT-17 and ICT-19 capabilities, is the public transportation to be developed as a Mobility as a Service (MaaS) UC to increase the quality of the transportation by digital mobility. The scenario will be developed by **ORO** in collaboration with **AIM** and will embed the infotainment service and the public safety critical service part. It involves the installation in several public service buses of an intelligent transportation system providing infotainment and public safety services in case of emergency situations.

Infotainment components will be provided through a captive portal in public transport vehicles containing municipality public services access, media streaming, social network access and online shopping services. The captive portal solution will be connected through 5G infrastructure to the Public Traffic Management center allowing real-time communication with the users. For public safety critical service surveillance cameras will be deployed in the transport vehicles and will be connected through 5G dedicated slice with the Municipality Command & Control Centre able to communicate with different stakeholders involved in providing interventions for public transportation passengers to identify threats to the public (healthcare emergency, thefts) and to allocate on the spot the appropriate infrastructure resources requested for emergency situations. The 5G infrastructure will orchestrate the infotainment versus public safety services, when a threat is identified by the system, the infotainment resources are back-logged and a high quality live stream is established to the public safety critical service. The existing service platform will be enhanced with an advanced SDN control plane solution to enable the creation of a network slice that can be allocated for provisioning of mission critical services (audio, video and data). Under emergency situations, network capacity dedicated to passengers' services will be reconfigured to create a slice around the incident location and will connect to ORO network backbone, where mission critical servers are hosted with guaranteed bandwidth. The creation of this infrastructure slice will be triggered either manually (triggered by the driver) or automatically by an external event alert through ZN NetOS™, whereas MC services will be provided through KCC's virtualized platform. The functionality of the **AIM** Digital mobility UC will be assessed trough a set of tests spanning from vertical applications performance evaluation to solution functionality. The KPIs to be evaluated are **Infotainment App Deployment Time**, **Service Availability and Reliability**, and **Incident Reporting Accuracy**.

The second scenario, also presented in right side of Figure 4-12 for the UC experimentation, is the smart energy metering LV UC with the purpose to show that 5G mMTC services can be used for an advanced energy metering deployments. Smart Energy Metering demands advanced requests of high data processing capacities, flexible provisioning capabilities, cost-efficiency and service customization. The above requirements will be addressed by deploying a 5G Smart energy UC to create automated capabilities for E2E deployment and in-life management over network virtualized infrastructures. The goal is to create and implement an E2E operational service framework for the Smart Energy metering solution starting from design and development to E2E orchestration over a 5G infrastructure assuring the E2E management, control and orchestration of the slice. The solution proposed for the Smart Energy use case brings several key benefits such as low latency, low battery consumptions, full automation operation for both deployment and in-life management, this will significantly reduce the operational expenditure. 5G will bring better performance, faster power reconnection after outages, and more cost-effective measures across smart metering Alba Iulia Municipality facilities. It will be demonstrated over the 5G-EVE infrastructure to provide energy metering services for energy consumers like public buildings and street lighting in the Alba Iulia Smart City environment, and also for energy sources like photovoltaic panel or national grid.

The scenario assumes metering data collection from endpoints scattered across a city up to 10k devices per 10 km^2, which requires scalability of network slice from get-go. The collected measurements will be transferred to the 5G-VICTORI central cloud facilities where will be stored, processed and analysed by the telemetry platform. Advanced analytics will be used to predict future demands and create incentives for citizens to reduce overall power consumption. Smart Energy Metering demands advanced requests of high data processing capacities, flexible provisioning capabilities, cost-efficiency and service customization, which can be done by creating automated capabilities for E2E deployment and in-life management over network virtualized infrastructures.

The E2E 5G facilities are delivered through the 5G-EVE project and extended to the Romanian cluster sites, deployed based on IaaS infrastructure, by implementing several open source components, as OpenStack for VIM, OSM or ONAP, OAI, and Kubernetes.

The UC experimentation activities related to ICT-17/ICT-19 capabilities are aggregated in Table 4-4. Several key points have been identified as a pre-requisite described here for the use cases demonstrations:

- UC experimentation describes the use case related requirements for demonstration in term of infrastructure capabilities, supported by ICT-17/ICT-19 projects.
- Physical infrastructure requirements for use cases validation, all HW capacity and networking connectivity.
- Virtualized infrastructure that contains details related to the network cloud capabilities for further NFV/VNF instantiation, for the automatic resources deployment.
- NFV/VNFs supporting the use cases experimentation, from network and application perspective.
- Orchestration Tools available for resource, slice and service orchestration, for automatic service deployment.
- Monitoring tools for use cases KPIs validation and dashboard exposure.
- Interworking layer capabilities related to 5G-VIOS orchestration capabilities.
- 5G-VICTORI service-design framework for the UCs.

4.4 Risk assessment

Due to the uncertainty related to the COVID-19 lockdown, for the FR/RO cluster there could be an impact on site integration and validation activities, leading to a delay of 3 months.

ORO is considering a mitigation plan for site integration activities by: (1) preparing in advance all possible activities required for site implementation (networking components, servers configuration, radio spectrum analysis, lab validation tests) supported by the initial surveys already executed; and (2) proper resource allocation for the preparation of the site activities after COVID-19 period. The mitigation plan will include also activities for UCs validation and experimentation also in the Orange LAB in Bucharest, a closed environment with limited COVID-19 impact.

Table 4-4: Use Case Experimentation related to ICT-17/ICT-19 capabilities

Cluster	**ICT-19 5G-VICTORI Romanian Cluster**				
ICT-17	**5G-EVE French Cluster**				
Use case	**Digital mobility - public safety**	**Smart energy metering LV**	**Facility capability**		**Details**
Use case Experimentation	Infotainment and public safety 5G services Application LCM; deployment and instantiation Immediate setup time(triggered) service Service management and automation C&C service instantiation & MEC Analytics function Evaluate application KPIs: availability; reliability; mobility; broadband connectivity; latency; coverage QoS experimentation, service optimization	Smart energy metering LV Application LCM; deployment and instantiation Service Setup Service management and automation Evaluate KPIs	ICT-17	ICT-19	Tools/Components
Physical Infrastructure	Physical network elements and auxiliaries				
Hardware/PNF	Control and compute servers; storage; networking; eNodeB PNF; antennas and cables	Control and compute servers; storage; networking; eNodeB PNF; antennas	x	x	extend computing capabilities to AIM
Transmission	IP/MPLS; L3VPNs; IPSec connectivity	IP/MPLS; L3VPNs; IPSec connectivity		x	sites connectivity: Paris-Bucharest;Bucharest-AIM
Devices	4G5G Video Cameras	5G IoT metering devices		x	specific device for use case experimentation
Spectrum	4G/5G Licensed spectrum	4G/5G Licensed spectrum			B20;N78
Cloud/Edge	MEC for video data analytics	N/A		x	MEC capabilities for video analytics
Virtualized Infrastructure	Cloud capabilities				
SDN/VIM	Hypervisor / OS Layer; KVM; Cloud native capabilities;	Hypervisor / OS Layer; KVM; Cloud native capabilities;	x		OpenStack; OSMv5; Docker; ONAP and SDNC
Monitoring	Infrastructure monitoring; VMs state monitoring	Infrastructure monitoring; VMs state monitoring	x		Prometheus; ONAP collection engines
NFV/VNF	Virtualized functions				
4G5G RAN	4G/5G eNodeB/gNB; dockerized component	4G/5G eNodeB/gNB; dockerized component	x		4G5G RAN OAI Mosaic5G

4G5G Core	4G Core vEPC; SDM; 5GCN AMF, UPF, UDM	4G Core vEPC; SDM; 5GCN AMF, UPF, UDM	x		4G5G Core OAI Mosaic5G
Use case App	Video analytics application	LowVoltage IoT application		x	Use case application for experimentation
MANO	Orchestration				
Resource Orchestration	Network resource orchestration and instantiation	Network resource orchestration and instantiation	x		OSMv5; ONAP; Kubernetes
Slice Orchestration	Slice service instantiation - video	Slice service instantiation - video	x		ONAP; OSM
Service Orchestration	Service instantiation - video	Service instantiation - video	x		ONAP SO; OSM
Catalogues	Service Catalogues;	Service Catalogues;		x	ONAP; SDC Catalogue
Inventory	System's resources, services, products	System's resources, services, products	x		ONAP A&AI
Service performance	optimize performance	NA			Quality monitoring data rates
Policy Framework	Policy based decision	NA	x		Data Collection, Analytics and Events
Service Monitoring Analysis	Application monitoring				
Data Visualization	Service data visualization; Dashboard	Service data visualization; Dashboard	x		Grafana
KPIs	KPI service validation	KPI service validation		x	
Interworking layer	5G-VICTORI cluster interworking				
Multi-site orchestrator	control and management framework for instantiation of vertical specific applications from the 5G-VICTORI repository; network service deployment; Inventories			x	5G-VIOS
Multi-site inventory				x	
Orchestration broker				x	
Service Design	5G-VICTORI Design-time framework			x	specification of the service in all aspects

5 Patras Facility Planning

5.1 Site Facility Implementation

The Patras (Greek cluster) facility, as developed in 5G-VINNI, is expanded and extended in order to comply with the 5G-VICTORI architecture and to support the deployment of the UCs running in Patras. It will also support cross vertical experimentation and KPI validation. This facility will include Patras and Rio sites and it will accommodate a number of UC/vertical scenarios employing multi-tenancy. Four UCs are going to be demonstrated, each of them with several scenarios (see deliverable D2.1 [1] for more details).

The Patras/Rio facility deployment will include the following main infrastructure/components:

5.1.1 Cloud infrastructure and MANO services

Currently, the Patras facility (see Figure 5-1) includes a cloud infrastructure/platform (owned/operated by the UoP) hosting 4G/5G core network components, as well as NFV and MEC deployments. The cloud infrastructure (UoP DC) offers a total computing power of 212 CPUs, 768 Gigabytes of RAM and 30 TB of storage. Two servers with 4x10GbE NICs, DPDK enabled, are available.

On top of UoPs' cloud infrastructure, a rich set of state-of-the-art SW tool is already available, comprising the facility's experimentation platform called Cloudville. The cloud platform uses OpenStack as cloud operating system, while OSM is available to allow NSD/VNF deployments. Prometheus alongside with Grafana are installed for monitoring purposes. At the same time, Elastic search and Kibana are installed and used to collect and visualize data extracted from IoT devices and sensors.

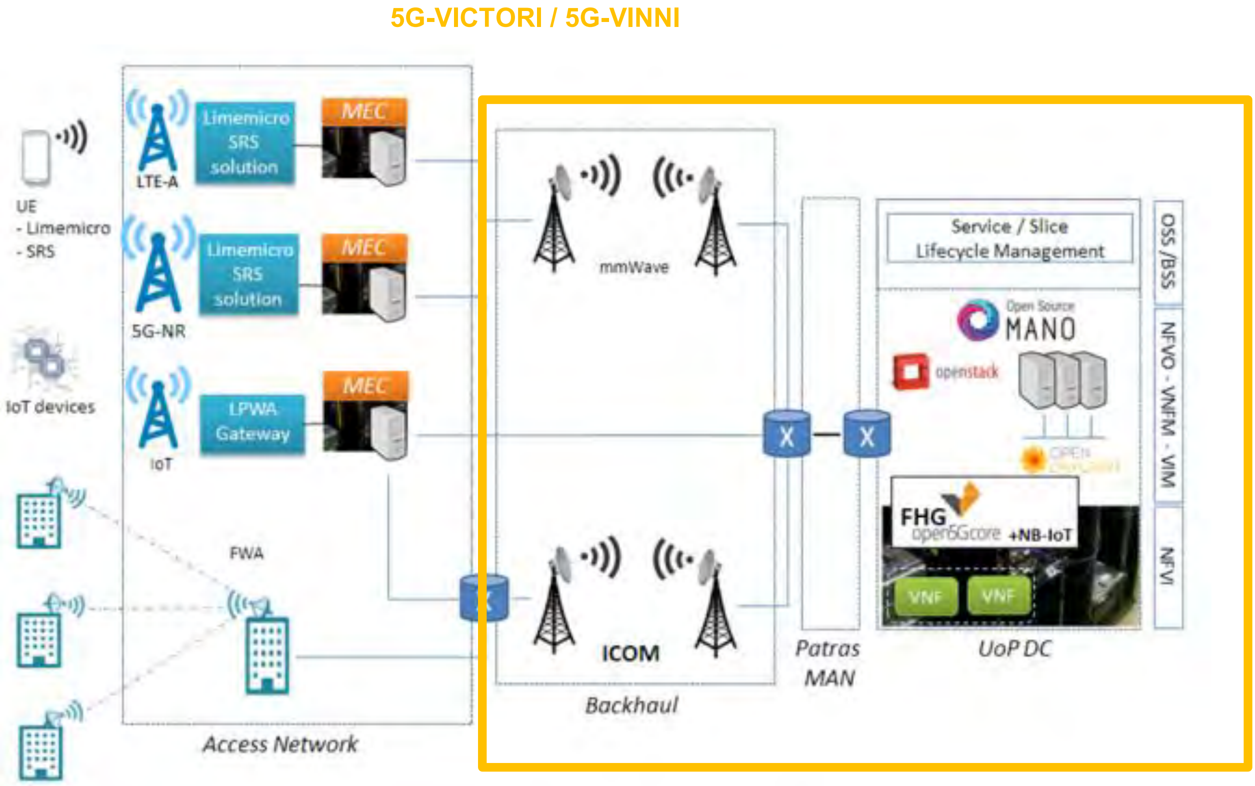


Figure 5-1: Patras/Greece 5G-VINNI facility

5.1.2 Access Network

In the Patras/Greece facility, to enable network slicing and UC validation, there are three outdoor 5G base stations (g/eNBs) planned to be installed together with MEC installation(s) at the Rio facility area, at selected places to support the vertical UCs' experimentation with at least six UEs. Currently, in UoP premises, there are 5G NSA devices available that are being tested in a lab environment together with a 4G capable device. Furthermore, other solutions with SDRs and Open Source 4G/5G implementations can be deployed.

5.1.3 **Transport Network (Backhaul)**

ICOM will provide state-of-the-art mmWave backhaul to the Greek facility. The UltraLink™-GX80 all-outdoor mmWave PtP Ethernet radio at 70/80 GHz (E-Band) provides a 10 Gbps backhaul capacity, and it will be used to interconnect the g/eNBs with the core network and the data centre at the UoP premises. ICOM will add support for SDN-based network slicing to the wireless backhaul.

IHP will bring to the Greek facility a V-Band (60 GHz) solution with beam steering capabilities for the train-to-track connectivity in UC # 1.1. The solution provides around 1 Gbps data rate and it will be used in conjunction with Sub-6 technologies in a multi-connectivity framework.

5.1.4 **Core 5G/IoT services**

The Patras' facility 5G core network will be provided by Fraunhofer's (**FhG**) Open5GCore implementation. To support NB-IoT, the Patras/Greece facility is planning to host the Open5GCore NB-IoT extension for the demonstration of low energy IoT communication.

Currently, for our lab experiments, Amarisoft-based solutions are being used for 5G, 4G and NB-IoT connectivity. These address the current stringent needs of the 5G UCs to provide low power, low cost-efficient communication for a massive number of devices. On the NB-IoT, LTE-M radio side there will be commercial licensed as well as Open Source solutions available.

5.1.5 **MEC**

UoP together with **ICOM** will implement and integrate MEC and Edge Computing functionality, and also provide the virtualization of edge IoT devices, i.e., IoT Slicing, as a VIM component. In particular, the Patras/Greece facility MEC functionality will be considered on two fronts:

- **IoT Resources Virtualisation:** A Virtualized Infrastructure Management (VIM) (sub-)component will be designed, implemented and integrated within the overall MANO architecture, to enable the virtualization of the available edge IoT resources (sensors/actuators) for access within individual network slices.
- **Mobile streaming applications support**: The facility will employ MANO mechanisms for the realization of high throughput, low latency, mobile types of applications and corresponding test cases. Such mechanisms will include DNS and traffic flow management (on Mp1 ETSI MEC interface) for baseline service orchestration, as well as mobility support mechanisms, i.e., mobility management events such as application context transfer, user redirection network/application level), and a subset of the Location Service (ETSI GS MEC 013) for triggering mobility management events.

5.1.6 **UoP Patras Autonomous Edge**

Patras 5G Autonomous Edge, is a mobile box, ideal for on-premise 5G deployments, containing everything from the 5G NR and 5G Core, Network and Service Orchestrations on a Virtualized environment based on OpenStack.

Figure 5-2: Patras/Greece Autonomous Edge

5.2 Planning and Components

With respect to the facility planning concerning the vertical UCs' onboarding there are various steps that are followed (not necessarily on a strictly sequential order), a roadmap of which is enlisted below. In the beginning the UCs were described and requirements (focusing on network services) were used as the basis for initial facility/deployment definition (main components and functionalities).

Network related requirements (Coverage, Capacity) and compute related (processing, storage, etc.) requirements per UC are identified. These requirements are being mapped on services requirements (e.g. isolation, reliability, mobility of a service, etc.). At the same time, facility dimensioning (network, compute resources) and required HW extensions are specified as a base for the facility planning. Simultaneously, physical and virtual network functions (VNFs/PNFs) will be developed, and network slices will be defined/designed.

The final step concerns the definition and design of network Services. In the meantime, it is crucial for the facility planning that lists of materials that need to be acquired and procurements processes are planned alongside facility surveys in order to ensure that all equipment is in place for lab testing. The process has several milestones where some steps are revisited.

5.2.1 UC # 1.1 - Transportation 5G-VINNI

Activity 1 and 2

This UC focuses on providing a prototype network deployment in order to support the necessary train operations through the creation of two separate infrastructure slices that will concurrently:

1) provide data services to train passengers using dedicated disaggregated heterogeneous femtocells deployed on-board, and
2) support time-critical rail services.

For the former, high-capacity links are needed to provide high-quality infotainment services to passengers, whereas for the latter low latency / ultra-reliable connections are needed in order to transmit data obtained from various sources (e.g. train status monitoring devices) in real-time to the train operations and control center. An initial identification of the high-level requirements of these services has been provided in 5G-VICTORI's deliverable D2.1 [1].

Aggregating the service requirements, the initial network deployment requirements have been derived in [1], and will be further refined in an iterative fashion. To address these requirements, this deployment solution will be based on a joint backhaul/fronthaul (FH/BH) network realized over heterogeneous wireless technologies, to support dedicated disaggregated virtualized access nodes on top of high-speed moving trains.

In particular, the 5G VINNI and 5G-VICTORI solutions integration will take place at four levels:

At the lowest level lies an on-board train network. This consists of several compute and network elements, all interconnected by fibre network. The proposed on-board network comprises a 10GB Ethernet LAN with SDN-capable switches, connecting Sub-6 and mmWave antenna modules to be installed on the roof of the train, and software-based 5G-NR and Wi-Fi APs to be placed inside the train. The train-internal wireless part of the on-board segment comprises of SW-based solutions for 5G NR and Wi-Fi, provided over an aggregation environment augmenting the overall capacity of the network, and controlled through a single Centralized Unit (CU). We consider the disaggregation of the base stations at a high-layer Packet Data Convergence Protocol (PDCP) that can be used for aggregating heterogeneous access technologies. The CU can be instantiated as a VNF on an (edge) data center – such as the data centre (DC) of **UoP** – and manage multiple heterogeneous Distributed Units (DUs) that integrate the radio-level characteristics of the base stations. At this point, a compute node is also necessary to deal with the handover management, while it can also act as a potential CU of the disaggregated 5G-NR cell. Moreover, cameras will be placed at the front and at the rear of the train realizing the critical service to be transported from the train to the Control Center located in the 5G-VINNI Patras facility.

At the second level, for the track-to-train connections, a heterogeneous wireless network will be deployed operating in the Sub-6 GHz frequency band provided by **UTH** (e.g. 5G NR access, high-throughput Wi-Fi), and mmWave units featuring beam tracking capabilities provided by **IHP**.

At the third level, the interconnection of the track side APs to the core network will be achieved through multiple Point-to-Point E-Band radio links with the UltraLink™-FX80 from **ICOM**, that provide up to 3 Gbps capacity, depending on installation restrictions. These will be aggregated at the central backhaul hub at Rio site. At this hub, the 5G-VICTORI deployment will converge to the 5G-VINNI main facility network at the fourth level, with the hub being connected to the core network at UoP premises through the 5G-VINNI E-Band PtP link with the UltraLink™-GX80, able to backhaul up to 10 Gbps.

Finally, a full 5G Base station unit with MEC capabilities (provided by 5G-VINNI) will be located at the Rio train station and will be also connected through mmWave BH to 5G-VINNI Patras facility.

As the proposed setup consists of highly complex and heterogeneous infrastructure elements, we plan to make use of SDN/NFV principles for the orchestration and management of the infrastructure. VNFs will run on computational or network resources. Especially for the access network nodes, we plan to make use of a fully softwarized control and data plane (CUs and DUs based on the OAI stack implementation, forwarding elements, passenger infotainment and operational services running). Other VNFs will comprise different modules, able to manage cross-technology components, in order to prioritize traffic, isolate different slices of traffic and setup new paths in case of cross-technology handovers (e.g. switching from mmWave to Sub-6 GHz technologies for communicating with the trackside network). At the same time, Infotainment services for passengers or operational services for trains can be delivered as VNFs or application functions over common computational or network resources.

At this stage, the requirements that are further elaborated are those affecting the facility planning and demo deployments, namely:

Table 5-1: Requirements of the facility and deployment solutions

Deployment-related Aspect	Facility Requirement (Refined)	Deployment Solution & Dependencies
Network coverage	• Coverage to be provided over ~2 km distance (two-way) from Kastelokampos station all the way to Rio station (for the demo a train will travel this distance forth and back).	• A number of wireless links will be deployed along the track providing full coverage. • Depending on the technology and in order to support high-speed mobility,

		each direction needs to be covered by different access network nodes/ links.
	• Coverage to be provided at selected station; coverage range 150 m	• One gNB will be deployed at a selected station site.
Network Mobility/ Handover and other service specifications	• Mobility/Handover support to be provided while train travels along the track.	• Coverage overlapping of wireless (access/transport) Track-to-Train links will be considered during site survey/ planning. • Wireless (access/transport) Track-to-Train connectivity will be performed over two links simultaneously.
	• At least 1 Gbps per access network node (onboard network) is required	Track-to-DC transport will be up to 3 Gbps, according to requirements and technical capabilities per site depending on installation restrictions, while the track-to-train network capacity will be up to 2 Gbps
UC network dimensioning	• At least 1 Gbps per wireless (access/ transport) Track-to-Train link is required	• The maximum Track-to-Train distance will be planned considering the data rate vs distance equipment specifications.
	• Track-to-DC Transport Aggregation connectivity of more than 2 Gbps is required	• The transport aggregation links will have capacity up to 3 Gbps and the network planning (locations of wireless aggregation transport nodes) will take into account the data rate vs distance equipment specifications, according to requirements and technical capabilities per site depending on installation restrictions.
MEC/EC Applications' compute requirements	• MEC/Edge Applications will be deployed on board the train with various requirements	• On-board the train a server will be deployed in order to host MEC/EC functionality and applications, with the following minimum characteristics: Intel Core i9 7980EX (18 cores) 16GB DDR, 480GB SSD.
	• On-board CU of disaggregated RAN nodes requirements: 1VM, 2 vcpus, 4GB RAM	
MEC/EC Compute requirements	• gNodeB and EPC core at train station • UoPs' MEC solution requirements: 1VM (2vcpus), 4GB RAM, for MEC functionality	• At selected station site, or at UoP DC a server will be deployed in order to host MEC functionality and applications and/or 5G core, with the following characteristics: (2-20) vCPUs,(4- 50GB RAM, 1 Gbps Ethernet interfaces and1 and 10GB Ethernet interfaces Autonomous Edge, to use as required by the test case

Activity 3

Figure 5-3 shows the area that was selected for the demo following a number of initial site surveys between the Rio (P3) and Kastelokampos (P1) train stations for the purposes of the demo. In Appendix Patras facility 1, reports on the sites survey can be found with details. Various points along the trackside have been thoroughly investigated but the specific ones that are shown on the map (P1, P2, P3) have been chosen as they simultaneously cover the requirements for power supply, line of sight with the main hub (P0) and distance between them. Alongside two train stations in Patras, the Rio and the Kastelokampos stations (2,168 km two-way, considering that for the demo a train will travel from Kastelokampos station all the way to Rio station and back) there will be 3 mmWave units (**ICOM**) with approximate range of 350 metres bridged with the mmWave backhaul links (see points P1, P2, P3 in Figure 5-3).

To demonstrate multi-technology track-to-train communication, the proposed setup comprises both mmWave (at P2 provided by IHP) and Sub-6 track-side APs to be deployed on stanchions along the track between the two stations as (P1 and P3). Each stanchion has a pair of mmWave and/or Sub-6 APs where corresponds, each one facing at the opposite direction of the track. To maximize connectivity and minimize the disconnection times between handovers from the train to the track APs, the proposed scheme requires antenna modules to be installed both at the front as well as at the rear of the train, as shown in Figure 5-4 and Figure 5-5.

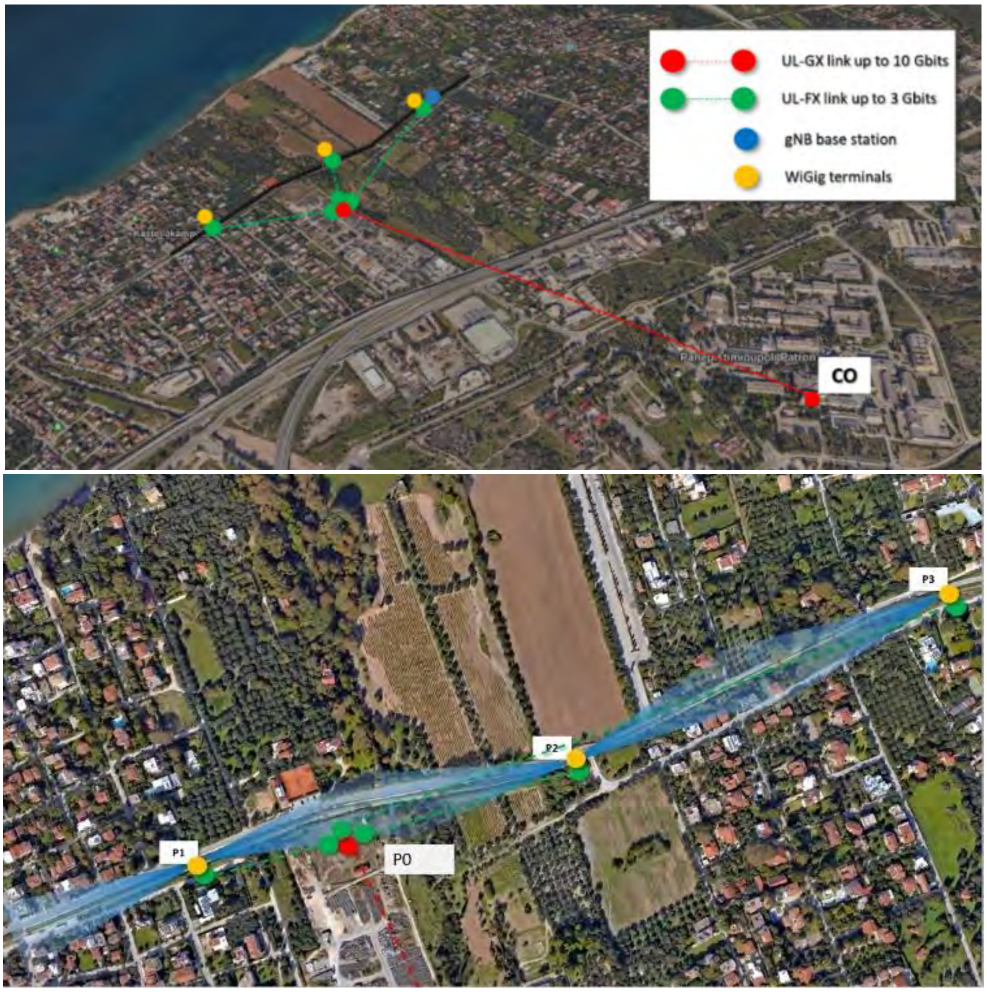


Figure 5-3: 5G-VICTORI/5G-VINNI combined deployment for moving train UC

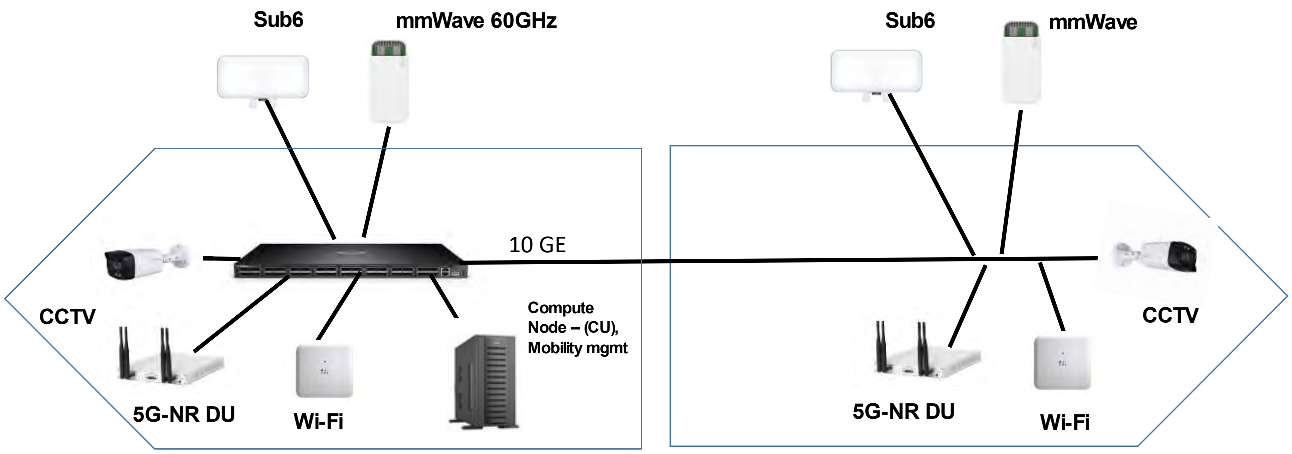


Figure 5-4: Onboard network architecture for 5G VICTORI

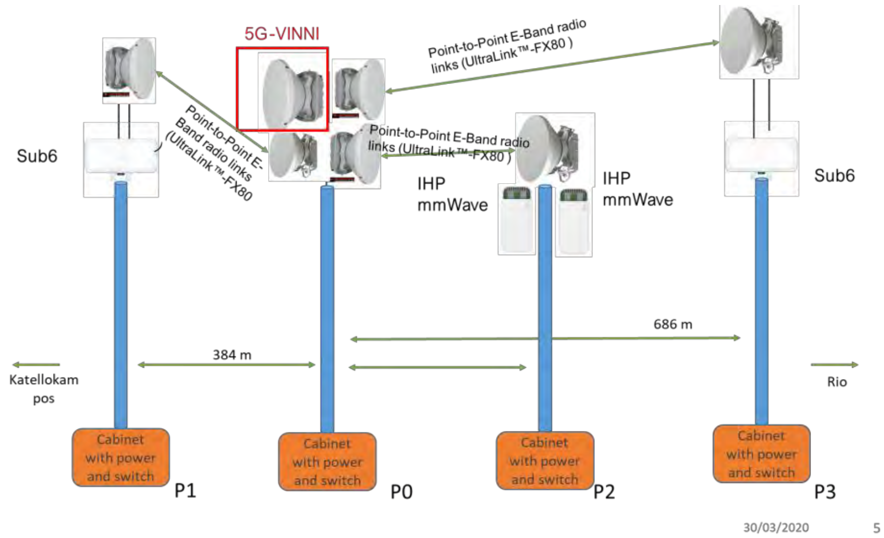


Figure 5-5: 5G-VICTORI deployment along the trackside for UC # 1.1

5.2.2 UC # 2 - Factories of the future

Activity 1 and 2

The main objective of this UC is to automate the monitoring process and improve the inspection methods and maintenance procedures of energy utilities as factories of the future, both for cost/time reduction and quality improvement. An initial identification of the high-level requirements of these services has been provided in [1]. Aggregating the service requirements, the network deployment requirements have been derived initially in [1], and will be further refined in an iterative fashion. At this stage, the requirements that are further elaborated are those affecting the facility planning and demo deployments, namely:

Deployment-related Aspect	Facility Requirement (Refined)	Deployment Solution & Dependencies
Network coverage	• Network coverage is needed over ~2,000 m^2 at Rio ADMIE premises, in order to complement the 1st level connectivity of the site.	• One NB-IoT Evolved Node B (eNB) and off-the-shelf LoRaWAN Gateway modules will be deployed.

UC network dimensioning	• Low Latency required	• Data processing in several MEC/ Edge sites will be incorporated.
MEC/EC Applications' compute requirements	• 1st level processing requirements (1-2(v)cpus), 2GB RAM). Central Processing requirements: 1-4VM, (2-8 (v)cpus), 4-16GB RAM and 1 GB of space each).	• Edge server will be deployed at Rio/Antirio site, with the following minimum characteristics: The autonomous Edge if deployed at field can provide 20 vCPUs, 50GB RAM, 1 and 10 Gbps Ethernet interface. • Central Processing will be provided at UoP DC site, with the following minimum characteristics: 200 vCPUs, 256GB RAM, 1 Gbps Ethernet interface.

In particular, the selected site for the proposed UCe will be the **ADMIE** facilities in Rio-Antirio, near Patras, Greece. The **ADMIE** complex includes storehouses as well as all the necessary installations for facilitating the ADMIE activities. As described in the UC, the monitoring, security and operation should be performed through the same digital infrastructure. Two facilities lie at different sides of the Rio-Antirio canal and they are separated by approximately 4 km of sea. The facility manages the Rio-Antirio underwater energy interconnection via a high voltage underwater cable with the special requirements that were described above. The cable lies along the Rio-Antirio bridge. The Rio **ADMIE** site and terminal station lie in a large area of land close to the Rio Rail station (P0 from previous UC). Here a control room is used to monitor the operational status of the cable. A set of legacy devices with no internet connection, and a set of LEDs that inform the personnel about the status of the cable, are used. The Antirio site, resides at the Antirio village (Greece), indicated by P4 in Figure 5-6.

Again the 5G-VINNI and 5G-VICTORI integration solution will be performed at four levels. At first level, as far as the vertical application/service and vertical/end-user network part is concerned, the following components will be deployed:

- CCTV data will be collected using off-the-shelf Wi-Fi equipment, tailored to the wireless environment of the area to support at least FHD streaming.
- Several monitoring devices deployed at key locations of the facility, consisting of oil pressure, tension, temperature, etc. These sensors will interconnect wirelessly through at least two redundant links (NB-IoT and LoRaWAN).
- A data management platform allowing scalable data collection, aggregation and processing of the collected information. This platform will be able to operate both at the edge (deployed at the edge data center) and the central cloud (located at the 5G-VINNI facilities in Patras) allowing data and functionalities to migrate from one site to the other
- A processing platform supporting a variety of user applications and services to facilitate optimal decision making and preventive maintenance strategies, as well as other possible enhancements including i) new inspection methods to allow faster and more accurate inspection of the facility; ii) new repairing, strengthening and upgrading methods; iii) novel data sampling techniques taking into account battery lifetime of the sensing devices.
- A data visualization platform able to combine input from sensing devices, aerial and ground imaging and 3D maps and providing faster decision making.

The network brings data from both sides (Rio and Antirio) to the processing units that exist at the Rio edge data center. In order to ensure a high degree of synchronization and data correlation, the integrated 5G VINNI/ 5G VICTORI facility will utilize an underwater fibre cable as the access transport solution at second level. To that respect, the data from the Antirio area will be transported to the edge data center together with the data gathered from Rio for synchronization and correlation. In the case of a potential non-availability of the optical fibre at the time of first phase of installations, a contingency plan has been made, according to which, both facility sites will be directly connected to the 5G-VINNI data centre through an extra mmWave backhaul link (**ICOM**) (as presented in Figure 5-6).

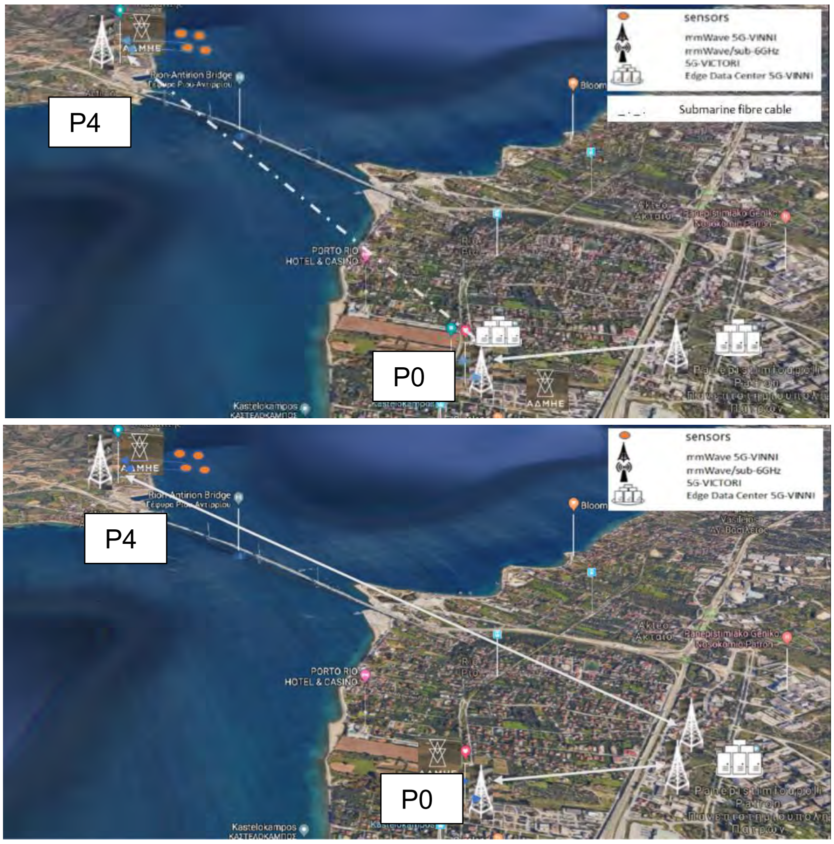


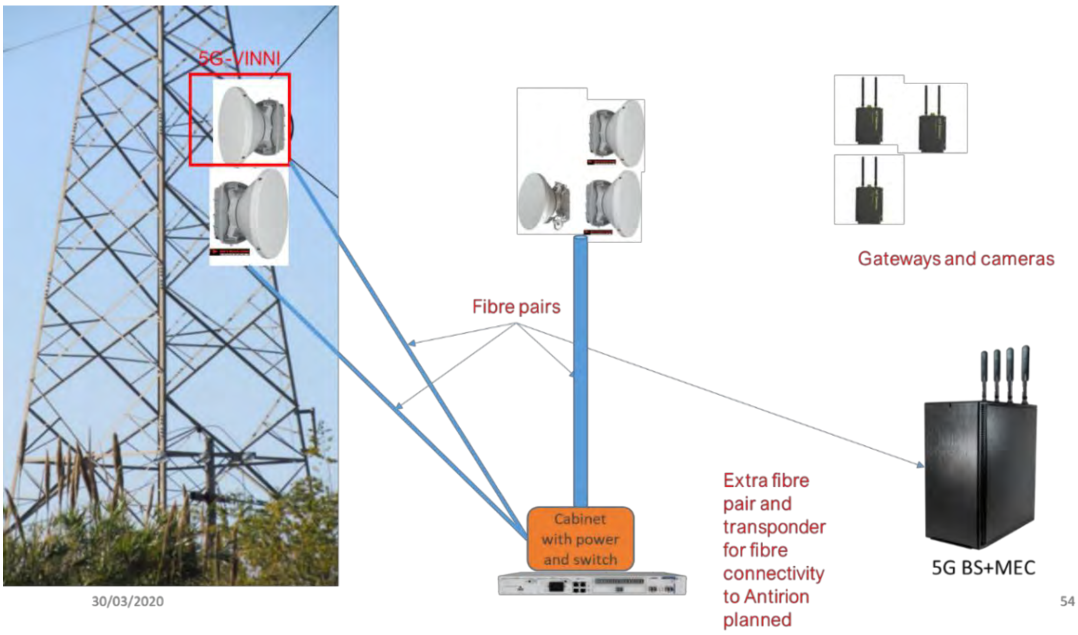
Figure 5-6: Two proposed alternative UC configurations at ADMIE facilities

Then at third level, the ICOM's mmWave BH installation will be used as aggregation transport over which data will be transferred for further processing and visualization at UoP's DC (5G VINNI premises).

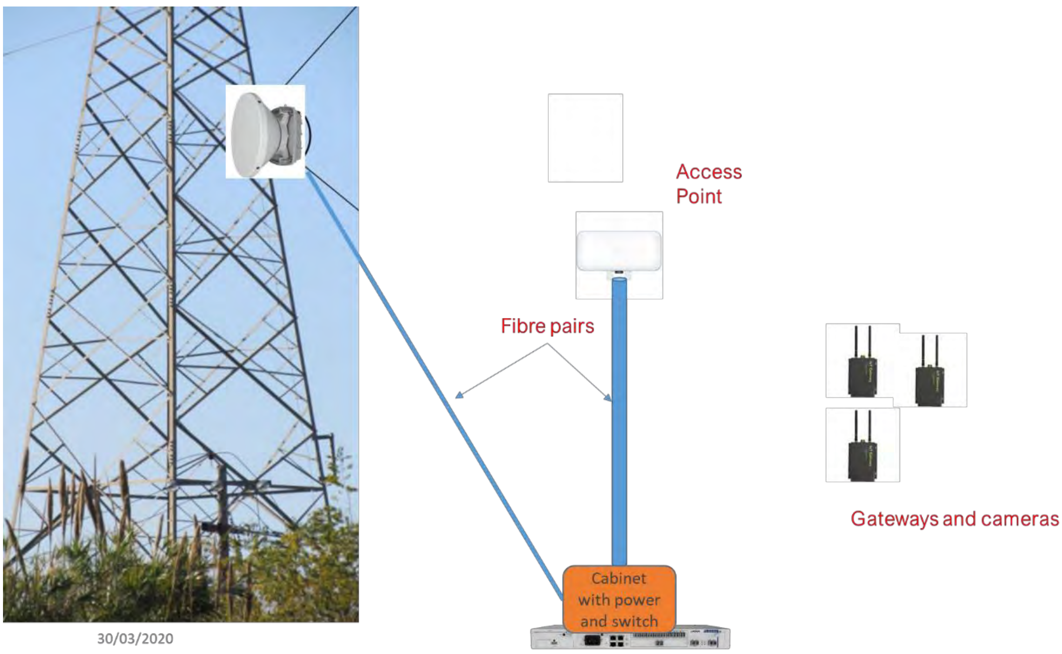
As the first step, the deployment of the new infrastructure associated with the 5G-VICTORI project will take place. This infrastructure involves the installation of the sensing devices at the predefined locations, powered on through either battery/solar cells or connected to the power supplies provided by ADMIE. The cells providing the gateway of the collected data will be installed (software defined NB-IoT cell, COTS LoRaWAN gateway, Wi-Fi AP) along with the edge data centre and the remote connection to the 5G-VINNI facility.

Activity 3

Figure 5-7 shows the placement area that was selected for the demo after some initial site surveys between the Rio (P0) and Antirio (P4) terminal stations for the purposes of the demo. Various points in the areas have been thoroughly investigated but the specific ones have been chosen as they simultaneously meet the requirements for, line of sight with the main hub (P0) and 5G-VINNI facility and distance among them. A detailed report of the site surveys is presented in section 8.1.



a)



b)

Figure 5-7: 5G-VICTORI deployment at P0 (a) and P4 (b) for UC # 2

5.2.3 UC # 4.1 - Energy -HV UC

This UC focuses on future energy services/applications related to real time gathering of energy consumption and load data (recovery of energy fed back during braking) in the RMS and EMS platforms. The former aims to assist infrastructure managers and railway operators to select optimal strategies and resources in a cost-effective and energy-efficient manner (e.g. by synchronizing decelerating and accelerating rolling stock). The objective of the latter is to assist substation operators to perform smart energy techniques such as demand-respond, peak management, substation stress avoidance, load balancing, efficient HV grid interaction and cost savings in the EMS platform (see D2.1 [1] for more details).

In view of these services, the trial will focus on gathering and comparing energy consumption and load data from both the decelerating/accelerating trains and power substations. The final HV trial is expected to take place at Corinth (Greece), where ADMIE feeds a range of primary substations. One of these primary substations (150kV/25kV), at *Loutropyrgos*, is used for TRA suburban trains traction (TPSS).

To achieve the correlation and synchronization of the data sets and showcase the capability to make decisions and perform operation for the UC, the trials will be executed in two phases which are detailed in following paragraphs.

1st Phase/Trial: Energy HV Use Case emulation at the Rio/Kastellokampos 5G-VICTORI trial.

Activity 1-3

The first part of the trial will be based on historical data taken from the electrical trains that operate at Loutropyrgos and the power station there. For proof of concept, and since there are no connected measuring devices on the trains able to feed the system with live data at the moment, the data measurement and/or gathering part will be emulated. The previously collected data will be used for emulating real time, high frequency sampling transmission from both the train and the power station (correlation will take place as train approaches P0 on the maps). To that respect the data management platform will be developed and real time synchronization between data from the train and power station will be showcased. This trial will utilize the infrastructure and the Patras facility Rio site (at Kastellokampos) available for UC # 1.1 and UC # 3 (the Rail and Media UC), offering great advantage as far as the number of antennas and (emulated) measurement points is concerned. The first phase of the trial will be able to emulate the stringent requirements (and deriving KPIs) with respect to Access network node capacity (requiring gNB capacity of >1-2 Gbps) and user data rates (1 Gbps). At the same time, as latency is a critical requirement, additional benefits may come from exploiting MEC computational power (in the case of the trial the MEC deployment of UC #1.1). The MEC to be used will probably be the Autonomous edge, since Loutropyrgos site will be a private 5G network (island) with no connectivity to Patras UoP DC.

2nd Phase/Trial: Energy HV private 5G trial at the Loutropyrgos private site.

Activity 1-3

Wthen the devices on-board at the Loutropyrgos trains as well as of the data management platform and the synchronization platform become available, the second phase of the trials will take place at this private site. A 5G base station (access) will be installed at the Loutropyrgos substation to provide the required coverage to the train and will be connected to the 5G-VINNI/UoPs autonomous edge/core solution that will be deployed (on VMs) at a local data center. For data collection purposes, measuring devices should be installed also at the **ADMIE** power station. The required access network node (gNB) capacity will be of >1-2 Gbps to provide the required user data rates (~1 Gbps). The required latency requirements of 30msec will be satisfied through incorporating/ basing the solution on MEC.

An initial identification of the high-level requirements of these services has been provided in deliverable D2.1 [1]. Aggregating the service requirements, the network deployment requirements have been derived initially in [1], and will be further refined in an iterative fashion. At this stage, the requirements that are further elaborated are those affecting the facility planning and demo deployments, namely:

Deployment-related Aspect	Facility Requirement (Refined)	Deployment Solution & Dependencies
Network coverage	• Network coverage is needed over ~2,000 m^2 at Loutropyrgos TRAINOSE and ADMIE premises.	• One gNB will be deployed.
Backhauling	• Only one level backhauling of at least 1-3Gbps is required because the trial takes place on a standalone site.	• Existing fiber deployment and /or other means of backhauling will be investigated

Use Case network dimensioning	• Low Latency required	• Data processing at MEC/ Edge site will be incorporated.
	• Access network node capacity of 1-2 Gbps is requied.	• The gNB will provide min 1 Gbps.
MEC/EC Applications' compute requirements	• 5-10 VMs (2-4vCPUs, 2-8 GB RAM, 20-100 MB of space).	• The autonomous Edge can provide 20 vCPUs, 50GB RAM, 1 and 10 Gbps ethernet interface.
MEC/EC compute requirements	• UoPs' MEC solution requirements: 1VM (2vcpus), xGB RAM, for MEC functionality	

5.2.4 UC # 3 Media 5G-VINNI

Activities 1 and 2

The main objective of this UC is to demonstrate efficient provisioning of eMBB downstream services in trains for infotainment purposes, as well as delivery of eMBB/uRLLC upstream surveillance and safety services. An initial identification of the high-level requirements of these services has been provided in [1]. Aggregating the service requirements, the network deployment requirements have been derived in [1] and will be further refined in an iterative fashion. At this stage, the requirements that are further elaborated are those affecting the facility planning and demo deployments, namely:

Deployment-related Aspect	Facility Requirement (Refined)	Deployment Solution & Dependencies
Network Coverage	• Network coverage to be provided at train station.	• One gNB will be deployed at the selected train station site.
UC network dimensioning	• Prefetching of approximately 15GB of content in 3-4 minutes that the train remains at the station when embarking passengers → At least 1.4 Gbps for two trains stopping simultaneously in opposite directions at the station	• The gNB (access network node) shall support at least 1.5 Gbps at the stopping point of the train on the platform.
Transport Access network	• The gNB shall be backhauled so as to be capable to provide 1.5 Gbps data rate at access network interface.	• The gNB will be backhauled accordingly ,taking into account the relevant installation restrictions
Core/Backbone network Connectivity	• The EPC shall be connected to a central CDN point. • The EPC shall be connected to the internet for miscellaneous content services. • The central CDN point shall be connected: o to a locally deployed (CDN) Source Content point o to a remote CDN aggregation and/or Source Content point.	• The EPC will be connected to: o Central CDN server(s), that will be locally deployed (at UoP) o to the public internet • The central CDN point shall be connected to local (CDN) Source Content server(s) as well as to a remote (CDN) Source Content server(s) that will be deployed at COSMOTE premises through public internet or through GRNET.

MEC/EC Applications' compute requirements	• At the MEC level, applications will be deployed for content prefetching and transfer, and optionally for streams optimizations. • At the train level, applications will be deployed on an onboard server (Edge server) for content reception, caching and distribution	• MEC server will be provided at the Rio train station, with the following minimum characteristics: 8 cores CPU, 16GB RAM, 2TB HDD, 2 Gbps NIC • Onboard (Edge) server will be deployed on the train in order to host EC functionality and applications, with the following minimum characteristics: 8 cores CPU, 16GB RAM, 2TB HDD, 2 Gbps NIC
(CDN) Source Content points deployment/ emulation	• Local (CDN) Source Content point (s) shall be emulated and interconnected. • Remote CDN Source Content point(s) shall be emulated and interconnected.	• A local (CDN) Source Content point will be emulated using a HD/4K videos server deployed on UoP premises. • Remote (CDN) Source Content point(s) will be emulated at COSMOTE premises in Athens providing in terms of content: o COSMOTE TV streaming content (on demand or live streaming) (running on a physical server). o HD/4K videos on Demand (running on a physical server) o 4K camera live feed. The streaming content can be processed at the Source Content points e.g. in order for COSMOTE TV streaming to increase quality compared to the existing one, which is tailored to SD 4G devices requirements. Streaming and processing is performed on physical servers requiring: min 8CPUs, 8GB RAM and specialized video encoding cards (HW).

The network mobility and handover requirements are as described for UC # 1.1. The 5G-VINNI / 5G-VICTORI network deployment used to support experimentation for this UC will be based on that of UC # 1.1 (see section 5.2.1).

More specifically, the proposed deployment scenarios for the specific UC assume that a train will approach the Rio station (P3 in previous maps) and will connect to the Rio station through 5G NR in order to download streaming content (COSMOTE TV content, 4K vides, 4K camera live feed) (in a "data shower" fashion). Moreover, the train station will be monitored through a 360° camera of high quality video. For this functionality:

- A 5G capable device (modem) will be on board the train along with an Edge server (on board).
- A 360° camera will be deployed at the Rio station for uploading content to a remote Operations Center (through the Rio station gNB).

For the integration with the 5G-VINNI facility, the CDN platform will be based on a three-level hierarchical design. On the top level, there will be the central CDN Cloud (which will be deployed at UoP premises), mainly responsible for receiving the (CDN) Source Content and preparing it to be delivered. The (CDN) Source Content point(s) will be located on premises, (i.e. as a video streaming server at UoP premises) to emulate operator streaming services, and/or remotely to emulate a Source Content point of a real CDN network deployment. The latter will be placed at COSMOTE's premises in Athens, providing access to: 4K video streaming server, 4K camera live feed, as well as COSMOTE TV streaming content. At the latter point, the COSMOTE TV streaming content will be processed to emulate higher quality services, as current content is tailored to SD 3G/4G mobile distribution.

At the second level, the MEC level, appropriate VNFs will be deployed constituting the MEC vCDN server and will provide the necessary functionalities and elements to support the content delivery (storage and streaming) to end users. At the third level, an additional Edge server will be deployed on board for serving the passengers even during disconnection periods. The Edge server will contain a subset of the MEC's vCDN functionalities and connected to the station's MEC server through a 5G modem whenever the train reaches the station. This Edge server will be responsible to serve the train passengers, who will connect to the server through an on-board Wi-Fi.

A similar setup is envisioned for the case of the second scenario of the UC (video surveillance application), targeting both the eMBB and the URLLC class of services. A 360° 4K video camera will be installed at the train station of Rio, which remains equipped with a 5G base station. The distributed vCDN solution can be optionally used again at the MEC level as an inverted version of the previous scenario, in the sense that now high quality video will be transmitted as uplink traffic. In this case, the video streaming and optimization processes will be supported at the MEC level. Another option is to locally process and optimize the video streams and deliver them to the central CDN Cloud through the 5G network. Therefore, the video streams from a 360° 4K video camera deployed in the area of the train station are either delivered to the Rio MEC-enabled host where they are optimized and dispatched by the appropriate vCDN components, or directly to the central CDN Cloud through the 5G core network after local optimizations.

Activity 3

The Rio train station area that was selected for the demo after some initial site surveys is depicted in point P3 of Figure 5-3.

Figure 5-8 shows the deployment at P3 for the Media UC. Various points in the area have been thoroughly investigated. The specific one has been chosen as it meets the requirement for access to 5G base station enabled with MEC capabilities.

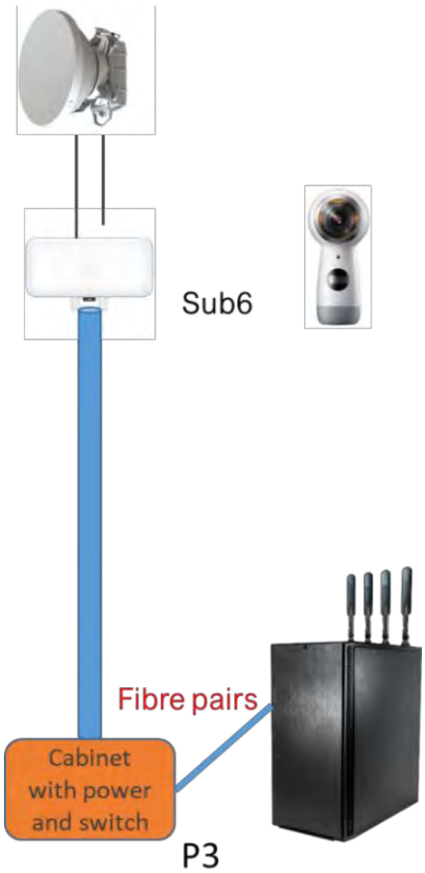


Figure 5-8: 5G-VICTORI deployment at P3 for UC # 4 (including equipment needed for UC # 1-3)

5.2.5 Roadmap for facility planning and implementation

Table 5-2 summarizes the roadmap for the facility planning and integration/implementation of the UCs.

Table 5-2: Roadmap for facility planning and implementation

Activity	Start / Finish Month	Dependencies
1. Network Requirement capture f. UC network dimensioning g. Network coverage h. Network Mobility/Handover and other service specifications	M6 - M14	All partners involved in each use case
2. Processing Requirement capture a. UC cloud/server dimensioning b. MEC requirements	M6 - M14	All partners involved in each use case
3. Site Survey and report /Initial planning a. UC # 1.1 b. UC #2 c. UC # 3 d. UC # 4.1	M6 - M12	All partners involved in each use case
4. Bill of Materials Listing a. HW/SW Equipment (additionally required to existing facilities infrastructure) b. Identifying the gaps between facilities & 5G-VICTORI test setups e.g. in terms of Capabilities Coverage, Spectrum licenses, hosting sites and etc.	M6 - M10	All partners involved in each use case
5. Network Slice Design for each UC a. UC # 1.1 b. UC #2 c. UC# 3 d. UC#4.1	M10 - M18	All partners involved in each use case
6. Lab testing and initial validation of services per UC a. UC # 1.1 b. UC #2 c. UC# 3 d. UC#4.1	M12 - M24	All partners involved in each use case
7. Second Site Survey and report a. UC # 1.1 b. UC #2 c. UC# 3 d. UC#4.1	M9 - M12	All partners involved in each use case
8. Procurement process a. Acquire parts and services for the installation and commissioning of each test network slice per use case	M10 - M18	All partners involved in each use case
9. Install and commission additional network entities	M18 - M24	All partners involved in each use case
10. Configure and validate the network slices	M18 - M24	All partners involved in each use case
11. Onboard each UC application to their appropriate network slices	M20 - M36	All partners involved in each use case
12. Test and validate applications a. Component and functional tests b. Report on observed KPI	M20 -M36	All partners involved in each use case
13. Prepare for the experimentation for the Project Review and Official Deliveries	M20 - M36	All partners involved in each use case

Figure 5-9 depicts the high-level planning (Gantt) for the Greek cluster.

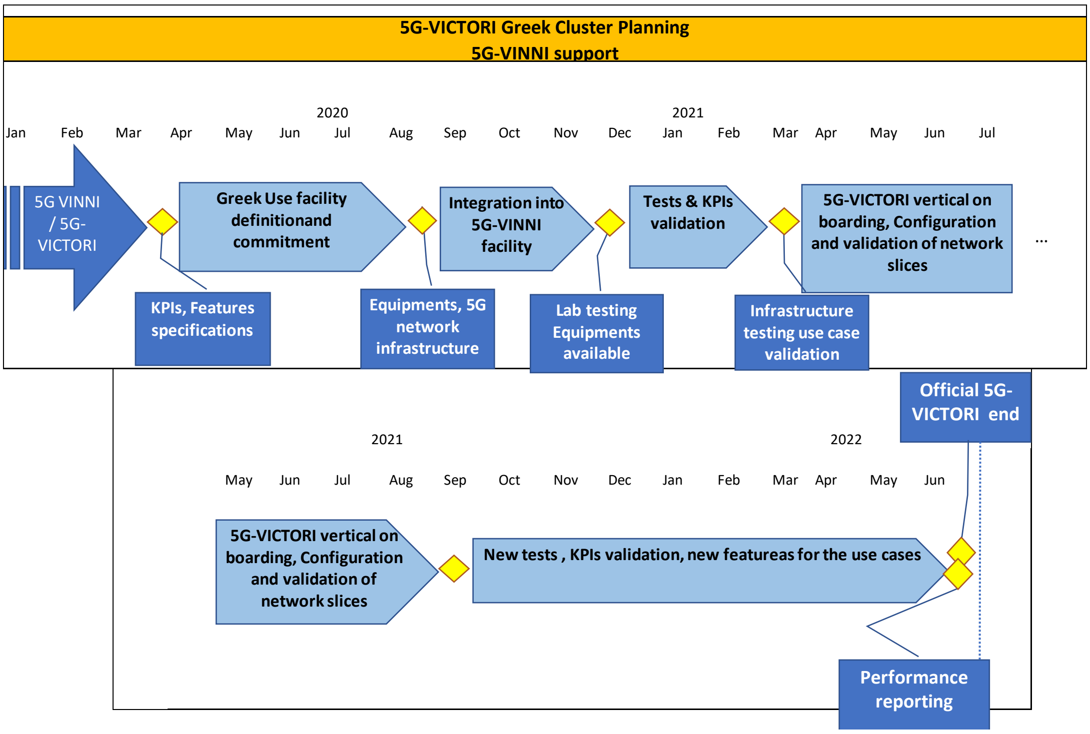


Figure 5-9: High-level planning of the Greek cluster

During the delivery of D2.2, a major lockdown took place in all 5G-VICTORI Greek cluster facilities, both in 5G facilities and vertical industry facilities. It is expected therefore that all procurements, lab tests, integration work and demonstrations will be delayed with respect to the initial plans. The roadmaps that are provided herein, have taken under consideration possible delays and facility changes up to 1/5/2020 and it is expected that a revision of the roadmaps will be evaluated in September 2020 before the delivery of D2.3.

5.3 Use Case Experimentation related to ICT-17/ICT-19 capabilities

The Patras 5G facility, by extending the ICT-17 5G-VINNI facility, will be used for the 5G-VICTORI UC experimentation. The facility uses various wireless technologies (such as mmWave, Wi-Fi, 5G NR, etc.), due to the nature of the UCs, in order to provide access to UEs or connectivity among devices/nodes of the facility.

As far as the mmWave technology is concerned, two distinct technologies will be deployed in support of UCs # 1-4, and the track-to-UoP data centre BH as well as the train-to-track connectivity. The track to UoP connectivity will be supported only through **ICOM** (E-Band) technology and, according to the Greek legislation, the frequency license will be provided as soon as the exact points of the antenna placement and specifications are declared to the Hellenic Telecommunications and Post Commission (EETT)[7]. However, for the train-to-track connectivity, **IHP**'s backhaul technology will be used.

For access technologies and especially for Wi-Fi technology, unlicensed bands are used for 802.11 in 5 GHz and 2.4 GHz across all facility sites and UC sites. Furthermore, technologies like LTE-A and 5G NR will be used for providing access to the 5G-enabled UE devices. Currently (status April 2020) all indoor and outdoor lab tests and experiments are performed through non-stand-alone 5G (stand-alone mode should be available by the UC execution time). Depending on the UC, NB-IoT capability will be provided by the facility. Finally, the application to EETT for using access technologies in licensed bands (3.5 GHz) will be approved by the time of 5G-VICTORI vertical onboarding and demonstrations.

[7] https://www.eett.gr/opencms/opencms/EETT_EN/index.html

5.4 Risk assessment

During the preparation of deliverable D2.2, and due to COVID-19, a major lockdown took place in all Greek Cluster site facilities. This includes the University of Patras, where 5G technologies are being developed and the sites of the vertical industry facilities. Although testing and development was not discontinued and was taking place remotely it is expected that the procurement of some of the required components/equipment, lab tests, integration work and demonstrations will be delayed with respect to the initial plans.

With respect to the facilities involved in the Greek cluster UCs, currently the ADMIE facility is not reachable for the planned site surveys and TRAINOSE rail services have been stopped. It should be especially mentioned that the rail services are currently being restored very slowly. As soon as the lockdown ends, a re-evaluation of the commitments will take place. The roadmaps that are provided herein, have taken under consideration possible delays and facility changes up to 1/5/2020 and it is expected that a revision of the roadmaps will be evaluated in September 2020 before the submission of deliverable D2.3.

Additional potential risks that have been identified and their corresponding contingency plans are presented in Table 5-3.

Table 5-3: Risk and contingency plan

Risk type	Level of risk (H/M/L)	Contingency plan
Delays due to COVID-19 lockdown on equipment procurements	M	Roadmap of demonstrations and trials will be reevaluated in September 2020
Spectrum availability and licensing is not in time due to market instabilities	M	At the moment of D2.2 delivery all facilities are negotiating spectrum availability with regulators
Delays due to COVID-19 lockdown on lab tests and integrations	M	Roadmap of demonstrations and trials will be reevaluated in September 2020
Delays due to COVID-19 lockdown on lab tests and software development	L	Roadmap of demonstrations and trials will be reevaluated in September 2020
Changes on facility commitment (UC # 1.1)	M	Alternative facilities will be sought planning will be performed again within the cluster
Changes on facility commitment (UC # 4.1)	M	Alternative facilities will be sought, planning will be performed again within the cluster
Changes on facility commitment (UC # 3)	M	Alternative facilities will be sought planning, will be performed again within the cluster

ICT-19 5G-VICTORI GREEK Cluster							
ICT-17 5G-VINNI GREEK Cluster							
	UC # 1.1	**UC # 2**	**UC # 4.1**	**UC # 3**	**Facility capability**		**Details**
Use case Experimentation	This UC focuses on providing a high mobility prototype network deployment in order to support the necessary train operations through the creation of two separate infrastructure slices that will concurrently: 1) provide data services to train passengers using dedicated disaggregated heterogeneous femtocells deployed on-board and, 2) support time critical rail services.	The main objective of this UC is to automate the monitoring process and improve the inspection methods and maintenance procedures of energy utilities as factories of the future, both for costs/ time reduction and quality improvement.	This UC focuses on future Energy services/applications related to real time gathering of energy consumption and load data (recovery of energy fed back during braking) in the RMS (rail managers) and EMS platforms. (substation operators)	The main objective of this UC is to demonstrate the efficient provisioning of eMBB down-stream services for infotainment purposes in trains, as well as the delivery of eMBB/uRLLC up-stream surveillance and safety services.	ICT-17	ICT-19	Tools/Components
Physical Infra	Network infrastructure capabilities				x	x	
Hardware/PNF	4G/5G Base Sation, On Board Network	5G BS, NB-IoT, Edge cloud equipment	5G BS, NB-IoT, Edge cloud equipment	4G/5G Base Sation, On Board Network , CDN servers, Source Content Equipment	x	x	4G/5G/NB-IoT HW.
Transmission/ BH links / Connectivity	Passenger<->Train<->Track<-> Edge/Core Data Centre (5G/Wifi/mmWave)	Device<->Power Station<->Power Station (NB-Iot, Lora, fiber, 5G)	Train <-> Power Station (5G/NB-Iot) <-> Core DC /EGDE	Passenger<->Train<-> Station (5G/Wi-Fi/mmWave) <-> Core DC <-> Source Content Equipment	x	x	Fiber, Switches., mmWave,Sub-6, Wi-Fi,4G,5G
Transmission/ Backhauling Techs	mmWave/fiber	mmWave		mmWave /fiber	x	x	mmWave / fiber

Devices	4g/5g mobile phones/laptops/sdr/cameras	4G/5G/NB-iOT/Lora camera/sensors	4G/5G/NB-iOT/Lora metering devices/sensors	4g/5g mobile phones/laptops/sdr/cameras		x	4G UEs, 5G UeEs, Wi-Fi, laptop, SDR
Cloud/Edge OR Cloud infrastructure	Core Data center	Autonomous Edge Cloud	Autonomous Edge Cloud	Core Data center/Autonomous Edge Cloud	x		Autonomous Edge/Data Centre
Virtualized Infrastructure					x		
SDN							
VIM	Openstack/Microstack						OpenStack/Microstack
Monitoring	netdata, grafana,prometheus						Netdata, Grafana,Prometheus
NFV/VNF							
4G/5G RAN	eNodeB, gNodeB,NB-Iot RAN				x	x	4G/5G NSA/NB-IoT (Amarisoft, srs,OAI), 5G SA
4G/5G Core	4G/5G SA NSA core				x	x	4G/5G NSA (Amarisoft, FH,srs), 5G SA
Use case App							
MANO							
Resource Orchestration	OSM				x	x	OSM (ver 6/7)
Slice Orchestration	OSM and Openslice				x	x	OSM (ver 6/7)
Service Orchestration	Openslice				x	x	
Catalogues	Openslice Service catalog, Service Specification				x	x	
Inventory	Openslice Service Inventory				x	x	
Service testing	5G-VINNI Service Testing framework support (Experimenter needs to buid scripts on TaaS on 5G-VINNI)				x		
Policy Framework							

Monitoring & Analytics				
Data Visualization	Grafana/Netdata	x	x	Grafana/Netdata
KPIs				
Dashboard	Grafana/Netdata/OSM	x	x	Grafana/Netdata/OSM
Interworking layer				
Multi-site orchestrator	OSM and Openslice		x	5G-VIOS (to be developed)
Multi-site inventory	Openslice in Service Level		x	5G-VIOS-Repository (to be developed)
Orchestration broker	Openslice Service Orchestrator and OSM			
Service Design	Openslice Service Spec design			

6 Conclusions

This deliverable provided the preliminary facility planning for the individual 5G-VICTORI sites. While deliverable D2.1 defined and described the proposed UCs and their specific requirements, as they are dictated by the associated vertical industries, the present document takes those requirements and the initial architecture blueprint for each of the ICT-17 sites and presents a high-level overview of the extensions and upgrades to the HW and SW components planned for the 5G-VICTORI sites. In short, it turns the site facility requirements definition per facility cluster (5G-VINNI [2], 5GENESIS [3], 5G-EVE [4] and the 5GUK testbed [5]) into an initial planning on how the facility shall look like.

This document represents the first release of the planning and experimentation procedures per facility. It is the first step towards a detailed description of the sites' architecture and components' upgrades that will be captured in deliverable D2.3 entitled "Final individual site facility planning", which will concentrate on the refined planning, and a detailed technical definition of the subsystems and their interconnection comprising any enhancements required per site.

An initial timeline and progress per site towards the completion of the sites' planning was sketched, pointing out the various activities to be carried out for both UC progress definition and the associated tests of the different technologies.

This deliverable provides input to the upcoming project activities within Work Package 2 (**WP2**), deliverable D2.3 "Final individual site facility planning", and deliverable D2.4 "5G-VICTORI end-to-end reference architecture", as well as activities of WP3 "Vertical Services to be demonstrated", and WP4 "Trials of Coexisting Vertical Services, validation and KPI evaluation".

We summarize in the sequel the achievements of each cluster up to May 2020.

6.1 Berlin Cluster facility

The 5G-VICTORI Berlin cluster extends the Fraunhofer FOKUS facility to Berlin Hauptbahnhof for the evaluation of the UCs that will be implemented in Berlin. A first assessment of the scenario has been carried out based only on the available documentation of the facility, given the inability to organize a site visit at the beginning of 2020 due to COVID-19. This issue has prevented a detailed planning for installation of the components in the infrastructure, which will be included in deliverable D2.3. Additionally, the Berlin cluster has decided to take into account additional facilities for the deployment and testing of the equipment for the as contingency measures for potential risks in late 2020.

In the framework of the ICT-17 5GENESIS project, the Berlin Platform is currently testing the HW and SW equipment on top of which the 5G-VICTORI facility builds up. The alignment between the two projects has been already defined with regard of the common equipment and the definition of the interconnection of sites. This equipment comprises the 5G access and transport solutions, the equipment connecting central and edge sites, cloud infrastructure and MANO servers, 5G core, edge computing, and monitoring, analytics and KPI evaluation support for the assessment of infrastructure-related KPIs.

The Berlin cluster has already identified the necessary vertical-specific equipment that support the 5G-VICTORI UCs. The partners have already sketched the setups and applications that will be part of the E2E assessment of all three UCs, for which some of the equipment is already available. There has been, however, little progress on an initial draft of the bill of material and the procurement of additional equipment needed for the UCs' implementation.

For UC # 1.2 the components to be installed at the Office, Wayside and on-board have been already defined, with an initial estimation of the required compute and storage capabilities.

For UC # 1.3 the on-board and wayside on dedicated HW has been specified, and the description of the different components has been included.

UC # 3 has sketched and developed a system architecture for the media delivery to trains, as a proof-of-concept implementation of that system.

The Berlin cluster will present the final site survey details and a thorough description and planning of the activities detailed in Table 2-2.

6.2 Bristol Cluster facility

The Bristol cluster has planned and scheduled eleven activities, ranging from the capture of network deployment requirements to the delivery of the experimentation in the test network in Bristol. In this deliverable, the Bristol cluster successfully addressed details on Activities 1 to 3 (i.e., Plan Activity, Requirement capture, and Site Survey and report, respectively). Topics such as the network dimensioning, coverage, and user dimensioning of the Digital Mobility UC and its three applications were discussed which followed by their network Mobility and MEC requirements. Besides, the Bristol cluster provided a preliminary report on the site survey including a detailed description of the various infrastructures involved in the Bristol cluster facility, technologies, cell capacity details and possible radio and access solutions. Furthermore, the initial UC experimentation related to ICT-19 capabilities were provided.

The Bristol cluster plans to present the final Site Survey Report and provide more details on the next activities such as Network Slice Design, Design Review, and a report on the Procurement process (Activities 4-6) in Deliverable D2.3.

6.3 FR/RO Cluster facility

The FR/RO cluster facility achievements are based on several actions and activities provided by **ORO**, activities that will further support the E2E cluster integration process, activities mainly related to 5G-EVE/ICT-17 facility as enabler for RO cluster and UCs analysis for further demonstration and experimentation.

It has been performed the alignment between the two projects (ICT-17/ICT-19) in term of planning and components delivery (e.g. Orchestration tool ONAP, RAN and Core 5GC network elements). Based on the identified requirements for FR/RO cluster the main hardware components have been procured (servers and RAN network elements), initial UC surveys being providing, starting the first UCs analysis related to radio coverage and mobility aspects. It has been identified a solution for equipment's connectivity from AIM to Bucharest Orange Lab, preliminary integration between ONAP and VIM instance, starting the experimentation of VNFs components on-boarding and deployment in lab infrastructure.

6.4 Patras Cluster facility

During T2.2, in the Greek cluster there was a close interaction between the Patras 5G facility leaders and vertical industry leaders, to ensure that an innovative 5G E2E infrastructure, suitable for the co-existence of various vertical industries and services was designed and planned. Due to the variety of vertical industries that will demonstrate 5G-enabled services and the nature of the cross-vertical services that will be demonstrated over the Greek 5G-facility there were numerous parameters and specifications that had to be considered. During this first planning phase there were four parallel activities that drove facility planning in the Greek cluster, that together with site surveying, major engineering work and licensing applications can be considered as significant milestones for the work that will be carried out in WP4. Specifically:

- with respect to the access network, a major milestone of NSA 4G/5G network has been set up, configured and tested for indoor and outdoor demonstrations.
- with respect to the transport network, major planning and engineering work has been initialized. The mmWave antennas have been set up already at the University of Patras site and engineering work is currently being carried out.

- with respect to resource and slice orchestration, major development with OSM and OpenSlice are currently supporting 5G VICTORI service delivery.
- Integration of the 5G facility with monitoring tools for KPI definition and monitoring (e.g. Netdata, Grafana, Prometheus).

6.5 Overall risk evaluation

By the time this deliverable is submitted, the 5G-VICTORI Consortium has acknowledged and witnessed the ongoing emergency related with outbreak of COVID-19 in Europe. As a consequence of the associated lockdown the majority of the sites where the UCs are planned to run, the different 5G-VICTORI clusters have incurred delays linked with planned site visits (due to restricted access to the facilities), procurement of equipment, lab tests, and integration work. It is expected that the timeline presented in the next release of the document may differ from that presented in this document, and it will be adapted to better reflect the impact of the current situation in the project.

The impact of COVID-19, and the associated risks this pandemic entails, cannot be fully estimated yet for each of the clusters. The impact for our project does not only come from the above mentioned internal restrictions, but also from delays incurred by the associated ICT-17 Projects (5GENESIS, 5G-EVE and 5G-VINNI). This is why the situation for the different 5G-VICTORI clusters may vary depending on the specific cluster situation. The risks that have been captured in this deliverable will be implemented in the Participant Portal as unforeseen risks, each with a likelihood of occurrence. A detailed report on this matter has been already made available to the European Commission for evaluation.

7 References

[1] 5G-VICTORI deliverable D2.1, "5G VICTORI Use case and requirements definition and reference architecture for vertical services", March 2020.

[2] 5G-VINNI "5G Verticals Innovation Infrastructure" ICT-19 Project, Online: https://www.5g-vinni.eu/

[3] 5GENESIS "5th Generation End-to-end Network, Experimentation, System Integration, and Showcasing" ICT-17 Project. Online: https://5genesis.eu/

[4] 5G-EVE "5G European Validation platform for Extensive trials" ICT-17 Project. Online: https://www.5g-eve.eu/

[5] 5GUK Test Networks, University of Bristol 5GUK Test Network, http://www.bristol.ac.uk/engineering/research/smart/5guk/

[6] 5GENESIS Project, deliverable D4.14 "The Berlin Platform (Release B)", January 2020.

[7] 5GENESIS Project, deliverable D3.5 "Monitoring and Analytics (Release A"), October 2019.

[8] OpenAirInterface "5G software alliance for democratising wireless innovation" Online: https://www.openairinterface.org

[9] Mosaic5G, Online: http://mosaic-5g.io

[10] ONAP Platform Architecture, Online: https://www.onap.org/architecture

8 Appendix

8.1 Patras Cluster

8.1.1 TRAINOSE site survey

The second site survey that concerned mainly the Transportation UC (UC # 1.1) – and possibly also the CDN and the Factories of the Future UCs – took place on the 6th of December 2019 with partners from **UoP**, **ADMIE** and **TRAINOSE**. The visit mainly concerned the facility sites of the Transportation use case (Rio) together with the main Train/Wagon Depot. Figure 8-1 illustrates the two main sites at Rio /Kastellokampos train stations. The scope of the visit was two-fold:

- Investigate facility availability and time plan for trials.
- Survey the wagons and engine of trains.

While we were visiting the Wagon Depot, TRAINOSE workers assisted our survey with respect to the availability of power, space and installation guidelines.

We investigated the specific trains that will be deployed in the trials as shown in the pictures. The type of trains is railbus (Figure 8-2) and schematic diagram of the wagons is available to the consortium partners that are involved in the UC. The length of each wagon is approximately 35 m and height 4.2 m and each train comprises two passenger wagons connected by a smaller engine wagon.

8.1.1.1 Inside the train

Each train consists of three separate wagons. Power availability in each wagon is 24V and/or 28V and there are several spaces available for installation. Cabling could be hidden underneath the roof and there are cable concealers available in each wagon. Especially in the "engine wagon" there is limited accessibility to the train roof via a cable that could be used for possible fiber link between the roof top equipment (antennas) and the in – train equipment (network equipment). It is noted that there is already a CB antenna installation with a cable going in the drivers compartment.

8.1.1.2 On top of the train

On the roof of the train there is a metallic (aluminum) structure that can be used for the antenna installation. This structure goes up to the front and the rear of each wagon and it can be used for both antennas envisaged for the Transportation scenario. Also, there is space available at the drivers end to *install cameras or any other equipment that is required for the use case.*

8.1.1.3 Wagon availability

There are three trains that are used for the specific connection. There were discussions about the availability of wagons in the Depot in order to perform installations. Special permissions could be granted for the train that will be used in the trials so that it can stay at the depot for a period of 3-7 days. This would give enough time for installations for a for technical work on the wagons that will be utilized for trials. It is noted that the depot is far away from the power poles at Rio station so testing should be carefully designed.

The team visited the following stations at Rio, Kastellokampos and Ag. Andreas.

Action points:

- **TRAINOSE** to investigate the facility availability with respect to time plan for constructions.
- **TRAINOSE** to define the details of possible services.
- **UoP** together with **UTH** to set up the onboard network architecture and list of equipment that are required.

Figure 8-1: Map of the area

Figure 8-2: TRAINOSE Railbus for UC # 1.1

Figure 8-3: Railbus at TRAINOSE depot

Figure 8-4: Moving train

8.1.2 ADMIE site survey

The first site survey that concerned the Energy use case took place on the 4th of December 2019 with partners from UoP, ICOM and ADMIE. The visit concerned the two sites of the Energy Use Case (UC # 2) at the end of the ADMIE submarine cable, Rio power station and Antirio power station.

Figure 8-5: ADMIE Rio and Antirio sites

The scope of the visit was two-fold:

1. Investigate the area for and site for antenna placement.
2. Definition of the UC architecture.

The first objective concerns all the Greek cluster UCs, as the power poles will be used for mmWave antenna installation that can extend the 5G-VINNI facility to any part of the area, as long as there is line-of-sight with the main facility. The second UC specific objective is related mainly to the Rio – Antirio submarine interconnection via a high voltage submarine cable, as described in deliverable D2.1 [1], but also investigation of other possible scenario that may be developed on top of the same infrastructure.

The first ADMIE site that was visited was the Rio ADMIE facility, which lies in a large area of land close to the Rio Rail station.

Figure 8-6 shows a view of the equipment used for the monitoring of the submarine cable. A set of legacy devices are used with no internet connection, and a set of LEDs, which inform the personnel about the health of the cable. These legacy devices can be enhanced and used for the purpose of the trial, and some points of discussion were:

3. Access permission to the devices.
4. New sensors placement (location and type).
5. Connection type.

The facilities in Rio serve also as a warehouse for ADMIE, where valuable equipment is stored. Key places, where smart motion sensors and 360° cameras can be deployed, were also discussed.

As shown in Figure 8-7, the Rio site lies along the rail tracks of the Rio-Kastellokampos connection and there are two large power poles that stand by the tracks, together with several poles along the railtracks.

Figure 8-6: Submarine cable monitoring equipment at Rio site

Figure 8-7: Google Maps view of Rio site and Kastellokampos train station

As far as the powerstation is concerned there were various issues discussed regarding the access permissions, installation permissions and space limitations were concerned. Specifically, administration issues about the equipment installations and synchronization of various technical teams were discussed. The possibility of having an electrically noisy and thermally unstable environment were discussed.

Then, there was a visit at the Antirio station with similar Objectives and activities. The main concern of the visit was the identification of line-of-sight between the two sites, as it is mandatory for the mmWave connection. The view from Antirio site is shown in Figure 8-9:

Figure 8-8: ADMIE power poles view from TRAINOSE station

Figure 8-9: Antirio site - view towards Rio

The following action points are pending:

1. ADMIE to investigate permissions.
2. ICOM with UoP to start facility extension planning.
3. UoP to discuss with the consortium about sensor installation, etc.

8.1.3 2nd site survey @ ADMIE site

ADMIE power tower

Aerial view of the route

Bird-eye view from “Kastelokampos” towards “Rion”

Actual view from from “Rio” towards Tower

9 Acronyms

Acronym	Description
RAN	Radio Access Network
HW	Hardware
SW	Software
UC	Use Case
CDN	Content Delivery Network
NR	New Radio
3GPP	3rd Generation Partnership Project
ICE	Intercity Express (Train)
RRH	Remote Radio head
SLA	Service Level Agreement
COTS	Commercial-off-the-Shelf
UE	User Equipment
FRMCS	Future Railway Mobile Communication System
BBU	Baseband Unit
MAC	Medium Access Control
DFN	Deutsche Forschungsnetz (German Research Network)
NFV	Network Functions Virtualization
MANO	Management and orchestration
NMS	Network Management System
OSM	Open Source MANO
NMS	Network Management System
CPU	Central Processing Unit
GPU	Graphics Processing Unit
KPI	Key Performance Indicator
GB	Gigabyte
RAM	Random-Access Memory
SSD	Solid-State Drive
TB	Terabyte
HDD	Hard Disk Drive
CBTC	Communications-based train control
ETCS	European Train Control System
CCTV	Closed-circuit television
HD	High-Definition
MC	Mission-Critical
MCPTT	Mission-Critical Push-To-Talk
MCX	Mission Critical Services
IMS	IP Multimedia Subsystem
SIP	Session Initiation Protocol
VM	Virtual Machine
APP	Application

RF	Radio frequency
SD	Secure Digital
BBU	Baseband Unit
GDPR	General Data Protection Regulation
HMI	Human Machine Interface
GPS	Global Positioning System
CAT-6	Category 6 Cable
VoD	Video on Demand
AP	Access Point
MEC	Mobile Edge Computing
CN	Core Network
eMBB	enhanced Mobile Broadband
URLLC	Ultra Reliable Low Latency Communications
5G-PPP	5G Infrastructure Public Private Partnership
API	Application Programming Interface
E2E	End-to-End
PTT	Push-To-Talk
PNF	Physical Network Function
NFV	Network Functions Virtualization
MPLS	Multiprotocol Label Switching
VPNL3	Virtual Private Network Layer 3
AR	Augmented Reality
VR	Virtual Reality
SDN	Software Defined Network
VIM	Virtualized Infrastructure Manager
MSq	Millennium Square
WTC	We The Curious
WS	Watershed
MIMO	Multiple-Input and Multiple-Output
CBAM	CloudBand Application Manager
VNFM	Virtual Network Function Manager
CBIS	CloudBand Infrastructure Software
CBND	CloudBand Network Director
VLAN	Virtual LAN
HTTP	Hypertext Transfer Protocol
AI	Artificial Intelligence
PNF	Plug and Play
NSA	Non-Standalone
IoT	Internet of Things
DNS	Domain Name System
BH	Backhaul
FH	Fronthaul
CU	Centralized Unit

PDCP	Packet Data Convergence Protocol
DC	Data Center
RMS	Record Management Service
EMS	Element Management System
TPSS	Traction Power Substation
vCDN	Virtualized CDN
EETT	Hellenic Telecommunications and Post Commission
NB-IoT	Narrowband Internet of Things