Broadcast and Multicast Communication Enablers for the Fifth-Generation of Wireless Systems

Deliverable D6.2

Development of Showcases and Demonstrators

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Editor(s):	Joe Eyles (BBC), Andrew Murphy (BBC), David Vargas (BBC), Jordi J. Gimenez (IRT)
Authors:	Joe Eyles, Andrew Murphy (BBC); Tim Stevens, Rory Turnbull (BT); Duy Kha Chau, Alain-Pierre Brunel (Broadpeak); Roman Odarchenko (Bundeslab); Tuan Tran (Expway); Heikki Kokkinen (Fairspectrum); Jordi J. Gimenez, Swen Petersen, Fabian Sattler, Benedikt Vogel (IRT); Menno Bot (one2many); Tero Jokela (TUAS); De Mi (UniS); Ece Öztürk (NOMOR); Ioannis Selinis (UniS);
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Abstract

This document presents a summary of and plans for the demonstrators developed within the 5G-Xcast project. The most relevant use cases are recapped, and nine demonstrators are presented. Within each demonstrator the concept and relationship to the use cases is first presented, followed by a technical description, and finished by the development plan and a record of the events attended. Some information about the 5G-Xcast Showcase at the European Championships 2018 is also given.

Keywords

5G, showcases, demonstrators, multicast, broadcast, unicast, hybrid broadcast service, low latency, spectrum, multicast on demand, convergence, object-based broadcasting, public warning, multilink.

[1] CO = Confidential, only members of the consortium (including the Commission Services)

PU = Public

Disclaimer

Executive Summary

This document presents the nine demonstrators and a showcase developed within WP6 of the 5G-Xcast project. The sections for each of the nine demonstrators first discuss the concept of the demonstrator itself. This is done in the context of the use cases. The sections then contain a technical description. The development plan is then presented with a timeline. Finally, a record of the events attended by each demonstrator is given. The document is concluded with some information on the 5G-Xcast Showcase at the European Championships 2018.

The demonstrators predominantly cover use cases belonging to the two verticals: Media and Entertainment, and Public Warning. A summary of both the Media and Entertainment Hybrid Broadcast and the Multimedia Public Warning use cases are given in this document. The demonstrators are targeted at selected events (for example EuCNC 2018, IBC 2018, MWC 2019 and EuCNC 2019). Furthermore, a showcase was organized in connection with the European Championships 2018 to demonstrate the Hybrid Broadcast Service.

In Section 2.1 IRT and EBU present their demonstrator, which targets the Media and Entertainment Hybrid Broadcast Service use case. This demonstrator is focused on the delivery of live TV and the access to additional on-demand content on mobile phones and TV-sets.

In Section 2.2 Broadpeak present their multicast Adaptive Bitrate (mABR) demonstrator, which is in collaboration with the Sat5G project from 5G-PPP Phase 2. This demonstrates caching and multicast content/VNF distribution to the edge over satcom, using low latency with mABR Live streaming and OTT Streams Synchronization.

In Section 2.3 Fairspectrum and TUAS present their spectrum management demonstrator, using a spectrum manager developed by Fairspectrum. This targets the Public Warning vertical.

In Section 2.4 Expway, IRT and EBU present their demonstrator, which shows a 5G network able to switch between unicast to broadcast according to user demands to optimise spectrum resources by the implementation of MBMS operation on Demand (MooD).

In Section 2.5 BLB, in collaboration with IRT, present their demonstrator, which shows a unicast stream being received via LTE and Wi-Fi interfaces, with a seamless switch between them and the ability to increase aggregated throughput via Multi-Link.

In Section 2.6 BT and Expway present their demonstrator in which the live, unmodified, BT Sport commercial service can be integrated using the 5G-Xcast content distribution framework to benefit from multicast/broadcast distribution. It shows content prepared for unicast distribution being distributed over both fixed and mobile networks with dynamic switching between multicast/broadcast and unicast delivery as the audience size changes.

In Section 2.7 the BBC present their demonstrator, which shows an object-based approach to content delivery. The content will be delivered as a number of objects over multicast (using the DASM system) and unicast. The user equipment then composites the objects depending upon the environment and user preferences.

In Section 2.8 TUAS, Fairspectrum, LiveU and one2many present their demonstrator, which targets the Public Warning vertical. They demonstrate using dynamic spectrum management to send public warning multimedia alerts to the user equipment.

In Section 2.9 Nomor Research, Bundleslab and Broadpeak present their demonstrator, which shows the gains and trade-offs in resource consumption, spectrum efficiency, service coverage, and quality of experience when multicast is introduced as a network optimization for delivering popular content, and the improvements in the observed trade-offs achieved by introducing multilink delivery for user equipment with a poor multicast channel signal.

This is an initial version of this deliverable, and the demo records will be updated once the demos have been presented. The conclusion, summary and outcome of the demos will be given in the upcoming Deliverable D6.4.

The following table also collects the deliverables where the final technical concept and the record of the different events are contained.

Hybrid Broadcast Service – Linear TV with Add-On Content	D6.5
Low latency mABR live streaming joint demo with SaT5G	D6.6 / D6.9
Spectrum Management Demonstrator	D6.8
Hybrid Broadcast Service “with MBMS on Demand (MooD)”	D6.7
Hybrid Broadcast Service “with Multi-Link”	D6.9
Converged, autonomous MooD in fixed/mobile networks	D6.9
Object-based Broadcast across a 5G Core network using Dynamic Adaptive Streaming over IP Multicast	D6.9
Multimedia Public Warning	D6.9
Reliable Multicast Delivery in 5G Networks	
5G-Xcast Showcase – European Championships 2018	D6.5

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List of Acronyms and Abbreviations

ABR	Adaptive Bitrate
AIT	Application Information Table
AL	Adaptation Layer
BC	Broadcast
BW	Bandwidth
CDN	Content Delivery Network
DASH	Dynamic Adaptive Streaming over HTTP
DVB-T	Digital Video Broadcasting – Terrestrial
DVB-SI	Digital Video Broadcasting – Service Information
eMBMS	Enhanced MBMS
eNB	Enhanced Node B
EPC	Evolved Packet Core
EPG	Electronic program guide
FLUTE	File Delivery over Unidirectional Transport
GW	Gateway
HD	High Definition
HDR	High Dynamic Range
HFR	High Frame Rate
HTTP	Hypertext Transfer Protocol
HW	Hardware
IP	Internet Protocol
LSA	Licensed Shared Access
LTE	Long-Term Evolution
mABR	Multicast ABR
MBMS	Multimedia Broadcast Multicast Service
MC	Multicast
MEC	Multi-Access Edge Computing
ML	Multi-link
MNO	Mobile Network Operator
MPEG	Moving Picture Experts Group
MW	Middleware
NFV	Network Functions Virtualisation
OBB	Object-based Broadcasting
OFDM	Orthogonal frequency-division multiplexing
OTT	Over-the-Top
PMSE	Programme Making and Special Events
PW	Public Warning
PWS	Public Warning System
QoS	Quality of Service
RAN	Radio Access Network
SDN	Software Defined Network
SDR	Software Defined Radio
STB	Set-top-box
SW	Software
TCP	Transmission Control Protocol
TS	Transport Stream
TV	Television
TVWS	TV White Space
UDP	User Datagram Protocol
UE	User Equipment
UHD	Ultra-High Definition
URL	Uniform Resource Locator
VoD	Video-on-Demand
VPN	Virtual Private Network

1 Introduction

This document presents the planning, technical description, and demo record for the development of showcases, demonstrators and trials that was carried out within WP6 of the 5G-Xcast project. The overall scope of WP6 and the relation to other work packages is illustrated in Figure 1.

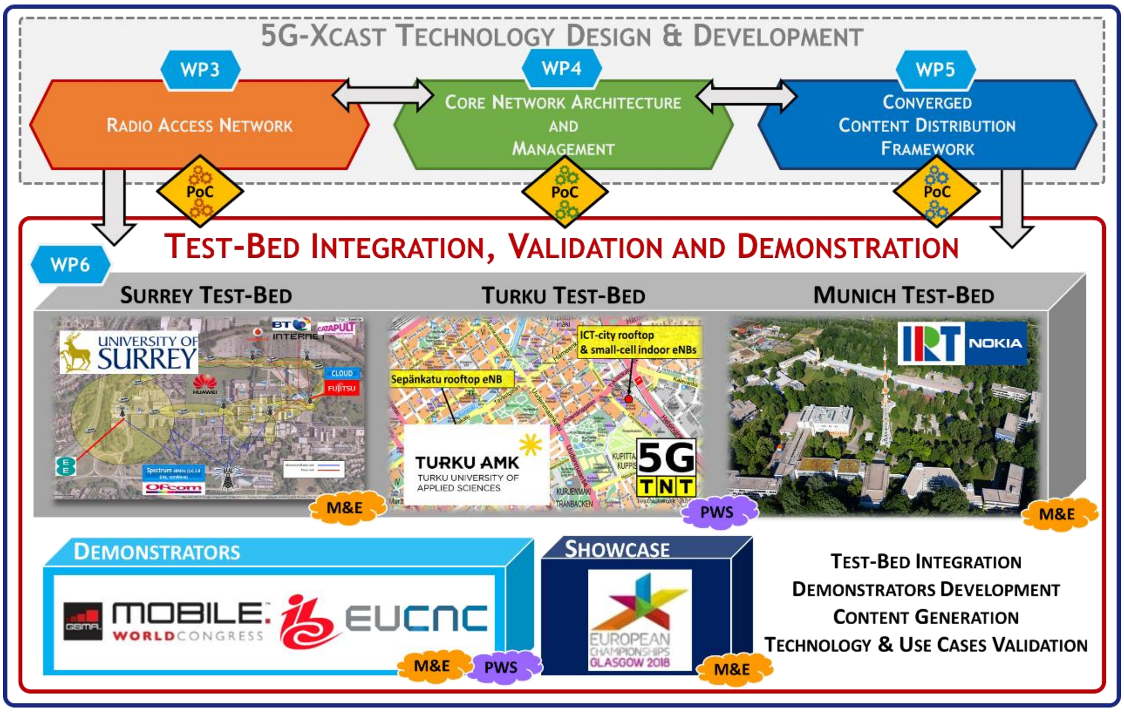


Figure 1. WP6 Scope: 5G-Xcast Test-bed Integration, Validation and Demonstration.

In the context of WP6, terminology is considered as follows.

A ***test-bed*** is a platform for development and testing of 5G solutions, including hardware, software, protocols, applications, measurement equipment, and validation tools. It may include both a laboratory environment and field test capabilities. Three complementary test-beds are available in 5G-Xcast: IRT/Nokia in Munich, 5GIC in Surrey, and TUAS in Turku.

A ***demonstrator*** is a specific arrangement of hardware, software, protocols and applications that aims to show the desired functionality of parts of a system but not mature enough to be integrated in a test-bed. 5G-Xcast demonstrators are foreseen to illustrate six different novel concepts:

- hybrid broadcast service
- object-based broadcasting
- public warning system
- RAN optimisation
- dynamic unicast – multicast - broadcast allocation
- spectrum sharing

A ***trial*** is equivalent to a demonstrator but implemented in a test-bed and may include a field test with an on-air signal and the capability to interact with commercially available equipment such as smartphones, tablets etc. A trial is usually a testing of the new solution for a limited period of time.

A ***demonstration*** is a practical proof of a technical concept or a functionality that has been implemented either as a demonstrator or in a test-bed. A demonstration can be internal or public. In 5G-Xcast several public demonstrations were foreseen in connection with the large events such as:

- IBC 2018
- MWC 2019
- EuCNC 2018
- EuCNC 2019

In addition, a ***showcase*** in connection with the European Championships 2018 will include a demonstration of hybrid broadcast service in the Munich test-bed.

The present document will concentrate on the development of ***showcases*** and ***demonstrators*** within the project.

1.1 Corresponding use cases

In the Media and Entertainment Hybrid Broadcast use case (see Section 2.3.1 in [4]) users have access to diverse linear and non-linear video, audio and text media coming from various sources, personalised and combined with social media, location-based features and interactivity. This could include linear and on-demand video and audio, social media, and interactive advertising being consumed on user equipment (UE) that range from fixed TV sets, mobile devices, and vehicle mounted devices. The access to this content and these services is enabled for a possible population of millions of concurrent viewers over a wide variety of environments and contexts such as indoors, over large geographic areas, and at venues (for example live sporting events). This has the benefit of giving the end users seamless access to audio and visual content delivered seamlessly across multiple networks, while giving the content service providers the ability to deliver this via standard interfaces (thus reducing the implementation complexity and costs). Additionally, network operators can benefit from a more efficient use of network resources.

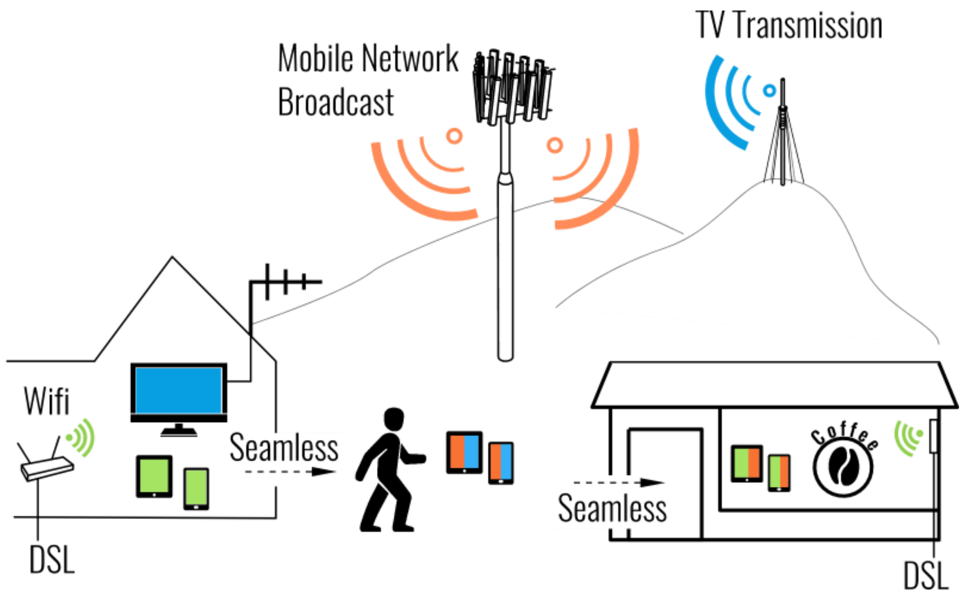


Figure 2: Hybrid Broadcast service use case, showing combinations of networks and technologies give a seamless experience as the user moves between different locations

The Multimedia Public Warning alert use case (see Section 2.4.1 in [4]) allows users in a targeted location to be notified with alerts carrying text, audio, video and other data types. For example, an alert for a missing child might include both text and a picture of the child, thus enhancing the alert in a way not possible when limited to a purely text-based alert. The multimedia approach may also allow disabled people to interact with the alert, for example by providing audio for visually impaired people. This is a Government or community service, connecting to users who have configured their user equipment (UE) to receive the type of alert, with devices ranging from mobile devices to devices for home usage only. Due to the nature of public warning, the network may also be experiencing significantly increased traffic, or even damage. This type of multimedia alert has the benefit of potentially faster and more informed responses or actions from members of the public, whilst being able to better include both able-bodied and disabled people.

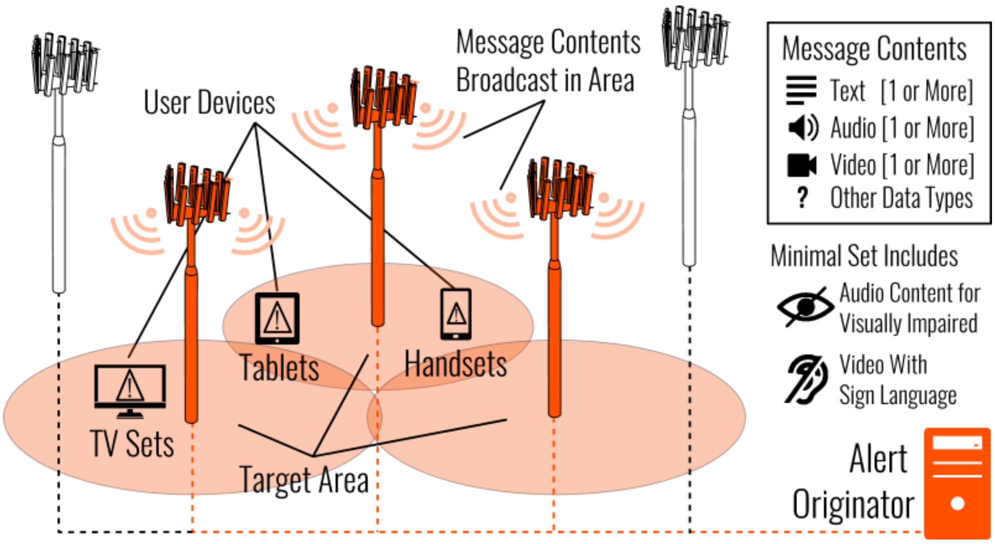


Figure 3: Multimedia Public Warning alert use case

The requirements for the Media and Entertainment Hybrid Broadcast, and Multimedia Public Warning use cases can be found respectively in Sections 2.3.1 and 2.4.1 in [4]; a summary is given here.

- The user should have a seamless experience on the move, including mobility between networks and UEs.
- The network resources should grow much less than linearly with audience size, particularly for large audiences of popular content.
- It should be possible for different network types to carry different content elements of a single user experience.
- The best available network should be used.
- The UE should be able to consume broadcast/multicast (BC/MC) and unicast (UC) content simultaneously.
- Content at different quality of experience (QoE) levels should be supported for different portions of the population in the same geographical area.
- Transition between BC/MC and UC should be optimized.
- Both conventional and object-based delivery should be enabled.
- Latency requirements should not be perceivable to the users.
- The interface between the content provider and the networks should be consistent, simple and transparent to the content provider.

- The solution should be flexible enough to allow usage under different network frameworks.

In addition, the public warning use case requires a high level of reliability.

2 Demonstrators

2.1 Hybrid Broadcast Service – Linear TV with Add-On Content

2.1.1 Concept and Relation to the Use Cases

IRT, in collaboration with the EBU, targets the development of a demonstrator focused on the Hybrid Broadcast Service use case defined in [4].

The proposed demonstrator involves several technical features to show the potential of 5G for media delivery in a hybrid fashion, combining:

- The ability to convey traditional always-on linear TV services in state-of-the-art formats.
- On-demand content, event related information and access to social media.

Live TV content and the signalling for add-on services based on the HbbTV standard are both included in an MPEG-2 TS and transmitted over the LTE eMBMS network. The broadcast signal is received by stationary eMBMS-enabled TV receivers and by smartphones simultaneously, without the need of unicast connectivity.

Users can access additional on-demand content either via a HbbTV application on TV sets or a HTML-based application on mobile phones. The on-demand content is delivered over the LTE unicast link in the mobile network.

The demonstrator highlights aspects such as:

- fixed/mobile convergence,
- combined use of unicast and broadcast capabilities on the same device,
- use of standardized 3GPP interfaces to deliver MPEG-2 TS including live TV programmes and HbbTV service information,
- free-to-air reception,
- reception on both mobile/portable user devices and stationary TV-sets.

2.1.2 Technical Description

The HbbTV concept, which is currently based on Digital Video Broadcasting (DVB) broadcast along with an auxiliary broadband connection, is extended to a framework in which the broadcast signal is carried over an LTE eMBMS session and the access to unicast data is provided with LTE unicast. Target receivers under consideration are smartphones and tablets as well as TV-sets.

MPEG-TS is specified as a container format to encapsulate audio and video streams together with programme and system information. Three TV programmes were encapsulated with one of them linked to HbbTV service information.

HbbTV services are available on many of the current set-top boxes and TV sets. The HbbTV services require a user device to be simultaneously connected to both a conventional broadcast network (i.e. DVB family of terrestrial, cable or satellite broadcast standards) and broadband network, which is usually integrated by common Ethernet and/or Wi-Fi interfaces. The project will explore the capability of the current and future 3GPP based 4G/5G specifications to provide a HbbTV service. The main video feed (linear TV) will be delivered as a DVB-SI compliant TS (MPEG2-TS). The type of services delivered through HbbTV could be: Enhanced Teletext, Catch-up services, Video-on-demand, EPG, Interactive advertising, etc.

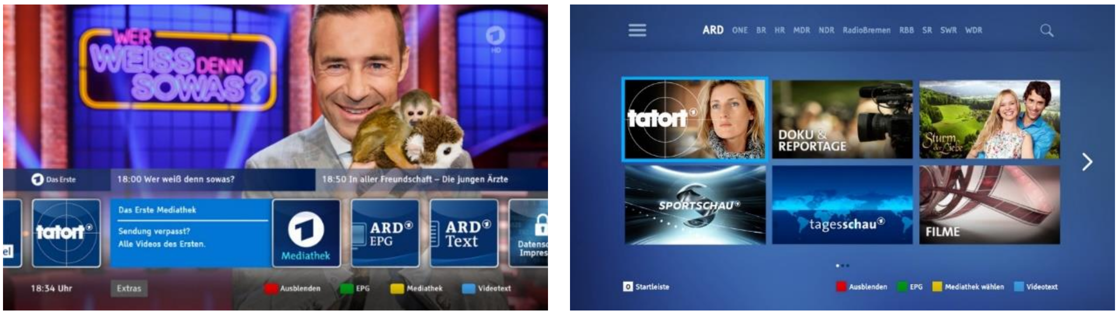


Figure 4: ARD Startleiste (Launcher) and HbbTV version of the ARD Mediathek

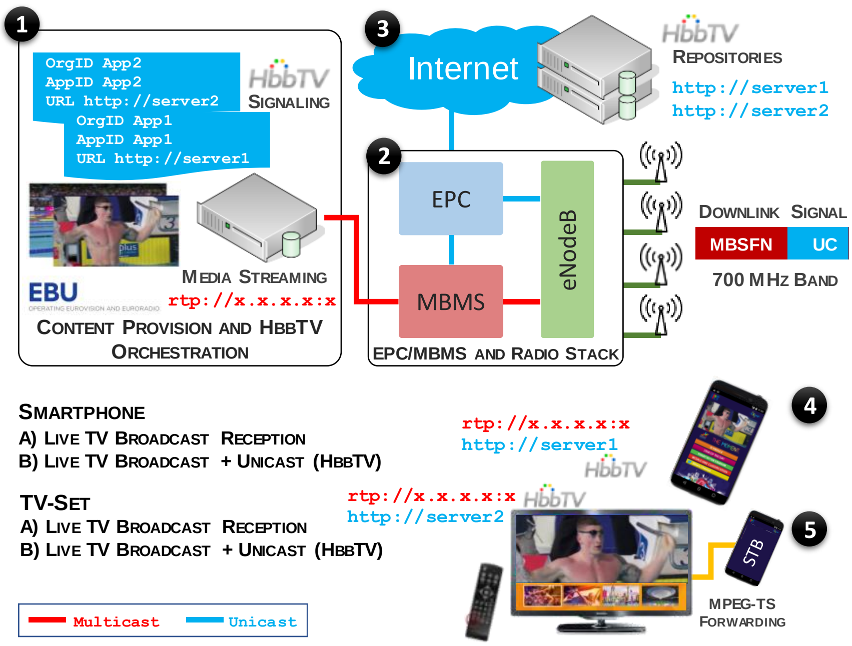
The screenshots in Figure 4 show the red button application and the catch-up service ARD Mediathek which are available through all ARD broadcast channels (e.g. “Das Erste”). Similar HbbTV services are offered nowadays by all major broadcasters in Europe.

HbbTV services are signalled through the linear broadcast service in the so-called application information table (AIT), the application shown in the left part of Figure 4 is marked as autostart and automatically loaded when the user tunes in to the broadcast service. Loading a HbbTV application means that the initial HTML page is loaded into the browser and waits for user interaction. Typically, HbbTV applications are activated when the user presses the red button on the remote control.

Two different HbbTV applications were developed, one meant to be displayed on a TV-set and another to be displayed on a smartphone.

Whilst the key enablers for this demonstration are included in 3GPP Release 14 (EnTV) the compliant equipment, chipsets and other components are not yet available. Therefore, the starting point is the current (pre-release 14) equipment already available at IRT.

A scheme of the demo setup is shown below highlighting (from 1 to 5) the different steps and functionalities implemented.



1. Content is provided by the EBU from the European Championships venues. Encapsulated in a MPEG-2 TS alongside live TV programmes, HbbTV signalling is inserted pointing to additional on-demand content offered by the broadcaster.
2. A small-scale computer-based solution including LTE EPC, MBMS and radio stack permits the delivery of the broadcast signal (MPEG-2 TS over RTP) over LTE downlink and the allocation of the remaining unicast capacity for on-demand traffic.
3. Internet connectivity provides access to the servers with on-demand content. Broadcasters can direct users to their own content repositories.
4. Smartphones with Expway's middleware allow users to watch live TV programmes via the broadcast system and on-demand content via a mobile web application and a unicast internet connection.
5. A smartphone acting as a set-top-box forwards the original MPEG-2 TS to a TV-set that can tune in to the live TV signal with the possibility to access HbbTV services.

2.1.3 Development Plan and Events

This demonstrator is initially targeted for the IBC conference taking place in Amsterdam in September 2018.

The development of the concept proposal was considered in the first phase, by specifying the technological aspects to be shown in the demonstrator. This involves the definition of the HBS to be implemented and the aspects related to user experience. A second step consists of preparing the necessary hardware and equipment for the demonstrator, as captured in the Demo Record below. The development of the demonstrator requires the preparation of a test signal which will already contain an MPEG-TS with associated service information and HbbTV signalling. This will help to determine an adequate data rate for the final demonstrator as well as assist the development of the app for the smartphone and the HbbTV app to be displayed on a TV-set, as per the subsequent steps in the development. The final MPEG-TS will be generated, taking advantage of the content provided by the EBU for the European Championships, to which the add-on information for the HbbTV applications will be linked.

	2018								
	J	F	M	A	M	J	J	A	S
Concept Proposal									
Hardware & Equipment preparation									
Test signal generation									
Smartphone App development									
HbbTV App development									
Branding Insertion									
Final content generation									
End-to-End testing									
Demonstrator Finalized									

At the time of completion of this deliverable, the demonstrator has been successfully shown at the following events:

- IBC Conference 2018
- Medientage 2018
- EBU Forecast 2018

DEMO RECORD

Hardware involved in the demonstrator	
- Amarisoft eNB+MBMS GW - IP Router - TV-set - Local HbbTV web-server (external PC) - 4 UEs with eMBMS middleware	
Software components	
- Smartphone application integrating access to MBMS API and Android API - HTML application for add-on content display in the smartphone - HbbTV standard-compliant application for TV-set	
Content description	
- MPEG TS containing 3 linear TV services and 2 HbbTV applications (1 to be displayed in the smartphone, a second to be displayed in the TV)	
Event 1. IBC 2018	
Place	Amsterdam
Date	
Audience	Worldwide broadcasters, content creators/providers, equipment manufacturers, professional and technical associations
Event 2. Medientage 2018	
Place	Munich
Date	24-26 October
Audience	German media and communication industry
Event 3. EBU Forecast	
Place	Geneva
Date	19-21 November
Audience	European broadcasters and broadcast industry

The complete information about the finalized demonstrator will be found in D6.5.

2.2 Low latency mABR live streaming joint demo with SaT5G

2.2.1 Concept and Relation to the Use Cases

This joint demo with Sat5G aims:

- To demonstrate caching and multicast content/VNF distribution to the edge over satcom, using low latency with Multicast Adaptive Bitrate (mABR) Live streaming and OTT Streams Synchronization.

- To address the Media & Entertainment use case 1: Hybrid broadcast service.

Several requirements have been defined for each use case in D2.1, see [4].

The mABR Demonstrator meets the following requirements related to Use Case M&E1:

- The user's device is able to automatically connect to the best available network to give the highest QoE to the user.
- The network resources required to deliver the service to a given audience should grow much less than linearly with audience size, particularly for large audiences of very popular content.
    - Minimizing the distribution costs for the content service provider
- The 5G-Xcast solution should be scalable to allow nationwide network coverage (e.g. >99 % of the populated areas, roads and railways), noting that capacity requirements are not uniform throughout the coverage area and may substantially differ across rural, sub-urban, and urban areas, as well as in crowded venues and hotspots. This means that the number of services of a given type to be provided in a given territory at the same time should be scalable.
- The 5G-Xcast solution should allow indoor, outdoor and in-vehicle coverage.
- The 5G-Xcast solution should be able to provide a sufficient data rate to deliver content up to UHD quality.
- Latency:
    - End-to-end latency is allowed to be in the order of 50ms or even higher.
        - Delay from live should be no worse than other delivery methods.
    - Difference in delay between different streams on the same device shall. not be perceivable by the users.
    - Channel change latency should be of the order of 1 second, not excepting additional contributions from latencies that may be outside the scope of the 5G-Xcast system such as communication with a decryption key server.

2.2.2 Technical Description

The device will receive Live channels either from satellite feed or broadband depending on the decision of the Service Router.

Channel delivery over satellite is done using mABR to optimize bandwidth usage.

CMAF & CTE packaging mechanisms are used to reduce latency.

The Nano Content Delivery Network (CDN) agent enables the synchronization of the streams between the devices at the Home Gateway level.

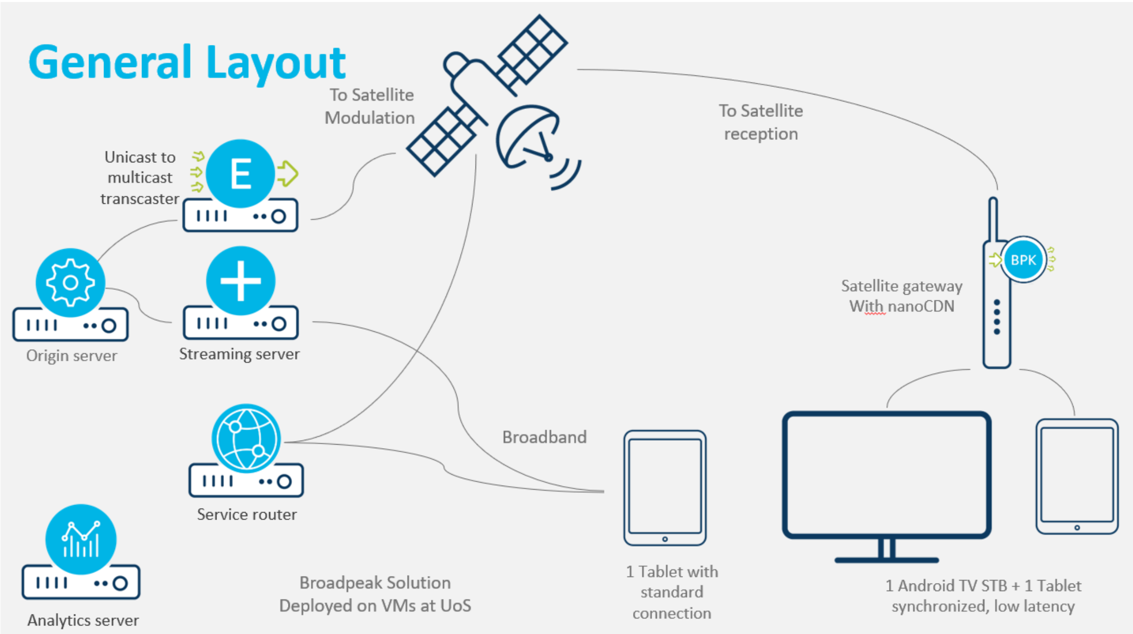


Figure 5: General layout for the mABR joint demo with Sat5G

All head-end servers are hosted at the 5GIC test bed in Surrey. This prototyping platform is managed by the University of Surrey.

2.2.2.1 *Efficient Edge Content Delivery through satellite*

Broadpeak will focus the demonstration on using Satellite Multicast capabilities for the delivery of live OTT channels. Broadpeak will also demonstrate low latency with a mABR Live streaming using CMAF/CTE and OTT Streams Synchronization to improve user experience.

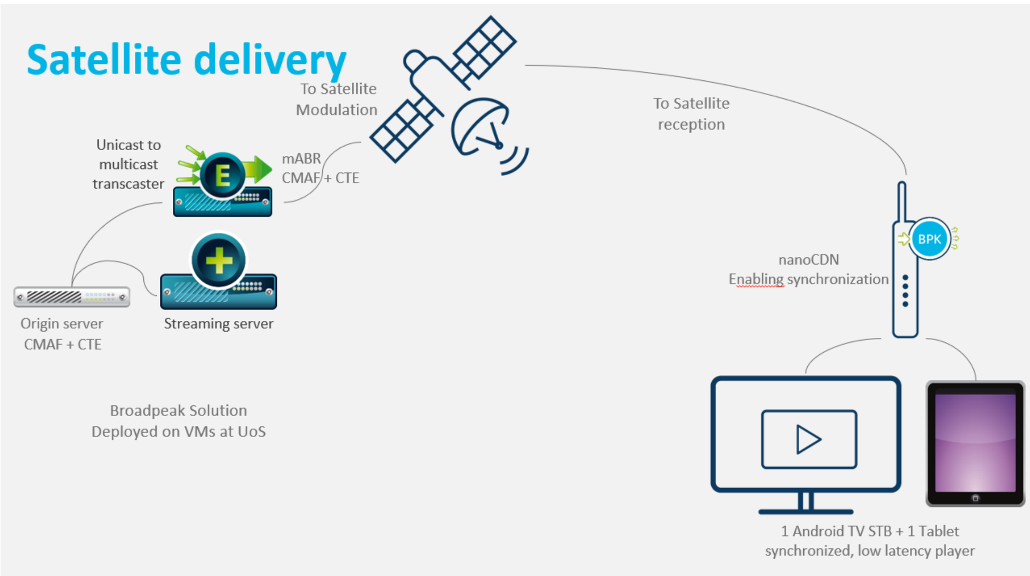


Figure 6: Efficient Edge Content Delivery through satellite

2.2.2.1.1 Low Latency using mABR, CMAF & CTE

Understanding Latency:

Video services delivered over **IPTV** or **Cable TV** managed networks typically experience low delay because there is guaranteed BW and a requirement for limited buffering in the set-top box (STB). For **HTTP video streaming**, it’s a whole different scenario. Secondary screens such as connected TVs, smartphones, and tablets are accessible on various unmanaged networks (i.e., 3G, 4G and OTT) where traffic is irregular. In order to ensure a good quality of experience without constant playout interruptions, players need to buffer a high quantity of video. This is what creates a high delay.

Apple recommends that HLS video chunks last six seconds, and three chunks are usually buffered in the players, implying an extra 18 seconds delay. Some Android players even require five MPEG-DASH chunks buffered in the player, meaning the delay can be longer than 30 seconds.

The Power of Multicast Technology:

By using **mABR technology** at the CDN level, operators can successfully stream video without needing to buffer massively on the player side to guarantee a good quality of experience. The solution involves deploying a **unicast-to-multicast** transcaster in the head-end and multicast-to-unicast agents in the Customer Premises Equipment (CPE) to bring the latency down to only a few seconds instead of the typical 30 seconds.

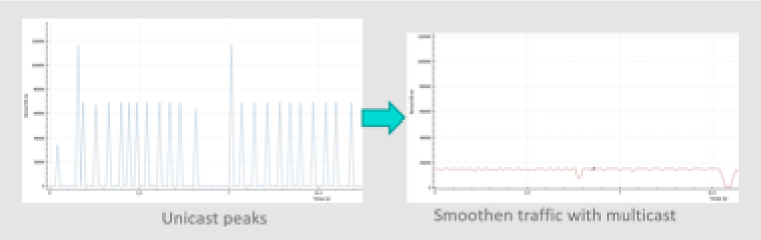


Figure 7: Smoothen traffic with multicast

Beyond employing **mABR technology** at the CDN level, there are additional steps operators can take to reduce latency. They can employ the low latency flavor of Common Media Application Format (CMAF) during packaging and rely on chunked transfer encoding. CMAF allows the creation of small 250ms chunks and chunked transfer encoding enables the processing of fragments on the fly before they are fully received. On the player side, operators need to adapt the volume of content to buffer to content. In this scenario, they would only buffer one second of video in the home network for good quality and low latency, and buffer more chunks in mobility to ensure good quality, although with longer latency.

It’s important to note that the additional steps mentioned above (i.e., CMAF, chunked transfer encoding) will not allow operators to achieve low latency by themselves. Without mABR technology, the video quality will suffer dramatically due to constant rebuffering. mABR is unique because it uses the same network as traditional IPTV and prioritizes traffic inside the network. The jitter inside the network is very low, hence only limited buffering is required in the device.

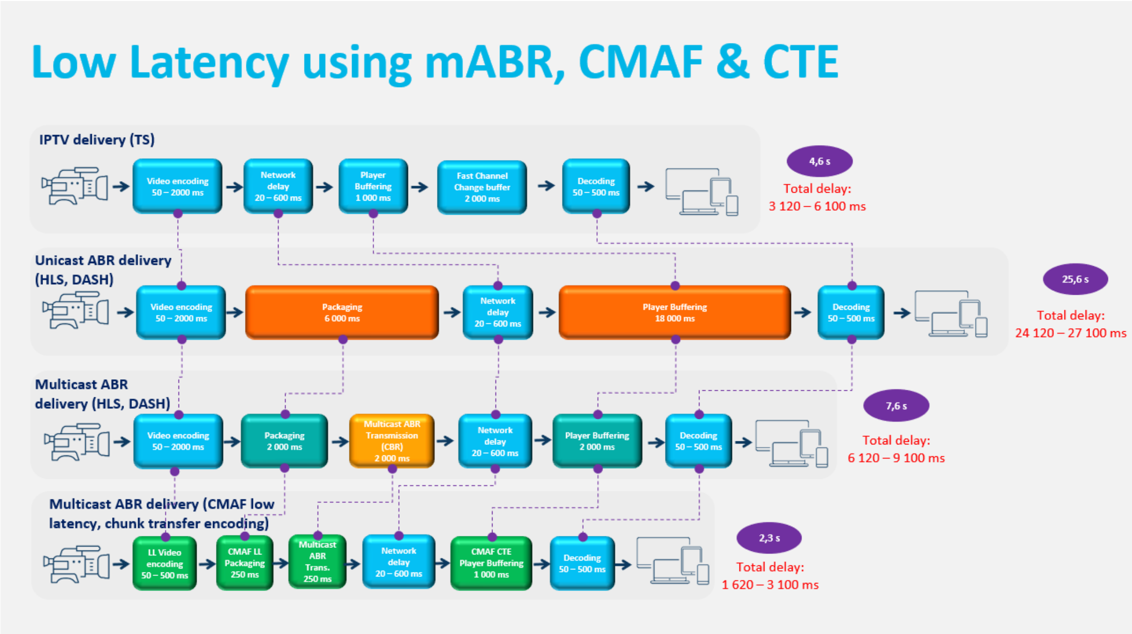


Figure 8: Usage of mABR with CMAF & CTE enables to reach a lower latency than traditional IPTV

2.2.2.1.2 Stream synchronization

In different use cases, several receivers close to one another may be in the situation where they play the same live content, for example:

- People following a show with various receivers, so that they can walk freely throughout their home and still keep an eye on their program.
- Bars or communities showing a sport event via several screens.

Whenever this happens, it is important that all displays are synchronized, so that they all show the same point in time naturally, but even more importantly so that the audios don’t interfere with each other, which can be particularly annoying for the human ear. Note that traditional Broadcast, where the same content is pushed to all users, does provide synchronization between screens while it is not the case for default OTT, which might be seen as a regression when migrating to a full OTT system.

Broadpeak mABR solution enables synchronizing all the devices connected on the same nanoCDN gateway to create a better user experience.

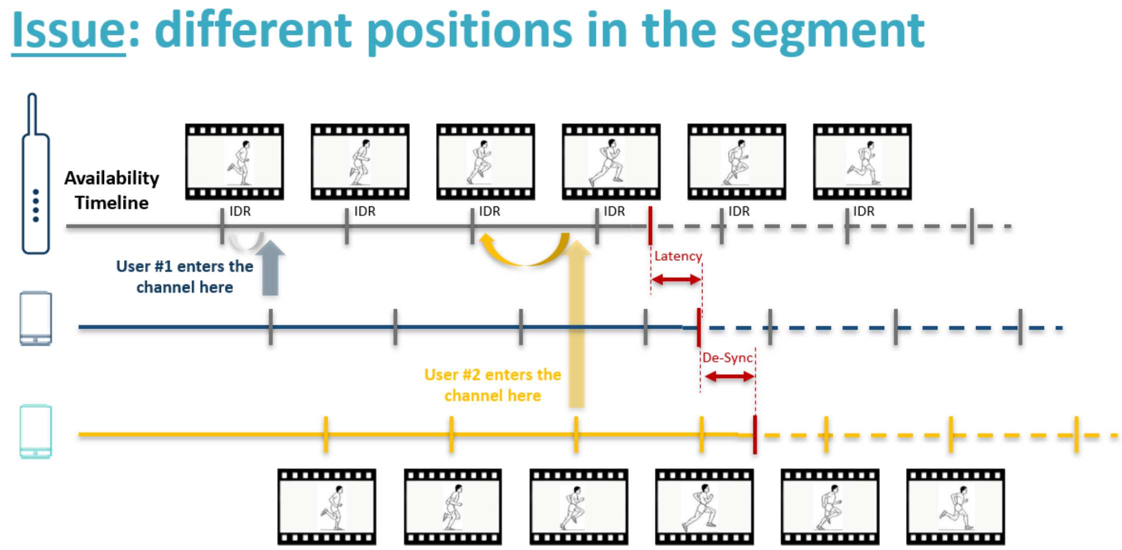


Figure 9: How to solve the desynchronization between User Equipments?

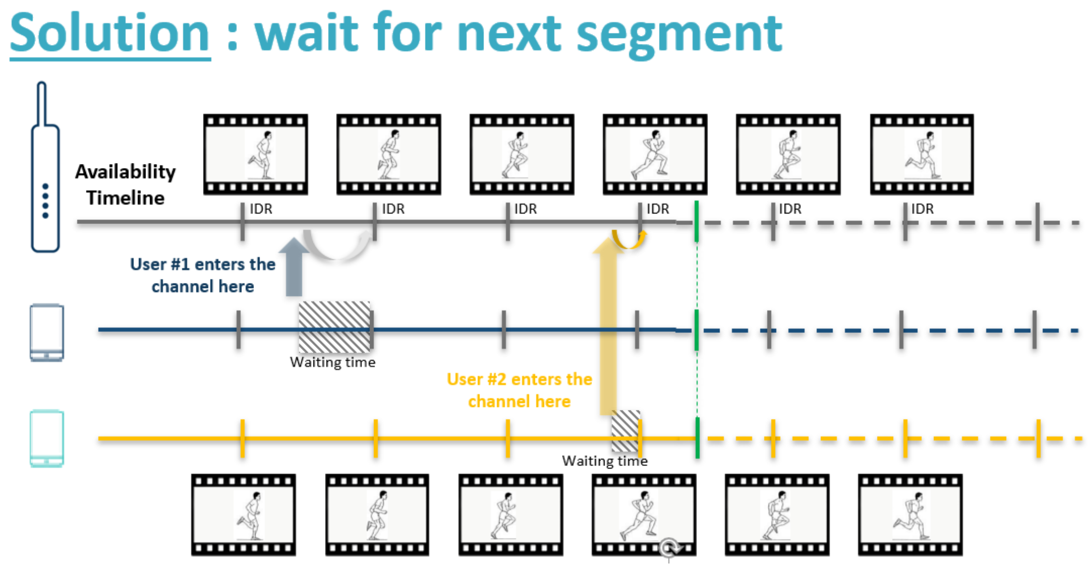


Figure 10: OTT Stream Synchronization principle

Waiting for the next segment allows sync between players in the house + optimized latency vs source stream. The drawback is a slower zapping time but this choice is configurable per channel.

2.2.2.2 *Hybrid Broadcast Service*

Users have access to audio-visual content and services delivered over a combination of several networks simultaneously. In order to provide a seamless user experience, the content is made available on different types of devices either at home or outdoor, including stationary and mobile conditions. The user's device is able to automatically connect to the best available network to give the highest QoE to the user. Different transport modes are used to enable this seamless user experience. Depending on the user context, the audio-visual content can be delivered through unicast or multicast ABR. The audience of a media is one of the triggers to switch between unicast and multicast ABR.

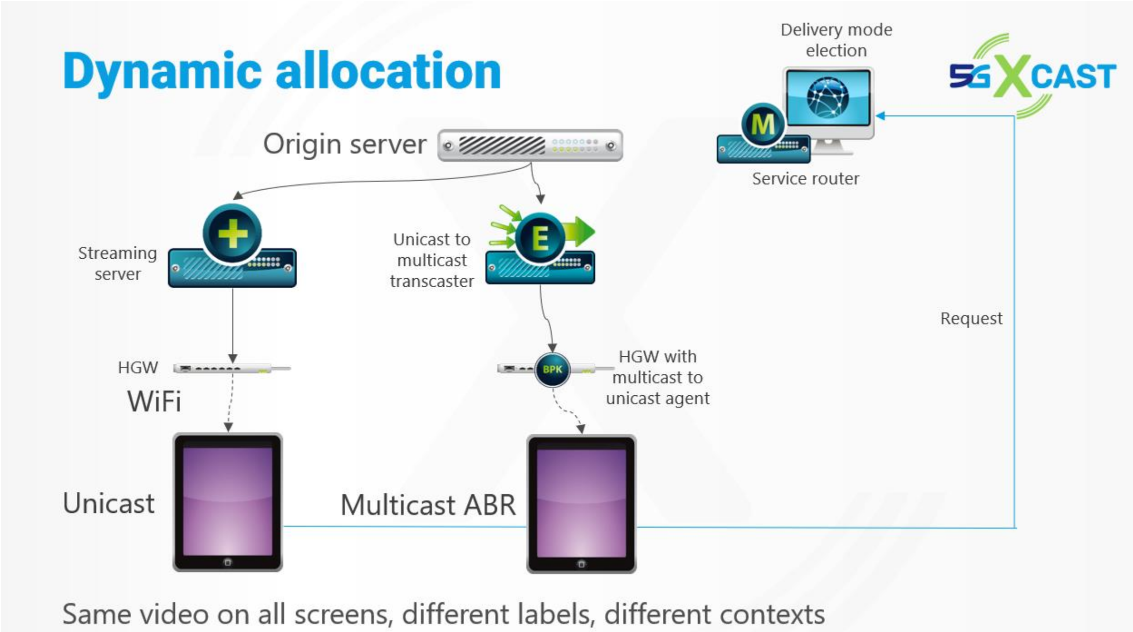


Figure 11: Dynamic allocation using the Service Router – BPK proposal

2.2.3 Development Plan and Events

A first step of the demo was showcased at the IBC 2018. Due to constraints related to the IBC show (short setup time, Wi-Fi congestion) it has been decided that we make a descriptive demo of the concept in order to focus on the messaging.

Figure 12: Demo of the concept at IBC 2018

A collaboration between Sat5G and 5G-Xcast projects has been initiated and will lead to a joint demo related to the media and entertainment vertical. The plan is to have this demo showcased at the EuCNC 2019 in Valencia. Within Sat5G, a use case focuses on the usage of satellite to convey live video content to mobile edge nodes in multicast in order to optimize the backhaul usage or even to replace it in regions where the infrastructure does not exist. The availability of this multicast contribution stream could be an element taken into account within 5G-Xcast in the convergent video delivery use case. The video content could be delivered from the edge node where it has been made available either in multicast via satellite, or in unicast using the broadband network to the end-users, as described in the use case and based on the context of each request. The service router concept defined in 5G-Xcast would be fed by content availability information provided within Sat5G. This would lead to an end-to-end optimized delivery of video content on 5G mobile networks.

	2018					2019					
	A	S	O	N	D	J	F	M	A	M	J
Concept proposal	■										
Solution development (Software dev)	■	■	■	■	■	■	■	■			
Hardware preparation at Surrey – Phase 1				■							
Setup remote access between UoS - iDirect – Broadpeak					■						
Install Bpk SW in UoS (Alpha version)						■					
Install iDirect SW in UoS							■				
Setup (VPN) between teleport and UoS for data path							■				
Install iDirect HW in UoS								■			
Upgrade Bpk SW in UoS (Beta version)								■			
Initial Test over Broadband									■		
Satellite link available										■	
End to end testing on Satelitte										■	
Demonstrator finalised											■

DEMO RECORD

Partners involved
- Avanti - Broadpeak - iDirect - University of Surrey
Hardware involved in the demonstrator
- iDirect Satellite Home Gateway - IP Router - USB ethernet adapter (Lava eSTS-E) - TV-set - Android Set-top box - Android Tablets - VMWare ESXi Host
Software components
- Broadpeak Origin Server (BkS350) - Broadpeak Transcaster (BkE200)

- Broadpeak Streamer (BkS400) - Broadpeak Analytics server (BkA100) - Broadpeak Service Router (umbrellaCDN) - Broadpeak multicast to unicast agent (nanoCDN) - Broadpeak Mediator (BkM100)	
Content description	
- 1 live channel streamed simultaneously in mABR over a satellite link and in unicast through a broadband network. The mABR live channel will be displayed on a TV set and on a tablet in order to demonstrate OTT Stream Synchronization. The unicast live channel be displayed on a tablet in order to demonstrate low latency (the unicast stream being displayed with a higher latency than the mABR stream).	
Event 1. IBC 2018	
Place	**Amsterdam**
Date	**14-18 September 2018**
Audience	**630 people**
Event 2. EuCNC 2019	
Place	**Valencia**
Date	**18-21 June 2019**
Audience	

The complete information about the finalized demonstrator will be found in D6.6.

2.3 Spectrum Management Demonstrator

The dynamic spectrum management and spectrum sharing demonstrators in 5G-XCast project are Dynamic spectrum management and spectrum sharing demonstrator in EUCNC 2018, coexistence management demonstrator in Turku and displayed as a video in EUCNC 2019, and a Public warning demonstrator combined with spectrum management in EUCNC 2019.

2.3.1 Concept and Relation to the Use Cases

The demonstrators verify the XCast solution for the requirement M&E1_R38 and M&E3_R1 (see [4]): "The 5G-Xcast solution should be flexible enough to allow operation under different spectrum usage frameworks." This aspect can be considered to relate to several use cases, whenever dynamic spectrum use is required. The technical solution being tested is a spectrum manager developed by Fairspectrum. This is in addition to the requirement 31 regarding supported frequency band flexibility. In mainstream exclusive spectrum, the 5G-XCast solutions work without specific spectrum management issues. Due to that, the spectrum management demonstrators concentrate on unlicensed spectrum, where coexistence management can improve the reliability of the 5G-XCast solutions, and on shared spectrum, where the selected sharing framework and related rules can accommodate a wide variety of QoS classes and service levels ranging from opportunistic access like on unlicensed spectrum to prioritized exclusive spectrum use.

The first demonstrations were related to the use cases M&E1 – Hybrid broadcast service and especially M&E3 – Remote live production (see [4]). Spectrum sharing between mobile network operators, a private LTE network (that can be used by a PMSE stakeholder for production for example) and conventional PMSE equipment was demonstrated. Spectrum sharing was shown in the EUCNC 2018. The demonstration was carried out by Fairspectrum and Turku University of Applied Sciences. 2.3 GHz was used for wireless camera communications in many European countries. ETSI has specified how Licensed Shared Access (LSA) helps mobile operators to use the same spectrum band as a secondary user. A part of the 2.3 GHz Program Making and Special Events (PMSE) users were expected to migrate the camera communication to LTE or 5G. This demonstration showed how the current license holders, PMSE, can be prioritized and how LSA can be used to manage spectrum sharing between current PMSE use, LTE based PMSE use and commercial LTE operator network. Although the demonstrator was transversal to different use cases, PW1 would benefit from the features implemented in it in order to evaluate and adapt the transmission to the most adequate spectrum band for the delivery of PW messages.

The recent development of coexistence management solutions has been concentrated on three technology families: Wi-Fi (IEEE 802.11), TVWS (802.11af) and CBRS GAA (WINNF, CBRS Alliance). The most extensive standards work has been carried out in 802.19.1 specifications. As the only native 3GPP technology, we demonstrate the coexistence management for CBRS GAA, which is the opportunistic access class of the US LTE band 48. We demonstrate a dedicated coexistence manager responsible for spectrum management among CBRS users. We study several algorithms for efficient resource (frequency and power) allocation among CBRS base stations operating as GAA users in the three-layer model and demonstrate the most potential one. As a part of the theoretical background study we provide: a detailed mathematical definition of the resource (power and frequency) allocation problem, a dedicated graph colouring implementation for spectrum allocation, two extensions of the above-mentioned algorithm, which deal with the problem of aggregated interference, a multi-choice algorithm that can be run on the coexistence manager, a solution to the power optimization problem that guarantees optimal power allocation among GAA base stations for a given frequency allocation scheme, and an analysis of the trade-off between power allocation and frequency split in case of interference limitations; mainly we have derived when it is better to reduce transmit power and keep the assigned frequency band unchanged, and when it is better to keep the transmit power unchanged and split orthogonally frequency band among base stations. The proof-of-concept in Turku is carried out managing the transmission BW only, and the PoC is carefully recorded, edited, and shown at EuCNC as a video.

The Public Warning demonstrator is aimed at developing part of the concepts investigated in the project (in WP3 and WP4) in order to deliver multimedia public warning messages with high reliability and coverage. The current Public Warning Systems are able to reach the target audience well with text messages and notifications in broadcasts. EMBMS is a multimedia broadcasting system, which can broadcast multimedia content over mobile networks to supporting mobile devices. Dynamic Spectrum management allows changes in spectrum capacity locally and temporarily. The EuCNC demonstrated system contains an administrative interface to create a PWS message and select the channels, time, and coverage. In this demonstration, a new spectrum resource is defined and created simultaneously with the message. Before sending the message, the spectrum resource for eMBMS is created using dynamic spectrum management. The PWS system sends a PWS multimedia message over an available channel to the mobile device. In addition to the multimedia warning, the message contains a trigger to an eMBMS PWS feed, which uses the dynamically created spectrum resource. The system creates an LTE channel in the 700 MHz band. The trigger message is sent over Wi-Fi. EMBMS content is received in the created LTE channel by the UE.

2.3.2 Technical Description

The trial presented in [5] was conducted in Turku University of Applied Sciences testbed (5GTNT). The 5GTNT testbed focuses on spectra below 6 GHz. Currently the 700 MHz 5G candidate band and the 2.3 GHz Licensed Shared Access (LSA) band are supported for LTE. Equipment for the 5G candidate band 3.4-3.8 GHz is currently being added to the testbed. The test network sites are in Turku University of Applied Sciences campus area in Turku, Finland. The testbed is an integral part of 5G Test Network Finland (5GTNF) ecosystem, which coordinates the integration of the Finnish 5G testbeds.

The system consists of PMSE equipment operating occasionally on 2.3 GHz band and an MNO LTE network operating on 700 MHz and 2.3 GHz bands. The latter represents MNO employing additional capacity on 2.3 GHz band using for example the supplemental downlink concept. Proprietary PMSE equipment represents an OFDM based proprietary solution for wireless cameras operating on the band. PMSE LTE is a rapidly deployable LTE network that can be used for PMSE purposes. Different ePCs (enhanced Packet Cores) are used for the MNO LTE and PMSE LTE networks. The ePC2 used for private network is a limited feature core that includes only necessary components for the data transmission, thus enabling rapid deployment when combined with a base station.

The spectrum manager orchestrates the operation of the different systems on 2.3 GHz shared band. PMSE system information is collected with a web based reservation system. The users of the devices make reservations for their intended use. The reservation system has been piloted in the Netherlands in 2017-2018. The control of the PMSE devices also takes place through the reservation system so that the user of the devices is informed about required spectrum use changes with an email, and the user has to deploy the configuration changes in the devices. Both PMSE LTE and MNO LTE systems have a direct machine-to-machine interface between the radio equipment and the spectrum manager. When the priority user changes the configuration of the LTE network, a notification about the change is automatically received in the spectrum manager. The spectrum manager processes the changed spectrum situation and evaluates if the lower priority use may cause harmful interference to the higher priority use. If there is a risk of interference, the spectrum manager evaluates which changes would be required to accommodate the higher priority use and to also maintain the best possible service level for the lower priority use. On the high level, this is implemented so that if there are frequency channels available, the lower priority use is transferred to those channels. If there are no other channels available, the power level of the secondary user is lowered, or the transmission is denied. In this demonstration, the higher priority user is able to select the frequency channel to be used. An option for this could be that the higher priority user has the right to the spectrum resource in the band, but the specific frequency channel is determined by the spectrum manager. The setup in the laboratory is shown in Figure 13.

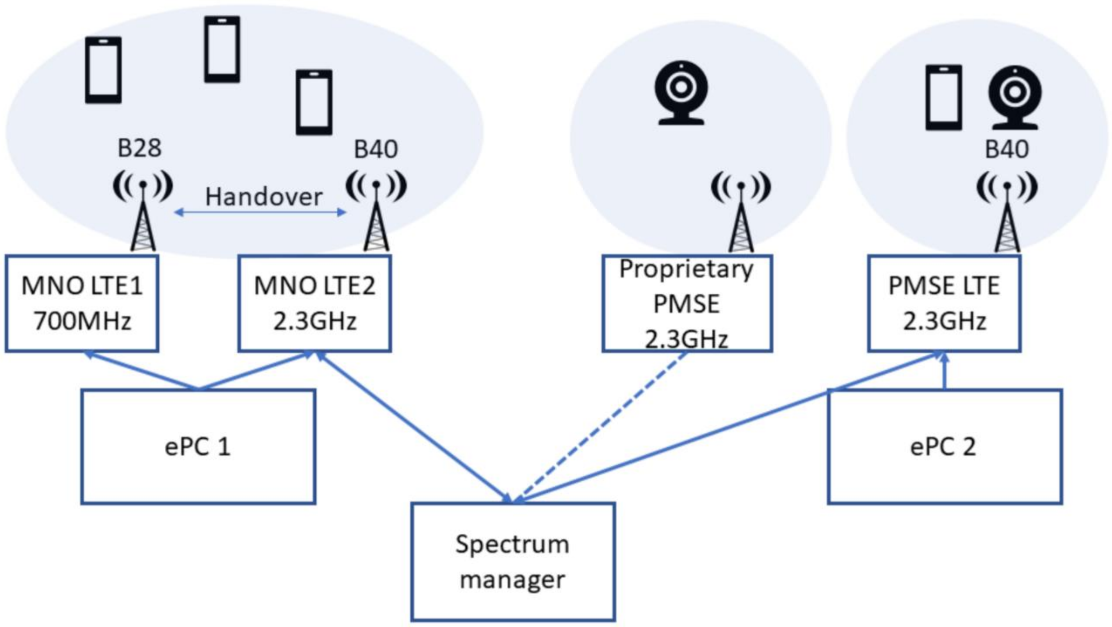


Figure 13: EUCNC18 Spectrum management demonstration

2.3.2.1 *Coexistence management*

The coexistence management proof-of-concept in Turku [7] is carried out for managing the transmission bandwidth only, and the PoC is carefully recorded, edited, and shown in EUCNC as a video, see Figure 14.

In coexistence management the Multi-choice algorithm scheme is illustrated in Figure 15. It is split conceptually into two main phases; the first one, where the Graph Coloring with Add Edge Procedure is applied (Alg. 2), and the second one, where node clustering is applied iteratively. In the first phase, only one solution is generated, i.e., the one where all devices transmit with the maximum allowable power (this is obtained by maximal band fragmentation). In the second phase, the remaining M_{max-1} solutions are created. The algorithm is discussed below.

1) Initialization and graph coloring: As in the previous algorithms, as the input to the algorithm we take the limitations coming from the SAS and from the CBSDs specifications, mainly the maximum equivalent transmit power for each device is provided. Next, as the parameter we take the acceptable interference level PINT. We start with the creation of the interference graph and calculation of the chromatic number X.
2) Phase 1 - Assignment colors to frequency bands: Next the algorithm enters the step of assignment of frequency subbands to the colors. Currently this is realized by generation of all X! possibilities and selection of the best one minimizing number of required guard bands. In particular, we check if each combination of color pairs can occupy adjacent frequency bands or if they need one channel of separation as a guard band to prevent excessive out-of-band interference. Next, we try all combinations of colors pair orderings and search for the one which requires the minimal number of guard bands. When we know the order of the colors and the places for the guard bands, we only need to choose how many channels (subbands) to assign to each color. We used two solutions. The first one assumes that every color should have the same amount of spectrum. The second one assumes assignment proportional to number of devices utilizing a given subband, i.e., colors with a higher number of devices should have more

spectrum than others. For example, if we have 3 devices associated with 2 colors (one device to one color, and two devices to the other color), then the first color should get 1/3 of the spectrum and the second color should get 2/3 of the spectrum. The former approach is hereafter called Equal assignment, whereas the latter is hereafter called Proportional Assignment. One may observe that the order in which coloring and assignment of frequency bands to colors are performed makes a difference. Thus, it may happen that there are some channels without a color, for example because the number of channels (without guard bands) is not always divisible by number of colors X. In such a case we simply add these free channels to random colors (CBSDs). Observe that the above described procedure is carried out for each subgraph (not connected to another subgraph) separately.

3) Phase 1 - Add edge procedure: In order to verify the correctness of the created graph and resultant frequency assignment, the total observed aggregated interference (denoted in the algorithm as PINT) is calculated for each node on its coverage area. If the aggregated interference from many CBSDs violates the interference constraint it has to be eliminated, and this is done by an application of the Add Edge algorithm (Algorithm 2), repeated as many times as the aggregated interference occurs. Once this constraint is fulfilled, the created graph is treated as the outcome of the first phase of the Multi-Choice Algorithm and delivered as input to the second phase. One may notice that this graph and its corresponding chromatic number guarantees interference free transmission with the maximum power for all I CBSDs. This means that the available spectrum has to be split into X orthogonal, not necessarily equal (as mentioned in the previous subsection), subbands of the bandwidth being the integer multiplication of 5 MHz. If such a division is possible, then we treat such a spectrum assignment as the first possible solution and store it. The created solution may however not be possible if the number of CBSDs is large and the interference graph very dense. To be more precise, when the final chromatic number X is greater than the number of available 5 MHz channels N, then it is impossible to split the spectrum as described earlier. In such a case the outcome of the first phase of the algorithm is the interference graph that guarantees the lack of an aggregated-interference problem. No possible solution for frequency assignment will be created then.
4) Phase 2 - Iterative procedure: The outcome from Phase 1 of the Multi-Choice Algorithm is, first, the network graph that may be colored in such a way that there will be no aggregated interference. Second, the chromatic number X, and third, if applicable, the unique solution for maximum transmit power. The ultimate goal of Phase 2 is to show the trade-off between the allocation of power and frequency to the CBSDs. The algorithm calculates the optimal power assignment for all potentially applicable numbers of frequency divisions. In other words, it starts with the case where all CBSDs are clustered together (i.e., they will use the same frequency or equivalently the number of colors in the graph is one) and optimizes the transmit power in the network, taking into account each 5 MHz band individually. If by m we denote the current number of CBSD clusters, then the algorithm starts with m = 1. Next, the number of colors is incremented, which is equivalent increasing by one the total number of CBSD clusters (m = 2). In other words, the entire band will now be split into two parts. Again, the optimal power assignment is applied. This procedure is repeated Mmax - 1 times, until the number of clusters equals the chromatic number X or when the number of clusters equals number of available 5 MHz channels.
5) Phase 2 - Merging Colors: An important issue is to find the method for cluster creation, mainly, how shall the CBSDs be assigned to the cluster? The method is chosen in order to decrease spectrum fragmentation. The input is the colored interference graph from Phase 1. It contains X various colors. In order to achieve

m colors, X − m + 1 colors have to be merged, and we propose to do this iteratively. The main idea is to each time merge the two least interfering colors in the interference graph. This is achieved through the maximization of the minimum pathloss between the CBSDs of two colors to be merged. Observe that at this stage the frequency allocation obtained in Phase 1 or previous iterations of Phase 2 are not used. Using this method, we can create any clusters count from 1 to Mmax.

6) Power optimization: Once the colors are merged, the next step is to assign frequency subbands to the merged colors, as described in Phase 1. After that the power optimization algorithms are applied for each frequency channel n independently. The power of the i-th CBSD Pi is the minimum out of all power values obtained as a result of poorer optimization carried for each active channel (for the i − th CBSD). While in the first phase the algorithms generate potentially only one feasible solution (i.e., the one where all transmit powers are maximal), in the second phase one will achieve Mmax − 1 solutions. The Coexistence Manager will then need to decide (based on a given decision criteria) which solution is the most suitable.

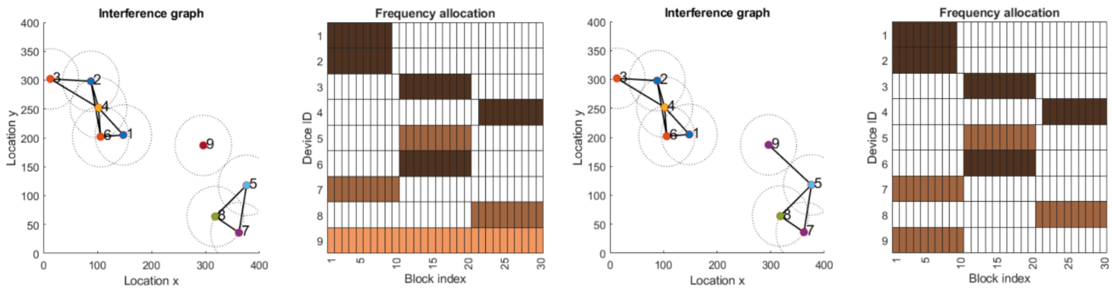


Figure 14: EUCNC19 Coexistence video demonstration

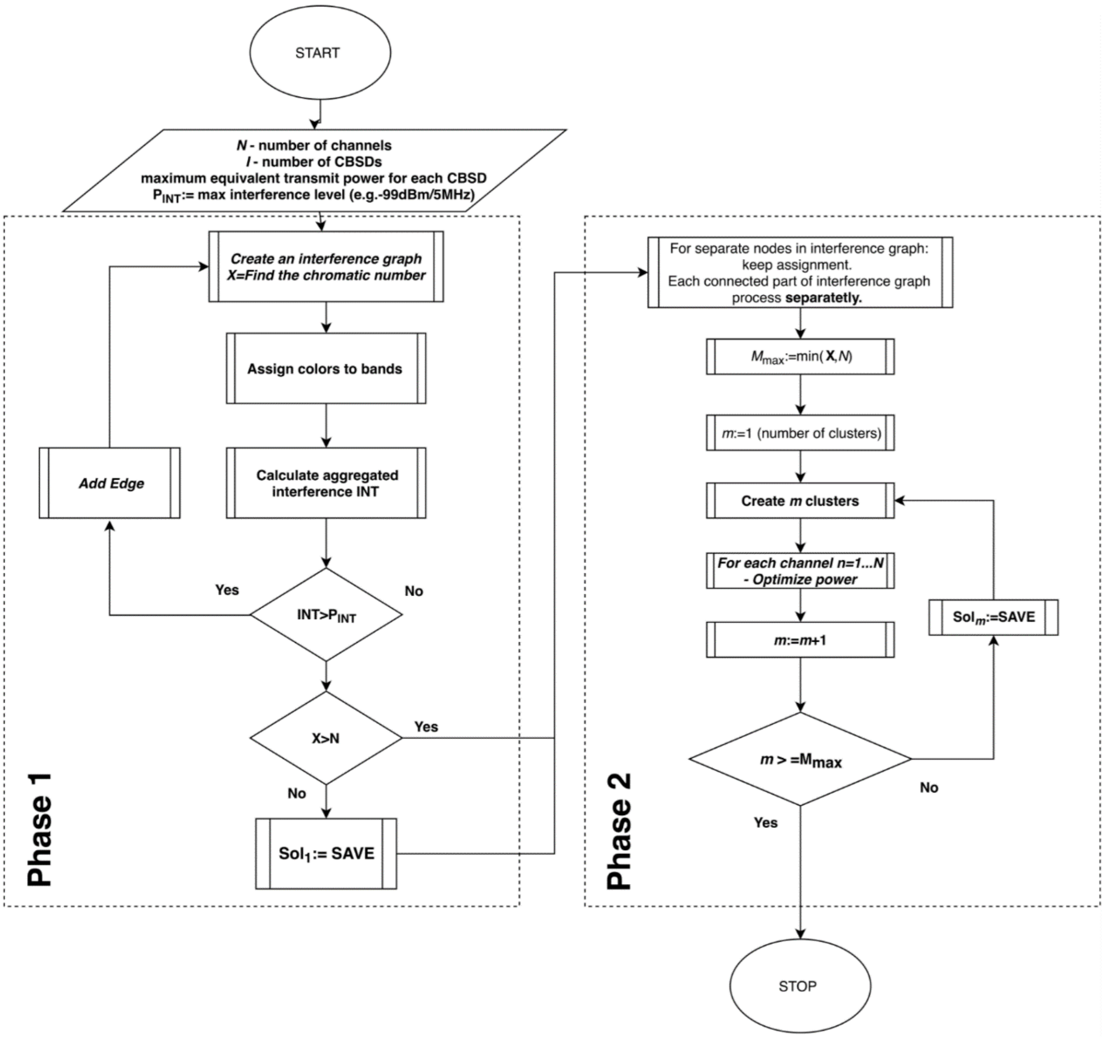


Figure 15: EUCNC19 Coexistence multi-choice algorithm

2.3.2.2 *PWS spectrum sharing*

The system creates an LTE channel in the 700 MHz band. The trigger message is sent over Wi-Fi. EMBMS content is received in the created LTE channel by the UE, see Figure 16 and Figure 17. The Public warning alert is created using the Common Alerting Protocol. The PWS requests a dynamic LTE spectrum from the spectrum management system. PWS requests a broadcast session with BM-SC to deliver content to BM-SC. BM-SC starts broadcasting. PWS performs a unicast trigger over Wi-Fi (FCM). The PWS app on the UE receives the trigger over Wi-Fi. PWS requests content from the eMBMS middleware (over LTE) and displays the content. The public warning is canceled by sending a cancelation message to the UE (LTE broadcast or Wi-Fi TBD). It stops the broadcast session in BM-SC and releases the LTE spectrum with spectrum management system.

The benefit of the system is that the basic message can reach as many channels as in the best case currently. The text-based message can be enhanced with any multimedia type including video in the end user devices, which support the feature. The delivery of the multimedia is very efficient as it uses broadcast instead of unicast. The spectrum capacity used for the multimedia PWS content is reserved only when needed, so that it is otherwise available for other purposes. It is possible to create a local multimedia PWS in emergencies where the public infrastructure is down due to the emergency.

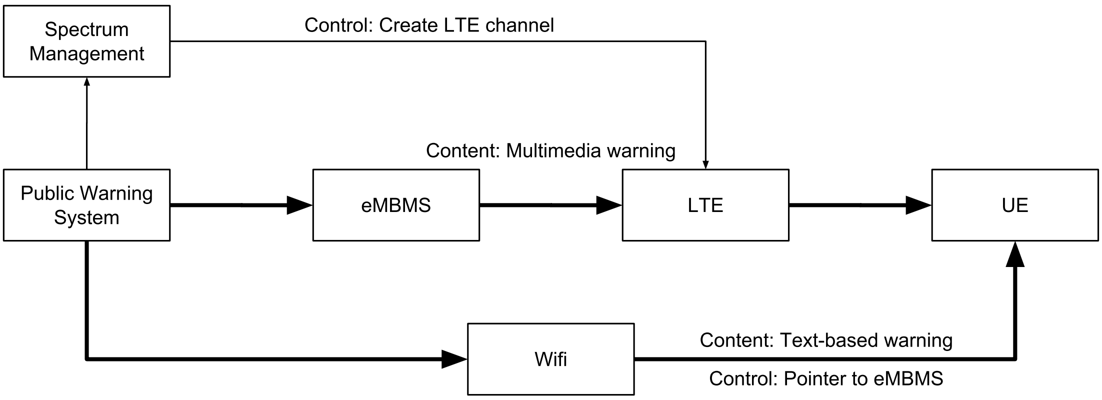


Figure 16: EUCNC19 Spectrum management public warning system demonstration

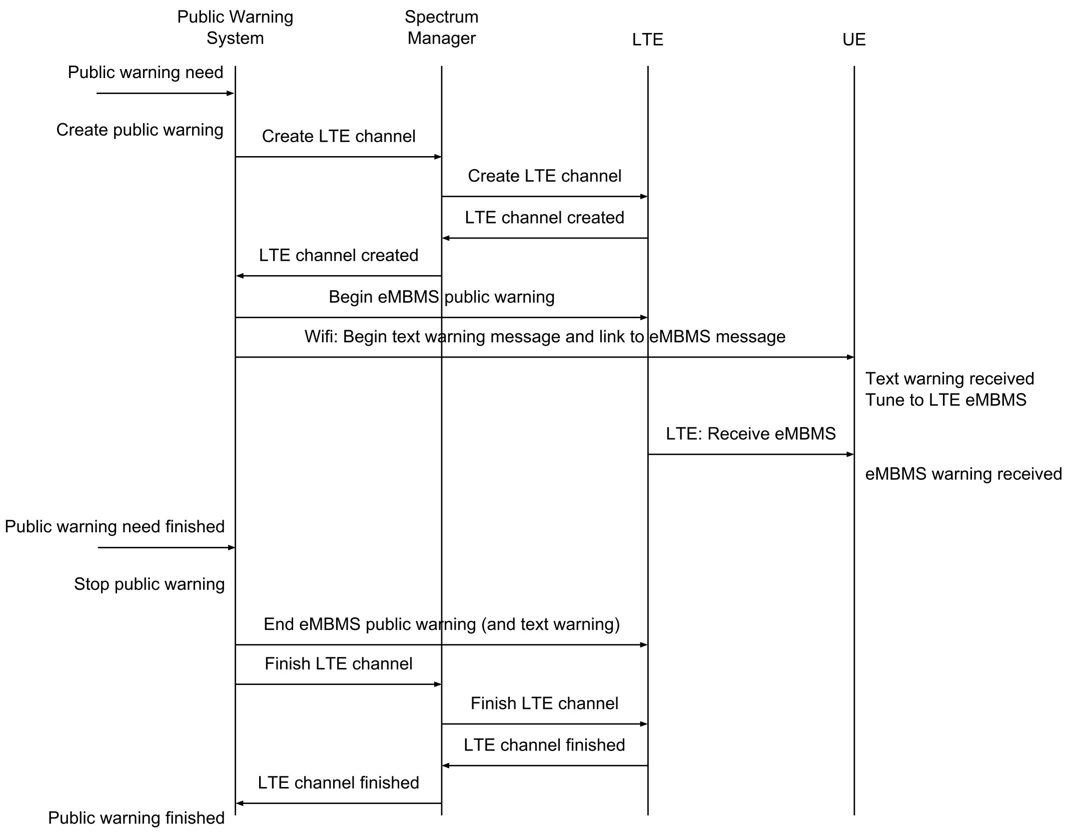


Figure 17: EUCNC19 Spectrum management public warning system messaging

2.3.3 Development Plan and Events

The spectrum management for PMSE demonstration was shown in EUCNC 2018.

	2017-2018								
	N	D	J	F	M	A	M	J	J
Concept planning	■								
Preparation of equipment		■							

Perform the demonstration in laboratory									
Create a video illustrating demonstration									
Perform a field trial with the demonstrator as part of larger measurement campaign									
Present the demonstration at EUCNC 2018 based on video									

DEMO RECORD

Partners involved	
- Fairspectrum - Turku University of Applied Sciences	
Hardware involved in the demonstrator	
- Nokia Basestations - Samsung S8 phones - Tektronics spectrum analyser - R&S DVB-T signal generator	
Software components	
- Fairspectrum spectrum manager - RTMP video streaming software - Cumucore core network	
Content description	
- Live streaming of content from cell phones	
Event EUCNC 2018	
Place	**Ljubljana**
Date	**18-21 June 2018**
Audience	**100 people**

Coexistence management demonstration will be shown as a video at EUCNC 2019.

	2019								
	J	F	M	A	M	J	J	A	S
Concept Proposal									
PoC preparation									
Perform the demonstration									
Create a video illustrating demonstration									
Show the video at EUCNC 2019									

DEMO RECORD

Partners involved	
- Fairspectrum - Turku University of Applied Sciences	
Hardware involved in the demonstrator	
- Nokia Basestations - Receivers - Tektronics spectrum analyser	
Software components	
- Fairspectrum spectrum manager - Cumucore core network	
Content description	
- TBD	
Event EUCNC 2018	
Place	**Valencia**
Date	**18-21 June 2019**
Audience	

The public warning with spectrum sharing demo is to be performed in Turku and video of the demonstration will be prepared.

	2019								
	J	F	M	A	M	J	J	A	S
Concept planning	■	■							
Preparation of equipment			■	■					
Perform the demonstration					■				
Create a video illustrating demonstration						■			
Video to Xcast youtube channel						■			

DEMO RECORD

Partners involved
- Fairspectrum - One2many - Turku University of Applied Sciences
Hardware involved in the demonstrator
- Nokia Basestations - Receivers

- Tektronics spectrum analyser
Software components
- Fairspectrum spectrum manager - One2many Public warning components - Cumucore core network
Content description
- TBD

The complete information about the finalized demonstrator will be found in D6.8.

2.4 Hybrid Broadcast Service “with MBMS on Demand (MooD)”

2.4.1 Concept and Relation to the Use Cases

Expway, IRT and EBU target the development of a demonstrator focused on the Hybrid Broadcast Service use case M&E1 as defined in [4]. The proposed demonstrator involves several technical features to show the potential of 5G for media delivery. The idea is to show a unified framework, a 5G network, able to convey different media services according to operator and user demands. From traditional always-on linear TV services to on-demand streaming; from user-agnostic delivery to adaptive streaming to device capabilities; from fixed TV receivers to users on the move. All within the same system.

The demonstration will show the value of point-to-multipoint transmission capabilities in 5G, especially for a large-scale distribution of popular content such as premium sports. But media delivery is not always based on broadcast technology. Unicast transmissions also play a role in the complete system in order to serve specific demands from individual users. The demonstrator also aims at showing when unicast and broadcast capabilities are essential for an efficient provision of media content.

The primary objective is to show that 5G technology is able to deliver both live TV and on-demand content exploiting different transmission modes. The second objective is to demonstrate the scalability of the system providing sustained quality of experience for increasing demands of high-quality content and the seamless switching between broadcast and unicast transmission modes.

As a summary, the demonstration will highlight the following aspects:

- fixed/mobile convergence
- combined use of unicast and broadcast capabilities and a seamless switching between them (MooD)
- delivery of free-to-air linear TV over broadcast with add-on content over unicast
- use of standardized 3GPP interfaces to deliver MPEG TS (for TV delivery with additional HbbTV service information) and MPEG-DASH (for adaptive streaming)
- reception on both mobile/portable user devices and stationary TV-sets

The idea of this demonstration is to show that eMBMS technology (a.k.a LTE Broadcast) is able to deliver the linear TV with add-on content produced by the broadcasters (described in Section 2.1). eMBMS is also able to optimize the network resources for the MNO during the important events (e.g. sports) thanks to MooD.

2.4.2 Technical Description

All following concepts will be demonstrated using a small-scale radio equipment called eBox that comprises the LTE EPC, eNB as well as the BM-SC and MBMS-GW for broadcast capabilities.

2.4.2.1 *Live TV Broadcast with embedded HbbTV signalling*

Live TV content and the signalling for the access to add-on services based on the HbbTV standard are both included in an MPEG-2 TS and transmitted over eMBMS. The broadcast signal is received by stationary eMBMS-enabled TV receivers and by smartphones simultaneously and without the need for unicast connectivity.

Users can access additional on-demand content either via a HbbTV application on TV sets or a HTML-based application on mobile phones. The on-demand content is delivered over the unicast link in the mobile network.

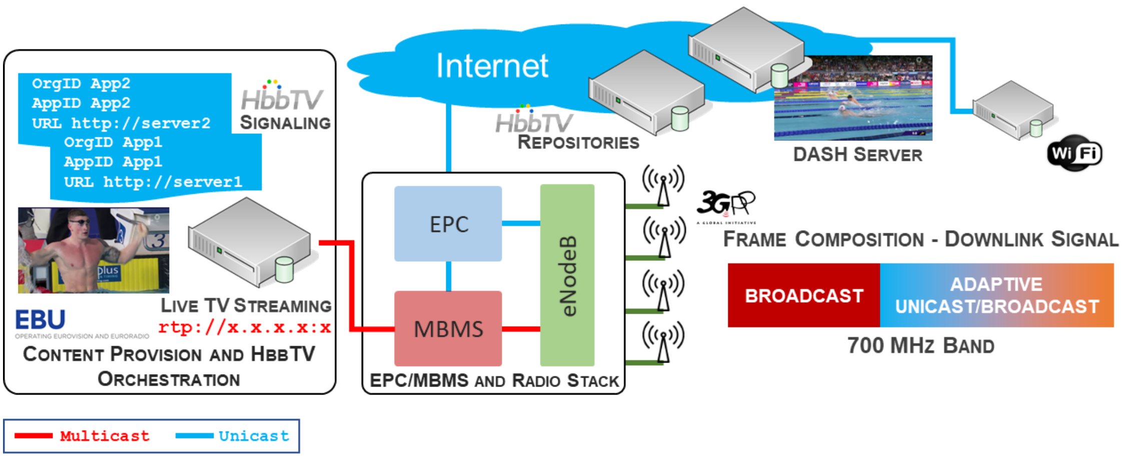


Figure 18: Transmission chain of the demonstrator

Two different types of content will be made available: The main live TV programme to be broadcast and a stream of a second programme, encoded with DASH with multiple profiles to adapt user requirements. Both services stream via unicast and live broadcast TV can be delivered in parallel using a maximum of 60% (up to 3GPP release 14) or 80% (from 3GPP release 14) system resources for broadcast within the same system.

Figure 19: Transmission chain of the demonstrator

2.4.2.2 *Adaptive Unicast/Broadcast switching according to demand (known as MooD)*

A live stream is originally delivered over unicast to a few smartphones. The content then becomes popular, the MooD feature is activated, and the network automatically switches to broadcast mode for that content to optimise the overall system resource usage and guarantee QoE. The smartphones with eMBMS middleware installed automatically switch to MBMS if they are in the coverage area of the broadcast signal. The switching is transparent to the users who do not experience an interruption while watching the content.

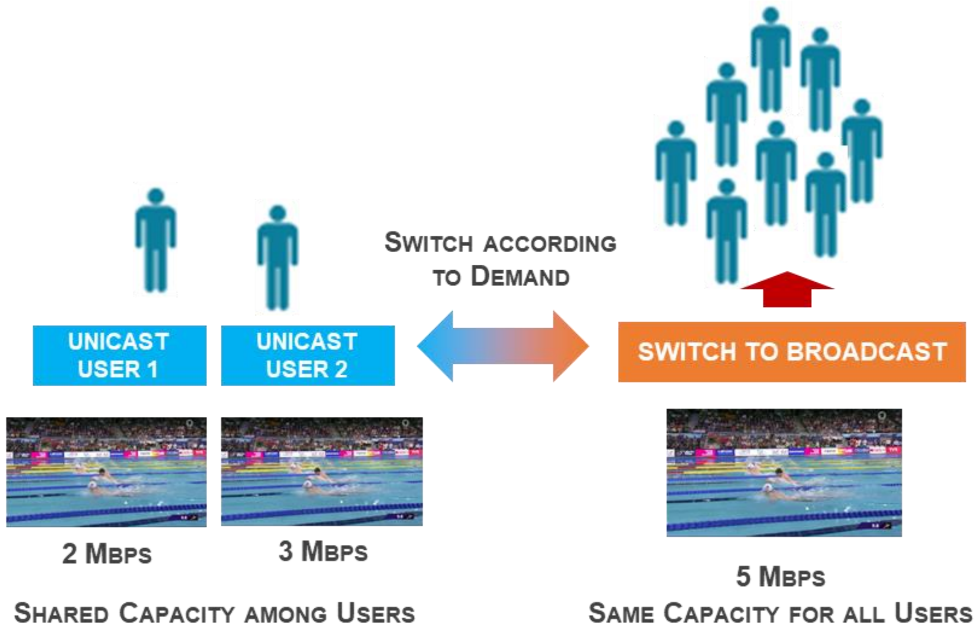


Figure 20: MooD enabling seamless transition between unicast to broadcast and vice versa

2.4.3 Development Plan and Events

This demonstrator is targeted for Mobile World Congress taking place in Barcelona, Spain in February 2019.

	2018				2019	
	Sep	Oct	Nov	Dec	Jan	Feb
Concept proposal						
Hardware & equipment preparation						
Integration of HbbTV setup into eBox having MooD feature						
Content generation						
End-to-End testing						
Demonstrator finalized						

DEMO RECORD

Hardware involved in the demonstrator
- Expway eBox including Amarisoft eNB and Expway BM-SC/BPM - TV-set (with USB-HDMI dongle) - Local HbbTV web-server (internal to eBox) - 13 UEs with eMBMS middleware
Software components
- Smartphone application integrating access to MBMS API and Android API - HTML application for add-on content display in the smartphone

- HbbTV standard-compliant application for TV-set - Expway demo App for MooD feature	
Content description	
- MPEG TS containing 1 linear TV services and 1 HbbTV applications (1 to be displayed in the smartphone, a second to be displayed in the TV) - DASH segments for 8 hours duration	
Event: Mobile World Congress 2019	
Place	**Barcelona**
Date	**25-28 February 2019**
Audience	

The complete information about the finalized demonstrator will be found in D6.7.

2.5 Hybrid Broadcast Service “with Multi-Link”

2.5.1 Concept and Relation to the Use Cases

BLB, in collaboration with the IRT and EBU, targets the development of a demonstrator focused on the Hybrid Broadcast Service use case defined in [4] with use of multilink solutions, described in [5].

The proposed demonstrator involves several technical features to show the potential of 5G for media delivery in a hybrid fashion, combining:

- The ability of seamless switching from multicast to unicast using multiple links.
- The ability to provide better QoE to the user using multiple links.
- On-demand content, event related information and access to social media.

A unicast stream can be received via LTE or Wi-Fi interfaces. To provide best QoE to the user, the user’s mobile device (user equipment) needs increased channel bandwidth. Multi-link would enable the possibility to deliver broadband content that would be impossible to deliver over a single link. For example, if a certain video stream needs 15 Mb/s and the single link is capable to deliver only 10 Mb/s, then this content could not pass over a single link. However, when bonding and aggregating at least two such links at the application layer, the total available bandwidth becomes 20 Mb/s which makes this delivery possible. So, to provide this possibility the multi-link functionality will be activated both on the network and at the UE’s.

Multi-link will allow the user to get the best quality video over unicast, will allow seamless and quick transition between multicast/broadcast mobile and unicast Wi-Fi areas, including during mobility.

2.5.2 Technical Description

Multi-connectivity (MC) of single user terminal to multiple radio access points is a 5G key enabler, which would satisfy requirements such as increased throughput, low delay, high reliability, seamless handover etc. on 5G mobile networks. Multi-connectivity supports simultaneous connectivity and aggregation across different technologies such as 5G, LTE, and unlicensed technologies such as IEEE 802.11 (Wi-Fi). In heterogeneous networks, multi-connectivity helps to provide an optimal user experience (e.g. high bandwidth, network coverage, reliable mobility etc.). One subcase of multi-connectivity is multilink.

There are several options for implementing ML strategies, which are also related to the key objective of the ML usage. ML can be used for improving reliability, providing ancillary information, increasing available bandwidth (e.g. higher video resolution), or performing traffic optimization. Due to this diversity, the use of multiple connections can be quite distinct in different models. The main methods for multi-connectivity can be described as:

1. “Replicate”: Deliver the same content over all available connections (Figure 21). In any single layer-2 link, especially in a wireless environment, the fluctuation in bandwidth, latency or error rate can be dramatic. Using multiple links as a virtual single broadband connection could mitigate these fluctuations. Seamless transition between single-L2-link and multilink could be achieved in a reliable way due to the use of simultaneous multiple networks in a dynamic way. In this case, mobility means the seamless transition between the coverage areas of different networks or technologies, with continuous QoS and QoE. For instance, the end user can enjoy a seamless viewing experience when moving from the office to the home using the same mobile device.

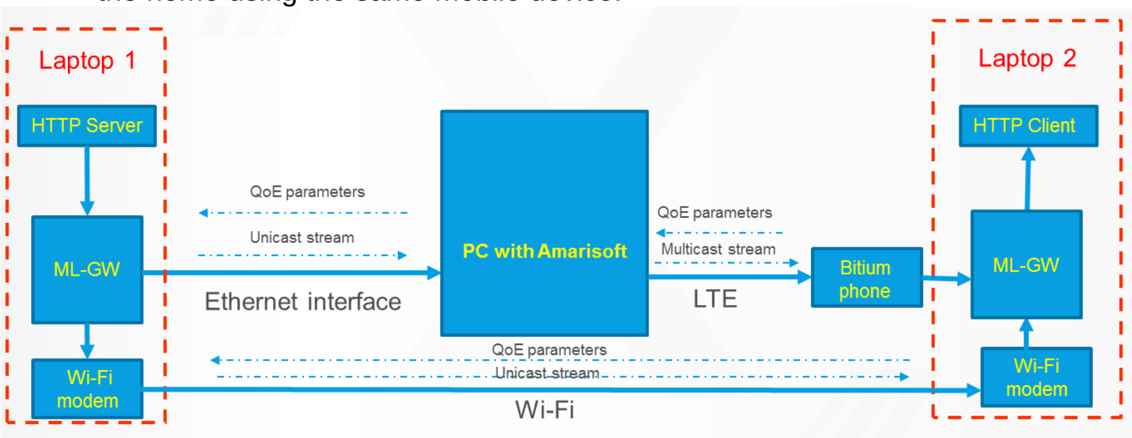


Figure 21: Scenario 1

2. “Bonding” or “Aggregation”: Treat all available links as a single virtual broadband link and split all the content between all available links dynamically according to the performance of each of the links and the total available “goodput” (Figure 22) For example, if a certain video stream needs 15 Mb/s and the single link is capable of only delivering 10 Mb/s, then this content could not pass over a single link. However, when bonding and aggregating at least two such links at the application layer, the total available bandwidth becomes 20 Mb/s which makes this delivery possible. This technology is advantageous to 5G-Xcast since video content (especially with the current high video resolution trend) is usually either a live stream or a very large file to download and individual links, even 5G ones, are not always sufficient.

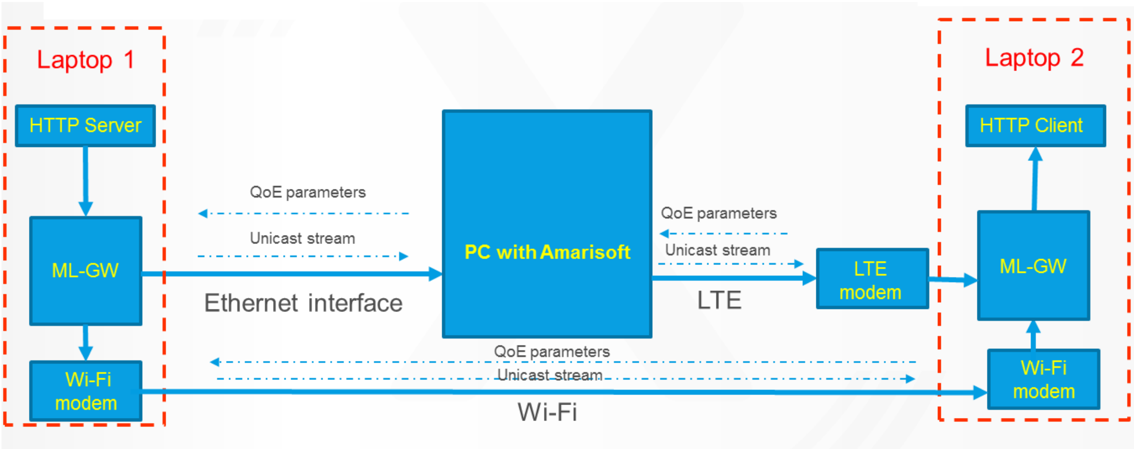


Figure 22: Scenario 2

To show these multilink features, based on the scenarios mentioned above (Figure 21, Figure 22), we proposed the following demo structure (Figure 23).

Figure 23: Multilink demo structure

This demo includes two laptops with pre-installed multilink middleware, a desktop PC with pre-installed Amarisoft, a Bitium phone and an LTE modem.

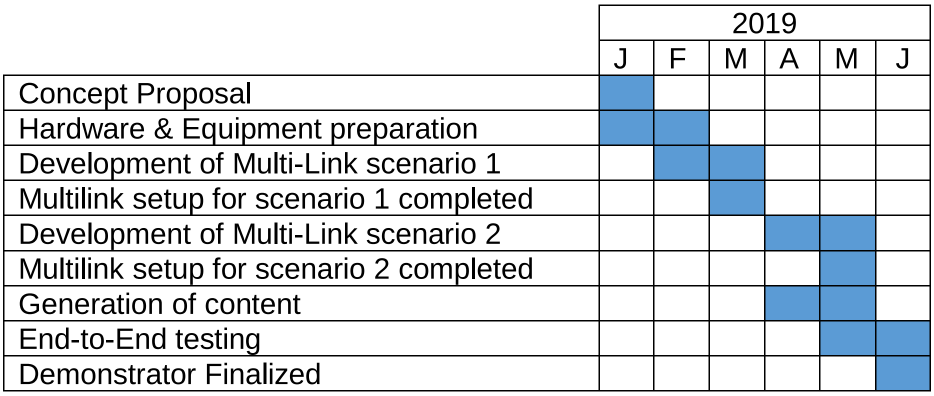
During this demo a ML-GW (Multilink Gateway) reroutes the data packets through the different available links, and a ML-MW (Multilink middleware) performs the adequate data merger operation at the UE. The ML-MW at the viewing user side communicates with the ML-GW which can be located either in the core network, the publisher, or the cloud depending, for example, on deployment constraints. These two entities (ML-GW and ML-MW) exchange information about the performance of each link.

The content transmitted from the ML-GW down to the viewing device is split or duplicated over available links, which are possibly from different operators or use different technologies according to their temporal performance. The decision whether to split or to duplicate depends on the desirable gains in throughput, ancillary information and reliability, and a function of the link conditions. The content is then reassembled at the viewing device (with eventual duplicates removed) as a coherent data stream ready for viewing. The content itself is not manipulated which means that the delivery is completely agnostic to the content.

2.5.3 Development Plan and Events

This demonstrator is initially targeted for the EuCNC conference taking place in Valencia in June 2019.

The timeline of the development process is shown below:



It is planned that the demonstrator will be shown at EuCNC 2019 conference.

DEMO RECORD

Hardware involved in the demonstrator	
- Amarisoft eNB+EPC - 2 PCs equipped with Wi-Fi and LTE modem	
Software components	
- Multilink middleware preinstalled on both laptops	
Content description	
- MPEG-DASH encoded live TV streams from the European Championships	
Event 1. EuCNC	
Place	**Valencia, Spain**
Date	**18-21 June 2019**
Audience	

2.6 Converged, autonomous MooD in fixed/mobile networks

2.6.1 Concept and Relation to the Use Cases

This PoC will showcase key features of the content distribution framework proposed in WP5. In particular, it will demonstrate:

- The use of multicast/broadcast as an internal network optimisation, rather than as a service to be sold.
- The use of simple unicast interfaces with content service providers to simplify integration and facilitate adoption.
- How client applications do not require any modification to benefit from the use of multicast/broadcast.

- How the framework is applicable to both fixed and mobile networks.

BT and Expway are working together to produce this PoC. We will show how the live, unmodified, BT Sport commercial service can be integrated using the 5G-Xcast content distribution framework to benefit from multicast/broadcast distribution. The PoC will show content prepared for unicast distribution being distributed over both fixed and mobile networks with dynamic switching between multicast/broadcast and unicast delivery as the audience size changes. BT will provide access to their BT Sport service which will be distributed using Expway's eBox which provides a mobile network with MBMS capabilities including MOOD. Bittium mobile devices will be used to receive and display the content through an unmodified BT Sport app. These devices are MBMS capable and will incorporate Expway's MBMS middleware along with an adaptation layer which will abstract the MBMS complexities and provide a unicast interface to the unmodified BT Sport app. A controller module will co-ordinate the delivery optimisation and facilitate different demonstration scenarios.

This demonstrator will also showcase a key feature of converged network where the Expway's eBox delivers the same content in mABR to the fixed network and in eMBMS in the mobile network. The end users using Bittium mobile devices perceive a transparent experience, meaning that the video playback isn't interrupted, when the connection is switched between fixed and mobile. These devices will incorporate Expway's converged middleware that comprises the capabilities of both multicast agent in mABR and MBMS client in LTE broadcast to allow a seamless experience seen by the application.

2.6.2 Technical Description

As discussed in Section 2.6.1, a key goal is for client apps to function unmodified, whilst the system delivers their content via the most appropriate path. This PoC uses the BT Sport app, which expects to request HLS/MPEG2-TS via HTTPS. This is of course a unicast protocol, pulled by the app & delivered over an encrypted path. The app expects to communicate with the BT servers, whereas the PoC needs to both intercept and also redirect the requests and responses, without the app being aware of this.

The overview for the mobile and fixed cases is show in Figure 24 and Figure 25 respectively, where the components being supplied by BT are coloured blue, and those from Expway orange.

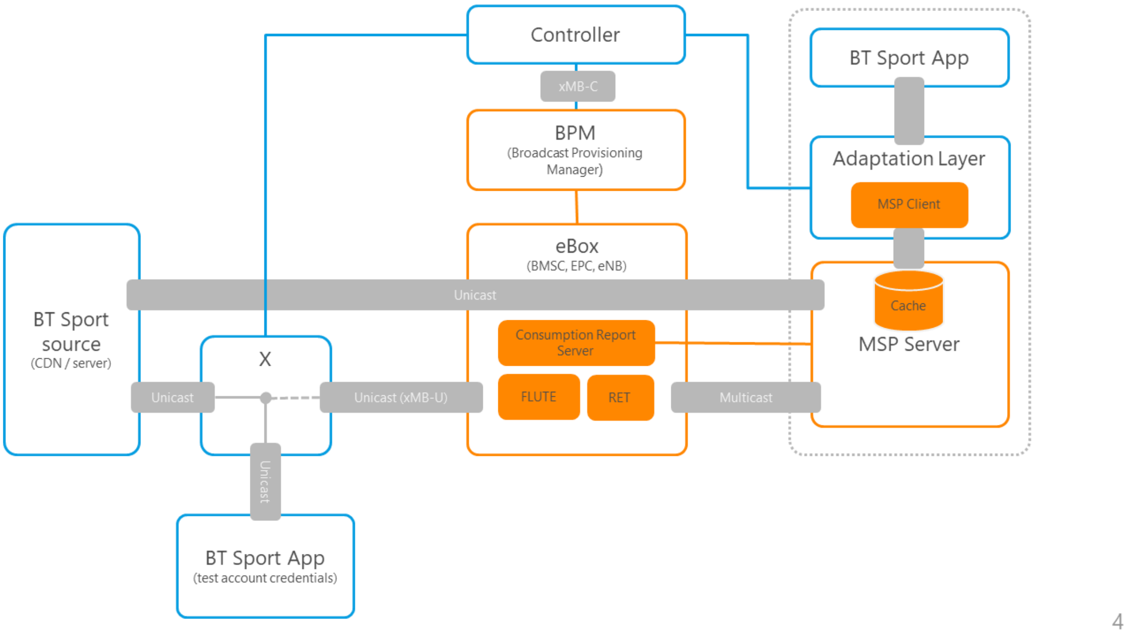


Figure 24: Main components of the mobile network PoC

In Figure 24, the BT Sport App, Adaption Layer (AL) and MSP Server (the eMBMS middleware) are all on the handset. HTTPS requests from the app are routed to the adaptation layer. This is configured to forward channels of interest down to the MSP, and all other unicast traffic from the app is carried in the usual way to the internet, without going through the AL or the MSP.

As the audience size changes, the business logic in eBox/Controller combination may choose to change the routeing path from MC to UC & vice-versa as appropriate.

There are therefore three possible data paths from the handset:

- Direct connection for non-PoC content (web pages, other video etc.), not shown in the figure.
- Requests for BT Sport content that we are multicasting. The content in this case will flow along the bottom grey path: obtained by the client connected to X, streamed from X, encapsulated into the FLUTE protocol in the eBox and delivered to the MSP on the handset. The app will be unaware of the changed data path, since it will continue to receive the recreated HLS/unicast as normal.
- Requests for BT Sport content that we are not multicasting. The requests and content in this case will flow along the top grey path, between the original BT Sport source (CDN server) and the app on the device. The MSP and eBox will not intercept the requests & responses in this unicast case.

The Controller and BPM comprise the business logic. They collect content request reports and inform the eBox whether content is to be multicast or not. In the PoC, this decision is based on simple metrics such as “is there more than one client connected to the same stream?”, or a checkbox being selected on a controlling web page. A deployed solution would employ more complex metrics.

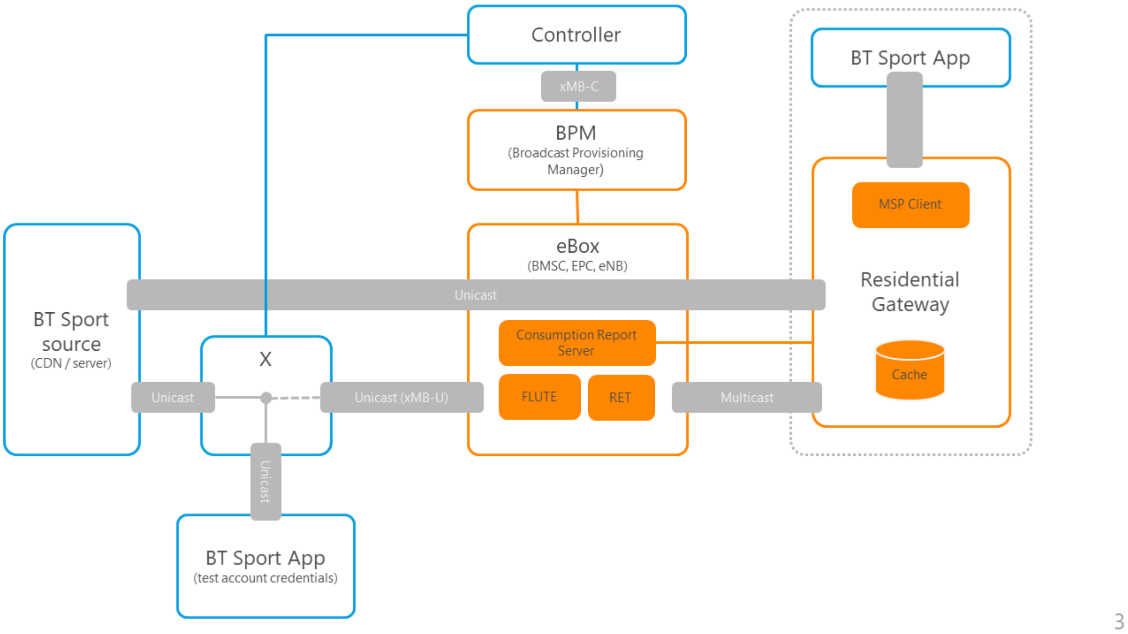


Figure 25: Main components of the fixed network PoC

Upstream of the eBox, we have the multicast generator, “Function X”. X provides an input source of BT Sport content for the eBox, so that the eBox can make the content available to the MSP (as either multicast or unicast). The BT Sport service requires valid login credentials and cookies, and X hosts an instance of the app which logs on to the service using a valid, test account. The app requests HLS content from the Sport source and makes the manifest and segments available for ingestion into the eBox. Additionally, X modifies the manifest in order to present a single bitrate version of the content: the Sport service normally offers multiple rates (ABR), allowing the client to select its preferred version. To simplify development for this PoC, we limit the content to a single rate, to avoid the complexities of adapting multiple rates across both the unicast and multicast paths.

For the fixed-network case, the architecture is similar, however the client-side is simplified because the MSP resides on the Residential Gateway. This means that the AL is no longer required; the client runs on a Wi-Fi device as normal. The device could be a computer, tablet or even smartphone running in wi-fi-only mode.

2.6.3 Development Plan and Events

The main steps and validation points to develop the PoC are shown in Figure 26. There are other tasks to be carried out which are not included in this list since they do not involve significant risk.

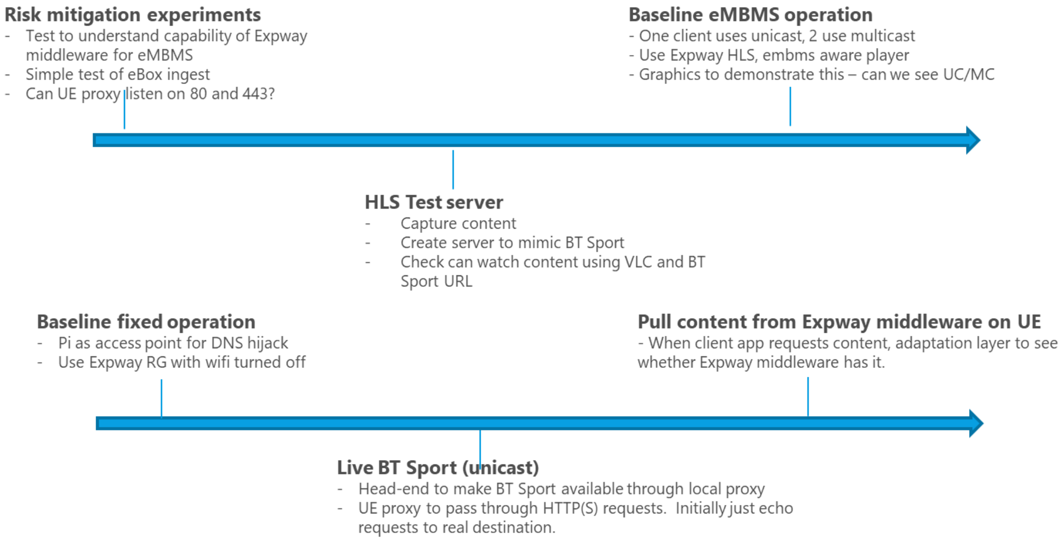


Figure 26: Main steps in PoC development

2.6.3.1 *Risk mitigation experiments*

Some of the key risks in building the PoC occur during the final steps when an attempt is made to integrate the various components. This leaves it too late to find alternatives and may result in significant wasted effort if earlier developments need to be discarded. It is prudent to try to identify as many of these risks as possible early in the project and carry out some simple experiments to gain confidence that the approach is correct.

Since the main new component is the adaptation layer and its integration with the UE, this is where most of the risk lies.

2.6.3.2 *HLS test server*

This seeks to replicate the live service as accurately as possible, by serving a repeatable, representative set of content that exactly mimics the live service. As well as being used for testing, it is also useful as a backup when the system needs to be demonstrated, in case there are any issues with the live service.

2.6.3.3 *Baseline eMBMS operation*

This step means setting up eMBMS as per the normal Expway system. It gives us a baseline of a working system to develop further. We will use any convenient content service and player to demonstrate this.

2.6.3.4 *Baseline fixed operation*

This too is a baseline system, however here we test that we can carry out DNS interception with the Expway residential gateway and provide necessary certificates to the player application. Our intention is to use the real BT sport service for this.

2.6.3.5 *Live BT Sport (unicast)*

In this step checks that we can get the real BT Sport service through the adaptation layer without using eMBMBS components. The adaptation layer would make unicast requests for content acting as a simple proxy. This test will put the adaptation layer in the content path for the first time.

2.6.3.6 *Pull content from Expway middleware on UE*

The final major step is to modify the adaptation layer to pull content from the Expway middleware, so that it is delivered by eMBMBS.

The basic timeline for these and other activities is summarised below (testing is of course continuing throughout the process):

	2018		2019					
	N	D	J	F	M	A	M	J
Concept proposal	■							
Hardware preparation & config	■	■	■					
Video content prep				■	■			
Baseline EMBMS			■	■	■	■		
Baseline fixed network				■	■	■		
BT Sport integration						■	■	
Demonstrator finalised								■

DEMO RECORD

Hardware involved in the demonstrator	
- Gigabyte core i7 mini PC x2 - Ettus SDR - HDMI monitor - Keyboard & mouse - Bittium mobile device x2 - Ethernet switch - Various cables	
Software components	
- Amarisoft EPC (including MBMS-GW) and eNB - Expway BM-SC and BPM - Webserver - Controller software - Demo visualisation software - BT Sport application - Adaptation Layer software - Expway eMBMS middleware	
Content description	
- HLS BT Sport footage (H.264 + AAC)	
Event: EUCNC 2019 (European Conference on Networks and Communications	
Place	**Valencia, Spain**
Date	**18-21 June 2019**
Audience	

The complete information about the finalized demonstrator will be found in D6.9.

2.7 Object-based Broadcast across a 5G Core network using Dynamic Adaptive Streaming over IP Multicast

Object-based broadcasting (OBB), has been proposed and developed to offer flexible, responsive, interactive and customized entertainment experiences to each audience member. While linear, scheduled, programs continue as in traditional broadcast, the content in OBB can be delivered in a form that is capable of being adapted in a way that responds to individual audience members, their preferences, their time and environment, and the device(s) that they are using.

A key concept in realizing these kinds of user experiences is the way that constituent parts of the media are handled, such that the individual media assets can be addressed separately as objects. These objects can be reassembled to create an optimized and personalised user experience on the user equipment (UE) (or, in general, on an edge device). The reassembling “manual”, i.e. metadata, describes the relationships and associations between various objects, and thus encodes the editorial intent. The precise combination of objects can be flexible and responsive to the audience member, enabling the adaptation to suit the user preferences, UE or system, environment, and even offer full interactivity.

5G-Xcast aims to bring the concept of OBB into the next generation of mobile networks. Today the number of different devices that can be used to consume linear media content is enormous, and thanks to improved mobile technology, wireless communications, and the popularity of headphone listening, the environments in which the audiences consume linear content also vary widely. Delivering identical content to every audience member inevitably results in a compromise of the user experience. By harnessing the full potentials of OBB in 5G, a consistently responsive and personalised experience can be provided across all possible devices for each audience member.

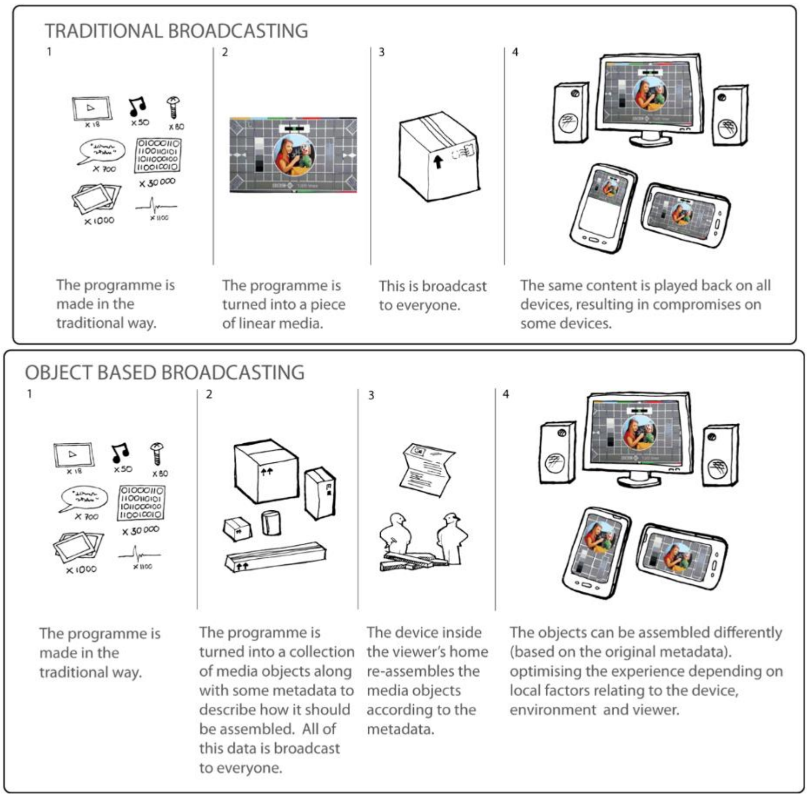


Figure 27: Traditional broadcast (top) vs OBB (bottom)

2.7.1 Concept and Relation to the Use Cases

The BBC has developed Forecaster5G to demonstrate OBB in the Hybrid Broadcast Service use case. The editorial objects that comprise a presentation are delivered to an OBB rendering application running on the UE using a mixture of multicast (MC) (via the Dynamic Adaptive Streaming over Multicast DASM system developed by BBC R&D) and unicast (UC). The UE renders the objects, taking into account the user's preferences and including personalisation.

A weather forecast application is an ideal illustration of the hybrid OBB approach as there is an explicit distinction between the video of the presenter and the backplate (in this case the weather map). Indeed, the presenter is traditionally filmed with a green screen and the backplate is then rendered in the studio. This is then combined into a single video stream for conventional broadcast distribution. This demonstrator, among other things, moves the rendering of the backplate from the studio to the UE, and thus can include personalisation elements.

The concept of the demonstrator is to show a hybrid of MC and UC objects being rendered seamlessly on the UE. The MC objects are delivered by the DASM system and include commonly used and bandwidth-heavy objects (for example the main video of the presenter). The less commonly used objects and less bandwidth-expensive objects (for example the weather symbols) are delivered over UC. The delivery mode of the objects is illustrated in Figure 28. The UE then renders the objects depending upon several factors, including user preferences (for example choosing between the main presenter or a sign language presenter), device orientation (portrait or landscape), and unique personalisation to the user (e.g. icons for the location of the user's friends on the weather map). Examples of the different renderings of the content is illustrated (without the unique personalisation) in Figure 29.

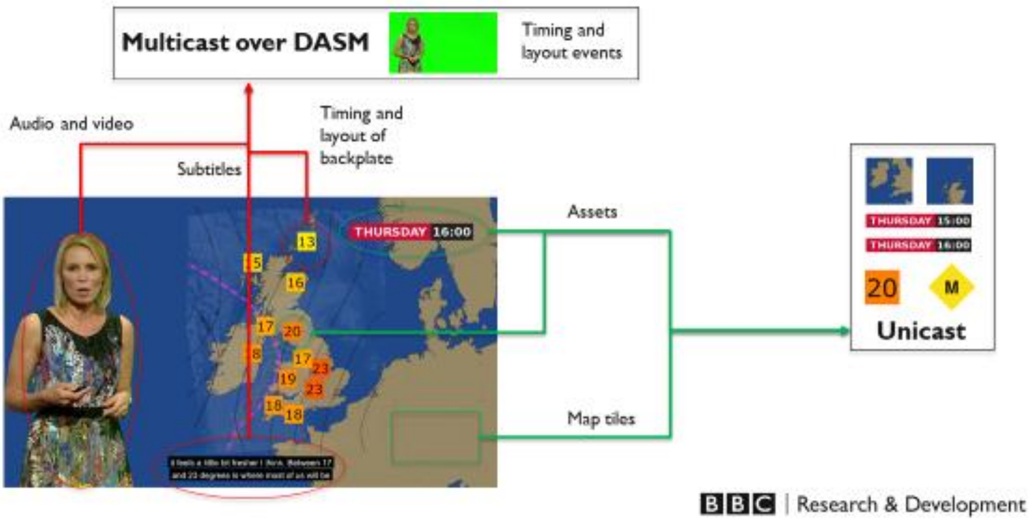


Figure 28: The origin of the objects in the Forecaster5G demonstrator

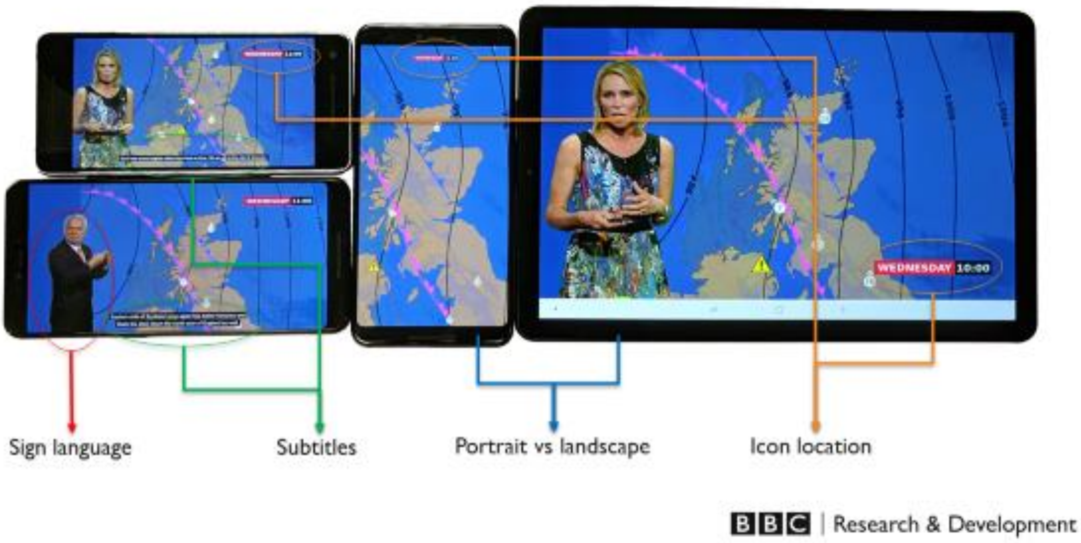


Figure 29: Examples of differently rendered content in the Forecaster5G demonstrator

2.7.2 Technical Description

The demonstrator consists of media objects delivered via a mixture of multicast and unicast. Weather symbols and map tiles are hosted on a conventional web server and are delivered via UC only. The streaming media assets are also hosted on a web server but are delivered via the DASM system. The aim of this system is to make MC distribution appear as similar as possible to UC at Layer 7 (HTTP). A *DASM Head-end* system delivers these objects to a population of MC receivers called *DASM Client Proxies*. In this demonstrator the MC transmission objects are a continuously looping stream of MPEG-DASH packaged media segments structured as one video adaption set for the main presenter video, an audio adaption set for the presenter's soundtrack and a video adaptation set for the sign language presenter. The video adaption sets have 5 representations each. The MPEG-DASH media segments are conveyed as MC HTTP resources using a profile of the QUIC transport protocol and are sent in UDP datagrams via source-specific IP multicast. All resources are also made available from a conventional HTTP origin server at the same URL as signalled in the MC HTTP resource. Unicast HTTP thus supports patch operations when a DASM Client Proxy receiver detects MC packet loss. To bootstrap MC reception, relevant UC responses are decorated with the HTTP Alternative Services (alt-svc) response header to indicate the availability of MC versions of services.

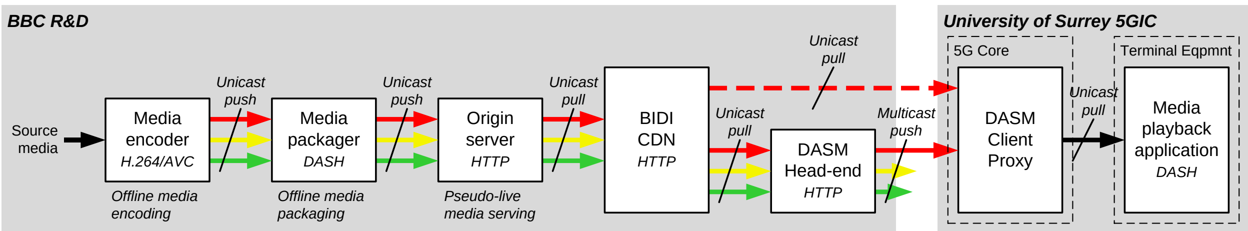


Figure 30: Schematic of the DASM system.

5GIC has designed a fully virtualized and componentized network sliced implementation of a 5G Core network based on the architecture specified in draft 3GPP 23.501 with service-based interfaces. Enabling functionalities in the Surrey test-bed also include Software Defined Network (SDN), Network Functions Virtualization (NFV) and Mobile Edge Computing (MEC), as detailed in [8]. This demonstrator delivers the commonly used media objects over MC across the 5GIC test-bed from the BBC DASM source. The DASM Client Proxy is instantiated at the customer-facing edge of the 5G Core, from there it is able to receive MC and convert it back to UC to service multiple instances of the Forecaster5G application running on different UE devices.

The UE is running a HTML/JavaScript/CSS object-based media playback application. This application receives the MC objects from the DASM Client Proxy over UC. Specifically, this includes the main presenter video, the sign language video, the audio, the subtitles, and a collection of embedded MPEG-DASH events which control the timing and layout of the backplate. The UE receives other objects over UC directly. Specifically, this includes the backplate assets (including weather symbols and map tiles), configuration files, and the locations and profile pictures of the user's friends. The application composites the objects in three layers, shown in Figure 31. The top layer consists of the subtitles and time and day overlay, with the timings given by the MPEG-DASH events received over MC. Note that, as seen in Figure 29, the time and day overlay is optimally placed in relation to the subtitles. The assets for the time and day overlay are also received over UC. The middle layer consists of the MC MPEG-DASH video. The bottom layer consists of a number of image assets fetched over UC, composed on the screen at times determined by the MPEG-DASH events (received over MC). The bottom layer also displays icons at the locations of the user's friends, thus personalising the experience for the user.

The objects displayed are chosen according to the user preferences. For example, the subtitles are only displayed if the user enables this option, and the presenter video can be switched to the signer video. The objects chosen to be displayed are then arranged to optimise the viewing experience, dependent upon the UE orientation, and the set of objects that are chosen. The assembly of the objects is controlled by a configuration file (fetched over UC).

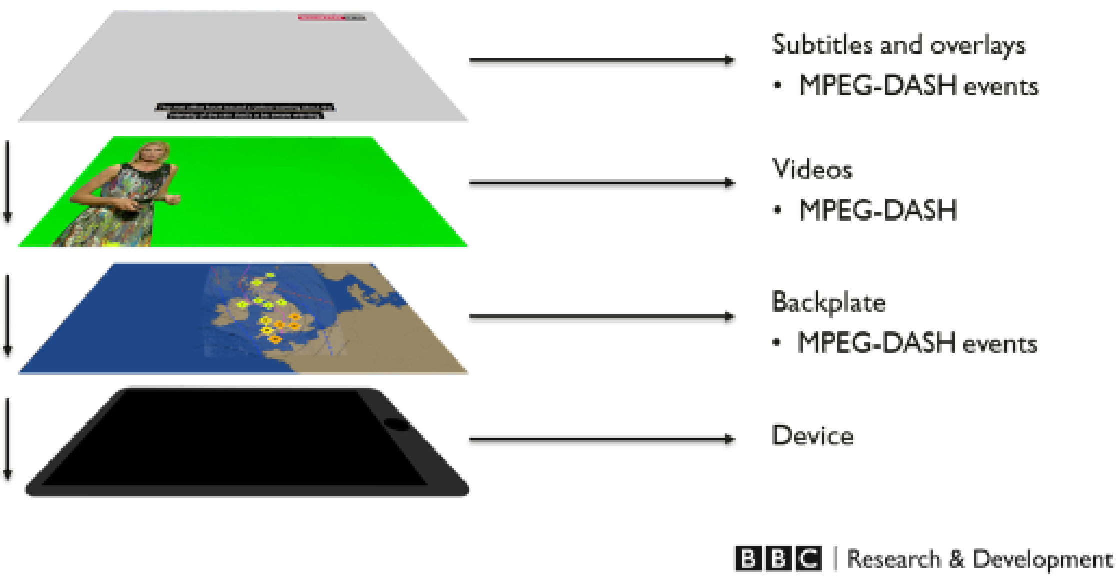


Figure 31: Schematic of the Forecaster5G Android application

2.7.3 Development Plan and Events

This demonstrator targets the EuCNC event in June 2019, taking place in Valencia, Spain.

Work begins in September of 2018 on the smartphone app. This is characterised by an exploration and subsequent finalisation of the technologies to be used and deployed on the UE. Work is then done in the smartphone app in parallel with patching the DASM system and preparing the hardware at the BBC. The hardware is then shipped to UniS where it is integrated into 5GIC. End to end testing begins in April of 2019, with the demonstrator being finalised in June of 2019.

	2018					2019					
	A	S	O	N	D	J	F	M	A	M	J
Concept proposal	■										
Smartphone app development		■	■	■	■	■	■				
DASM patch set prepared				■	■						
Hardware preparation at BBC					■	■	■				
Integration into UniS 5GIC							■	■	■		
End to end testing									■	■	
Demonstrator finalised											■

DEMO RECORD

Hardware involved in the demonstrator	
- 4 UEs - Server at the BBC - Server at the venue - Router	
Software components	
- Smartphone application consuming and rendering OBB content - DASM client proxy - DASM head end	
Content description	
- MPEG-DASH pseudo-live stream of a weather forecast, including: o Main presenter on green screen o Sign language presenter on green screen o Backplate/weather map, controlled by MPEG-DASH events	
Event 1. EuCNCN June 2019	
Place	**Valencia, Spain**
Date	**18-21 June 2019**
Audience	

The complete information about the finalized demonstrator will be found in D6.9.

2.8 Multimedia Public Warning

2.8.1 Concept and Relation to the Use Cases

The demonstrator for Public Warning will be implemented by TUAS, Fairspectrum, LiveU and one2many and is based on the PWS use case as described in Section 2.4 of [4].

LiveU Multilink is a technology to simultaneously use connections of more than one network for a single service. Dynamic Spectrum management allows changes in spectrum capacity locally and temporarily. PWS allows sending of public warning multimedia alerts to the UE. The benefit of the system is that the basic communication capacity can be increased by taking into use dynamic spectrum resources. The resulting communication capacities are further combined using multilink. All together this should result in a faster delivery of the PWS alert.

2.8.2 Technical Description

2.8.2.1 *Architecture*

The demonstrated system contains a default network (Wi-Fi) and an additional network (LTE) to demonstrate the performance improvement of multilink and dynamic spectrum management. In this demonstration, a new spectrum resource is defined and created. The additional spectrum capacity is added to the default LTE capacity using multilink.

The trigger for the PWS alert is send using the Public LTE to the UE. The UE will fetch the multimedia components using Wi-Fi, which in turn is using a bonded LTE connection by multilink.

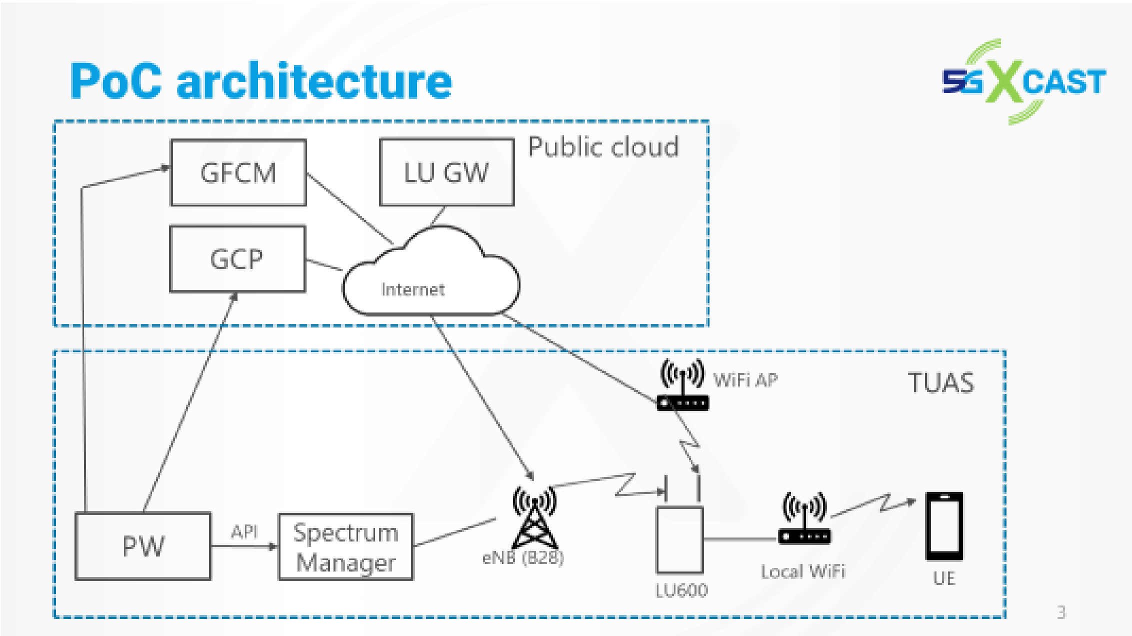


Figure 32: PoC architecture

The system creates an LTE channel in the 700 MHz band (B28). The content is sent by default over Wi-Fi. The Wi-Fi connection is enhanced with the capacity of the created LTE channel by the UE, see Figure 32.

2.8.2.2 *Public warning alert call flow*

Starting point of the call flow is that the PWS has an alert to send to the UE. The alert contains multimedia components. Using the Common Alerting Protocol specification, the multimedia component can be embedded together with the alert or provided as separate files which are referenced by the alert using URI.

1. Request dynamic LTE spectrum from spectrum management system.

The PWS, related middleware or a manual method is used to request LTE spectrum from the spectrum management system.

2. Push content to content server (or make available GCP).

The alert with its multimedia components are made available to system (CDN or content server) that can be addressed by the UE. This step is mentioned as typically the PWS itself cannot be addressed by the public directly.

3. Perform unicast trigger over Wi-Fi or LTE (Google FCM).

The PWS or related middleware or a manual method uses Google FCM to trigger the PW app on the UE to fetch the alert. As Google FCM is used, this trigger can be received on either Wi-Fi or public LTE.

4. App on UE receives trigger.

5. Request content from Wi-Fi.

The PW App will request the content.

6. Content fetched from content server, bonded LTE links by multilink to improve throughput.

Large multimedia components such as audio and video should benefit from multilink.

7. Display content.

The user can select to play the multimedia content in the PW App.

2.8.3 Development Plan and Events

This demonstrator is targeted for EUCNC taking place in Valencia, Spain in June 2019. Depending on experience gathered whilst testing the solution in TUAS a decision will be made as to if and how the demonstrator might be presented at EUCNC.

	2018		2019			
	N	D	J	F	M	A
Concept proposal	■	■	■			
Software development	■	■	■	■		
Integration in TUAS network				■	■	
Content generation					■	
End-to-End testing					■	■
Demonstrator finalized						■

For this demonstrator the following software is developed:

- Public warning app with capability to receive alerts over unicast.
- Fairspectrum API for dynamic spectrum management.
- Public Warning logic to host media files in the cloud, utilize the Fairspectrum API and send alert using Google Firebase Cloud Messaging.

DEMO RECORD

Hardware involved in the demonstrator
- Nokia eNB - Wi-Fi AP - LiveU FieldUnit

- Android phone	
Software components	
- Fairspectrum dynamic spectrum management system - LiveU gateway - One2many public warning platform - One2many public warning application	
Content description	
- Public warning content to be defined	
Event 1. EUCNC 2019	
Place	**Valencia**
Date	**18-21 June 2019**
Audience	

The complete information about the finalized demonstrator will be found in D6.9.

2.9 Reliable Multicast Delivery in 5G Networks

2.9.1 Concept and Relation to the Use Cases

Nomor Research, Bundleslab and Broadpeak collaborate on developing a demonstrator focused on Hybrid Broadcast Service use case to show

- the gains in and trade-offs among resource consumption, spectrum efficiency, service coverage, and QoE when multicast is introduced as a network optimization (against unicast) for delivering popular content, such as the Olympic games, as well as
- the improvements in the observed trade-offs achieved by introducing multilink delivery for UEs with poor multicast channel signal.

This demonstrator has been proposed as an extension to the WP3/WP5 PoC based on Nomor Research's 5G system-level simulator.

Unicast delivery of multimedia content can starve the network resources, especially when there is a popular event, such as Olympic games or weekly-aired TV where most people watch the same content. Therefore, enabling multicast delivery for such content would be a valuable optimization in terms of spectrum efficiency and resource allocation. However, to maintain and/or provide high user experience when compared to unicast transmission, multicast session parameters need to be adjusted according to the worst UE conditions such that the coverage of such UE is established, which would in return restrain certain network properties. Instead of this trade-off, some application layer intelligence techniques can be used for these UEs so that both unicast and multicast sessions could be enhanced.

In this regard, this demonstration will first compare the case where all the content passing through the 5G network is sent via unicast to the case where multicast session is initiated for delivering the most popular contents. As the second part of the demonstration, we target enabling the application layer intelligence technique, multilink technology, for UEs with poor multicast reception and show the further improvements. Specifically, multilink will enable the delivery of multicast services via a combination of multicast and unicast delivery modes in the RAN.

In light of this, the demonstrator will consist of DASH streaming in conjunction with Multilink delivery and QoE monitoring. The system-level simulator with 5G capabilities (5G simulator) developed by Nomor will be used. Broadpeak will contribute to QoE measurement by means of their QoE library and QoE Analytics Server solution, while Bundleslab will contribute by defining a simplified version of their Multilink solution that will be implemented by Nomor in the 5G system-level simulator.

Overall, the observations will contribute to a deeper understanding of the improvements achieved and to deriving the conditions under which deployment of such technologies benefits the end-to-end network.

2.9.2 Technical Description

The demonstration is comprised of an ATSC 3.0 content server, 5G system-level simulator and an ATSC 3.0 client. While the content server is sending the pre-generated multimedia content via unicast or multicast to the 5G simulator, the simulator will handle the multilink functionality when enabled and act as a forwarding entity with realistic channel model for the ATSC 3.0 client through which the content playback will be shown.

The demonstration will be shown through the scenarios where

1. all multimedia content is sent via unicast,
2. multicast transmission is used for popular content delivery and the multicast session parameters are adjusted such that the edge UE coverage is established, and
3. multicast transmission is used for popular content delivery and multilink technology is used by means of packet duplication for edge UE coverage, where the duplicated multicast packet is transmitted to the cell-edge UE over unicast alongside the on-going multicast delivery.

The abovementioned evaluation results will be observed through the QoE Analytics Server collecting required metrics from the QoE library on the client device and the 5G simulator through its graphical user interface illustrating the simulated network and network-related KPIs.

An architectural diagram of the described demonstration is shown in Figure 33, where several parts of the architecture are highlighted to illustrate these scenarios.

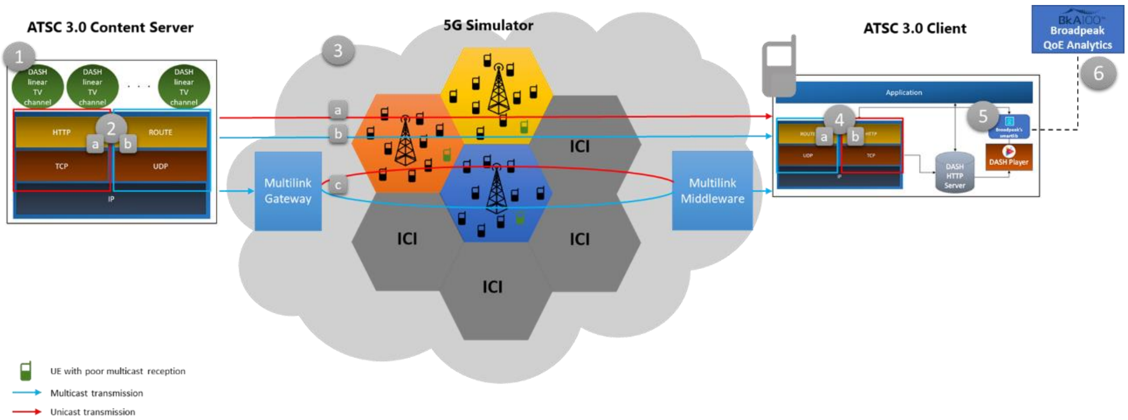


Figure 33: Architectural diagram of the demonstration

- ATSC 3.0 Content Server:

The content server will be responsible for the pre-generated content storage and its delivery to the 5G simulator as denoted by (1) and (2) in the figure.

1. Multimedia Content: The content will be a popular content and made up of audio and video streams. It will be pre-encoded, DASH-ed and stored in the ATSC 3.0 Content Server.

2. ATSC 3.0 Service Delivery: The popular multimedia content will be passed to the 5G simulator via either unicast or multicast. In the demonstration case of pure unicast transmission, the stack denoted by (a) will be used whereas in the multicast delivery cases, the content will be packetized and transmitted for each MPEG DASH segment according to ATSC3.0 ROUTE protocol represented by (b).

- 5G Simulator:

NOMOR's system-level simulator "RealNeS", that is used in WP3 to develop and analyze RAN methods and protocols and to perform the system-level simulations required in the context of the evaluation 3GPP's proposal for IMT-2020, can also be operated as a live demonstrator with a graphical user interface on top of it. Since RealNeS can be operated on high-performance but off-the-shelf PCs or laptops it is highly portable and hence ideal for live demonstrations at exhibitions. It is primarily focused on the user plane, covering the various protocol layers from a large set of data traffic generators over UDP/TCP and down to a detailed emulation of the physical layer. Accurate spatial channel models are used, where the latest model from [2] has been added during the first year of this project. It allows for simulation of both generic environments such as "dense urban", "rural" or "indoor" as defined in [2] or [3] and real-world scenarios, where actual geographical, building and mobility data can be imported for more illustrative demonstrations.

For the purpose of this demonstration, standard IP interfaces are used to exchange live content as user-plane traffic between the server, 5G RAN simulator and client devices. Furthermore, it will provide the multilink functionality when enabled. The simulator will also provide network-related KPIs through its graphical user interface.

The client device will be modelled with a realistic channel from the simulator. Apart from the client device where the playback will be observed, a few more UEs will be created within the simulator without any external device representation, consuming simulator-generated background traffic. This way, the improvements in the selected KPIs will be demonstrated in a more complete way.

3. Multimedia Content Transmission: The passed content will be transmitted in the RAN via (a) unicast, (b) multicast or (c) multilink as a combination of multicast and unicast. In case of (a) and (b), the 5G simulator will simply forward the content to the client device whereas when multilink is enabled (c) the simulator handles the multilink functionality through emulated Multilink Gateway and Multilink Middleware.

Multilink Gateway initiates unicast session for the UE with poor multicast reception. The captured multicast content is duplicated onto the initiated unicast session. The duplicate unicast stream will be sent alongside the original multicast stream.

Multilink Middleware captures the multicast and unicast transmitted packets, performs packet reordering and duplicate detection and forwards the merged stream to the UE.

- ATSC 3.0 Client:

The client will be responsible for receiving the forwarded content, forming DASH segments and send the segments to the player application for playback through which the QoE measurement will be done.

4. ATSC 3.0 Service Reception: In the demonstration case of pure unicast transmission, the stack denoted by (a) will be used for receiving the content whereas in multicast reception cases, the received popular multimedia chunks are depacketized and packed

together to generate the original MPEG DASH segments according to ATSC3.0 ROUTE protocol represented by (b).

5. Content playback and Broadpeak QoE library: Received segments are used by the player application for content playback. During playback, the integrated BPK QoE library collects metrics, such as initial playout delay, rebufferings, content quality, etc. and sends these to the BPK QoE Analytics Server.

- Broadpeak QoE Analytics Server:

6. Broadpeak QoE Analytics Server: Collected metrics are used to quantitatively indicate the user satisfaction.

2.9.3 Development Plan and Events

This demonstrator is targeted for European Conference on Networks and Communications (EuCNC) taking place in Valencia, Spain in June 2019.

	2018						2019			
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Concept proposal										
Multilink Integration into 5G simulator										
ATSC 3.0 interfacing with 5G simulator										
Player integration with the client device										
QoE library and Analytics Server integration with player										
End-to-End testing										
Demonstrator finalized										

DEMO RECORD

Hardware involved in the demonstrator
- 1-2 UEs (tablets) - ATSC 3.0/ROUTE Server - ATSC 3.0/ROUTE Receiver box - 5G RAN system-level simulator laptop - Router
Software components - Player and player application

- QoE library - 5G RAN system-level simulator multilink functionality - ATSC 3.0 software	
Content description	
Pre-encoded, DASH-ed and stored in the ATSC 3.0 Content Server. The content will have different Representations with different encoding parameters (low to high resolution, low to high bitrate, etc.)	
Event 1. EUCNC June 2019	
Place	**Valencia, Spain**
Date	**18-21 June 2019**
Audience	

The complete information about the finalized demonstrator will be found in D6.9.

3 5G-Xcast Showcase – European Championships 2018

The European Championships is a new multi-sport event which brings together some of the European leading sports championships every four years.

The inaugural edition took place simultaneously in Glasgow (UK) and Berlin (Germany) between 2 and 12 August 2018. Future editions take place every four years.

The event is produced jointly by the European sports federations, the host cities of Glasgow and Berlin, and the European Broadcasting Union (EBU).

Around 4500 athletes are expected to compete in seven different sports. Aquatics, cycling, gymnastics, golf, rowing, and triathlon competitions will be held in and around Glasgow at 12 different venues. The athletics will be staged in Berlin involving 3 different venues.

The European Championships 2018 presents an opportunity for the 5G-Xcast to demonstrate some of the key concepts being developed in the project. Several aspects underscore this opportunity, including:

- A distinct European dimension of the event.
- Enduring popularity of live sports.
- Geographic location of the project partners is favourable.
- Access to content will be ensured as the EBU is the rights holder.
- The EBU event producers, including the host cities, the sports federations and the EBU, are open to innovation and prepared to support a 5G-Xcast showcase.

3.1 The scope of the showcase – Initial considerations

The scope of the demonstration was taken into consideration in WP6. Some of the key issues are outlined below:

Type of demonstration	The nature of the showcase will primarily depend on what the project will be capable of demonstrating at the time of the European Championships in August 2018, given that at that point in time the 5G-Xcast technical solution will not yet be fully developed. It is currently assumed that the demonstration will focus on the M&E use cases, in particular the distribution of audio/visual media content.
Location	Several possibilities are currently being considered, including: • 5G-Xcast test-beds • Sports venues • Fan zones • Brussels A decision on the location(s) of the demonstrations will have a significant impact on the logistics and resources required for the demonstration.
Transmission equipment and infrastructure	The requirements on transmission equipment will depend on the type of demonstration, whereas the infrastructure

	requirements will be largely determined by the location of the demonstration.
Terminal (receiving) equipment	The issue of terminal equipment is yet to be addressed. It is assumed that user equipment with 5G point-to-multipoint capabilities will not be generally available for the demonstration.
User interface and application	An effective showcase requires an attractive user application to show how 5G-Xcast innovation can support an improved and immersive user experience. However, developing such an application is not foreseen in the project. Therefore, we are considering the possibility of integrating an external application into the showcase. It is currently being investigated whether an application developed by the EU funded project *2-Immerse* could be used.
Content	There will be two possible sources of audio/visual content: • The main broadcast production which will include multiple live TV feeds and additional content for on-demand access and social media. This content will be made available by the EBU. • Content produced by innovative production trials that might be conducted during the event. Various possibilities are currently being considered including UHD/HDR/HFR production, 180 degrees panorama in 8K, amongst others.

3.2 Agreed Technical concept

The European Championships showcase aimed to highlight the expected impact of the 5G-Xcast project. The showcase used audio/visual material produced in state-of-the-art formats and illustrated how a new appealing European broadcast media service could be provided to large audiences in the 5G environment, including the following aspects:

- Fixed/mobile convergence.
- A combination of unicast and broadcast capabilities.
- Use of standardized 3GPP interfaces to encapsulate legacy DVB TS and service information.
- Free-to-air reception.
- Mobile/portable user equipment and traditional TV-sets.

The showcase will illustrate the potential business impact of new 5G technologies not only for broadcasters but also for fixed and mobile network operators, media and entertainment companies, and other industries interested in using point to multi-point distribution technologies for their purposes.

Technical Concept

The showcase focused on the 5G-Xcast M&E use case 1 “Hybrid broadcast service” (see [4]) with a subset of features that went a step beyond the well-known HbbTV service.

Traditional HbbTV requires at least one regular DVB broadcast feed along a secondary broadband connection providing the intended HbbTV user experience. Current set-top box or HbbTV integrated large screens integrate traditional terrestrial broadcast standards like DVB-T and DVB-T2, digital cable DVB-C, DVB-C2 and digital satellite

DVB-S, DVB-S2 while broadband capabilities get integrated by common Ethernet and/or Wi-Fi interfaces.

Given that the 5G-Xcast technical solution was not fully developed at the time of the European Championships 2018, the showcase incorporated the available pre-5G technologies. It explored the ability of current and future 3GPP based 4G/5G specifications to provide a HBS user experience in a fully wireless environment combining broadcast and unicast transmission to, first, access the broadcast signal and, later, establish a point-to-point connection to access on-demand and added value content from the HBS-server.

The following figures present the architecture of the demonstrator at the transmission and reception sides where several points are highlighted.

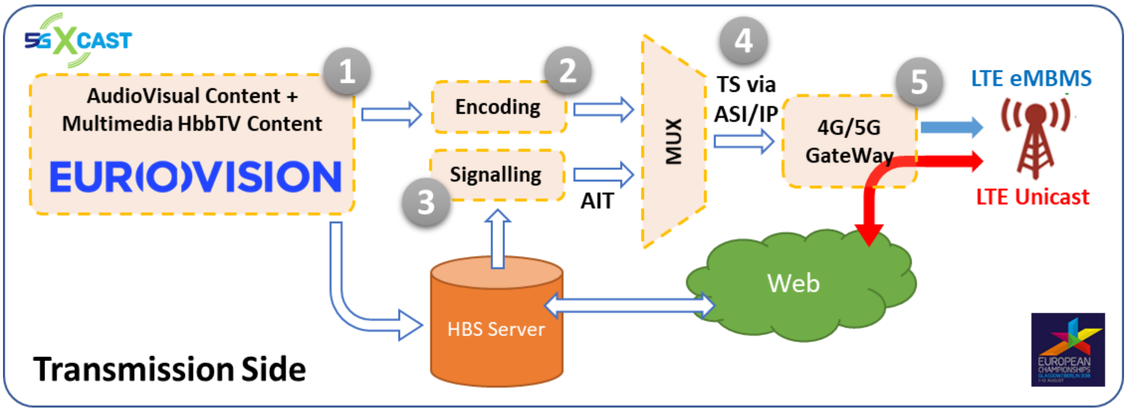


Figure 34: Transmitter chain for showcase

Content provision (1)

- UHD/HD streams: Live audio/visual content from the event encoded and multiplexed into an LTE eMBMS carrier.
  - Available formats (UHD, HD). From the UE side, HD would be the best option.
- HBS content: Graphics and content (live or pre-recorded) stored on the HBS server.
  - The type of graphics and their availability.
  - Added value content (classification, specific information of the event, …).

Encoding (2)

- From the receiver side H.264 is preferred.

HbbTV signaling insertion (3)

- HbbTV signaling (AIT tables) generated according to the content to be displayed.

Multiplexing (4)

- Multiplexing of the audio/visual + HbbTV data information into an MPEG TS.

Radio signal generation (5)

- Insertion of the MPEG-TS stream into LTE eMBMS carrier.
- LTE Amarisoft used as EPC+RAN solution (eMBMS operation together with unicast communication).

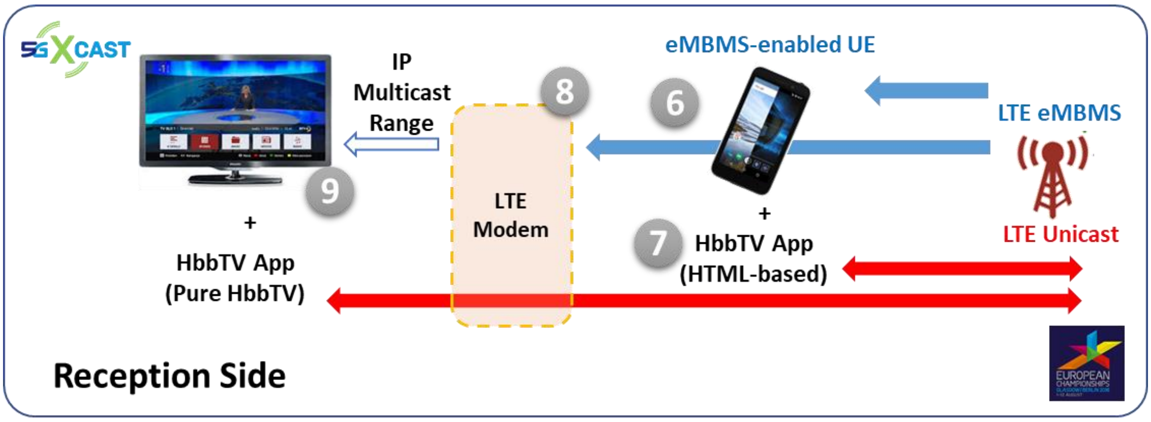


Figure 35: Receiver chain for showcase

Radio signal reception in portable/mobile devices (6)

- Audio/visual content broadcast via eMBMS received in LTE eMBMS-enabled UEs (Bittium Tough Mobile + Expway Middleware).

HbbTV content in portable/mobile devices (7)

- HbbTV App based on HTML is available at the UE providing access via a unicast connection (LTE unicast) to the HbbTV server.

Radio signal reception in TV-set (8)

- The unavailability of TV-sets with eMBMS interfaces made it necessary to emulate the functionality via an LTE modem (UE with eMBMS + unicast connection) and the forwarding of the content via IP to a IPTV set.
- Android LTE devices commonly provide streaming with unicast IP address. The possibility to route the traffic to a multicast IP address range needs to be studied.

HbbTV content in TV-set (9)

- The HbbTV Application developed for the TV-set is shown. The content was accessed via IP connection and LTE unicast radio link.

The complete information about the finalized showcase will be found in D6.5.

A Appendix: Demonstration and showcase planning guidelines

A.1 Planning Guidelines

The following recommendations are in part derived from the guidelines and lessons learnt available in [1]. The overall methodology in 5G-Xcast can be accordingly also divided into three steps:

1. Planning phase:
   - The **planning must start well in advance**, identifying rough dates including premises where the showcase/demonstrator is supposed to be developed.
   - Stablishing a **reasonable goal** from the very beginning.
   - Identify a **responsible person** that will lead the whole process. Every single showcase/demonstrator should be ideally managed by different persons. The overall coordination in between showcases and persons responsible can always be driven by the tasks and work package leaders.
2. Publicity aspects
   - It is highly recommended that joint events, like regular 5G-Xcast F2F meetings are used to publicize the demonstrator's capabilities.
   - Social media can be a good source for publicity. Every test-bed should ideally arrange regular video demos showing the demonstrators capabilities. Regular updates showing the ongoing progress is also highly recommended.
   - Regular technical events like IEEE conferences, workshops, can be also used to disseminate the demonstrator capabilities and arrange individual meetings with parties interested.
3. Technical aspects
   - **Don't Reinvent the Wheel**; it's important to identify potential synergies and the potential reuse of expected outputs available from other projects well in advance, e.g. 2IMMERSE.
   - Diversifying the demonstrator's capabilities also helps to ensure that demo is a success.

General considerations for the showcase demo:

- The exhibit you propose should be visually attractive and/or "do something" and/or have object(s) to touch.
- A proposal should be formulated as a concise text explaining the concept (a few bullet points will do at this stage) plus possibly images or on-line references to get an idea of the visual effect.
- Specification of the showcase should contain clear and enough information concerning:
  - The setup of each showcase.
  - The detailed procedure of the showcase.
  - The description of the GUIs and dialogs that should appear to the "viewers/experimenters".
  - The results expected from the point of view of the "viewer" (including metrics, if relevant).
  - The outcomes expected from the point of view of the project .
- It is important for developers responsible for components, to be fully aware of the selected showcase and its individual steps, to ensure that all interfaces involving their components are taken into accounted and documented fully. An incremental, iterative development process should be adopted taking in consideration the showcases. Adequate reporting documents will need to be active during these times

in order for updates relating to specific incremental phases to be included and documented.

- For coordination, a showcase record should be widely distributed from the beginning, including information as presented in the next table.

DEMO RECORD

Hardware involved in the demonstrator	
-	
Software components -	
Content description	
Event 1.XXX	
Place	
Date	
Audience	

References

[1] Dario Sabella and Miquel Payaró, Flex5Gware experience in setting up joint events, FLEX5GWARE (Oct, 2017)

[2] 3GPP, "TR 38.901: Technical Specification Group Radio Access Network; Study on channel model for frequencies from 0.5 to 100 GHz (Release 14)", 3GPP, Sophia Antipolis, France, Tech. Rep. 3GPP TR 38.901, V14.1.1 (2017-12), 2017.

[3] ITU-R, "Report ITU-R M.2412-0 (10/2017); Guidelines for evaluation of radio interface technologies for IMT-2020", ITU, Geneva, Switzerland, 2017.

[4] D. Ratkaj and A. Murphy, Eds., "Definition of Use Cases, Requirements and KPIs," Deliverable D2.1, 5G-PPP 5G-Xcast project, Oct. 2017.

[5] B. Altman, Ed., "Application Layer Intelligence," Deliverable D5.3, 5G-PPP 5G-Xcast project, Nov. 2018.

[6] *Jokela et.al. Trial of spectrum sharing in 2.3GHz band for two types of PMSE equipment and mobile network, BMSB.*

[7] *Kliks et.al. Coordinated Spectrum Allocation and Coexistence Management in Wireless Networks: CBRS Use Case. IEEE Access, submitted.*

[8] 5GIC, "The Flat Distributed Cloud (FDC) 5G Architecture Revolution," 5G Innovation Centre (5GIC), Guildford, UK, 5G Whitepaper, 2016.