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

D3.3 Preliminary use case specification for media services

This project has received funding from the European Union's Framework Program Horizon 2020 for research, technological development and demonstration

5G PPP Research and Validation of critical technologies and systems

Project Start Date: 1st June 2019

Duration: 36 months

Call: H2020-ICT-2019

Date of delivery: 2021-07-31

Topic: ICT-19-2019

Version 1.0

Project co-funded by the European Commission

Under the H2020 program

Dissemination Level: **Public**

Grant Agreement Number:	857201
Project Name:	VertIcal demos over Common large scale field Trials fOr Rail, energy and media Industries
Project Acronym:	5G-VICTORI
Document Number:	**D3.3**
Document Title:	Preliminary use case specification for Media Services
Version:	1.0
Delivery Date:	2021-05-31 (**2021-07-31**)
Responsible:	**RBB**
Editor(s):	Annette Wilson (**RBB**)
Authors:	Miggi Zwicklbauer, Annette Wilson, Tümay Karaca (**RBB**) Anita Chen, Louay Bassbouss (**FhG**) Stefan Schinkel (**PXI**) Maria-Evgenia Xezonaki, Vasileios Theodorou (**ICOM**) Jean Ghenta, Horia Stefanescu, Marius Iordache, Carmen Patrascu (**ORO**) Ioanna Mesogiti, Elina Theodoropoulou, Fofy Setaki (**COSM**) Tanya Politi, Panagiotis Papaioannou (**UoP**) Jesús Gutiérrez (**IHP**)
Keywords:	Media Services, Content Delivery Network, Digital Mobility, Prioritized Communication, Infotainment, Artificial Intelligence,
Status:	Draft
Dissemination Level	**Public**
Project URL:	https://www.5g-victori-project.eu/

Revision History

Rev	Description	Authors	Date
0.0	First draft with D3.3 ingress and structure suggestion.	Miggi Zwicklbauer (**RBB**)	2020-03-31
0.1	Updated draft and ToC	Annette Wilson (**RBB**)	2021-03-18
0.2	Insert contribution in Chapter 4	Carmen Patrascu (**ORO**)	2021-03-23
0.3	Update UC and TCs descriptions, adding descriptions on UC figures	Jean Ghenta, Horia Stefanescu (**ORO**)	2021-04-09
0.31	Update on UHA app testcase MDAe04	Carmen Patrascu (**ORO**)	2021-04-11
0.32	Insertion of Chapter 2	Tümay Karaca (**RBB**)	2021-04-20
0.33	Insertion of Chapter 3	Maria Evgenia Xezonaki, Vasileios Theodorou (**ICOM**), Ioanna Mesogiti, Elina Theodoropoulou, Fofy Setaki (**COSM**), Tanya Politi, Panagiotis Papaioannou (**UoP**)	2021-04-24
0.4	Editing and updates	Annette Wilson (**RBB**)	2021-05-14
0.41	Review of Document	Ioanna Mesogiti, Maria Evgenia Xezonaki,Vasileios Theodorou (**ICOM**), Tanya Politi, Panagiotis Papaioannou (**UoP**), Stefan Pham (**FhG**)	2021-05-21
0.42	Update of Chapter 3	Ioanna Mesogiti, Maria Evgenia Xezonaki,Vasileios Theodorou (**ICOM**), Tanya Politi, Panagiotis Papaioannou (**UoP**)	2021-05-21
0.5	Editing and conclusions	Annette Wilson (**RBB**)	2021-05-27
0.6	Inclusion of further contributions and corrections	Anita Chen (**FhG**), Maria Evgenia Xezonaki (**ICOM**), Ioanna Mesogiti (**COSM**), Annette Wilson (**RBB**),	2021-05-31
0.61	Intermediate Review	Jesús Gutiérrez (**IHP**)	2021-06-15
0.7	Revisions by editor and cluster leaders	Anita Chen (**FhG**), Maria Evgenia Xezonaki (**ICOM**), Ioanna Mesogiti (**COSM**), Annette Wilson (**RBB**),	2021-07-05
0.8	Review version ready	Annette Wilson (**RBB**)	2021-07-06
0.9	Incorporation of section 2 “Testing Methodology” to the document	Anna Tzanakaki, Markos Anastasopoulos (**IASA**)	2021-07-30
1.0	Last revision and submission of the document	Anna Tzanakaki (**IASA**), Jesús Gutiérrez (**IHP**)	2021-07-31

Table of Contents

EXECUTIVE SUMMARY 6

ACRONYMS 8

1 INTRODUCTION 9

1.1 Objectives 9

1.2 Document Structure 11

2 TESTING METHODOLOGY 12

2.1 Testing Methodology Description 12

2.2 Test case development 14

3 CDN SERVICES AT THE 5G-VICTORI FACILITY IN BERLIN 16

3.1 Description 16

3.2 CDN Services Berlin Test Cases 16

3.2.1 Description 16
3.2.2 MCBg01: Aggregation of relevant content for cache prefilling 19
3.2.3 MCBg02: Pre-Fill Media Content in Station Cache from RBB Catalogue (via public CDN) 20
3.2.4 MCBg03: Data Shower High Speed Transport from Station Cache to Train Cache 21
3.2.5 MCBg04: Media Distribution in the Train (via Wi-Fi) 23
3.2.6 MCBg05: Collecting of Playback Metrics (using MPEG-SAND) 26
3.2.7 MCBg06: Shared Resource Allocation (SRA) in the Train using collected playback metrics and via dedicated Gateway 28

4 CDN SERVICES AT THE 5G-VICTORI FACILITY IN PATRAS 30

4.1 Description 30

4.2 CDN Services Patras Test Cases 31

4.2.1 Description 31
4.2.2 MCDv01: CDN Application Scenario Deployment 33
4.2.3 MCDv02: CDN Connectivity Evaluation 36
4.2.4 MCDv03: MEC Periodic Update 38
4.2.5 MCDv04: Data shower from MEC to train cache 39
4.2.6 MCDv05: Content distribution to passengers onboard 42
4.2.7 MCSv01: 360° camera Scenario Initialization 44
4.2.8 MCSv02: 360° camera HQ streaming 46
4.2.9 MCSv03: 360° camera FoV rotation 47

5 DIGITAL MOBILITY AT THE 5G-VICTORI FACILITY IN ALBA IULIA 50

5.1 Description 50

5.2 Infotainment/ Video Services in Dense, Static and Mobile Environment Test Cases 52

5.2.1 Description 52

5.2.2 MDIe01: User authentication using captive portal 53
5.2.3 MDIe02: Captive portal data availability 54

5.3 Prioritized Communication to Command and Control Center Test Cases 55
5.3.1 Description 55
5.3.2 MDCe01: Establishment of basic E2E connectivity over a specific slice 55
5.3.3 MDCe02: Establishment of advanced E2E connectivity over three different slices with different QoS metrics configured 56
5.3.4 MDCe03: Load test for observing the QoS prioritization among slices with congestion on radio part 58
5.3.5 MDCe04: Stability test - injecting traffic over one slice for 7 consecutive days 59

5.4 AI Recognition and Identification of Emergency Situation Test Cases (UHA application) 60
5.4.1 Description 60
5.4.2 MDAe02: Detection of violence in the bus 62
5.4.3 MDAe03: Health issue with one passenger 63
5.4.4 MDAe04: Lost item – detection and alerting 64

6 CONCLUSIONS 66

7 REFERENCES 68

7.1 General and project-specific references 68

7.2 Standards references 68

7.3 Other references 68

LIST OF FIGURES 69

LIST OF TABLES 70

Executive Summary

5G-VICTORI focuses on large-scale field trials for advanced use case (UC) verification in commercially relevant 5G environments for a number of verticals. These verticals include **Transportation**, **Energy**, **Media** and **Factories of the Future,** as well as a few specific UCs involving cross-vertical interaction. The project demonstrates that these different vertical services can share a common 5G infrastructure including common radio access, transport and core networks as well as compute resources, rather than each vertical developing its own dedicated infrastructure to support its needs. The UC validation will cover both technology and business perspectives and be conducted under real life conditions for each vertical sector.

In Work Package 2 (**WP2**), entitled “Description – Use cases/ Specifications”, the UCs and infrastructure planning for all facilities are in described deliverable D2.1 [1]. Additionally, the 5G-VICTORI infrastructure/facility planning for all facilities has been specified in deliverables D2.2 [2] and D2.3 [3]. For running WP2 UCs, 5G-VICTORI exploits the main sites of all ICT-17 infrastructures, namely 5G-VINNI [4] (Patras, Greece), 5GENESIS [5] (Berlin, Germany) and 5G-EVE [6] (France/Romania), and the 5GUK testbed [7] (Bristol, UK).

This document focuses on media services and how the 5G-VICTORI infrastructure is required to deliver bandwidth-hungry media content for both train operators and passengers. The services are operated and used in dense static environments and aim to transfer large amounts of high-quality content at high speed and with a high degree of reliability deliver sensitive, security-relevant content in real-time. To achieve this mmWave connectivity and network slicing services will be used. This deliverable presents the test case specifications for such media services at three 5G-VICTORI facilities, as defined in Task 3.2.

The 5G-VICTORI infrastructure is required to deliver bandwidth-hungry media content in dense static environments to provide very fast large amounts of high-quality content and with high degree of reliability sensitive, security-relevant content in real-time. This deliverable presents the test case specifications for such media services at three 5G-VICTORI facilities, as defined in Task 3.2.

A common approach ensures that the test cases have the same structure, are easily identifiable and ordered sequentially. The following services will be addressed:

- At the facility in Berlin, the Data Shower application will be tested, allowing large quantities of data to be transferred from the station’s CDN cache to a train’s server for use by passengers.
- At the 5G facility in Patras, a data shower application similar to that of Berlin will provide a train with as much video-on-demand (VoD) and live content as possible when it arrives at a train station, while a 360° surveillance application will enable a train operator’s security personnel to remotely monitor activity at multiple operator facilities. The aforementioned services are all derived from the Content Distribution Network UC.
- In the 5G-EVE cluster in Alba Iulia Municipality (**AIM**), the services, based on the Digital Mobility UC, revolve around infotainment and public safety. The infotainment is provided through a portal in public buses, via on-board Wi-Fi and 5G backhauling. Three on-board cameras are used for public safety and Artificial Intelligence (AI) recognition of safety issues and prioritized communication with the Control and Command Centre ensures that safety alters can be triggered.

For each of the services, the required test cases have been specified and will form the basis of lab tests and/or demos to be conducted in **WP4** “Trials of Coexisting Vertical Services, validation and KPI evaluation”. The test cases enable the validation of Key Prediction

Indicators (KPI) at the vertical service level. The outcome of this work will provide input to Task 3.2 and will facilitate the update of tests in **D3.4** [8] and the associated test and demo results.

Acronyms

Acronym	Description
3GPP	Third Generation Partnership Project
5G	Fifth Generation cellular system (3GPP related)
5GENESIS	The Berlin ICT-19 Cluster [5]
5G-EVE	The Alba Iulia ICT-17 Cluster [6]
5G-VINNI	The Patras ICT-19 Cluster [4]
AI	Artificial Intelligence
AIM	Alba Iulia Municipality
CCC	Command and Control Center
CCTV	Closed Circuit Television
CDN	Content Delivery Network
D2.1	Deliverable D2.1 [1]
D2.2	Deliverable D2.2 [2]
D3.3	Deliverable D3.3
D4.1	Deliverable D4.1 [9]
E2E	End to End
GPS	Global Positioning System
eMBB	Enhanced Mobile Broadband
MD5	Message-Digest Algorithm 5
MEC	Mobile Edge Computing
MBB	Mobile BroadBand
mmWave	Millimetre Waves
SAND	Server and Network-assisted DASH
SRA	Shared Resource Allocation
TOC	Table of Contents
UC	Use Case
UE	User Equipment
uRLCC	Ultra-Reliable Low Latency Communications
VoD	Video-on-Demand
WiFi	Wireless Local Area Network
WP2	Work Package 2: Description – Use cases/ Specifications
WP3	Work Package 3: Vertical Services to be demonstrated

1 Introduction

5G-VICTORI focuses on large-scale field trials for advanced use case (UC) verification in commercially relevant 5G environments for a number of verticals. These verticals include **Transportation**, **Energy**, **Media** and **Factories of the Future**, as well as some specific UCs involving cross-vertical interaction. 5G VICTORI leverages 5G networks to conduct large-scale trials for advanced use case (UC) verification in commercially relevant 5G environments for the abovementioned Verticals, in addition to specific UCs involving cross-vertical interaction. The validation will cover both technology and business perspectives and be conducted under real life conditions for each vertical sector.

This document is the first release in Task 3.2, and it defines media related services or applications that can be tested and evaluated independently or together with other services on one or more of the 5G facilities. For each service to be demonstrated several test cases are defined in a preliminary form. The test cases described are needed to thoroughly assess the infrastructure's efficacy across different locations and verticals, especially in dense and static environments where bandwidth-hungry media content is delivered. The final specifications will be provided in **D3.4**.

In this context, the 5G-VICTORI infrastructure will facilitate fast delivery of large amounts of high-quality content as well as sensitive and security-relevant content delivery in real-time with high degree of reliability. As such, the test cases described in this deliverable are needed to thoroughly assess the infrastructure's efficacy across different locations and verticals, especially in dense and static environments where bandwidth-hungry media content is delivered.

1.1 Objectives

The objective of the deliverable is to define detailed preliminary test case specifications for media services that can be demonstrated by the 5G-VICTORI platforms (see Figure 1-1 for an overview).

For each service to be demonstrated several test cases are defined in a preliminary form. The test cases described are needed to thoroughly assess the infrastructure's efficacy across different locations and verticals, especially in dense and static environments where bandwidth-hungry media content is delivered. The final specifications will be provided in deliverable **D3.4**.

Figure 1-1 below provides an overview of the media services, which are described in detail in **D2.1** [1], and covered in this document as well:

- **UC #3** Content Delivery Network Services: this UC will be tested in two different facilities: the 5G-VICTORI facility in Berlin and the 5G-VICTORI facility in Patras. A Data Shower application will be tested in Berlin, while both Data Shower and 360° Camera Applications will be tested in Patras.
- **UC #1.2** Digital Mobility: for this UC, three services will be conducted in Alba Iulia Municipality (**AIM**): Infotainment and Video Services, Prioritized Communication to Command and Control Center, and AI Recognition of Emergency Situations.

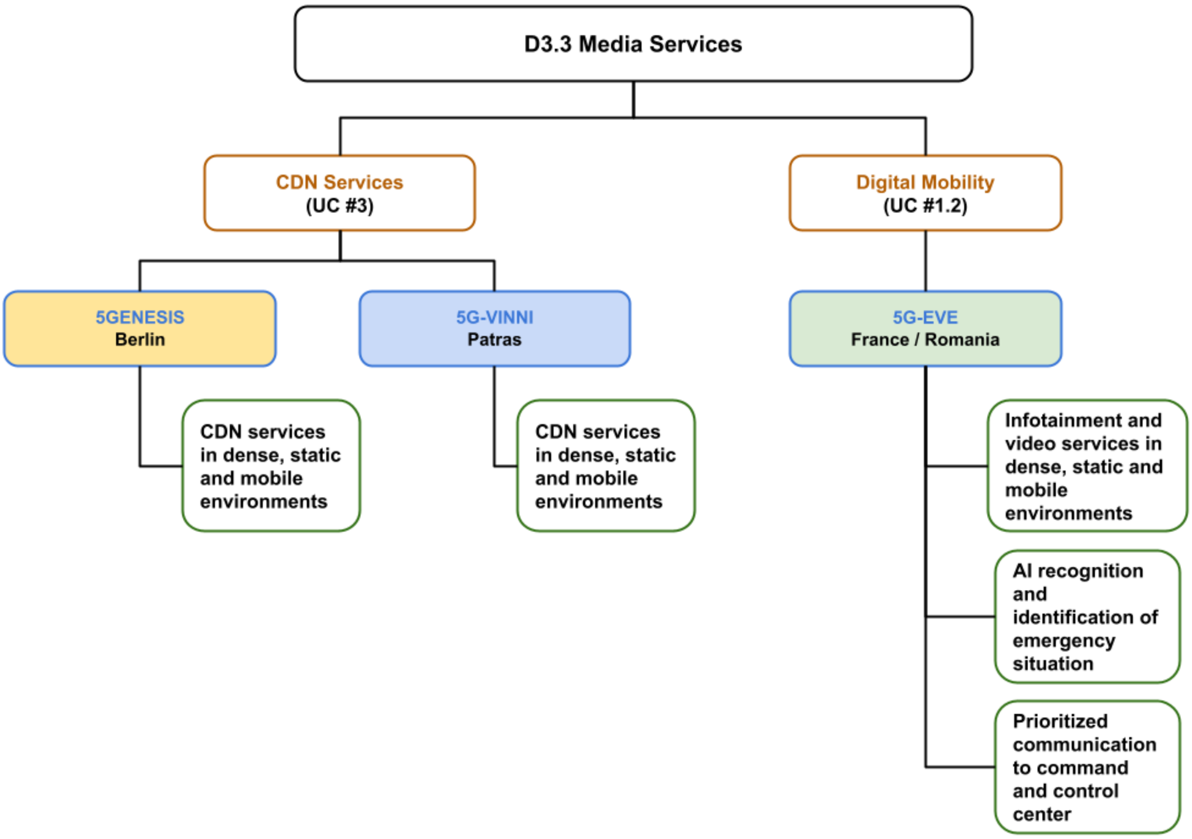

Figure 1-1 Media UCs, Clusters and Services

The specific objectives of the vertical services listed in this document are:

1. **CDN Services in Berlin**: The objective is to utilize mmWave connectivity to extend streaming service's CDN to trains, by equipping them with caches filled with content. This allows large amounts of media data to be transferred between caches on server placed in Berlin main train station to a train while stopped at a platform. The focus is on the rapid transfer of large amounts of media content within a very short time period over a short distance.
2. **CDN Services in Patras**. The objective here is to also use mmWave connectivity to transfer as much media content as possible between a cache in the station to one on a train. Similar, to the Berlin service, the focus is on the rapid transfer of large amounts of media content within a very short time period over a short distance. A further objective is to use mmWave and 5G air interface connectivity to provide high resolution, low latency video streaming capabilities for surveillance purposes.
3. **Digital Mobility in Alba Iulia**: The objective is to increase the safety and comfort of passengers. The infotainment is provided through a captive portal in public buses, via on-board Wi-Fi and 5G backhauling. For public safety three surveillance cameras are deployed on the buses, connected over Ethernet to the 5G router. The focus is on network slicing, services use three network slices for three different "clients" with different quality of service needs: one Enhanced Mobile Broadband (eMBB) slice for infotainment, one eMBB slice to convey the video for analytics and one ultra-Reliable Low Latency Communications (uRLLC) slice used to trigger the threats alarm.

1.2 Document Structure

The document is structured into six sections.

Following the introduction, section 2 provides an introduction on the testing methodology followed in the project, which stems from standards targeting this topic. It also provides guidelines for test case development.

Section 3 describes the media services to be demonstrated at the 5G-VICTORI facility in Berlin. It includes a general description and individual tables containing detailed information for each test case.

Section 4 describes media services to be demonstrated at the 5G-VICTORI facility in Patras.

Section 5 describes media services to be demonstrated at the 5G-VICTORI facility in Alba Iulia Municipality.

In each of these last three sections, a description of the vertical UC and cluster is provided. This is followed by a general description of the test cases including individual tables containing detailed information for each test case.

Finally, Section 6 concludes the deliverable.

2 Testing methodology

2.1 Testing Methodology Description

In general, this deliverable follows the unified approach specified in **D4.1** [9] to describe the test cases. Also, requirements and KPIs are listed, including the necessary components and configuration. Then, the test procedure and measurements methods are defined. Finally, the expected results are described. The test cases reported here are the continuation and refinement of the media services described in **D2.1** [1] and **D2.2** [2]. The individual test cases will be validated and form the basis of the media service demonstrations in WP4, and are in line with the 5G-VICTORI testing methodology of deliverable **D4.1** [9].

To successfully demonstrate the planned UCs in the different sites, it is necessary to validate the functionality of the developed services and stress test their performance under realistic conditions. The ultimate objective of the testing process is:

1) to verify compliance with the values required for the service to operate reliably in the specified UC, and,
2) to estimate the confidence interval of the expected performance curve of the system thus assisting vertical users and operators to obtain reasonable assurance that the system operates within specific performance bounds [12].

As 5G services are deployed over distributed environments, the standardized testing methodology applied in distributed automated systems (see [10]) has been adopted. Aligned with this standard we consider each service to be composed of a set of elements which need to be tested. The collection of all Elements Under Test (EUT) form the Service Under Test (SUT). Figure 2-1 depicts the SUT and EUT entities and their interactions during the test setup process. Connectivity between the different components of the system is achieved through a set of communication protocols. A simplified version of the protocol communication stack is also depicted [11].

In this diagram, the layers that are part of the 3GPP network are referred to as lower communication layers (LCL). The communication stack also includes the application/service under test. The Open Systems Interconnection (OSI) layers related to providing data to the application are referred to as the higher communication layers (HCL). The interface between LCL and HCL is referred to as communication service interface (CSIF).

In order to verify that E2E services are provided over the infrastructures with the required KPIs, supplementary checks need to be also conducted in order to assess the performance of all entities involved including the communication protocols [10]. Therefore, for the assessment of the overall system performance, it is important to differentiate between the 3GPP network's performance (i.e., including only the LCL measured at the CSIF) and the overall system performance including the application layer. In Figure 2-1 the orange arrow depicts a measurement point for assessing the performance for an application from the vertical perspective point of view. The blue arrows indicate two options to measure the 3GPP network's performance, i.e., including and excluding the IP layer. In the same figure it can be also observed how messages are transmitted from a SUT (i.e. energy metering platform) (e.g., a programmable logic controller) to a target application device (e.g., MEC element). The source application function (AF) is executed in the source operating system (OS) and forwarding information to the application layer interface of the source communication device. In the higher communication layers (HCL), which are not part of the 3GPP system, information is processed. From the HCL the data is transferred to the lower communication layers (LCL), which are part of the 3GPP system. After transmission through the physical communication channel and the LCL of the target communication device, the data is passed to the HCL and lastly to the target application device.

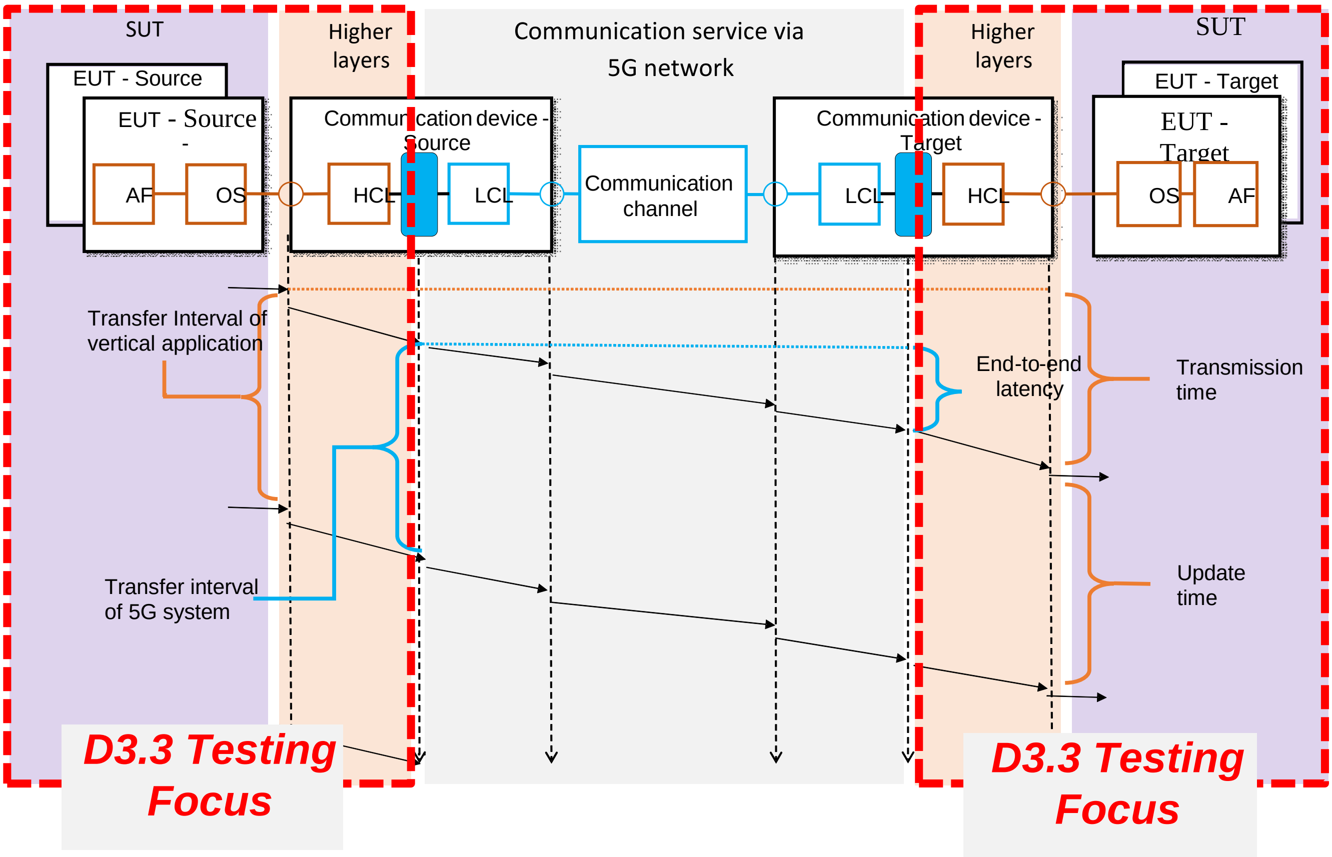

Figure 2-1: Services to be tested and parameters to be evaluated [11]

As deliverable D3.3 focuses on testing of services, the corresponding analysis is limited to the upper layers of the communication system including the applications and the HCL. As the testing results for the services need to be reproducible, the 5G system providing lower communication services will be considered as fixed. Although the various parameters of the 5G communication network influence the performance of the services, it will be not be examined in the present deliverable, as these aspects will be addressed by deliverable D4.1. However, all services will be tested under a precisely described and controlled 5G environment indicating parameters related to:

i) the environment where the network will be deployed (spatial extent of the real-world facilitates),
ii) propagation environment in which the application operates during testing,
iii) background network traffic including the number of wireless devices, number of virtual links established in the cloud environment hosting the 5G platform,
iv) Positions of wireless devices and distances between them,
v) type of 5G user equipment and CPEs,
vi) Time during which tests were conducted on the system under test, vu network topology and network devices,
vii) vi) type of servers hosting the 5G platform.

Apart from baseline parameters which are considered fixed, an extended set of performance tests will be conducted measuring as shown in Figure 2-1 parameters related to *latency* (i.e. Transfer interval of vertical application: Time between the transmission of two successive pieces of data from the source application, Transmission time: Time measured from the point when a piece of data is handed from the application layer interface of the source application device, until the same piece of data is received at the application layer interface of the target application device, update time: Time between the reception of two consecutive pieces of data at the application layer interface to the target application device), *throughput*, *availability*, *reliability*, *jitter* etc.

Performance testing will be carried over multiple test groups [12]. Each test group will investigate the performance parameter(s) of interest and consists of one or multiple test cases. For each test case, each baseline parameter (e. g. number of devices, 5G network topology, compute resources allocated to the RAN and Core functions,) has been assigned a specific value. To cover additional deployment options, the value of one or more baseline parameters may be altered within a test group, i.e. from one test case to the next, in order to assess the impact of the altered baseline parameter(s) on the performance parameter(s).

Although the baseline parameters do not vary within a test case, the performance parameters measured or achieved may exhibit a range of values. For example, the number of devices might be increased incrementally to establish the system's maximum performance in a high-density environment. Also, the impact of the number of devices on, e.g. the achieved/ measured transmission time might be analyzed [12].

Once performance parameters and baseline parameters for the SUT have been defined, it is necessary to establish the testing system to measure and/or calculate corresponding performance values. The testing system needs to accurately measure the performance parameters and to accurately maintain the baseline parameters.

In the context of the 5G-VICTORI project performance testing will be carried out in three different environments:

- Laboratory environment using software to emulate devices and system components.
- Physically emulated environment, for example an environment resembling the topology of the actual environment where the system will be deployed.
- Real world environment testing where all components will be tested on-site at the actual facilities while system is in operation.

In the following subsection, a description of the process/methodology that will be followed in the development of tests cases is provided following the ETSI EG 202 810 V1.1.1 standard [10].

2.2 Test case development

A pre-requisite for the specification of executable test cases is the availability of test descriptions. Such descriptions should capture all equipment used in the testing process, pre-conditions, equipment operation, as well procedures and messages exchanged during the testing process. Test descriptions provide valuable and easily understandable documentation. Additional test documentation in interoperability testing is especially important because of the large number of different interfaces involved in a test as well as its basis on multiple EUTs.

In order to facilitate the specification of test cases, test description tables contain the following information:

- *Test-case ID*,: A detailed description of the test IDs used to distinguish the various use cases and services to be tested. The ID number is unique 6-character string of letters and number providing a specific piece of information about the type of use case, the group where this use case belongs, the 5G cluster that this service belongs etc. The test case ID structure in WP3 follows a set of specific principles. These principles, are described below:

  To keep the test case IDs concise, a single letter indicates the type of vertical service:

  - **M** stands for **Media**

  A second prefix letter represents the use-case within each vertical service area:

  - **MC** = **M**edia **C**DN services
  - **MD** = **M**edia Digital Mobility services

  The third and fourth letters indicate the service type and cluster, respectively.

  Accordingly, the partners have used the following ID numbers for the test cases reported in this deliverable:

  - MCBg for **M**edia/ **C**DN services
  - MCDv for **M**edia/**C**DN services
  - MCSv for **M**edia/Surveillance services
  - MDCe for **M**edia/**D**igital Mobility/Prioritized **C**ommunication to Command and Control Center
  - MDIe for **M**edia/**D**igital Mobility/**I**nfotainment and Video Services
  - MDA for **M**edia/**D**igital Mobility/**AI** Recognition and Identification of Emergency Situation

- *Title, Testbed name*: Title of the use case and facility over which the testing process will be conducted.
- *Description of test* in concise manner explaining the purpose of the test. The description is also used to distinguish this test from any other test in the document
- *Key use-case requirements and KPIs*: The requirements and KPIs listed in the test case tables with a label come from **WP2** deliverable D2.1, which uses a unique numbering, being an example **S-FU-5301** (Smart Factory and Functional related and a number). These are categorized with:
  - User = vertical service related, Facility = network related
  - Type: Functional (FU), Performance (PE), Capacity (CA), or Other (OTH).
- *Network performance and KPIs*
- *Network functional requirements and KPIs*
- *Listing and configuration of all components used in the testing process*. This includes a list of test specific pre-conditions including information about equipment configuration, the initial state of the SUT, etc.
- *Test procedure specification*. This section defines a sequence of elementary actions and checks being executed on different test entities.
- *Measurements*: This section provides information for the results to be obtained per test
- *Expected results* giving emphasis on tests that failed or the performance achieved didn't met performance the associated KPIs. For this case, description where the test case has failed, as well as the location where the error/unexpected performance has been observed will be highlighted.

3 CDN Services at the 5G-VICTORI facility in Berlin

3.1 Description

Streaming services usually deliver their content via Content Delivery Networks (CDNs), which are caches placed at strategic network nodes. CDNs enable a higher level of service reliability and can be designed to optimize the distribution of network loads and transmission costs. However, due to high consumption of media content on public transportation, especially in environments of limited bandwidth, service reliability decreases while transmission costs increase. As such, the CDN solution at 5GENESIS [5] in Berlin follows the multi-CDN approach, so that integration into the CDN infrastructure of content providers can transition smoothly.

The Data Shower approach that is being developed in 5G-VICTORI extends the streaming CDN services to trains, by equipping them with caches filled with content via wireless data links. The data shower utilizes mmWave connectivity, which allows large amounts of media data to be transferred between caches within a very short time period. This allows for a transfer of media content from the train station's CDN cache to the train's cache at data rates of up to 2.5 Gbit/s or even higher. In the future, data showers will be installed at selected locations along the train route. This is necessary to ensure that not only the most recent content is stored in the train cache (which is especially relevant for news content), but also that older, archived content is removed. Due to cost considerations, data showers will initially be installed at train stations, leveraging on existing physical infrastructures. The Berlin Central Station, a facility of "Deutsche Bahn", is considered as the place to validate this use case under real/operational conditions using the on-demand video catalogue of **RBB** (RBB Mediathek).

Following the data shower concept, Video-on-Demand (VoD) content will be preloaded on a train's content cache, which acts as an edge server of the content providers' CDN. These caches hold copies of content in order to optimize media delivery for end users. In this use case, the data shower approach is used to fill the cache in the train during a train stop at the station. It is assumed that viewers use their personal mobile devices, such as smartphones, tablets, laptops, to consume media streams. The personal devices are connected to the trains' on-board Wi-Fi network.

In the context of 5G-VICTORI, development work will focus on streaming/viewing VoD content on trains.

3.2 CDN Services Berlin Test Cases

3.2.1 Description

The test cases for the Berlin CDN services are derived from "UC #3 Data Shower Application", as described in detail in deliverable D2.1 [1]. In order to allow a large amount of data to be transferred between two endpoints within a short period of time, a data shower is required for such purposes (see Figure 3-1). It allows for network connections to be established for high data rates (> 2 Gbps) at specific geographical locations.

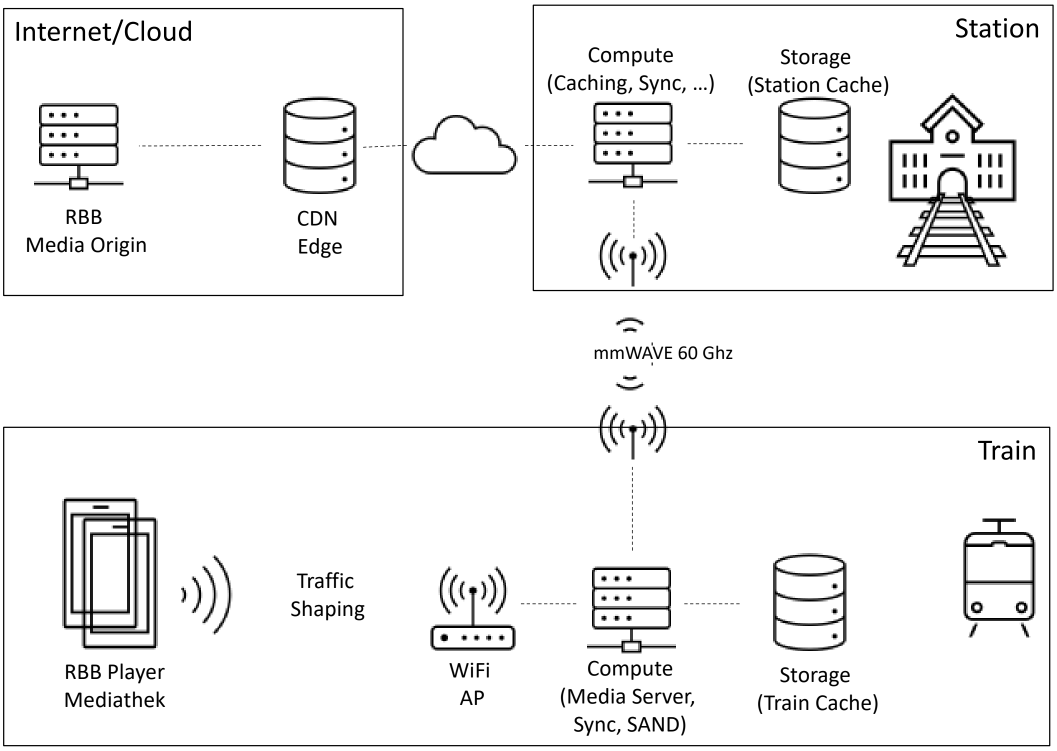

Figure 3-1 VoD Data Shower

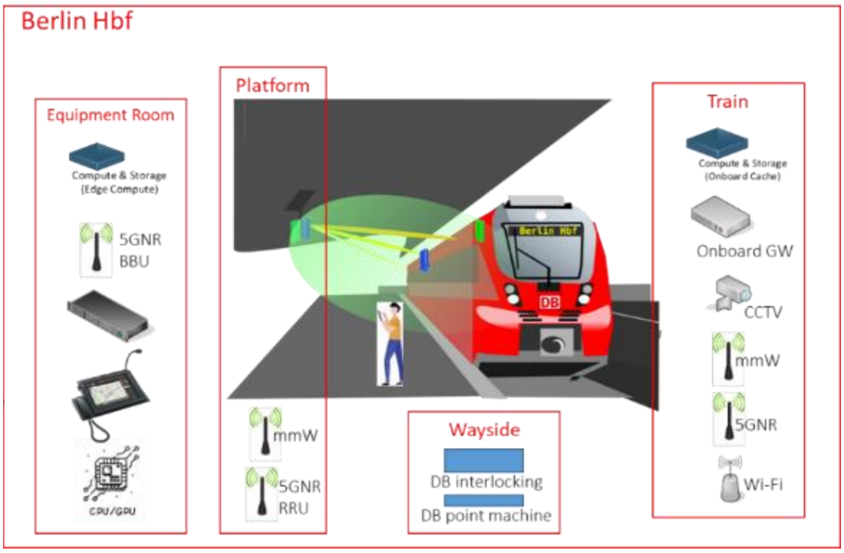

Figure 3-2 Berlin Central station facility in support of the Berlin UCs, UC #1.2 benefits from 5G connectivity to users throughout the station

The data transfer is made from the trackside part of the platform to the train on the move using mmWave connectivity (see Figure 3-2).

The application is used to push recommended media items to a media cache on the train, which compensates for any potential data transmission bottlenecks in the CDN. See Figure 3-1 for a full block diagram of the hardware and applications used in the context of media services. The data shower consists of a data source, data transmission system and data sink. The transmission system is comprised of the 5G Core Network, 5G base station and 5G modem. On the radio level, 60 GHz mmWave are used for transmission, depending on which band is able to provide superior service.

The media cache in the train station serves as the data store, which preloads the relevant media items from the content provider's CDN prior to the train entering the station (5G platform). Once media items are requested from the App & Media Server (hosted by a physical infrastructure on the train), the media items can then be accessed by passengers through a media application on their personal devices. To assess the feasibility of the data shower approach and the end-to-end workflow, the tests listed below cover all aspects of the use case: content aggregation, updating caches in the station and onboard the train, transmission of the data to and in the train, and usage and quality metrics measurement.

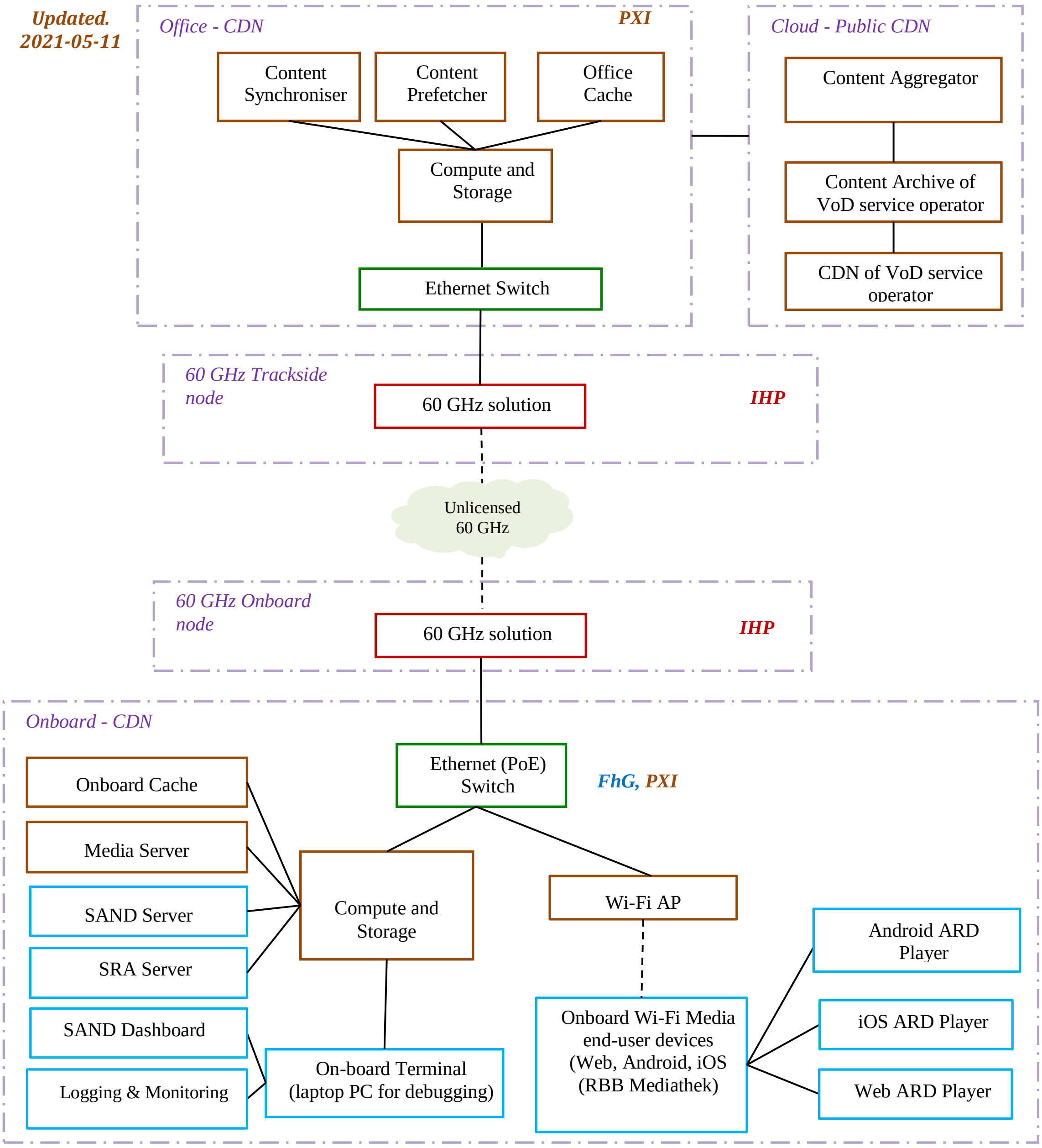

Figure 3-3 HW and Applications Block Diagram for Media Services

3.2.2 MCBg01: Aggregation of relevant content for cache prefilling

Due to limited storage capacity on the train, *subsets* of content can only be made available to train passengers, rather than *entire* content archives provided by VoD service providers. The aim of the test described in Table 3-1 is to specify, find and fetch a relevant subset of content from the VoD archives and successfully upload the content to the station's media cache.

Table 3-1 MCBg01: Aggregation of relevant content for cache prefilling

MCBg01	**Aggregation of relevant content for cache prefilling**	
Testbed	**5GENESIS Berlin [5]**	
Description	Storage capacity on the train is limited and will not be sufficient to store the entire content archive for any VoD service provider. It is therefore not feasible to simply copy the content archive to the media cache on the train. Instead, a relevant subset of content must be specified (in terms of total number of assets as well as different qualities of each) to upload to the cache. A subset may be identified by either of the following entities: human content editor, preselected subset, or machine learning algorithm. The content subsets are then sent to the 5G platform, which crawls content archives for matching content and collects the respective resource's location from the content providers' CDNs. Resource locations are then sent to the 5G platform's prefetching service, which requests the respective resources from the media cache in the station and downloads the resources from the VoD service providers' CDN. This test case determines whether or not the 5G platform can: fulfill the defined aggregation tasks, initiate the subsequent prefilling mechanism accordingly and verify the integrity of the asset collection. The test case will be verified by checking the built-in logging system to confirm that all actions performed as expected. The output list of media files and segments of all aggregated media contents must also be equivalent to the list of media files available in the CDN origin.	
Key Use Case requirements and KPIs	• Catalogue of video content is available	
Network performance requirements and KPIs	N/A	
Network Functional requirements and KPIs	N/A	
Components and Configuration	Components	• 5G Platform
	Configuration	Runtime-dependent human configuration or predefined collection
Test procedure	Pre-conditions	• Connectivity shall be available across all infrastructure components of the "Architectural deployment" figure • Internet connectivity to the Aggregator shall be ensured. • Partner CDN URLs shall be accessible. • CDN cache size needs to be known.

	Test Case steps	Observe input data and service logs to validate whether or not the service is successfully implemented in the following steps: • Receive content subset configuration • Find content that matches given configuration in content archive and report potential deviations • Get CDN URLs for content items • For adaptive bitrate streaming formats, get segment URLs referenced in (nested) stream manifests • Compile a list of video and video segment URLs • Send list to prefetching service
Measurements	Methodology	N/A
	Complementary measurements	N/A
	Calculation process	N/A
Expected Result	Prefetching services receive an asset collection that can be parsed/processed.	

3.2.3 MCBg02: Pre-Fill Media Content in Station Cache from RBB Catalogue (via public CDN)

Following the test procedure described in test case MCBg01, a predetermined set of media content (from the RBB Catalogue) must be used to fill the cache in the train station, as described in Table 3-2. The aim of this test case is to assess if the content is successfully downloaded and queryable for any interested customers. In order for this test case to succeed, media assets must be accessible and properly indexed.

Table 3-2 MCBg02: Pre-Fill Media Content in Station

MCBg02	**Pre-Fill Media Content in Station**
Testbed	**5GENESIS Berlin [5]**
Description	The assets collection that has been determined and assembled in MCBg01 must be used to fill the station cache. For this, the 5G Platform must parse the asset collection, extract relevant assets, download (including verification) and store them in a consistent and predictable fashion. Once all assets have been downloaded, the successful download must be announced/queryable for any interested consumers. Furthermore, any mismatch/ lack of data shall be reported.
Key Use-case requirements and KPIs	• Relevant Media Content is available via public CDN • 2TB+ local cache size
Network performance requirements and KPIs	• 200+Mbps downlink throughput to public Internet

Network Functional requirements and KPIs	• Stable Internet connectivity to public CDN	
Components and Configuration	Components	5G platform
	Configuration	Asset collection of MCBg01 via API call or by injection.
Test procedure	Pre-conditions	Successful acquisition of asset collections derived in MCBg01. Alternatively, this information can be constructed and injected into the test case (if the test cases are not performed sequentially).
	Test Case steps	Under continuous monitoring of the components' service logs, the following steps are necessary: 1. Ingestion of the asset collections from MCBg01 2. Downloading of the items referenced in the collections. a. This affects all selected streams as well as the selected bitrates of the individual streams. 3. Verification of the downloaded items 4. Consistency check and reporting of any missing/corrupt/unavailable data at its origin
Measurements	Methodology	1. Get the aggregated list of media content (list of URLs to HLS playlists *.m3u8) to download. 2. Create list of all related files to download (audio/video segments, subtitle files, manifests) 3. Download all list files to the Station cache 4. Check if all files are downloaded properly
	Complementary measurements	N/A
	Calculation process	• Number. of chunks • Average chunk size • Time per chunk (min/max/avg) • Missing/dropped chunks per 1000/chunks
Expected Result	The assets provided by the Prefetcher have been stored on disk, are accessible and properly indexed.	

3.2.4 MCBg03: Data Shower High Speed Transport from Station Cache to Train Cache

In cases where media content is contained in the station's media cache but it is not completely uploaded to the train's cache, it is necessary to ensure that the remaining content can be uploaded via a 5G data link. In Table 3-3, this test case ensures that all remaining content is transferred to the train while the train is stationary at a station. For this test case to succeed, all content must be successfully transferred within a short period of time and over a high data rate.

Table 3-3 MCBg03: Data Shower High Speed Transport from Station Cache to Train Cache

MCBg03	**Data Shower High Speed Transport from Station Cache to Train Cache**	
Testbed	**5GENESIS Berlin [5]**	
Description	Media data in the station cache (that were not contained in the train's media cache already), also known as "media content delta", shall be uploaded to the train's media cache via the 5G data link whilst the train is stopped at the station. To transmit the media content delta during the train's standing time, an average data rate of at least 2.5 Gbps is required. The test case succeeds if the entire media content delta is transmitted to the train cache.	
Key Use-case requirements and KPIs	N/A	
Network performance requirements and KPIs	The mmWave data link between station and should be able to support a 2.5+Gbps downlink throughput for a single UE	
Network Functional requirements and KPIs	N/A	
Components and Configuration	Components	1. 5G data link 2. Media cache in station (5G platform) 3. Media cache on train (5G train)
	Configuration	1. List of media items that need to be copied by file, diff or API call 2. Network deployment shall be performed as depicted in the Architectural Deployment Figure
Test procedure	Pre-conditions	1. No mmWave connectivity between train and station is established yet
	Test Case steps	3. mmWave connectivity between train and station is established 4. Data synchronization process starts upon connection 5. Data synchronization process stops if media content delta is transmitted or connection breaks
Measurements	Methodology	1. Assert that all data transmitted via the 5G Link from the Media Cache in the station are copied properly to the Media Cache in the train. MD5 hashes of the copied files can be used to ensure the integrity of the files. 2. Assert that the amount of transmitted data fits within the available bandwidth and duration of the train stop at the station 3. Assert that an interruption in connectivity does not leave the data in an inconsistent state

	Complementary measurements	1. While performing steps 1 - 3, radio network quality measurements (RSSI/RSRQ) will be collected along with the UE/train position and timestamps. 2. While performing steps 1 - 3, real-time data rate measurements may be also collected. 3. Traffic conditions are also monitored and noted in each iteration.
	Calculation process	1. The time between an operation request and response is calculated – timestamps from the service and network layer messages are used for the calculations. (e.g. update request, update success, etc.). 2. For each set of tests/ iterations (for the specific conditions), the mean/ median/ max./ min of "Available edge cache update times" will be calculated. 3. Connectivity-related indicators, such as data rate, will be measured by the duration of the edge cache update session and the amount of data received. 4. For each set of tests/ iterations (for the specific conditions) the mean/ max./ min received data and data rate values will be calculated.
Expected Result	1. Assert that all data transmitted via the 5G Link from the Media Cache in the station are properly copied to the Media Cache in the train. MD5 hashes of the copied files can be used to ensure the integrity of the files. 2. Assert that the amount of transmitted data fits within the available bandwidth and duration of the train stop at the station	

3.2.5 MCBg04: Media Distribution in the Train (via Wi-Fi)

The aim of this test case is to determine whether or not the train passengers can access and stream content from the train cache via the train's 5G-VICTORI Wi-Fi connection. In Table 3-4, this test case allows passengers to continue using the content providers' standard Video on Demand VoD application/website (while in the train) to access content available on the train's cache. To ensure the success of this test case, the video player must be able to stream the content with sufficient quality.

Table 3-4 MCBg04: Media Distribution in the Train (via Wi-Fi)

MCBg04	**Media Distribution in the Train (via Wi-Fi)**
Testbed	**5GENESIS Berlin [5]**

<table>
<tr><td>Description</td><td colspan="2">Passengers use their smartphones/ tablets/ laptops on the train and connect their devices to the Wi-Fi hotspot. The railway company (e.g. "Deutsche Bahn", in case of Berlin Cluster setup at Berlin Central Station) usually offers a Wi-Fi hotspot to passengers, but in the 5G-VICTORI demonstration setup, a separate Wi-Fi (or dedicated Wi-Fi AP) will be provided in order to interface with other components required for the Media Services Use Case e.g. the Media CDN Cache in the train.

Once a passenger device is connected to the 5G-VICTORI Wi-Fi network onboard the train, the ARD Mediathek native Android/iOS App as well the Web App can be used (without any modifications) to watch the content from the ARD/RBB Catalogue. Only content available on the train's cache will be offered for the User via the Mediathek application. To enable this, all requests made by the Mediathek application running on passenger devices to download media content from the public CDN (e.g. Akamai) will be intercepted by the Proxy Server, which is configured to serve content from the local CDN Cache in the train. This way, the passengers do not need to install a separate ARD Mediathek Application configured to use the 5G-VICTORI setup. A sub-test case with the same behavior is targeted for only relaying contents owned/provided by RBB.</td></tr>
<tr><td>Key Use-case requirements and KPIs</td><td colspan="2">• U-FU-6301
• U-FU-6302</td></tr>
<tr><td>Network performance requirements and KPIs</td><td colspan="2">• Number of concurrent users
• Average bitrate per user</td></tr>
<tr><td>Network Functional requirements and KPIs</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Components and Configuration</td><td>Components</td><td>1. ARD Mediathek App for Android, iOS and Web (either the default app or a developer version to allow for HTTP only if SSL certs cannot be procured)
2. Wi-Fi Hotspot/Gateway
3. Media Cache in the train
4. Media Server in the train to serve content from the Media Cache</td></tr>
<tr><td>Configuration</td><td>1. Media Server needs to be equipped with the SSL certificates for the domains served or the consuming apps (web or native) have to support plain HTTP transport.</td></tr>
<tr><td>Test procedure</td><td>Pre-conditions</td><td>N/A</td></tr>
</table>

	Test Case steps	1. Passenger connects device to the 5G-VICTORI WiFi Network in the train 2. Passenger installs the ARD Mediathek Android/iOS App if not done yet. This step is optional if the passenger decides to use the Web App instead. 3. Passenger opens the native ARD Mediathek iOS/ Android App or the Web App in a Browser 4. The ARD Mediathek App shows available content from the local Media Cache in the train. Content that is not available in the local Media cache shall not be displayed in the App in order to improve the User Experience. Therefore, users do not need to select a content item first to see if it is available or not. 4a - Passenger browses only the RBB Catalogue (as available on the train) and finds appropriate content to watch 5. The train's DNS resolver redirects all domains in question (i.e., media.ard.de to the train cache) 6. The App receives the URL of the HLS playlist manifest file (*.m3u8) and passes it to the underlying video player 7. The Video player parses the manifest file and requests video/ audio segments via HTTP 8. The HTTP requests to download video/ audio segments, which are intercepted by the Media Server as well and served from the local Media Cache 9. The Video Player receives the audio/ video segments and starts playback. User should be able to use playback functions (play/ pause/ seek/ stop) as usual
Measurements	Methodology	1. Only content available in the Media Cache is displayed in the ARD Mediathek App 2. The ARD Mediathek can play available media content properly in the appropriate bitrate, resolution and codec
	Complementary measurements	N/A
	Calculation process	• Apache benchmark (ab) with 10/20/50/100 concurrent requests
Expected Result	1. Only content available in the Media Cache is displayed in the ARD Mediathek App 1a - Only RBB content is available 2. The ARD Mediathek can play available media content in the appropriate bitrate, resolution and codec	

3.2.6 MCBg05: Collecting of Playback Metrics (using MPEG-SAND)

The aim of this test case is to collect metrics on the performance of the service under evaluation in terms of the video stream's playback and presentation quality. Table 3-5 outlines the metrics that will be gathered and used to monitor and analyze the service. In order for the test case to succeed, all network and playback metrics must be collected and synced with the Master Server.

Table 3-5 MCBg05: Collecting of Playback Metrics (using MPEG-SAND)

MCBg05	**Collecting of Playback Metrics (using MPEG-SAND)**	
Testbed	**5GENESIS Berlin [5]**	
Description	Once passengers are connected to the Wi-Fi network in the train, they are able to watch content that was already pre-fetched in the train's CDN cache. To ensure that the content is played back properly on the client and presented in the expected quality, it is important to monitor and analyze streaming sessions and report any faulty/problematic sessions. This requires collecting playback metrics for each streaming session and storing them in a database for further analysis. The playback metrics that are being addressed in 5G-VICTORI follow the "Server and Network Assisted DASH" (SAND) specification, which is part of the MPEG-DASH standard. Example playback metrics are as follows: average throughput, buffer level, initial playout delay, HTTP request/response transactions, representation switch events, and playlist. These metrics will be used as inputs for test cases concerning “Shared Resource Allocation” and “Monitoring QoS for the End-to-End Workflow”. The playback metrics are collected on the streaming client and reported to the SAND Server via HTTP. Some metrics can be collected by network elements (e.g. Proxy Streaming Server in the train in our case) present on the path between the origin server and the client and reported to the same SAND Server. This is practical if the client player cannot be extended to capture playback metrics, which is the case with the ARD Mediathek native application. On the other hand, the player metrics collected on the client (e.g., start time, buffer level, etc.) provide more insights into the streaming sessions and make it easier to detect and fix errors.	
Key Use-case requirements and KPIs	Access to ARD player on the respective platforms	
Network performance requirements and KPIs	N/A	
Network Functional requirements and KPIs	N/A	
Components and Configuration	Components	1. **SAND Client**: will be integrated in the ARD Mediathek Web App to collect player metrics on the client 2. **SAND Proxy**: will be integrated in the Media Server (in the train) to collect network metrics of streaming sessions (no need to update the ARD Mediathek iOS and Android App) 3. **SAND Master Server** (Cloud): will be deployed in the cloud and collect all streaming metrics from all SAND Local Servers in all trains.

		4. **SAND Local Server** (Train): is a standalone component deployed in the train in order to temporarily store player metrics reported by the SAND Client and SAND Proxy. Once reconnected to the Internet, the metrics are then sent to the SAND Master Server.
	Configuration	1. SAND Client and SAND Proxy need to be configured with the SAND Local Server's endpoint 2. SAND Local Server needs to be configured with the SAND Master Server's endpoint running in the cloud
Test procedure	Pre-conditions	N/A
	Test Case steps	1. The SAND Client integrated in the ARD Mediathek Web App sends playback and network metrics of each session to the SAND Proxy via HTTP 2. The Local SAND Server integrated in the Media Server in the train intercepts HTTP requests of media segments and report network metrics to the SAND Proxy via HTTP 3. The SAND Local Server syncs the collected metrics with the SAND Master Server once the train is connected to the public internet
Measurements	Methodology	1. Collect playback metrics in the player and export them in a suitable format 2. Export collected playback metrics on the SAND Server in same format 3. Make sure that the reported metrics are identical by comparing all items and values in both exported lists.
	Complementary measurements	N/A
	Calculation process	N/A
Expected Result	1. Assert that the playback metrics (such as download speed, buffer level, startup time, requested bitrate, playback events, errors occurred) collected on the client corresponds to the actual session (e.g. if the video playback stalls, make sure that a corresponding playback event is intercepted and that a proper metric is reported). 2. Assert that the playback metrics collected on the client are reported to the SAND Local Server. 3. Assert that the network metrics collected on the SAND proxy correspond to the actual access history of video/ audio segments via the Media Server. 4. Assert that the network metrics collected on the SAND proxy are reported to the SAND Local Server. 5. Assert that all the metrics collected in all local SAND servers are synched properly with the master SAND Server running in the Cloud.	

3.2.7 MCBg06: Shared Resource Allocation (SRA) in the Train using collected playback metrics and via dedicated Gateway

In order for train passengers to enjoy smooth video playback, bandwidth resources should ideally be fairly allocated to all. In Table 3-6, this test case aims to ensure that there is a fair allocation of bandwidth resources to passengers on the train using the available Wi-Fi connection. In order for this test case to succeed, train passengers should be able to stream video content from the local cache without interruptions.

Table 3-6 MCBg06: Shared Resource Allocation (SRA) in the Train using collected playback metrics and via dedicated Gateway

MCBg06	**Shared Resource Allocation (SRA) in the Train using collected playback metrics and via dedicated Gateway**	
Testbed	**5GENESIS Berlin [5]**	
Description	When several users on the train stream videos at the same time, they compete for bandwidth that a common Wi-Fi access point can provide. During playback, this can lead to unwanted behavior, such as playback discontinuities or fluctuations of video quality when streaming with adaptive bit rates. For example, like with streaming solutions such as “Dynamic Adaptive Streaming over HTTP” (DASH) or HLS. The streaming metrics collected in TC "MCBg05" are used in this case to enhance the streaming experience and network bandwidth utilization in multi-user scenarios. By means of the “Shared Resource Allocation” (SRA) feature within SAND, the App & Media Server manages the assignment of network bandwidth to clients (traffic shaping) such that the average QoS is maximized.	
Key Use-case requirements and KPIs	- The bandwidth is distributed fairly between competing users in the same Wi-Fi network in the train	
Network performance requirements and KPIs	N/A	
Network Functional requirements and KPIs	N/A	
Components and Configuration	Components	1. **SRA Monitor**: This component monitors the collected SAND playback metrics and makes sure that the available bandwidth is distributed fairly between the clients. It may also manipulate the DASH/HLS manifests and limit the available representations that fit within the available bandwidth. 2. **SRA Client**: This component will be integrated into the DASH/HLS player and control the representations that can be requested according to the available bandwidth. This will be used only for the ARD Mediathek Web App.

	Configuration	2. The SRA Monitor shall be configured with the available bandwidth and strategy for distributing bandwidth fairly among the users 3. The SRA Monitor needs to be configured with the endpoint of the SAND Local Server in the train to monitor current sessions and assign a bandwidth to each session. 4. The SRA Monitor needs to be configured with the Media Server's endpoint in the train to assign a bandwidth for each session.
Test procedure	Pre-conditions	• Streaming session is started
	Test Case steps	1. The SRA Monitor connects to the SAND Local Server and monitors current streaming sessions 2. The SRA Monitor calculates the bandwidth to be assigned for each session from the overall available bandwidth and the Manifest file of each session 3. The SRA Monitor assigns the bandwidth of the WiFi connection (associated with the corresponding session) or tells the integrated SRA Client (in the player) to the requests' segments according, to the available bandwidth
Measurements	Methodology	1. Select a reference video with at least 5 different video bitrate levels (show visual elements on top of the video indicating the bitrate level). 2. Assign a max bandwidth to each client that only allows to certain bitrate levels to be played (e.g., the first 3 levels). 3. Play content in ARD player across multiple platforms and make sure that only the permitted bitrate levels are selected.
	Complementary measurements	Measure the optimal utilization of bandwidth provided by the Wi-Fi access point
	Calculation process	• The bandwidth assigned to each user is calculated from the overall available bandwidth in the Wi-Fi network in the train divided by the current number of connections. • The player selects the video/audio stream with a bitrate near the assigned bandwidth • The calculation process is dynamic and will be repeated each time the context is changed (e.g. a new playback session is initiated or completed).
Expected Result	All clients connected to the Wi-Fi Network in the train should be able to play video content from the local cache without playback discontinuities or fluctuations. Bandwidth is also fairly distributed between the players.	

4 CDN Services at the 5G-VICTORI facility in Patras

4.1 Description

The CDN services UC that will be implemented at the 5G-VINNI facility in Patras [4], are derived from media streaming applications, which need to benefit from the 5G capabilities in order to cover their streaming requirements. The test cases for Patras CDN services are derived from the UC #3 Data Shower and 360° camera Applications, as described in detail in D2.1 [1].

The first scenario of the UC has as its main objective to showcase that it is possible to provide, through a multi-stage caching CDN platform, continuous TV and VoD content to railway passengers as they move between train stations, without full 5G coverage along the tracks. In other words, the application will showcase how the combination of the advanced, multi-stage CDN platform with the 5G-enabled "data shower" when available, can alleviate delays and content gaps occurring when content is delivered directly from the existing content origins.

The scenario considers a multi-level hierarchical CDN deployment in a railway environment for proactive storage of large amounts of VoD/live content on a train to serve the passengers' needs during their trips. The central CDN server will receive COSM VoD/live content. It will be connected (via the mmWave transport deployment of 5G-VINNI [4]) to a cache component (ICOM's Main Cache) - which will serve as the main caching point and will be periodically updated with content-, located at the train station. When the train arrives at the station, the data shower functionality will take place; in the short train stop duration, the Main Cache will fill another cache component, deployed on the train (ICOM's Edge Cache), with as much content as possible so that the passengers will be able to stream their content of preference through an onboard Wi-Fi without interruptions until the next train stop. The scenario will make use of the network infrastructure deployed at UoP central premises and at TRAINOSE railway premises. Figure 4-1 graphically represents the described setup.

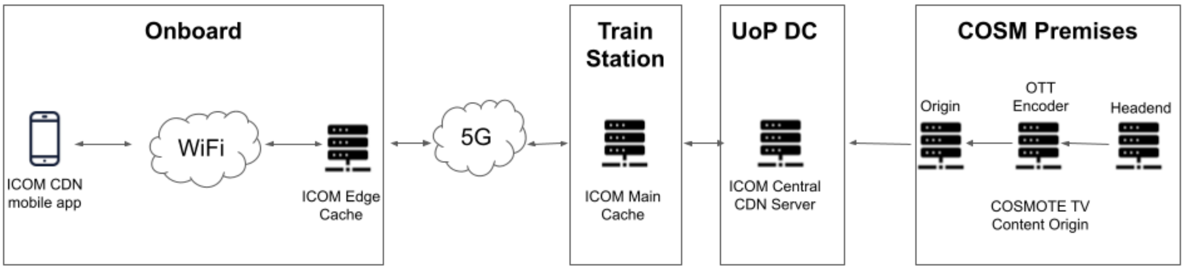

Figure 4-1 5G-VICTORI – 5G-VINNI/ Patras CDN Data Shower Scenario

Another UC of media streaming related applications can be found in the sector of surveillance. In a railway environment, the security personnel of a train operator are in charge of remotely monitoring the ongoing activity at multiple operators' facilities (e.g., at train stations). The use of high-resolution VR/360º cameras deployed at train stations is essential so as to receive the footage in high quality and identify in clarity any issues/ events through zoom-in or zoom-out functionalities. However, when the camera administrator rotates the field-of-view to observe different areas, the new angles will be received with a delay due to their high quality, leading to streaming lags and therefore motion sickness. This scenario has as its main objective to provide a remote surveillance application without motion sickness impacts during transitions between the various angles of view, by implementing stream processing and optimization work to provide footage in lower quality (but with very low latency using the 5G-VINNI [4] infrastructure) for camera administration purposes, while the angle rotations are in motion.

When the rotation stops, the streaming will return to high resolution. The scenario will make use of the network infrastructure deployed at UoP central premises and at **TRAINOSE** railway premises, adding a 360º camera and a server for streams optimization near the 5G base station at the monitored area, as well as a remote client which will be receiving the footage through the deployed 5G network slices. Figure 4-2 graphically represents the described setup.

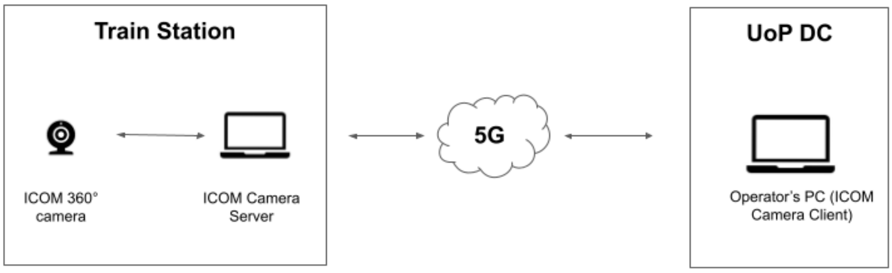

Figure 4-2 5G-VICTORI – 5G-VINNI/ Patras Remote Surveillance Scenario

4.2 CDN Services Patras Test Cases

4.2.1 Description

The Data Shower application is used to provide a train with as much VoD and live content as possible when it arrives at a train station, so that the passengers will have enough content to watch until the train reaches the next station for a subsequent content update. For this, caches will be deployed at the train station and onboard the train, with the first being periodically updated from the central CDN servers and the latter being updated by the station cache at a very high data rate via the 5G-VINNI [4] infrastructure. The architectural deployment that will support the Data Shower scenario's testing is depicted in Figure 4-3.

The test cases for this scenario, indicated by MCDv prefixes, cover all the necessary aspects from deployment and connectivity, to periodic updates of the station cache, the update of the train cache in very high data rates and the distribution of the content to the passengers.

The remote surveillance scenario will utilize a 360° camera with high resolution capabilities deployed at the train station, which will lower the footage quality when streaming to a remote operator. The remote operator rotates the field-of-view, so that the footage is able to be sent at a very low latency and be received in time to avoid interruptions while viewing. The architectural deployment that will support the testing procedure of the 360° camera scenario is depicted in Figure 4-4. The test cases for this scenario (indicated by MCSv prefixes) cover all necessary aspects: from deployment and connectivity, to high quality video streaming during angle-of-view stability periods, and lower resolution video streaming with low latency during angle-of-view rotation periods for motion sickness avoidance.

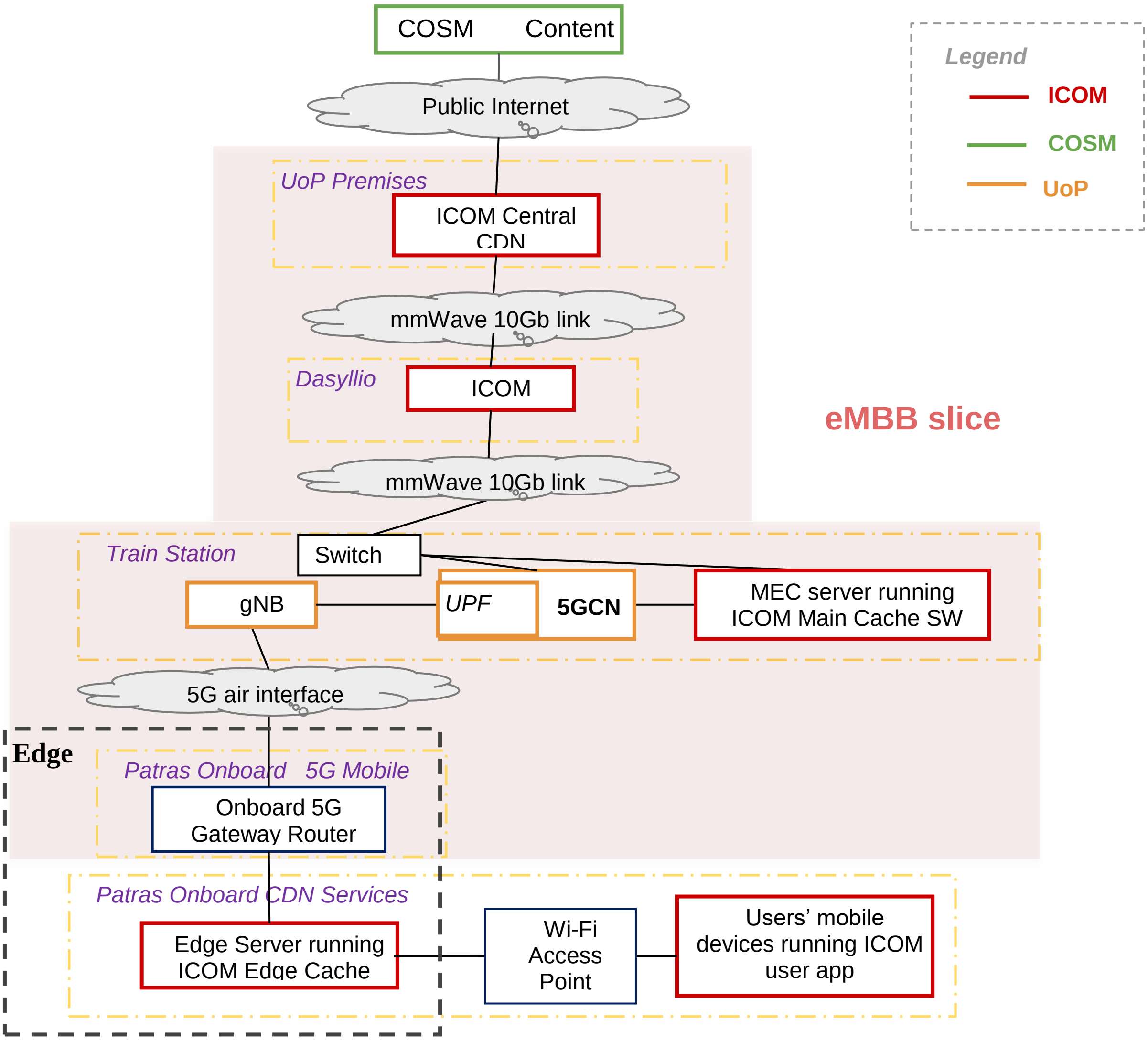

Figure 4-3 5G-VICTORI – 5G-VINNI/ Patras CDN Data Shower Scenario Architectural Deployment

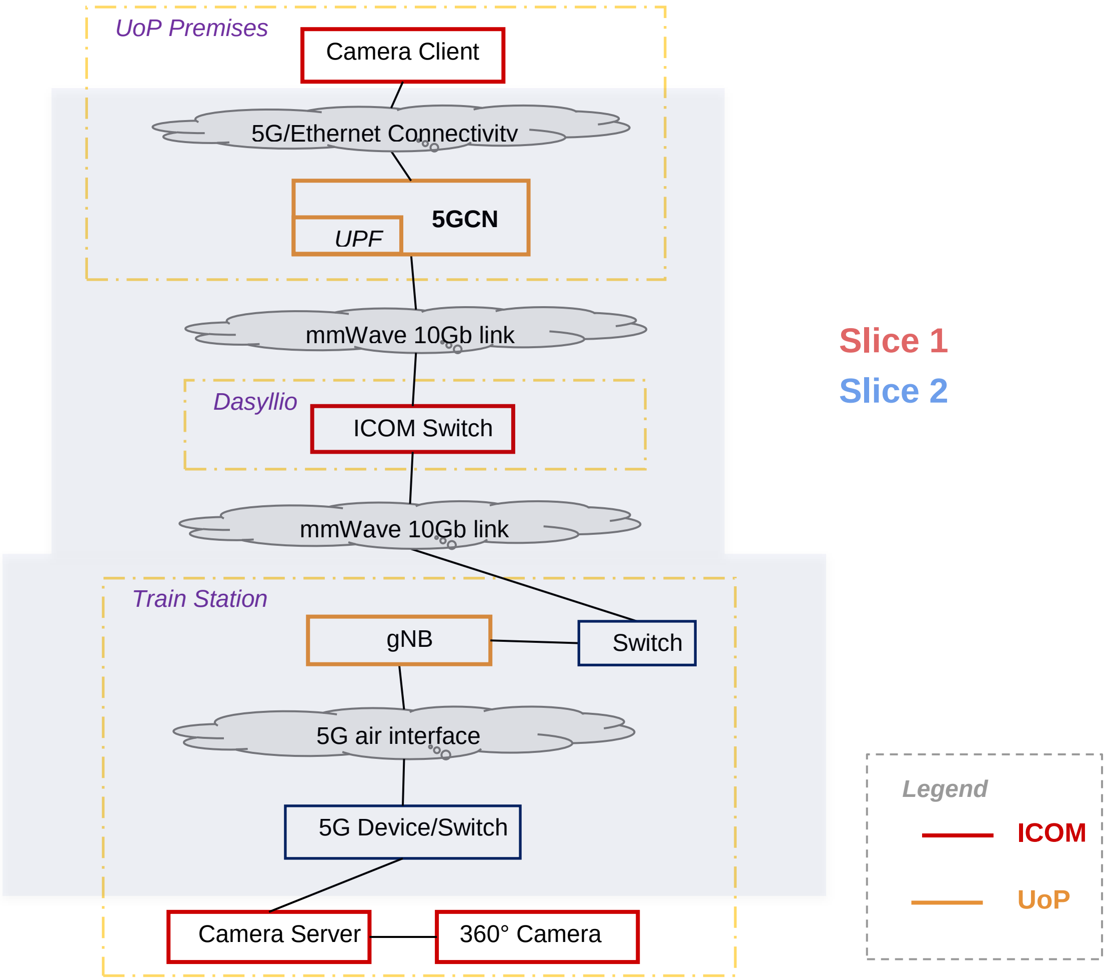

Figure 4-4 5G-VICTORI – 5G-VINNI/ Patras Remote Surveillance Scenario Architectural Deployment

4.2.2 MCDv01: CDN Application Scenario Deployment

The first test case (see Table 4-1) of the MCDv test cases group concerns the initialization of CDN components that will facilitate the scenario deployment over the 5G-VINNI facility [4], as well as the evaluation of the initialization process. It is important to achieve a low deployment time of the components as VNFs, leading to quick deployment of the application in general, and this test case facilitates this verification.

Table 4-1 MCDv01: CDN Application Scenario Deployment

MCDv01	**CDN Application Scenario Deployment**
Testbed	**5G-VINNI Patras [4]**
Description	The initial test case aims at validating and evaluating the deployment of CDN components over the 5G-VINNI facility through its orchestration layer and verifying initial connectivity between all components. Focus will be placed on the evaluation of aspects related to easiness and speed of deployment, creation of interfaces, steps required for fine tuning of deployment, etc.
Key Use-case requirements and KPIs	**U-PE-6217:** Low deployment time of CDN's VNFs and for the complete graph of CDN application.
Network performance	**Network KPIs:** The total duration shall be as minimum as 90 minutes.

requirements and KPIs		
Network Functional requirements and KPIs	• Capability to deploy an end-to-end service upon request.	
Components and Configuration	Components	• 5G Base station & MEC server available at train station • Content provider's niche End-Point (Transcoder) deployed • 4K VoD/live COSMOTE TV content to be streamed • Central CDN server / Content receiver at Up • Edge server available in train • 5G modem available in train • Wi-Fi AP available in train • Passengers' mobile devices • ICOM CDN app available on the mobile devices
	Configuration	• Network deployment shall be performed as depicted in Figure 4-3 • The content provider niche end-point resides where the transcoder feed is accessible. • The central CDN server needs to be located at UoP for elimination of delays for content transmission. • A tenant is created on MEC server hypervisor. • The on-board Edge server is configured with an on-board 5G modem (in order to allow the latter to communicate with the 5G base station at train station) and with a Wi-Fi AP for the passengers to connect to it. • The ICOM CDN app is installed in passengers' UEs, as it is the interface to select content of preference from the on-board server.
Test procedure	Pre-conditions	• Connectivity shall be available across all infrastructure components of Figure 4-3, that is: • Connectivity shall be ensured between the MEC server (that will host the Main Cache) and central CDN server. • Connectivity shall be ensured between the MEC and on-board server that will host the Edge Cache. This connectivity will be done via the 5G-VINNI 5G mobile network, specifically via the gNB deployed at the train station and the 5G modem of the server onboard the train. • Connectivity shall be ensured between the Passengers' UEs and be able to connect to Wi-Fi AP at train. • The ICOM CDN app is installed in the passengers' UEs, as it is the interface to select preferred content

		• The ICOM CDN app is available as deployable software components
	Test Case steps	1. The user logs into the 5G-VINNI Orchestration platform 2. The SW components of the ICOM CDN app are on-boarded. The on-boarding time needed is measured. 3. The user triggers the deployment of the SW components on different infrastructure resources. a. The CDN Main Cache is deployed on the MEC server as VNF. b. The Edge Cache is deployed on the Edge server. The total time required for the deployment of the components is measured. 4. The passenger UEs are connected to the CDN application. Simple end-to-end connectivity at the Application Layer is verified. Otherwise, configuration activities are performed. The time needed for these activities is measured.
Measurements	Methodology	For step 2: to estimate the onboarding time, the time duration notification that may be available from the platform can be used. Alternatively, the time is measured by capturing the timestamps of each interaction/ process initiation of finalization. The on-boarding shall be performed at least once through the 5G-VINNI orchestrator. For step 3: to estimate the deployment time, the time duration notification that may be available from the platform can be used. Otherwise, the time is measured by capturing the timestamps of each interaction/ process initiation of finalization. The mean/max/min deployment time values are calculated.
	Complementary measurements	Amount of data for each CDN component shall be noted. Traffic conditions of 5G network shall be identified. Possibly signal strength of 5G modem onboard
	Calculation process	For step 2: the total on-boarding time is calculated using the time duration notification that may be available from the platform. Otherwise, the time is measured by the time difference between the initiated time of the on-boarding and the time in which the finalization notification is received. For step 3: the total deployment time is calculated using the time notification that may be available from the platform. Otherwise, the time is measured by the time difference between the initiated deployment time and the time in which the finalization notification is received. The mean/max/min deployment time values are calculated using the measurements collected over all repetitions of the procedure.
Expected Result	Smooth and quick onboarding and deployment of CDN components. Total time of CDN components' on-boarding and deployment shall be <90 min. Connectivity between CDN components shall either be pre-configured or configured within the 90 min timeframe.	

4.2.3 MCDv02: CDN Connectivity Evaluation

After completing MCDv01, the required components to support the scenario are verified to be functional. This test case, as described in Table 4-2 will focus on the evaluation of the end-to-end connectivity across all CDN components, as it is crucial to verify that the required high data rate to support the data shower application is supported by the communication links between the various components.

Table 4-2 MCDv02: CDN Connectivity Evaluation

<table>
<tr><th>MCDv02</th><th colspan="2">Basic Connectivity Evaluation</th></tr>
<tr><td>Testbed</td><td colspan="2">5G-VINNI Patras [4]</td></tr>
<tr><td>Description</td><td colspan="2">The second test case aims at verifying and evaluating the end-to-end connectivity across all CDN components (including VNF). Focus will be placed on the evaluation of aspects related to data rate and latency achieved between the various CDN interfaces.</td></tr>
<tr><td>Key Use-case requirements and KPIs</td><td colspan="2">U-PE-6210: Very high data rates for proactive transfer of large volumes of high quality (e.g. 4K) VoD or TV streaming content from central CDN servers to local MEC host
U-PE-6211: Very high data rates for proactive transfer of prefetched high quality VoD or TV streaming content from MEC host to on-train Edge server</td></tr>
<tr><td>Network performance requirements and KPIs</td><td colspan="2">Network KPIs:
Data rate between MEC Main Cache & Central CDN server: ~ 100 Mbps
Data rate between MEC Main Cache & Edge Cache: 150-500 Mbps depending on live channels parameters / VoD content amount</td></tr>
<tr><td>Network Functional requirements and KPIs</td><td colspan="2">U-FU-6310: Very high data rates for proactive large volume and high-quality content transfer from central CDN server to local MEC host
U-FU-6311: Very high data rates for proactive transfer of prefetched content from MEC host to on-train Edge server.</td></tr>
<tr><td rowspan="2">Components and Configuration</td><td>Components</td><td>• 5G Base station & MEC server available at train station
• Content provider's niche End-Point (Transcoder) deployed
• 4K VoD/live content to be streamed
• Central CDN server / Content receiver at UoP
• Edge server available in train
• 5G modem available in train
• Wi-Fi AP available in train
• Passengers' mobile devices
• ICOM CDN app available on the mobile devices</td></tr>
<tr><td>Configuration</td><td>• Network deployment shall be performed as depicted in Figure 4-3.
• The Central CDN server needs to be located at UoP to eliminate content transmission delays.
• The onboard Edge server is configured with an onboard 5G modem (in order to allow the latter to communicate with the 5G base station at train station) and with a Wi-Fi AP for the passengers to connect to it.
• he ICOM CDN app is installed in passengers' UEs as it is the interface to select content of preference.
• Pinging between CDN components shall be enabled.</td></tr>
</table>

<table>
<tr><td></td><td></td><td>iperf or other data rate measuring tools shall be available and configured to be able to take measurements between the CDN components interfaces.
The radio interface measurement tool shall be available at the on-board 5G modem or/and other UEs.</td></tr>
<tr><td rowspan="2">Test procedure</td><td>Pre-conditions</td><td>Connectivity shall be available across all infrastructure components of Figure 4-3, that is:
Connectivity shall be ensured between the server that will host the Main Cache and the Central CDN server.
Connectivity shall be ensured between the MEC server and the on-board server that will host the Edge Cache. (via 5G-VINNI 5G mobile network, specifically via the gNB deployed at train station and the 5G modem of the on-board server)
Connectivity shall be ensured between the Passengers' UEs shall be able to connect to Wi-Fi AP at train.
The ICOM CDN app is installed in passengers' UEs as it is the interface to select content of preference
The ICOM CDN app is deployed over the 5G-VINNI facility.</td></tr>
<tr><td>Test Case steps</td><td>The user accesses the CDN components.
Ping requests and data rate measurements are performed between all corresponding CDN components / all CDN interfaces. Connectivity is verified and RTT/latency measurements are noted.
iperf sessions requests are performed between all corresponding CDN components / interfaces. Connectivity is verified and data rate measurements are noted.
The passenger UEs are connected to the CDN application. End-to-end Connectivity at the Application Layer is verified.</td></tr>
<tr><td rowspan="3">Measurements</td><td>Methodology</td><td>For step 1: Ping tests are performed between interfaces of the CDN application.
For step 2: Data rate (iperf) tests are performed between interfaces of the CDN application.</td></tr>
<tr><td>Complementary measurements</td><td>Traffic conditions of 5G network shall be identified. Radio interface quality shall be identified.</td></tr>
<tr><td>Calculation process</td><td>For step 1: For each set of ping tests between interfaces the mean/ median/ max./ min latency values (in ms) will be calculated.
For step 2: For each set of tests/ iterations between interfaces the mean/ max./ min data rate values (Mbps) will be calculated.</td></tr>
<tr><td>Expected Result</td><td colspan="2">Connectivity between CDN components shall either be pre-configured or configured within the 90min deployment time timeframe.
End-to-End connectivity is verified.</td></tr>
</table>

4.2.4 MCDv03: MEC Periodic Update

This test case, Table 4-3, stems from the need to verify that ICOM's Main Cache, located at the MEC server at the station, is constantly kept updated with new VoD or live content that has not yet been received. This will ensure that there will be fresh content available to push on the train when it arrives at the station.

Table 4-3 MCDv03: MEC Periodic Update

MCDv03	**MEC Periodic Update**	
Testbed	**5G-VINNI Patras [4]**	
Description	The purpose of this test case is to ensure that the server at the train station is periodically updated with content considered as popular. This update should be performed with a high frequency and in a push-based manner, so that the latest popular content is available at the station when the train arrives.	
Key Use-case requirements and KPIs	**U-PE-6210:** Very high data rates for proactive transfer of large volumes of high quality (e.g. 4K) VoD or TV streaming content from central CDN servers to the local MEC host. (TL1b,c)	
Network performance requirements and KPIs	**Network KPIs:** Data rate between MEC Main Cache & Central CDN server: ~ 100 Mbps High Connectivity to external hosts.	
Network Functional requirements and KPIs	**U-FU-6310:** Very high data rates for proactive transfer of large volumes of high quality (e.g. 4K) VoD or TV streaming content from central CDN servers to local MEC host. **KPIs**: Network Slicing	
Components and Configuration	Components	• MEC server available for Main Cache • Content provider's niche End-Point (Transcoder) deployed • Central CDN server / Content receiver • 4K VoD/live content to be streamed
	Configuration	• Connectivity between components performed as depicted in Figure 4-3 and described in MCDv01 • The Central CDN server needs to be located at UoP for elimination of delays for content transmission. • ICOM's Main Cache is deployed on 5G-VINNI MEC server • Message tracing tool shall be enabled at various CDN components. • Database and data monitoring tools shall be installed at MEC and Main Cache servers/components
Test procedure	Pre-conditions	• End-to-end connectivity over CDN is verified through finalization of MCDv01 & MCDv02. • Applications for CDN and performance measurements capturing are running on all devices. • Identification of traffic conditions over the Central CDN - MEC Main Cache connection.
	Test Case steps	1. The central CDN server receives the content from the Content Provider. 2. The central CDN server will communicate periodically with the Main Cache at the MEC server

		and update it with the latest popular content that has not yet been received in previous updates (in a push manner). 3. The MEC Main Cache's database will be checked in order to verify that the content has been received (and refreshed). 4. The interval between the two periodic updates and their duration will be measured. 5. The amount of received data during a periodic update will be measured.
Measurements	Methodology	• For evaluating various time indicators, both service and network layer messages will be captured with their timestamps (from message flows or database fields). • For evaluating connectivity indicators, data reception timestamps (from message flows or database fields) along with information on associated Data volumes will be captured.
	Complementary measurements	N/A.
	Calculation process	1. The time between an operation request and response is calculated - timestamps from service and network layer messages are used for the calculations (e.g. update request, update success etc.). For the "periodic update time", the time between the performance of two periodic updates will be calculated. 2. For each set of tests/ iterations (for the specific conditions) the mean/ median/ max./ min "periodic update times" will be calculated. 3. Connectivity - related indicators, such as data rate, will be measured by the time to update and the amount of data. 4. For each set of tests/ iterations (for the specific conditions) the mean/ max./ min received data and data rate values will be calculated.
Expected Result	Latest and non-received (since last update) content pushed on Main Cache at MEC	

4.2.5 MCDv04: Data shower from MEC to train cache

The data shower concept is the core focus of the virtualized CDN solution that is examined in the context of the Media UC, therefore it is crucial that its requirements are covered. For the data shower functionality, the test case MCDv04 is necessary in order to evaluate the available data rate and the content that will be transferred on the train through the data shower mechanism, which both have very high target values.

Table 4-4 MCDv04: Data shower from MEC to train cache

MCDv04	**Data shower from MEC to train cache**
Testbed	**5G-VINNI Patras [4]**
Description	The purpose of this test case is to ensure that the server on the train is updated with popular content that was not yet acquired each time a train station was reached, and therefore obtains 5G connectivity. This can be either VoD content that was not completely transferred during the previous stop due to its size, or live

	content that was shown during the train's trip from one stop to another and shall be stored on the train to be played as time-shifted (delayed by some minutes). This update should be performed in a pull-based manner, i.e. the train server requesting content from the station server, so that when leaving the station, the train server contains as much popular content as possible (from the previous stop's available download).	
Key Use-case requirements and KPIs	**U-PE-6211:** Very high data rates for proactive transfer of prefetched high quality VoD or TV streaming content from MEC host to on-train Edge server. (TL1c)	
Network performance requirements and KPIs	**Network KPIs** Data rate between MEC Main Cache & Edge Cache: 150-500Mbps, depending on live channel parameters and/or amount of VoD content. (TL1c) Amount of content transferred: 10 - 15GB VoD content / content from 3 live channels (TL1)	
Network Functional requirements and KPIs	**U-FU-6311:** Very high data rates for proactive transfers of prefetched 4K VoD content from MEC host to on-train Edge server. **KPIs** Network Slicing	
Components and Configuration	Components	• 5G Base station & MEC server available at train station • Content provider's niche End-Point (Transcoder) deployed • 4K VoD/live content to be streamed • Central CDN server / Content receiver at UoP • Edge server available in train • 5G modem available in train • WiFi AP available in train • Passengers' mobile devices • ICOM CDN app available on the mobile devices
	Configuration	• Network deployment shall be performed as depicted in Figure 4-3. • The ICOM CDN SW modules are deployed on MEC and Edge servers as in MCP02 and MCP03. - The on-board Edge server is configured with an on-board 5G modem (in order to allow the latter to communicate with the 5G base station at train station) and a WiFi AP for passengers' connection. • Ping/ iperf of other data rate measuring tools are available at on-board 5G modem. • A message capturing tool is set up (at network node or MEC server). • Radio interface measurement tool shall be available at the on-board 5G modem or/and other UEs.
Test procedure	Pre-conditions	1. CDN SW components are up and running. 2. Definition of initial position of the test. 3. Definition of traffic conditions of access network node.
	Test Case steps	1. The train starts entering the station. At this time, the MEC server at the station will have a certain amount of content (that is available) loaded from central CDN servers. 2. Once the train's 5G modem is connected to the 5G base station at the train station, latest content (content

		which the Edge server has not been updated with) starts being transferred from the MEC server of the train station to the Edge server of the train with a very high data rate, so as to transfer the highest possible volume of content on the train. 3. The data transfer is performed for the complete time period that the on-board 5G modem is connected to the 5G base station; i.e. as the train approaches the train station, during the time the train stops at the train station and as the train leaves the station. 4. The amount of data received is measured along with the time that connectivity is available between the on-board 5G modem and 5G access node at the train station.
Measurements	Methodology	• Steps 1-4 will be performed at least once • At least 10 GB of data should be transferred to the train server during the train's stop in order to be acceptable and sufficient. • For the evaluation of the various time indicators, service layer messages and network layer messages will be captured with their timestamp (from message flows or database fields). • For the evaluation of the connectivity indicators, data reception timestamps (from message flows or database fields) along with information on associated data volumes will be captured.
	Complementary measurements	1. While performing steps 1-4, radio network quality measurements (RSSI/RSRQ) will be collected along with the UE/train position and timestamps. 2. While performing steps 1-4, real time data rate measurements may be also collected. 3. Traffic conditions are also monitored and noted in each iteration.
	Calculation process	1. The time between an operation request and response is calculated – timestamps from the service and network layer messages are used for the calculations. (e.g. update request, update success, etc.). For the "Edge cache update time" the time at which the application session is running will be calculated. 2. For each set of tests/ iterations (for the specific conditions), the mean/ median/ max./ min "Available edge cache update times" will be calculated. 3. Connectivity - related indicators, such as data rate, will be measured by the duration of the edge cache update session and the amount of data received. 4. For each set of tests/ iterations (for the specific conditions) the mean/ max./ min received data and data rate values will be calculated.
Expected Result	Latest and non-received (since last update) content pushed on Edge Cache in the train, with duration values longer than the travel time until the next train stop. At least 10 GB of data should be transferred to the train server during the train's stop in order to be acceptable and sufficient.	

4.2.6 MCDv05: Content distribution to passengers onboard

This test case, see Table 4-5, will examine: connection of the passengers to ICOM's CDN application, selection of their preferred VoD/live content, distribution of the content to the passengers and the streaming continuation during the trip. The desired result of the test case would be to have enough Wi-Fi capacity to support the maximum number of passengers that can travel on the train and enough content stored onboard so that no streaming interruptions occur.

Table 4-5 MCDv05: Content distribution to passengers onboard

MCDv05	**Content distribution to passengers onboard**	
Testbed	**5G-VINNI Patras [4]**	
Description	This test case focuses on verifying that the train passengers connect successfully to the ICOM CDN application and can select their content of preference to watch. We need to ensure that the on-board Edge server, which has stored the result of the data shower during its stop at the station, serves the passengers by streaming their selected content through an on-board Wi-Fi AP.	
Key Use-case requirements and KPIs	**U-PE-6212:** Uninterrupted streaming of high-quality videos or TV content to train passengers (TL1a)	
Network performance requirements and KPIs	**Network KPIs** Wi-Fi data rate per passenger: ~15Mbps (TL1a)	
Network Functional requirements and KPIs	**U-FU-6313:** The number of users able to be served must be at least equal to the total train capacity	
Components and Configuration	Components	• 5G Base station & MEC server available at train station • Content provider's niche End-Point (Transcoder) deployed • 4K VoD/live content to be streamed • Central CDN server / Content receiver at UoP • Edge server available in train • 5G modem available in train • Wi-Fi AP available in train • Passengers' mobile devices • ICOM CDN app available on the mobile devices
	Configuration	Network deployment shall be performed as depicted in Figure 4-3. The ICOM CDN SW modules are deployed on MEC and Edge servers as in MCP02 and MCP03. • The on-board Edge server is configured both with an on-board 5G modem (in order to allow the latter to communicate with the 5G base station at train station) and with a Wi-Fi AP for the passengers to connect to it. • The ICOM CDN app is installed in passengers' UEs as it is the interface to select content of preference.

		• Ping/ iperf of other datarate measuring tools are available at passenger UEs. • An application layer message capturing tool is set up. • Radio interface measurement tool shall be available at other UEs - for comparison purposes. • A traffic monitoring tool may also be set up.
Test procedure	Pre-conditions	1. CDN SW components are up and running. 2. End-user Application is running on all devices. 3. End user connectivity through on-board Wi-Fi AP is verified. 4. Definition of initial position of the test. 5. Definition of traffic conditions of access network node.
	Test Case steps	1. The passengers is onboard already or boards the train once it stopped at the station. They connect to an on-board Wi-Fi. 2. They open the CDN app and navigate through the interface in order to select the content they would like to watch. 3. The passenger(s) select(s) the preferred content, and the Edge server starts streaming the selected content to the passenger through the Wi-Fi. 4. The train departs, connectivity between 5G modem and gNB is lost at some point. 5. However, the UE continues to receive content from Edge Server for some time. 6. The time between the loss of connectivity and the loss of app content is measured. 7. The total time between the request for content and loss of app content is measured. 8. The continuity of content streaming is constantly monitored throughout the trip from one station to another, for each passenger/UE.
Measurements	Methodology	• At least 1 iteration of the test case (i.e. one trip between two stations). • At least 2 passengers (watching different content - VoD or live content). • ~15 Mbps Wi-Fi capacity per passenger • For the evaluation of the various time indicators, service layer messages and network layer messages will be captured with their timestamp (from message flows or database fields). • For the evaluation of the connectivity indicators, data rates will be monitored.
	Complementary measurements	1. Radio network quality measurements (RSSI/RSRQ) will be collected along with the UE/train position and timestamps. 2. While performing steps 3-6, real time data rate measurements may be also collected. 3. Traffic conditions are also monitored and noted in each iteration.

	Calculation process	1. The time between an operation request and response is calculated – timestamps from the service and network layer messages are used for the calculations. For the "viewing time", the time at which the application session is running at passenger UE will be calculated. For each set of tests/ iterations (for the specific conditions) the mean/ median/ max./ min "Viewing times" will be calculated. 2. Connectivity - related indicators, such as data rate, will be measured by supplementary tools installed at UEs. For each set of tests/ iterations (for the specific conditions), the mean/ max./ min received data and data rate values will be calculated. 3. Additionally, other application layer KPIs such as session setup times, etc. will be calculated using timestamps of the service and network layer messages.
Expected Result	Uninterrupted VoD or time-shifted high-quality content streamed to the UEs of train passengers. At least 2 passengers (one watching VoD and the other watching live content). ~15 Mbps Wi-Fi datarates per passenger for smooth 4K streaming. Approximately 15 min viewing time between loss of connectivity and loss of app content is needed onboard.	

4.2.7 MCSv01: 360° camera Scenario Initialization

The first test case of the MCSv test cases group, see Table 4-6, concerns the initialization of the components that will facilitate the scenario deployment over the 5G-VINNI [4] facility, as well as the verification and evaluation of the connectivity between these and the end-to-end connectivity across all components. It is important to achieve a low deployment time of the involved components, leading to quick deployment of the application in general, and this test case facilitates this verification.

Table 4-6 MCSv01: 360° camera Scenario Initialization

MCSv01	**360° camera Scenario Initialization**
Testbed	**5G-VINNI Patras [4]**
Description	The initial test case aims at setting up the scenario in terms of deployment, slicing and connectivity. It will verify and evaluate the end-to-end connectivity across all components. Focus will be put on the evaluation of aspects related to data rate and latency achieved between the various interfaces, to ensure that an eMBB and a uRLLC slice can be supported.
Key Use-case requirements and KPIs	**U-PE-6213 & U-PE-6214:** Very high data rates for high resolution video transmission from 360° camera to the receiving control center **U-PE-6215 & U-PE-6216:** Very low latency for lower resolution video streams transmission from 360° camera to the receiving control centre.
Network performance requirements and KPIs	**Network KPIs:** Low deployment time of scenario components. Deployment time should be as low as 90 min. (TL1) Data rate between Camera server and Camera receiver: 50-100 Mbps Latency between Camera server and Camera receiver: up to 20 ms
Network Functional	**U-FU-6314 & U-FU-6315:** Very high data rates between 360° camera server and camera client/receiver.

requirements and KPIs	**U-FU-6316 & U-FU-6317:** Very low latency for lower resolution video streams transmission from 360° camera to the receiving control centre.	
Components and Configuration	Components	• 5G Base station available at train station • 5G modem available at train station • 4K 360° camera at train station • Camera server (PC/Laptop) at train station • Camera Client (Windows PC) at UoP • gNB at UoP • 5G modem available at UoP
	Configuration	• Network deployment shall be performed as depicted in Figure 4-4 Figure 4-4. • The 360° camera will be configured to communicate with the camera server to send the streams for optimization • The camera server will be configured to communicate with the 5G modem at train station • The camera client will be configured to communicate with the 5G modem at UoP • Ping between components shall be enabled • iperf or other data rate measuring tool shall be available and configured to be able to take measurements between the component interfaces.
Test procedure	Pre-conditions	Connectivity shall be available across all infrastructure components of Figure 4-4, that is: • Connectivity shall be ensured between the 360° camera/camera server and the 5G Core at UoP (via 5G-VINNI 5G mobile network, specifically via the gNB and the 5G modem deployed at the train station). • Connectivity shall be ensured between the camera client and the 5G Core at UoP (via 5G-VINNI 5G mobile network),
	Test Case steps	Once all the components are deployed: 1. Ping requests and data rate measurements are performed between all components/interfaces. Connectivity is verified and the RTT/latency measurements are noted. 2. iperf sessions requests are performed between all components/interfaces. Connectivity is verified and the data rate measurements are noted.
Measurements	Methodology	**For step 1**: Ping tests are performed between the interfaces of the application. **For step 2**: Data rate (iperf) tests are performed between the interfaces of the application.
	Complementary measurements	Not relevant for this test case

	Calculation process	**For step 1**: For each set of ping tests between interfaces, the mean/ median/ max./ min latency values (in ms) will be calculated. **For step 2**: For each set of tests/ iterations between interfaces, the mean/ max./ min data rate values (Mbps) will be calculated.
Expected Result	Initial operation and connectivity verification. Smooth & quick onboarding and deployment of scenario components. Total time of components' on-boarding and deployment shall be <90min. Connectivity between CDN components shall either be pre-configured or configured within the 90min timeframe. End-to-End connectivity is verified.	

4.2.8 MCSv02: 360° camera HQ streaming

After completing MCSv01, the required components to support the scenario are verified to be functional. As described in Table 4-7, the scope of MCSv02 is to ensure that the camera footage is being streamed in high quality to a camera operator when the field-of-view (FoV) is stable.

Table 4-7 MCSv02: 360° camera HQ streaming

MCSv02	**360° camera HQ streaming**	
Testbed	**5G-VINNI Patras [4]**	
Description	This test case will examine the camera HQ footage streaming to a camera operator when the FoV is stable. The aim is to ensure that the operator receives the footage in HQ when he is not rotating the FoV.	
Key Use-case requirements and KPIs	**U-PE-6213 & U-PE-6214:** Very high data rates for high resolution video transmission from 360° camera to the receiving control center	
Network performance requirements and KPIs	**Network KPIs** Data rate between Camera server and Camera receiver: ~ 50-100 Mbps (TL1a,b)	
Network Functional requirements and KPIs	**Requirements** **U-FU-6314 & U-FU-6315:** Very high data rates for high resolution video transmission from 360° camera to the receiving control center **U-FU-6316 & U-FU-6317:** Very low latency for lower resolution video streams transmission from 360° camera to the receiving control center **KPIs** Network slicing	
Components and Configuration	Components	• 5G Base station available at train station • 5G modem available at train station • 4K 360° camera at train station • Camera server (PC/Laptop) at train station • Camera Client (Windows PC) at UoP • 5G-NR connectivity at UoP • 5G modem available at UoP
	Configuration	• Network deployment shall be performed as depicted in Figure 4-4.

		• The 360° camera will be configured to communicate with the camera server to send the streams for optimization • The camera server will be configured to communicate with the 5G modem at train station • The camera client will be configured to communicate with the 5G modem at UoP • iperf or other data rate measuring tool shall be available and configured to be able to take measurements between the component interfaces.
Test procedure	Pre-conditions	Connectivity shall be available across all infrastructure components of Figure 4-4 Figure 4-4, that is: • Connectivity shall be ensured between the 360° camera/camera server and the 5G Core at UoP (via 5G-VINNI 5G mobile network, specifically via the gNB and the 5G modem deployed at the train station) • Connectivity shall be ensured between the camera client and the 5G Core at UoP (via 5G-VINNI 5G mobile network)
	Test Case steps	1. The 360° camera continuously sends the 360° streams to the camera server in both high and lower qualities. These streams are sent to the other end via the 5G network through two concurrent network slices; one eMBB for the high quality stream and one uRLLC for the lower quality stream. 2. The camera operator selects a FoV to receive. 3. The preferences are communicated to the server and the operator starts getting served with the footage in high quality by the eMBB slice.
Measurements	Methodology	For step 3: • Monitor the eMBB stream on the camera operator's screen for at least 20 sec. • Data rate (iperf) tests are performed between the interfaces of the application.
	Complementary measurements	
	Calculation process	For step 3: For each set of tests/ iterations between interfaces, the mean/ max./ min data rate values (Mbps) will be calculated.
Expected Result	Angle of view displayed in high quality on the camera operator's screen.	

4.2.9 MCSv03: 360° camera FoV rotation

The test case described in Table 4-8 is necessary to verify the smoothness in the camera footage watched by the operator and the motion sickness avoidance when he changes the angle of view.

Table 4-8 MCSv03: 360° camera FoV rotation

MCSv03	**360° camera FoV rotation**
Testbed	**5G-VINNI Patras [4]**

<table>
<tr><td>Description</td><td colspan="2">This test case will examine the camera FoV rotation from the camera operator. The aim is to ensure that while the operator rotates the FoV, he receives the footage of the new angles without motion sickness, until the angle is stable again (he stops rotating).</td></tr>
<tr><td>Key Use-case requirements and KPIs</td><td colspan="2">U-PE-6215 & U-PE-6216: Very low latency for lower resolution video streams transmission from 360° camera to the receiving control center (TL1a/b)

U-FU-6318: Video continuity when switching to a new FoV during head motion, for smooth and seamless transition from high to lower resolution video and vice versa. (TL1a/b)</td></tr>
<tr><td>Network performance requirements and KPIs</td><td colspan="2">Network KPIs

Latency between Camera server and Camera receiver: up to 20 ms</td></tr>
<tr><td>Network Functional requirements and KPIs</td><td colspan="2">Requirements

KPIs

Network slicing</td></tr>
<tr><td rowspan="2">Components and Configuration</td><td>Components</td><td>• 5G Base station available at train station
• 5G modem available at train station
• 4K 360° camera at train station
• Camera server (PC/Laptop) at train station
• Camera Client (Windows PC) at UoP
• 5G-NR connectivity at UoP
• 5G modem available at UoP</td></tr>
<tr><td>Configuration</td><td>• Network deployment shall be performed as depicted in Figure 4-4.
• The 360° camera will be configured to communicate with the camera server to send streams for optimization.
• The camera server will be configured to communicate with the 5G modem at train station.
• The camera client will be configured to communicate with the 5G modem at UoP.
• iperf or other data rate measuring tool shall be available and configured to be able to take measurements between the component interfaces.</td></tr>
<tr><td rowspan="2">Test procedure</td><td>Pre-conditions</td><td>Connectivity shall be available across all infrastructure components of Figure 4-4, that is:

• Connectivity shall be ensured between the 360° camera/camera server and the 5G CoreatUoP (via 5G-VINNI 5G mobile network, specifically via the gNB and the 5G modem deployed at the train station)
• Connectivity shall be ensured between the camera client and the 5G CoreatUoP (via 5G-VINNI 5G mobile network).
• The camera operator is already watching a specific FoV on his screen in high quality, after having completed MCSv02.</td></tr>
<tr><td>Test Case steps</td><td>1. The 360° camera continuously sends the 360° streams to the camera server in both high and lower qualities. These streams are sent to the other end via the 5G network through two concurrent network slices; one eMBB for the high quality stream and one uRLLC for the lower quality stream.</td></tr>
</table>

		2. The camera operator uses the mouse to rotate the FoV he is watching, and shall continue rotating for a while. During the rotation, he starts getting served by the uRLLC slice with the footage in lower quality but with very low latency, in order to have no gaps between the consecutive images. 3. The camera operator stops the rotation at a specific FoV. He then starts again, getting served by the eMBB slice with the footage in high quality.
Measurements	Methodology	• Steps 2-3 will be performed for at least 2 times. • Step 3 (FoV stability) will have at least 20 sec duration before repeating the test case steps. • -ata rate (iperf) tests are performed between the interfaces of the application.
	Complementary measurements	
	Calculation process	For steps 2 and 3: For each set of tests/ iterations between interfaces, the mean/ max./ min data rate values (Mbps) will be calculated.
Expected Result	FoV is displayed with low latency in lower quality in camera operator's screen during rotation, and in high quality once it is stabilized.	

5 Digital Mobility at the 5G-VICTORI facility in Alba Iulia

5.1 Description

Digital mobility is one of 5G-VICTORI's UCs, as an extension of 5G-EVE [6] (ICT 17) capabilities, hosted in Alba Iulia Municipality (**AIM**) with the objective to increase the safety and comfort of passengers. The UC developed in AIM, together with the Public Transportation Company and with Orange Romania (**ORO**) support is structured around two components: infotainment and public safety.

The infotainment is provided through a captive portal in public buses, via on-board Wi-Fi and 5G backhauling. The captive portal provides authentication for Internet services but also integrates on the landing page information from different sources (weather, general information about Alba Iulia, etc.).

For public safety three surveillance cameras are deployed on the buses, connected over Ethernet to the 5G router. The information from the CCTV cameras is processed by the edge computing node which is installed in the bus (experimental) or in one ORO site. The purpose of the processing is to detect one of the following cases: (1) lost item; (2) violence in bus; (3) health issue with one of the passengers; (4) passenger falling in an emergency break. Once one of these cases is identified, a secured and guaranteed connection is opened towards AIM Command and Control Center (CCC), alerting it about the incident and providing a live connection to the bus cameras. This enables the authorities to intervene by allocating the appropriate resources for the emergency situation identified.

Two of three cameras are used to monitor the mobility of passengers inside the bus in order to detect lost items or violence or health issues. The images are transmitted towards MEC and Analytics application with a frequency of 5 frames per seconds. If one of the aforementioned cases is detected a trigger is sent to the CCC to take proper measurements and to announce it to the competent authorities. The third camera collects images from the front side of the bus (Figure 5-2).

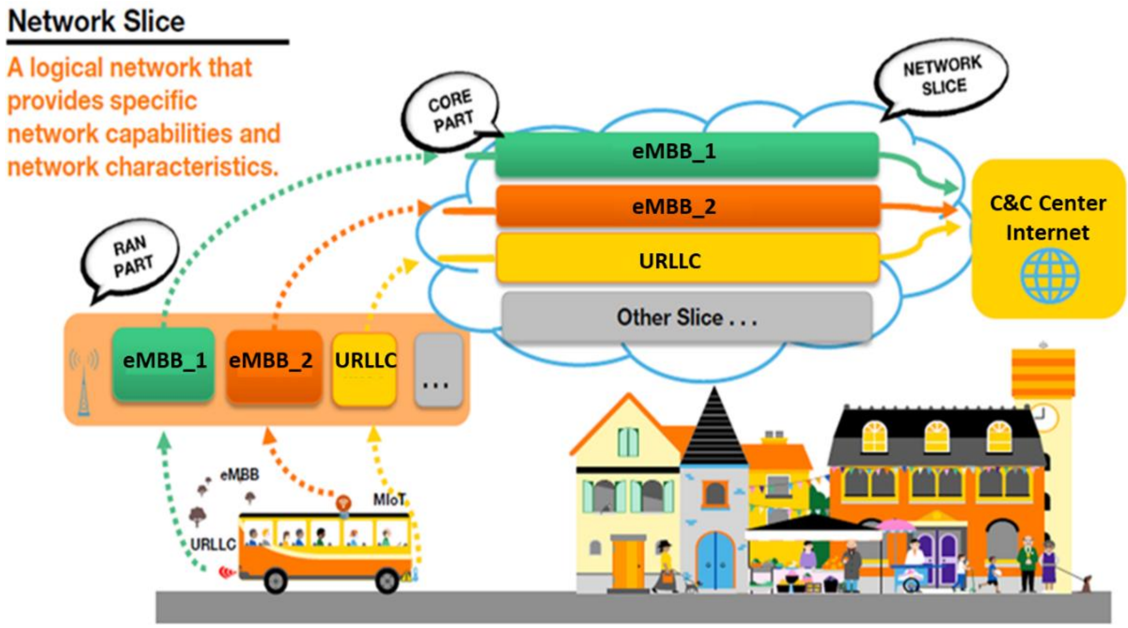

Figure 5-1 5G network slicing in the Bus

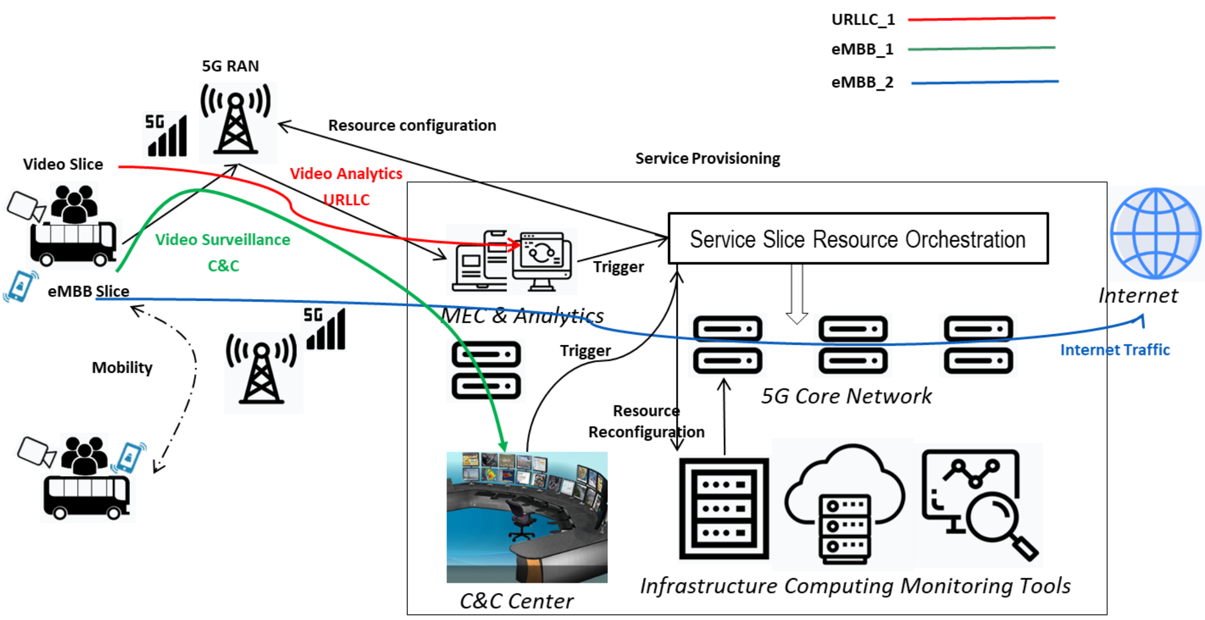

Figure 5-2 Network slice configuration

The infrastructure deployed in the bus comprises:

1. One 5G router providing Wi-Fi connectivity in bus and also Ethernet connectivity for connecting the CCTV cameras
2. Three CCTV cameras with Full HD resolution and a bitrate of 3-5 Mbps
3. Accelerometer and GPS positioning system
4. Edge computing node (some experiments will be performed with an edge computing node with limited processing capabilities).

In terms of network configuration, as depicted in Figure 5-2, three slices need to be provisioned in the 5G network (access & core part):

1. eMBB_1 slice transporting Wi-Fi traffic for the interactive services (Internet traffic)
2. eMBB_2 slice transporting video traffic from the video cameras towards the Command & Control Center
3. URLLC slice for the emergency services transporting the critical traffic (signaling traffic when an exceptional situation is detected in the bus).

The following describes the architecture of the UC shown in Figure 5-3. The UC is deployed on a multi-domain and multi-orchestrator network infrastructure provided by the 5G-EVE [6] project through a 5G-VICTORI portal named 5G-VIOS (VICTORI Infrastructure Operating System). Via this platform the vertical related user can register, deploy, experiment and monitor/evaluate the UCs. The French cluster of the 5G-EVE project [6] has been extended to Romania with another two site facilities: Bucharest and Alba Iulia. The aforementioned portal is deployed in Bucharest, connected via an IPSec tunnel with Chatillon cluster.

The architecture of the solution contains another four components:

1. Front-end – comprises the 5G UEs (installed on the bus) necessary to provide passengers with access to the municipality portal and the internet, also to transport the images from video cameras towards MEC & Analytics server
2. 5G RAN – the USRPs are installed at the Alba Iulia location nearby bus route, offering 5G coverage to the 5G routers

3. AIM Edges – the 5G Core Network components along with Mobile Edge Computing where the AI/Recognition application is deployed in order to analyze the CCTV video streaming using training data sets
4. Back-end – hosts the captive portal which provide surveys, alerts, information, user authentication, hosts the streaming services offered to passengers.

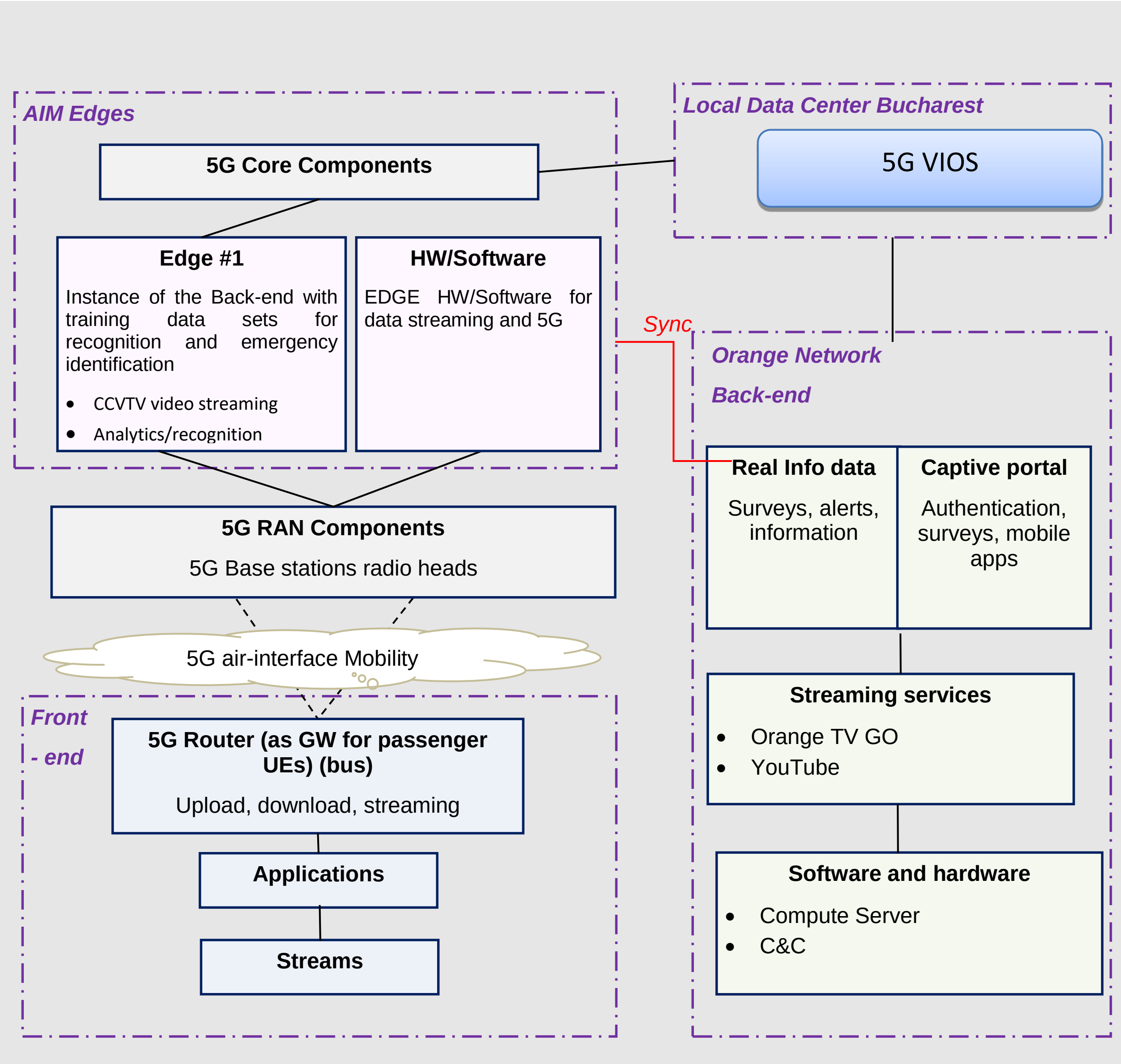

Figure 5-3 Digital Mobility in Alba Iulia: Infotainment and Video Services/AI recognition and identification of emergency situation

5.2 Infotainment/ Video Services in Dense, Static and Mobile Environment Test Cases

5.2.1 Description

Two test cases are developed in order to verify the functionality of the infotainment component:

1. to check the authentication process provided through the captive portal
2. to check the interconnection with different data sources offering the access of the passengers to media services, tourist information and public surveys via Wi-Fi AP provided by a 5G UE GW router.

5.2.2 MDIe01: User authentication using captive portal

The aim of this test case described in Table 5-1 is to check the user authentication process using the captive portal. The UE attaches to SSID Wi-Fi from the bus, is redirected to the portal which is offering administration information such as surveys, local news and tourism ads. For free internet access an authentication procedure based on MSISDN is performed, the traveler inputs the number on the captive portal, receives a code by SMS, which can be used in the portal for gaining free internet access.

Table 5-1 MDIe01: User authentication using captive portal

<table>
<tr><th>MDIe01</th><th colspan="2">User authentication using captive portal</th></tr>
<tr><td>Testbed</td><td colspan="2">5G-EVE Alba Iulia [6]</td></tr>
<tr><td>Description</td><td colspan="2">The purpose of this test-case is to check the user authentication steps (user connected over Wi-Fi for Internet access over the MBB slice)</td></tr>
<tr><td>Key Use-case requirements and KPIs</td><td colspan="2">Not relevant</td></tr>
<tr><td>Network performance requirements and KPIs</td><td colspan="2">Not relevant</td></tr>
<tr><td>Network Functional requirements and KPIs</td><td colspan="2">eMBB slice is enabled in the network. No specific KPIs needed.</td></tr>
<tr><td rowspan="2">Components and Configuration</td><td>Components</td><td>1. One laptop/tablet
2. Wi-Fi AP
3. Wi-Fi portal
4. eMBB slice configured over 5G network</td></tr>
<tr><td>Configuration</td><td>1. One laptop/tablet is connected to the Wi-Fi AP;
2. After the successful authentication, the user can browse the Internet.
3. The backhaul of the Wi-Fi AP is assured over the eMBB slice.</td></tr>
<tr><td rowspan="2">Test procedure</td><td>Pre-conditions</td><td>Connectivity shall be ensured across the Network deployment depicted in Figure 4-1 4-2.
The Bus shall be in the 5G network coverage.
The user phone number shall be registered to the 5G network.</td></tr>
<tr><td>Test Case Steps</td><td>1. The laptop/tablet connects to the Wi-Fi SSID from the bus
2. The user is redirected towards the authentication page (captive portal)
3. On the portal there is diverse information shown (news from the city, sightseeing, etc)
4. The user can request free Wi-Fi: (a) introduces his/her phone number, (b) receive an SMS with the code.
5. Using the phone number and code, the user can authenticate on the portal and gain free Wi-Fi access.</td></tr>
<tr><td rowspan="3">Measurements</td><td>Methodology</td><td>N/A</td></tr>
<tr><td>Complementary measurements</td><td>N/A</td></tr>
<tr><td>Calculation process</td><td>N/A</td></tr>
<tr><td>Expected Result</td><td colspan="2">The user is redirected towards the captive portal; the user can request free Wi-Fi access; the user successfully authenticates on the portal and can browse the Internet.</td></tr>
</table>

5.2.3 MDIe02: Captive portal data availability

The scope of the test case in Table 5-2 is to check the successful integration of the portal with different content sources. The portal should contain information from multiple data sources, all of equal importance from municipality point of view. Another objective of the test case is to measure the time necessary to display the requested information, the backhaul of the Wi-Fi AP being an eMBB slice.

Table 5-2 MDIe02: Captive portal data availability

<table>
<tr><th>MDIe02</th><th colspan="2">Captive portal data availability</th></tr>
<tr><td>Testbed</td><td colspan="2">5G-EVE Alba Iulia [6]</td></tr>
<tr><td>Description</td><td colspan="2">The captive portal integrates various data sources to provide relevant information to the users. In this test we check that portal loads all the necessary data (from selected data sources) and measure the loading times.</td></tr>
<tr><td>Key Use-case requirements and KPIs</td><td colspan="2">Browsing time (latency) – time to display the requested information <3s; Service availability>99%</td></tr>
<tr><td>Network performance requirements and KPIs</td><td colspan="2">Not relevant, the KPIs are measured at application level for this use-case.</td></tr>
<tr><td>Network Functional requirements and KPIs</td><td colspan="2">eMBB slice is enabled in the network. No specific KPIs needed.</td></tr>
<tr><td rowspan="2">Components and Configuration</td><td>Components</td><td>1. One laptop/tablet
2. Wi-Fi AP
3. Wi-Fi portal
4. eMBB slice configured over 5G network
5. One synthetic monitoring tool.</td></tr>
<tr><td>Configuration</td><td>1. Connectivity shall be ensured across the Network deployment depicted in Figure 4-1 4-2.
2. The Bus shall be in the 5G network coverage.
3. One laptop/tablet is connected to the Wi-Fi AP.
4. The backhaul of the Wi-Fi AP is assured over the eMBB slice.
5. One synthetic monitoring tool (software) is installed on the laptop/tablet. In the synthetic monitoring tool a predefined test is configured to measure how fast the information loads on the captive portal. Once executed, the test runs with a periodicity of 5 min. The duration of the test is maximum 1 minute.</td></tr>
<tr><td rowspan="2">Test procedure</td><td>Pre-conditions</td><td>N/A</td></tr>
<tr><td>Test Case Steps</td><td>1. The laptop/tablet is connected to the Wi-Fi AP.
2. The synthetic monitoring test is executed over 24 hours.
3. The results of the loading times are registered by the synthetic monitoring tool.</td></tr>
<tr><td>Measurements</td><td>Methodology</td><td>The synthetic monitoring test is started and executed over a duration of 24 hours. The synthetic monitoring tool registers the results of the loading times for each of the data sources integrated with the captive portal.

When the loading times exceeds a threshold (5s) for one data source, the test is marked as unsuccessful for that specific data source.

The synthetic monitoring tool presents the following results:</td></tr>
</table>

		1. min/average/max loading times for each of the data sources 2. Total number of unsuccessful tests for each data source 3. Total number of successful test for each data source
	Complementary measurements	N/A
	Calculation process	Browsing time is calculated as an average of the "average loading times" (for all data sources) for all the successful tests Service availability is calculated as: Total number of successful tests (for all data sources) divided by the total number of tests (for all data sources).
Expected Result	The KPIs are achieved.	

5.3 Prioritized Communication to Command and Control Center Test Cases

5.3.1 Description

The Digital Mobility Public Safety UC is using three network slices for three different “clients” with different quality of service needs: one eMBB slice for infotainment, one eMBB slice to convey the video for analytics and one URLLC slice used to trigger the threats alarm. Four test cases are defined:

1. To check the stability of an e2e connectivity over one slice
2. To test the prioritization of resource allocation on radio part when 2 of 3 slices are using the maximum needed bandwidth
3. To test the deployment of all network slices
4. To test the connectivity over interactive slice to the CCC, over Wi-Fi AP, testing also the DNS resolution.

5.3.2 MDCe01: Establishment of basic E2E connectivity over a specific slice

The scope of this test case is to verify the establishment of E2E connectivity over an interactive eMBB slice for a tablet which is already authenticated on the portal towards the Control and Command Centre server, using ping and traceroute. As described in Table 5-3, to also verify the FQDN function, necessary to browse over the internet, the server of the CCC will be checked with ICMP protocol having as attribute the IP or the URL of the server.

Table 5-3 MDCe01: Establishment of basic E2E connectivity over a specific slice

MDCe01	**Establishment of basic E2E connectivity over a specific slice (user->Wi-Fi AP -> 5G backhaul -> Internet/specific destination)**	
Testbed	**5G-EVE Alba Iulia [6]**	
Description	Test device connected over Wi-Fi, authenticated to the network. One slice configured in the network. Ping is working from test device towards one test IP (Command & Control or other)	
Key Use-case requirements and KPIs	Not relevant (as basic connectivity is tested)	
Network performance requirements and KPIs	Not relevant	
Network Functional requirements and KPIs	Testing e2e connectivity over the eMBB preconfigured slice, no specific KPIs defined	
Components and Configuration	Components	1. One laptop 2. Wi-Fi AP 3. eMBB slice configured over 5G network.

	Configuration	1. One laptop/tablet is connected to the Wi-Fi AP.
Test procedure	Pre-conditions	1. Connectivity shall be ensured across the Network deployment depicted in Figure 4-1 4-2. 2. The Bus shall be in the 5G network coverage. 3. The laptop is already authenticated to the Wi-Fi AP 4. The Wi-Fi AP connected on uplink to the 5G network on the eMBB slice
	Test Case Steps	1. On the eMBB slice the laptops should have access to the Command & Control. 2. In order to test this from the laptop a ping & traceroute are executed: a. towards the IP of the Command & Control server b. towards the URL of the Command & Control servers
Measurements	Methodology	ICMP messages sent towards IP and URL of the C&C servers. Check if the procedure is successful. If it is failed the traceroute procedure is used to identify the break point
	Complementary measurements	N/A
	Calculation process	N/A
Expected Result	The ping towards the IP of the Command & Control server works. The ping towards the URL of the Command & Control server works (meaning that also the URL is resolved by the DNS service).	

5.3.3 MDCe02: Establishment of advanced E2E connectivity over three different slices with different QoS metrics configured

This test case checks the deployment of three different network slices having three different quality of service metrics: one slice for interactive service, one slice to transport video and one slice with URLLC capability. For each slice one tablet or laptop is used, measuring the performance of the network (bandwidth, jitter, latency) through iperf application.

Table 5-4 MDCe02: Establishment of advanced E2E connectivity over three different slices with different QoS metrics configured

MDCe02	**Establishment of advanced E2E connectivity over three different slices with different QoS metrics configured**
Testbed	**5G-EVE Alba Iulia [6]**
Description	Three slices configured in the network. Connect test devices over 5G radio and test connectivity over each slice towards test IP. This use-cases also checks the different slices creation
Key Use-case requirements and KPIs	N/A

Network performance requirements and KPIs	• Network slice capabilities/management (Yes/No); • E2E latency for interactive service (in ms) <30ms; • E2E latency for public safety service (in ms)<5ms; • High bandwidth required for data intensive public safety applications and HD video streaming>20Mbps; • Jitter for URLLC <1ms	
Network Functional requirements and KPIs	• Network slice capabilities/management (Yes/No)	
Components and Configuration	Components	1. Three laptops/tablets, 2. Wi-Fi AP 3. Three slices configured over 5G network: URLCC, eMBB, eMBB_2 (video for analytics).
	Configuration	1. Three laptops/tablets are connected to the three different slices: for eMBB the connection is performed over the Wi-Fi AP, for eMBB_2 & URLCC the connection is performed directly over 5G using SIM. 2. The three slices are configured in the 5G network with the needed QoS. 3. On each of the three laptops/tablets iperf is activated for measuring network performance (bandwidth, latency and jitter)
Test procedure	Pre-conditions	1. Connectivity shall be ensured across the Network deployment depicted in Figure 4-1 4-2. 2. The Bus shall be in the 5G network coverage. 3. No congestion in the network (5G or Wi-Fi) 4. A test server with IP addresses on each of the slices
	Test Case Steps	1. Configure the three slices 2. Attach devices on each of the three slices 3. Check that successful network connectivity is in place for all the slices (ping/traceroute towards the specific IP addresses of the test server) 4. Run iperf tests (as per methodology), write down results
Measurements	Methodology	1. Check if all three slices are up 2. The iperf is performed utilizing a test server with connectivity within all the three slices. 3. Three tests are performed on all the slices simultaneously (one test/slice). On the 2 eMBB slices, the traffic flow is configured with a bandwidth of 25 Mbps. For the URLCC slice, the traffic flow is configured with a bandwidth of 100kbps. 4. The tests are repeated three times, resulting in a total number of 9 tests. 5. The KPIs have to be achieved for each of the tests.
	Complementary measurements	N/A
	Calculation process	N/A
Expected Result	The three slices are successfully configured. Connectivity is up and running over the three slices. The KPIs are achieved.	

5.3.4 MDCe03: Load test for observing the QoS prioritization among slices with congestion on radio part

Once the threat alarm is triggered, the CCC operator needs to access cameras images from the bus to decide what further emergency measures to be taken. In that respect, the QoS of the slices with guaranteed bandwidth and low latency must be fulfilled. To test this scenario (see Table 5-5), the radio cell is congested pushing traffic through all three slices, checking if the critical services are prioritized against the interactive ones.

Table 5-5 MDCe03: Load test for observing the QoS prioritization among slices with congestion on radio part

MDCe03	**Load test for observing the QoS prioritization among slices with congestion on radio part**	
Testbed	**5G-EVE Alba Iulia [6]**	
Description	Iperf_1 connected over eMBB slice. Congest radio cell by pushing traffic. Iperf_2 connected over slice eMBB_2 (dedicated for cameras) push 20M IP traffic. Iperf_3 connected over slice_3 (URLLC) push 100kb stream of traffic. Check QoS parameters for each of the slice.	
Key Use-case requirements and KPIs	Prioritization of slices shall be performed based on slices characteristics.	
Network performance requirements and KPIs	• E2E latency for interactive service (in ms) < 30 ms; • E2E latency for public safety service (in ms) < 5 ms; • High bandwidth required for data intensive public safety applications and HD video streaming > 20 Mbps; • Jitter for URLLC < 1 ms	
Network Functional requirements and KPIs	N/A	
Components and Configuration	Components	1. Three laptops/tablets, 2. Wi-Fi AP, 3. Three slices configured over 5G network: URLCC, eMBB, eMBB_2 (video for analytics).
	Configuration	1. Three laptops/tablets are connected to the three different slices: for eMBB the connection is performed over the Wi-Fi AP, for eMBB_2 & URLCC the connection is performed directly over 5G using SIM. 2. The three slices are configured in the 5G network with the needed QoS. 3. On each of the three laptops/tablets iperf is activated for measuring network performance (bandwidth, latency and jitter)
Test procedure	Pre-conditions	1. Connectivity shall be ensured across the Network deployment depicted in Figure 4-1 4-2. 2. The Bus shall be in the 5G network coverage. 3. Congestion in the 5G radio part by pushing traffic with iperf_1 4. A test server with IP addresses on each of the slices 5. Necessary devices are already registered to the 5G network.
	Test Case Steps	1. Configure the three slices 2. Attach devices on each of the three slices 3. Check that successful network connectivity is in place for all the slices (ping/traceroute towards the specific IP addresses of the test server)

		4. Run iperf tests (as per methodology), write down results
Measurements	Methodology	1. Check if all three slices are up 2. The iperf is performed utilizing a test server with connectivity within all three slices. 3. On eMBB slice, the traffic flow is configured with a bandwidth higher than the total available bandwidth of the 5G cell. 4. Three tests are performed on the 2 slices (eMBB_2 and URLCC) simultaneously (one test/slice). For eMBB_2 the traffic flow is configured with a bandwidth of 20Mbps For the URLCC slice, the traffic flow is configured with a bandwidth of 100kbps. 5. The tests are repeated three times, resulting in a total number of 6 tests. 6. The KPIs have to be achieved for each of the tests
	Complementary measurements	N/A
	Calculation process	Extract from iperf the average, min and max values for throughput and latency, for both slices
Expected Result	The three slices are successfully configured. Connectivity is up and running over the three slices. The KPIs are achieved, meaning that even if the 5G cell is congested with lower priority traffic, the throughput, delay and jitter from the eMBB_2 & URLCC slices is achieved while dropping lower priority traffic.	

5.3.5 MDCe04: Stability test - injecting traffic over one slice for 7 consecutive days

Being a use case in the public safety and security area, the availability and the stability of the services are very important. The following test case described in Table 5-6 measures the performance of the E2E connectivity over one slice for a period of seven days. The interactive slice was chosen to be tested to also check the connectivity via Wi-Fi AP. The expected result is to have network availability over 99.9% and latency lower than 30ms.

Table 5-6 MDCe04: Stability test - injecting traffic over one slice for 7 consecutive days

MDCe04	**Stability test - injecting traffic over one slice for 7 consecutive days**	
Testbed	**5G-EVE Alba Iulia [6]**	
Description	Check the stability of the e2e connection by injecting constant traffic over a 7-day period.	
Key Use-case requirements and KPIs	N/A	
Network performance requirements and KPIs	Network availability>99.9%, E2E latency for interactive service (in ms) <30ms;	
Network Functional requirements and KPIs	N/A	
Components and Configuration	Components	1. One laptop/tablet, 2. Wi-Fi AP, 3. One slice configured (e.g. eMBB)
	Configuration	1. One laptop/tablet is connected to the Wi-Fi network using the eMBB slice as backhaul.

		2. Iperf is activated for measuring network performance (bandwidth, latency and jitter) and Network availability.
Test procedure	Pre-conditions	1. A test server with IP addresses on eMBB slice
	Test Case Steps	2. Configure the eMBB slice 3. Connect the laptop/tablet to the Wi-Fi AP 4. Check that successful network connectivity is in place for the eMBB slice(ping/traceroute towards the specific IP addresses of the test server) 5. Run iperf tests (as per methodology), write down results
Measurements	Methodology	1. The iperf is performed utilizing a test server with connectivity in the eMBB slice. 2. On the eMBB slice, the traffic flow is configured with a bandwidth of 20 Mbps. 3. The test is run for 7 days.
	Complementary measurements	N/A
	Calculation process	Extract from iperf the average, min and max values for throughput and latency, for both slices
Expected Result	The KPIs are achieved	

5.4 AI Recognition and Identification of Emergency Situation Test Cases (UHA application)

5.4.1 Description

The second component of the Digital Mobility UC is Public Safety and Security (section 5.2 in deliverable D2.3 [3]). The aim is to identify threats to the bus passengers such as thefts and healthcare emergency or lost items that can represent potential terrorist dangerous using footage from two cameras installed in the bus, and to allocate on the spot the appropriate infrastructure (dedicated slice) resources requested for the emergency / interventions / first responders' teams to maximize the intervention efficiency. Along with aforementioned emergency situations, the third camera with field of view in front of the bus is used to identify a potential reason for a sudden brake. Therefore, four test cases are developed to check the efficiency of AI algorithms, one for each situation.

The development of AI recognition application comprises the following stages:

- depth assisted pose estimation through different convolutional neural net models, and training data sets
- achieve temporally stable pose tracking from a single camera in varying light conditions
- identify the meaning of poses (sitting, standing, laying on floor)
- track movement
- identify hazardous movements (fall, hit against, violent and sudden), and trigger an alert
- isolate people/human bodies from the imagery, and compare the remaining image areas against pre-stored 'empty bus's captures
- detect new objects (baggage, box, clothing)
- study if the objects can be classified to a certain extent, and if that is viable, or just to track them as objects of any sort

- assign new objects to people (new passengers who potentially bring them on board when boarding)
- track when a pre-assigned passenger leaves the bus but the pre-assigned baggage stays behind, and trigger an alert
- approach extreme cases, when passengers exchange baggage

The main requirement to have a high passenger pose detection accuracy is to create an in-depth map from the camera footage. This will be used to detect the floor's height relative to the camera. The acquired depth coordinates, although often fluctuating due to the ever-changing light conditions, are quasi accurate and in world coordinates (with the camera's eye point being the origin). A basic brush tool is introduced to allow the operator to classify areas within the bus and assign functionality to them: 'entrance', 'floor', 'seating'. Next to the mark up the system acquires 3D data for each area that can be analyzed against the skeleton's positions, headings, and velocities. MDAe01: Passenger fall detection in an emergency brake

One of the events which can occur when travelling on a bus is an emergency brake. In this scope, an accelerometer is used to highlight such an event. To see if there is a consequence of the sudden brake among passengers, possible injured passengers laying on the floor or in any other unusual position, the footage from two video cameras installed inside the bus is analyzed. The third video camera, at the front of the bus, is used to identify the scenario which led to the emergency brake. Table 5-7 describes this test case.

Table 5-7 MDAe01: Passenger fall detection in an emergency break

MDAe01	**Passenger fall detection in an emergency brake**	
Testbed	**5G-EVE Alba Iulia [6]**	
Description	We automatically identify if one or more passengers fall while the bus is decelerating or accelerating beyond a threshold. Then, an alert is triggered accordingly.	
Key Use-case requirements and KPIs	Primary: minimum 75% passenger pose detection accuracy from the video stream. Based on that alerts will be triggered. Secondary: categorizing the remaining 25% of the poses to avoid and/or radically reduce false alerts.	
Network performance requirements and KPIs	Min 10 Mbits/s connection for the camera video streaming with maximum 20 ms latency.	
Network Functional requirements and KPIs	The application needs reliable connectivity and handover between Edge nodes.	
Components and Configuration	Components	1. Working RGB camera. 2. GPU compute capability in the Edge node. 3. UHA people pose detection code for the parallel AI network execution. 4. Accelerometer. 5. Volunteer test passengers.
	Configuration	1. RTX-2080 GPU. 2. UHA pose detector written in C++ and OpenCL/Cuda.
Test procedure	Pre-conditions	1. Test signals both from the camera and the accelerometer shall be sent to the Edge node to verify connectivity. 2. Also the Edge node shall send a test alert to the Backend.
	Test Case Steps	1. Camera stream and accelerometer data are received by UHA's Edge code.

		2. Pose detection starts. 3. In case of a simulated emergency breaking incident passengers falling, laying on the floor or in any other unusual pose are detected and further evaluated. 4. An alert that contains the detection results is sent to ORO's backend server.
Measurements	Methodology	Monitoring frequency is minimum 5 times per second.
	Complementary measurements	The number of falls to be manually counted. That shall be the ground truth data.
	Calculation process	The detection accuracy will be calculated through the comparison of the automatic detections and the ground truth data.
Expected Result	Performance and detection accuracy is expected to fall within the thresholds described above. The aim is to prove that low error fully automated fall detection in an emergency breaking event can be realised in real-time.	

5.4.2 MDAe02: Detection of violence in the bus

Each passenger is detected and marked once he/she boards on the bus and until he/she gets off the bus. The mobility of the skeleton is analyzed, unusually fast movement of the legs or the arms shall be detected using the pre-defined thresholds. As described in Table 5-8 the aim of this test case is to detect violence in the bus.

Table 5-8 MDAe02: Detection of violence in the bus

MDAe02	**Detection of violence in the bus**	
Testbed	**5G-EVE Alba Iulia [6]**	
Description	We are automatically detecting if one or more passengers make sudden body movements (acceleration above threshold value) while the bus is driving normally or is still. Then an alert is triggered accordingly.	
Key Use-case requirements and KPIs	Primary: minimum 75% passenger body motion tracking accuracy from the video stream and follow on pattern recognition that looks for violent body movements. Based on the outcome alerts will be triggered. Secondary: categorizing the remaining 25% of the movements to avoid and/or radically reduce false alerts.	
Network performance requirements and KPIs	Min 10 Mbits/s connection for the camera video streaming with maximum 20 ms latency.	
Network Functional requirements and KPIs	The application needs reliable connectivity and handover between Edge nodes.	
Components and Configuration	Components	1. Working RGB camera. 2. GPU compute capability in the Edge node. 3. UHA people pose detection and movement tracking code for the parallel AI network execution. 4. Volunteer test passengers.
	Configuration	1. RTX-2080 GPU. 2. UHA pose detector and movement tracker written in C++ and OpenCL/Cuda.
Test procedure	Pre-conditions	1. Test signals both from the camera and the accelerometer shall be sent to the Edge node to verify connectivity. Also the Edge node shall send a test alert to the Backend.

	Test Case Steps	2. Camera stream received by UHA's Edge code. 3. Pose detection and motion tracking starts. 4. Unusually fast movement of the legs or the arms shall be detected. Initially through a dedicated and hard coded algorithm that looks for values within pre-set thresholds. Developed by UHA *Potential follow-on/spin out research projects (beyond the scope of 5G-Victori):* • detection of unusual body movements and gesture via deep learning to classify various forms of human activity (ex. fight, smoking, drinking & eating, dance, exercise); • knife, firearm and other sorts of weapons detection. • In case an unusual movement is detected an alert is sent to ORO's backend server.
Measurements	Methodology	Monitoring frequency is 10-15 times per second.
	Complementary measurements	The number of anti-social incidents to be manually counted. That shall be the ground truth data.
	Calculation process	The detection accuracy will be calculated by comparing the automatic detections against the ground truth data.
Expected Result	Performance and detection accuracy is expected to fall within the thresholds described above. The aim is to prove that low error fully automated fall detection in an emergency break event can be realized real-time.	

5.4.3 MDAe03: Health issue with one passenger

This test case (see Table 5-9) is trying to identify a possible health issue with a passenger. If the traveler's head drops under a specific height and the velocity is above the threshold, then is considered as a fall. For this specific person the following are recorded: the 'type' of the incident and the 'timestamp'. A loop through the list of incidents is performed and only unique occurrences are recorded (while a person is on the floor no new record is added).

If the passenger manages to recover (stands up) then depending on the elapsed time since the detection, the incident gets reclassified to 'recovered' or 'recovered but late'. If the person cannot recover at all then the incident gets reclassified to 'serious'.

Table 5-9 MDAe03: Health issue with one passenger

MDAe03	**Health issue with one passenger**
Testbed	**5G-EVE Alba Iulia [6]**
Description	We detect if a passenger falls and does not recover within reasonable time. Then an alert is triggered accordingly.
Key Use-case requirements and KPIs	Primary: minimum 75% passenger pose detection accuracy from the video stream. Based on that alerts will be triggered. Secondary: categorizing the remaining 25% of the poses to avoid and/or radically reduce false alerts.
Network performance requirements and KPIs	Min 10 Mbits/s connection for the camera video streaming with maximum 20 ms latency.

Network Functional requirements and KPIs	The application needs reliable connectivity and handover between Edge nodes.	
Components and Configuration	Components	1. Working RGB camera. 2. GPU compute capability in the Edge node. 3. UHA people pose detection code for the parallel AI network execution. 4. Accelerometer. 5. Volunteer test passengers.
	Configuration	1. RTX-2080 GPU. 2. UHA pose detector written in C++ and OpenCL/Cuda..
Test procedure	Pre-conditions	1. Test signals both from the camera and the accelerometer shall be sent to the Edge node to verify connectivity. Also the Edge node shall send a test alert to the Backend.
	Test Case Steps	2. Camera stream and accelerometer data are received by UHA's Edge code. 3. Pose detection starts. 4. Passengers either falling or in unusual pose not moving for more than a number of seconds shall be detected. 5. Such pose candidates are compared against the accelerometer's data. If the bus didn't go into a sudden break a moment earlier we assume it's no accident but a potential medical emergency and the pose candidates are forwarded to the alerting mechanism. 6. An alert is sent to ORO's backend server.
Measurements	Methodology	Monitoring frequency is minimum 5 times per second.
	Complementary measurements	The number of falls and unusual poses to be manually counted. That shall be the ground truth data
	Calculation process	Detection accuracy will be calculated through the comparison of the automation outcome and the ground truth data.
Expected Result	Performance and detection accuracy is expected to fall within the thresholds described above. The aim is to prove that low error fully automated detection of body poses that might require medical attention can be realised in real-time	

5.4.4 MDAe04: Lost item – detection and alerting

Although AI is quite effective in detecting human bodies and tracking these throughout frames, it is not a 100% reliable method. In bad light conditions (night time) body shadows and reflections can trigger false skeletons to appear in the scene or cause loss of temporal continuity in movement. To avoid this type of errors, each newly detected skeleton is classified as ‘ghost’ and retain each until one boards the bus from the entrance area to the rest of the bus. Then a ghost becomes a ‘passenger’. It is imperative to have visual clarity at the entrances. Through such strict control the algorithm knows the exact number of people on board. If it loses track of a skeleton, it can re-associate it through nearest neighbor search and distance to movement trajectories. This is required to maintain good tracking to associate objects (bags, trollies, coats) to passengers. The test case, described in Table 5-10, will implement the above to detect lost items and issue an alert.

Table 5-10 MDAe04: Lost item – detection and alerting

MDAe04	**Lost item – detection and alerting**
Testbed	**5G-EVE Alba Iulia [6]**

Description	We track passengers as they enter and leave the bus. We also track carried baggage that we link to the passenger's body pose when entering. If the baggage stays on board while the passenger (to whom it has been linked) leaves we trigger an alert.	
Key Use-case requirements and KPIs	Primary: minimum 75% passenger pose and 75% object detection accuracy from the video stream. Based on that alerts will be triggered. Secondary: categorizing the remaining 25% of the poses and objects to avoid and/or radically reduce false alerts.	
Network performance requirements and KPIs	Min 10 Mbits/s connection for the camera video streaming with maximum 20 ms latency.	
Network Functional requirements and KPIs	The application needs reliable connectivity and handover between Edge nodes.	
Components and Configuration	Components	1. Working RGB camera. 2. GPU compute capability in the Edge node. 3. UHA people pose detection code for the parallel AI network execution. 4. Accelerometer. 5. Volunteer test passengers with items.
	Configuration	1. RTX-2080 GPU. 2. UHA pose detector written in C++ and OpenCL/Cuda.
Test procedure	Pre-conditions	1. Test signals both from the camera and the accelerometer shall be sent to the Edge node to verify connectivity. Also the Edge node shall send a test alert to the Backend
	Test Case Steps	1. Camera stream and accelerometer data are received by UHA's Edge code. 2. Pose and object detection starts. 3. Poses are registered as new passenger at the entrance door. If carried objects are detected that are connected to the human body skeleton, then those get registered and linked to the pose's ID. 4. When a tracked pose leaves the bus through the doors but one or more of the linked objects remain on board and alert is triggered and sent to ORO's back-end server.
Measurements	Methodology	Monitoring frequency is minimum 5 times per second.
	Complementary measurements	The number of lost items to be manually counted. That shall be the ground truth data.
	Calculation process	Detection accuracy will be calculated through the comparison of the automation outcome and the ground truth data.
Expected Result	Performance and detection accuracy is expected to fall within the thresholds described above. The aim is to prove that low error fully automated detection of body poses and associated carry items or luggage can be realized in real-time. An extreme case, such as the passenger throws the object from the bus, or in through a window, is not handled.	

6 Conclusions

The 5G-VICTORI partners involved in media services have provided detailed, comprehensive test cases for each service and 5G facility to be used. The overall objective of this activity is to deliver bandwidth-consuming media content in dense and static environments, while in a short period of time, each test case thoroughly examines different components of the 5G-VICTORI infrastructure to ensure this goal.

At the 5G-VICTORI facility in Berlin, a data shower service will be tested as part of UC #3. This service ensures that: passengers can view the full range of the most advanced VoD offerings while connected to the train's Wi-Fi. The available content can be used by all passengers, and collection of playback metrics can allow monitoring of the quality of the service. The 5G infrastructure will allow the full range of content in the VOD library to be cached and transferred to the train at high speed in a short period of time and space. For this service, 6 test cases have been defined:

- MCBg01: Aggregation of relevant content for cache prefilling.
- MCBg02: Pre-Fill Media Content in Station Cache from RBB Catalogue (via public CDN).
- MCBg03: Data Shower High Speed Transport from Station Cache to Train Cache.
- MCBg04: Media Distribution in the Train (via Wi-Fi).
- MCBg05: Collecting of Playback Metrics (using MPEG-SAND)
- MCBg06: Shared Resource Allocation (SRA) in the Train using collected playback metrics and via dedicated Gateway

The test case descriptions are aligned with the Berlin 5G facility descriptions provided in D2.3 [3].

At the 5G-VICTORI facility in Patras, in addition to a data shower service, a 360° camera application will be also trialed. The data shower service ensures that passengers are provided with the most popular live and VoD content while connected to the train's Wi-Fi. For this, five test cases have been identified:

- MCDv01: CDN Application Scenario Deployment
- MCDv02: CDN Connectivity Evaluation
- MCDv03: MEC Periodic Update
- MCDv04: Data shower from MEC to train cache
- MCDv05: Content distribution to passengers onboard

The remote surveillance service enables an operator to control and view video content from a 360° camera in the station. 5G technology enables this service to offer both the low latency and high quality required for a real-time surveillance service. For this service three test cases have been identified:

- MCSv01: 360° camera scenario initialization
- MCSv02: 360° camera HQ streaming
- MCSv03: 360° camera FoV rotation

The test case descriptions are aligned with the Patras facility descriptions detailed in D2.3.

For the Alba Iulia 5G facility three digital mobility media services designed to increase the safety and comfort of passengers have been defined. The key benefits that 5G technology brings on Digital Mobility use case are high service reliability, low latency and full automation operation for both deployment and in-life management. The Alba Iulia facility use case has two major components: the infotainment and the public safety.

There are ten different use cases defined for validating 5G capabilities (eMBB and URLLC) and the associated KPIs at service and network level:

- User Experience Data Rate
- Network Latency Round-Trip
- Service and slice instantiation
- Network Slicing and traffic prioritization
- Analytics Service Reliability.

The purpose of the first two test cases is to validate the user authentication process on the captive portal and measure its availability when in traffic over an eMBB slice.

The next four test cases are defined to show and validate the network slicing capability and associated KPIs (availability, throughput, delay, jitter) of the 5G ecosystem. The use case demonstrated in the Romanian cluster is using three types of slices with different radio access needs:

- 2 x Enhanced Mobile Broadband (eMBB)
- 1x Ultra-Reliable and Low-Latency Communication (URLLC)

One key aspect tested is the capability to prioritize traffic among the slices.

The last four test cases will verify the AI capability of the use case, recognition of emergency situations in the public transportation: violence, fallen passengers, health issues and lost item. The video information collected from the cameras installed in the Bus is transported through 5G prioritized slice and analyzed in the Mobile Edge Computing (MEC) cluster where the Analytics applications are deployed. In case of emergency situation identified by AI algorithms an alarm is triggered for alerting, giving the possibility to Command and Control Center operator to access the images from CCTV cameras in order to dispatch the appropriate interventions team.

The test case descriptions for the aforementioned three services are aligned with the 5G facility description in D2.3 [3].

For all the media services, the partners involved have listed a total of 24 test cases. For each of the test cases included in this document, as much detail as is possible (at this point in time) has been provided and is considered sufficient to allow the tests to be planned and conducted.

As a next step, the test cases described in this document will be conducted in lab environments and/or on-site demos as part of WP4 activities. The results of these tests will feedback into Task 3.3. The individual cases will then be updated to include any results or necessary changes. The final specifications will form the basis of deliverable **D3.4** with a potential to extend the test cases definitions included in this deliverable.

7 References

7.1 General and project-specific references

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

[2] 5G-VICTORI deliverable D2.2, “5G VICTORI Use case and requirements definition and reference architecture for vertical services”, May 2020.

[3] 5G-VICTORI deliverable D2.3, “Final individual site facility planning”, June 2021.

[4] 5G-VINNI “5G Verticals Innovation Infrastructure” ICT-19 Project, Online: https://www.5g-vinni.eu/

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

[6] 5G-EVE “5G European Validation platform for Extensive trials” ICT-17 Project. Online: https://www.5g-eve.eu/

[7] 5GUK Test Networks, University of Bristol 5GUK Test Network, http://www.bristol.ac.uk/engineering/research/smart/5guk/

[8] 5G-VICTORI deliverable D3.4, “Final use case specification for Media Services”

[9] 5G-VICTORI deliverable D4.1, “Field trials methodology and guidelines”, September 2020, https://www.5g-victori-project.eu/wp-content/uploads/2020/10/2020-09-25-5G-VICTORI_D4.1_v1.0_Website_Version.pdf

7.2 Standards references

[10] ETSI EG 202 810 V1.1.1 (2010-03). ETSI Guide. Methods for Testing and Specification (MTS); Automated Interoperability Testing

[11] 3GPP TS 22.104 V18.1.0 (2021-06): Technical Specification Group Services and System Aspects; Service requirements for cyber-physical control applications in vertical domains; Stage 1 (Release 18)

7.3 Other references

[12] ACIA White Paper, Performance Testing of 5G Systems for Industrial Automation, [Online]. Available at: https://5g-acia.org/whitepapers/performance-testing-of-5g-systems-for-industrial-automation-2/. Feb, 2021.

List of Figures

Figure 1-1 Media UCs, Clusters and Services 10
Figure 2-1: Services to be tested and parameters to be evaluated [11] 13
Figure 3-1 VoD Data Shower 17
Figure 3-2 Berlin Central station facility in support of the Berlin UCs, UC #1.2 benefits from 5G connectivity to users throughout the station 17
Figure 3-3 HW and Applications Block Diagram for Media Services 18
Figure 4-1 5G-VICTORI – 5G-VINNI/ Patras CDN Data Shower Scenario 30
Figure 4-2 5G-VICTORI – 5G-VINNI/ Patras Remote Surveillance Scenario 31
Figure 4-3 5G-VICTORI – 5G-VINNI/ Patras CDN Data Shower Scenario Architectural Deployment. 32
Figure 4-4 5G-VICTORI – 5G-VINNI/ Patras Remote Surveillance Scenario Architectural Deployment 33
Figure 5-1 5G network slicing in the Bus 50
Figure 5-2 Network slice configuration 51
Figure 5-3 Digital Mobility in Alba Iulia: Infotainment and Video Services/AI recognition and identification of emergency situation 52

List of Tables

Table 3-1 MCBg01: Aggregation of relevant content for cache prefilling ... 19
Table 3-2 MCBg02: Pre-Fill Media Content in Station ... 20
Table 3-3 MCBg03: Data Shower High Speed Transport from Station Cache to Train Cache ... 22
Table 3-4 MCBg04: Media Distribution in the Train (via Wi-Fi) ... 23
Table 3-5 MCBg05: Collecting of Playback Metrics (using MPEG-SAND) ... 26
Table 3-6 MCBg06: Shared Resource Allocation (SRA) in the Train using collected playback metrics and via dedicated Gateway ... 28
Table 4-1 MCDv01: CDN Application Scenario Deployment ... 33
Table 4-2 MCDv02: CDN Connectivity Evaluation ... 36
Table 4-3 MCDv03: MEC Periodic Update ... 38
Table 4-4 MCDv04: Data shower from MEC to train cache ... 39
Table 4-5 MCDv05: Content distribution to passengers onboard ... 42
Table 4-6 MCSv01: 360° camera Scenario Initialization ... 44
Table 4-7 MCSv02: 360° camera HQ streaming ... 46
Table 4-8 MCSv03: 360° camera FoV rotation ... 47
Table 5-1 MDIe01: User authentication using captive portal ... 53
Table 5-2 MDIe02: Captive portal data availability ... 54
Table 5-3 MDCe01: Establishment of basic E2E connectivity over a specific slice ... 55
Table 5-4 MDCe02: Establishment of advanced E2E connectivity over three different slices with different QoS metrics configured ... 56
Table 5-5 MDCe03: Load test for observing the QoS prioritization among slices with congestion on radio part ... 58
Table 5-6 MDCe04: Stability test - injecting traffic over one slice for 7 consecutive days ... 59
Table 5-7 MDAe01: Passenger fall detection in an emergency break ... 61
Table 5-8 MDAe02: Detection of violence in the bus ... 62
Table 5-9 MDAe03: Health issue with one passenger ... 63
Table 5-10 MDAe04: Lost item – detection and alerting ... 64