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

Deliverable D2.1

Definition of Use Cases, Requirements and KPIs

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Editor(s):	Darko Ratkaj (EBU), Andrew Murphy (BBC)
Authors:	David Gomez-Barquero, Irene Alepuz, Jordi J. Gimenez (UPV); Athul Prasad, David Navratil (NOK); Andrew Murphy, David Vargas (BBC); Jonathan Hart, Matt Stagg, Rory Turnbull, Sean Grant, Steve Appleby, Tim Stevens (BT); Maël Boutin (BPK); Noam Amram (BLB); Tuan Tran (EXP); Clemens Kunert, Javier Morgade (IRT); Baruch Altman (LU); Menno Bot, Peter Sanders (O2M); Belkacem Mouhouche, Louis Christodoulou (SEUK); Giovanna D'Aria (TIM); Tero Jokela (TUAS); Darko Ratkaj, Francesco De Angelis (EBU); De Me (UNIS)
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Abstract

This document describes the use cases (developed under task T2.1) and their associated requirements and KPIs (task T2.2) that are the targets for developments within the 5G-Xcast project.

The use cases address the vertical sectors covering Media & Entertainment, Public Warning, Internet of Things, and Automotive.

Keywords

5G, Automotive (Auto), benchmark, KPIs, Internet of Things (IoT), Media and Entertainment (M&E), Public Warning (PW), requirements, state-of-the-art, use cases, verticals

Executive Summary

This document describes the use cases identified in task T2.1 and specifies their respective requirements and Key Performance Indicators (KPIs) as defined in task T2.2. These use cases, requirements and KPIs will be the target for the developments within the other Work Packages (WPs) of the Project.

The use cases are intentionally high-level and broad in nature with the specification of detailed technical requirements and KPIs being carried out in the technical Work Packages, specifically WP3, WP4 and WP5.

The requirements and KPIs will be used to benchmark both the state-of-the-art technologies as well as the new techniques developed within 5G-Xcast.

The use cases focus on applications that have the most to gain from the concepts being developed within the 5G-Xcast project, specifically:

- enhanced point-to-multipoint (PTM) capabilities;
- a dynamically adaptable network architecture with layer independent network interfaces;
- dynamic and seamless switching between unicast, multicast and broadcast modes or their simultaneous use;
- the potential to exploit built-in caching capabilities; and
- the convergence of mobile, fixed and terrestrial broadcast networks.

In total, six high-level use cases are presented. The use cases target four vertical sectors encompassing *Media & Entertainment (M&E)*, *Public Warning (PW)*, *Automotive (Auto)*, and *Internet of Things (IoT)*. While all considered use cases will be used for the definition of KPIs and requirements to be met by the 5G system developed within the project, only a subset of the use cases will be experimentally demonstrated.

The demonstration use cases within the project come from the Media & Entertainment and Public Warning verticals.

As well as describing the actual use cases, the document outlines the methodology developed within the Work Package for both the definition of the use cases themselves and their related requirements. Finally, discussion of wider issues relating to the use cases is also presented.

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List of Terms, Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
5G	5th Generation
5G-PPP	5G Public-Private Partnership
AAC	Advanced Audio Coding
ABR	Adaptive Bit Rate
AR	Augmented Reality
ATSC	Advanced Television Systems Committee
Auto	Automotive
AVC	Advanced Video Coding
CDN	Content Distribution Network
DASH	Dynamic Adaptive Streaming over HTTP
DL	Downlink
DSL	Digital Subscriber Line
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting
eMBMS	evolved Multimedia Broadcast Multicast Service
eMTC	enhanced Machine Type Communication
EPG	Evolved Packet Gateway
HD	High Definition
HEVC	High Efficiency Video Coding
HTTP	HyperText Transfer Protocol
IMT	International Mobile Telecommunication system
IoT	Internet of Things
IP	Internet Protocol
ITS	Intelligent Transport System
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LoS	Line-of-Sight
LTE	Long Term Evolution
MBMS	Multimedia Broadcast Multicast Services
MBSFN	MBMS over Single Frequency Networks
MIMO	Multiple-Input Multiple-Output
MooD	MBMS operation on-Demand
MP3	Moving Picture experts group layer-3 audio
MPEG	Moving Picture Experts Group
MR	Mixed Reality
M&E	Media and Entertainment
NB-IoT	NarrowBand IoT
NGMN	Next Generation Mobile Networks Alliance
NLoS	Non-LoS
NFV	Network Function Virtualisation
OFDM	Orthogonal Frequency Division Multiplexing
OTT	Over-The-Top
OB	Outside Broadcast
PTM	Point-to-Multipoint

PTP	Point-to-Point
PW	Public Warning
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RSU	Road Side Unit
RTP	Real-time Transport Protocol
R&D	Research and Development
SD	Standard Definition
SDN	Software Defined Networking
SC-PTM	Single Cell – Point-to-Multipoint
TR	Technical Report
TS	Technical Specification
UE	User Equipment
UHD	Ultra-High Definition
UL	Uplink
URL	Uniform Resource Locator
V2X	Vehicle to anything
VoD	Video on Demand
VR	Virtual Reality
WP	Work Package

Glossary of Terms

These terms are extracted, mostly unchanged from [1] and [2] and are reproduced here for convenience.

Table 1 – Glossary of terms

Term	Definition
Amber Alert	A warning system that quickly alerts the public about abducted children who are in imminent danger
Broadcast service	A service denoting unidirectional distribution to a potentially unlimited number of concurrent users.
Conversational multimedia service	An interactive real time (no store and forward) service, usually bi-directional where low end-to-end delays (< 100 ms) and a high degree of synchronisation between media components (implying low delay variation) are required. Video telephony and video conferencing are typical conversational services.
Distribution of multimedia services with user control	Broadcast services where information is broadcast as a repetitive sequence and the ability to access sequence numbering allocated to frames of information enables the user (or the user's terminal) to control the start and order of presentation of information
Hybrid multimedia service	Consists of both linear and on-demand elements. They complement each other in the sense of enriching the linear offering but also in order to inter-relate both types of services. This requires a certain level of integration when producing the content. Examples include slideshows for digital radio or second screen television.
Linear audio-visual service	Refers to the “traditional” way of offering radio or TV services. Listeners and viewers “tune in” to the content organized as a scheduled sequence that may consist of e.g. news, shows, drama or movies on TV or various types of audio content on radio. These sequences of programs are set up by content providers and cannot be changed by a listener or a viewer. Linear services are not confined to a particular distribution technology. For example, a live stream on the Internet is to be considered as a linear service as well.
Messaging multimedia service	An interactive, non-real-time (via store and forward) user to user service, which might typically provide combined voice and text, audio and high-resolution images.
Multimedia service	A service that handles several types of media (such as audio and video) in a synchronised way from the user's point of view. It may involve several parties and connections (different parties may provide different media components) which both can be added and deleted within a single communication session. Multimedia services are typically classified as interactive (i.e., conversational, messaging, retrieval) or distribution (i.e., with/without user control) services.
Multipoint	A service attribute denoting that the communication involves more than two network terminations
Object based broadcast	With object-based broadcasting the programme is captured in the conventional way but stored as a set of its component parts, be they audio, video, captions or other material along with detailed metadata that describes how these should be assembled. These component parts are then delivered separately and rendered on the device in the form most suitable for a particular user and presented in a way that takes account of the capabilities of the device, the environment and the user’s preferences.

Term	Definition
	Examples of services enabled by object-based broadcasting are BBC R&D's Venue Explorer [3] and Forecaster [4] demos, and its Internet Protocol (IP) end-to-end 4k production at the 2014 Glasgow Commonwealth Games [5].
On-demand audio-visual service	A communication service providing any type of audio-visual content, which gives users the freedom to choose when to consume the content. The user can select individual pieces of content and can control the timing and sequence of the consumption. Examples of popular on-demand services are TV catch up and time-shifting. Other forms of on-demand services include downloading content to local storage for future consumption or access to audio-visual content for immediate consumption.
Point-to-multipoint (PTM)	A service attribute denoting that data is concurrently sent to all users (broadcast) or a pre-determined subset of all users (multicast) within a geographical area.
Point-to-point (PTP)	A service attribute denoting that data is sent from a single network termination to another network termination.

1 Introduction

Point-to-multipoint[1] (PTM) transmission could be a more efficient delivery mechanism compared to point-to-point (PTP) whenever a service or an application requires the same content to be delivered to multiple users or devices at the same time. This is why PTM is considered to be an essential feature for 5G applications in a number of vertical sectors, namely *Media & Entertainment (M&E)*, *Public Warning (PW)*, *Automotive (Auto)* and *Internet of Things (IoT).*

In M&E use cases, PTM will facilitate the distribution of audio-visual media content and services, in particular when covering popular live events that attract large concurrent audiences. PTM network coverage could either be localized to a specific venue or extended to a wide area, potentially the size of a whole country. Efficiency gains that might be achieved with PTM will be even more significant when the emerging high quality (and hence potentially bandwidth hungry) immersive content formats such as UHD, 360 deg., virtual and augmented reality (VR/AR) become more prevalent.

A novel use case based on 5G PTM is a dedicated wide-area coverage broadcast network, potentially shared among several network operators and initial standardisation work on this has been undertaken in 3GPP Release 14 [7] with further service requirements for 5G Stage 1 considered under 3GPP Release 15 [8].

5G PTM in combination with caching capabilities would facilitate time-shifting and non-real-time media consumption. At the same time, pre-emptive delivery of content to the storage in the device could help to balance the network load over time and reduce expensive capacity over-provisioning, hence making the delivery more cost-efficient. This method could be applicable to non-time-critical information services (e.g. news alerts) that could be conveniently ‘pushed’ (content pre-positioning) to the devices rather than being ‘pulled’ by the end users at the time of the consumption.

Another M&E use case is the use of 5G PTM in TV production. IP-based technology is increasingly being used to carry the audio and video involved in the production of TV and Radio programmes. The ability to move from the use of broadcast-specific equipment, cabling and signals towards commodity IT equipment and infrastructure is an active area of research in the field.

The use of IP in production is particularly challenging for the network infrastructure due to very stringent requirements in particular on throughput, latency, time synchronisation, and reliability.

In particular, production of sports events often requires processing of difficult visual scenarios as the image changes from one frame to another are relatively large and include both high level of details and a lot of movement. This results in higher bandwidth output for any video encoder than more stationary sceneries.

The high bitrates are also needed to enable video to be captured and transferred in the highest possible quality in order to maintain a suitable quality after downstream editing and onward distribution to the end user. As 5G could potentially provide a very high throughput comparable to that of a dedicated production network infrastructure (i.e. SDI) even the transfer of uncompressed video might be possible.

In current productions video is captured as a minimum, in 1080p50fps quality, and increasingly in UHD / 4k and 360 deg. quality. Even higher resolutions (e.g. 8k) are expected

[1] In the context of the 5G-Xcast project, point-to-multipoint encompasses both broadcast modes (addressing all users) and multicast modes (addressing groups of users).

to be introduced in the future. Multiple camera feeds and in the future multiple 360 deg. feeds may increase the volume of video streams even further.

A very low latency is required in any application that requires audio/video feedback to those involved in the production such as via in-ear audio monitors or video monitoring in live production. Furthermore, very high reliability (i.e. very low packet loss rates) is also required. This is even more challenging when combined with a need for low latency since this severely limits or even removes the possibility to request re-transmissions or apply error correction schemes.

Most R&D work to date on IP-based production has relied on fixed networks based on fibre connectivity. Remote production would require dedicated contribution links from the site back to the centre studio, often including satellite connections. In recent years cellular multi-link bonding has also gained a lot of traction due to the lower cost, simplicity and its increased bandwidth and reliability. However, the capabilities of 5G may allow devices connected wirelessly to become part of a seamless extension to those running on fixed infrastructure. In addition, 5G might facilitate remote production in those locations where suitable fixed network infrastructure does not exist or may not be practical to use it (e.g. outdoor sports, festivals).

A typical application where all of the stringent requirements come together is in a live remote on-site production (such as a sports event or a live cultural event).

For IoT, 5G PTM could facilitate the delivery of common data such as software and operating system updates to a large number of connected devices. In these cases, the main 5G requirements are very high reliability and, for some devices, low power consumption. Scheduled updates would allow operators to perform non-time-critical broadcasting during off-peak times without negatively affecting unicast network traffic. These use case may also be relevant for connected 5G smart cities and a variety of industrial applications.

There are a number of automotive use cases where 5G PTM transmissions can play a role, such as delivering media content, entertainment and information services, navigation data, road safety information and traffic services. Other examples include software updates in the vehicles. The main 5G technical requirements for vehicular communications are related to throughput, latency, reliability, and velocity.

A key requirement for PW applications is a secure and reliable delivery of alert messages to the general population in emergency situations. 5G PTM capabilities would ensure that PW messages reach a large number of users simultaneously without causing network congestion or even significantly increasing the traffic load.

1.1 Objective of the document

This document aims to define the overall use cases that the 5G-Xcast solution will address. It also details the methodology of use case definition by describing the consistent elements that make up every 5G-Xcast use case.

In terms of requirements, again the methodology developed within the Work Package for capturing the relevant information is described along with the actual requirements and KPIs themselves in terms of the conditions needed to enable a given use case.

Finally, some discussion is presented which captures discussion within the Work Package on commonalities across the use cases and some thoughts on potential implementation scenarios, demonstrations and a brief summary of the state-of-the-art.

It is not the intention of this document to prescribe particular technical solutions to address the use cases, nor is it the aim to define detailed technical requirements. As such the use cases are intentionally high-level and somewhat broad in nature and the detailed technical solutions are left of the other technical Work Packages, (i.e. WP3, WP4 and WP5) to enable.

1.2 Structure of the document

The document is structured as follows. Firstly, the methodology of the use case definition is described including that used for the definition of the requirements and KPIs. Secondly each vertical sector is addressed in turn and the use cases described in detail. Finally, there is some discussion of the use cases including aggregated requirements, potential convergence issues, potential demonstrators and some notes on the state-of-the-art.

2 Use Cases

In the context of 5G-Xcast, a use case and its respective requirements are defined as below.

2.1 Definition of use cases

A use case is defined by the following elements:

Description

This is a short narrative (i.e. one or two paragraphs) to answer the question *'What is the use case all about?*', not *'How is it enabled?'*. It may include illustrative examples. Technical details and jargon should be avoided.

Services

The list of services and applications that are delivered within that particular use case.

This refers to the information being transmitted, not the act of transport of that information through the system or the processing in the device. For example, in M&E use cases this refers to the audio-visual content and services.

Note: As the number of different services and application is potentially unlimited, the use case description will be based on representative *categories* of services for each of the 'verticals' addressed in the project, as appropriate.

User devices

The user devices targeted in the use case are specified.

Note: In some use cases, a number of different devices may be targeted at the same time, both current and future. Therefore, it is not possible to provide an exhaustive list of user devices. Instead, a limited number of representative *types* of user devices should be listed for each use case (e.g. for M&E this may include TV set, tablet, mobile phone, vehicle mounted devices, and/ or AR/VR headset).

Environment

The end user environment in which the use case occurs.

For M&E, PW and IoT use cases two broadly defined environments have been considered to be sufficient to define all relevant use cases:

- *Home / indoor environment* where users are largely stationary, the installed network infrastructure is known and permanently available to the user.
- *Out of home / outdoor environment* where the users may be either stationary of moving, including in cars or public transport. From the user perspective, this environment is transient. The user may have a limited knowledge about the available network infrastructure and have no control over it.

Automotive use cases are always outdoors and an important differentiator is speed of vehicles, as follows:

- Urban environment: 0-50 km/h
- Sub-urban environment: 0-100 km/h
- Motorway environment: 0-250 km/h

Pre-conditions

A brief description of what the 5G system will ensure is true before allowing the use case to start representing a reference or starting point for the use case. An example might be an operator that has a service/network infrastructure in place that can be configured to address a specific use case, e.g. a mobile operator has deployed a 5G unicast point-to-point network.

Note that the pre-conditions are not a mandatory part of the use case definition.

Post-conditions

The state of a system after the use case has been completed, for example a telecom operator runs both a mobile network and a fixed network.

Note: For permanent use cases (e.g. 24/7 delivery of content) this element may not be relevant.

Note that the post-conditions are not a mandatory part of the use case definition.

Benefits

These explain the expected benefits of this particular use case for the stakeholders and what is the motivation for the use case. This is the place to include the ambition from different viewpoints, such as:

- *"As a service provider, I want to…"*
- *"As a network operator, I want to…"*

2.2 Use cases requirements

Each use case is accompanied by a detailed set of conditions that need to be fulfilled in order for a particular use case to be enabled. This is where the use case description has been translated into specific KPIs. Only those requirements have been specified for each use case that are relevant for WP3, WP4, WP5, and WP6 to carry out work within the scope of the project.

Each of the final requirements has been formulated from a viewpoint of one or more actors in this use case. The actors are identified on the basis of their functional roles, as follows:

1 - User

2 - Content service provider*

3 - Network operator

4 - CDN operator**

5 - Cloud provider**

6 - Content producer

7 - Public authority

* Content services should be distinguished from electronic communications services. In this approach, the latter are considered to be provided by the network operators.

** CDN operator and Cloud operator do not appear in the final list of requirements.

Note that each requirement can be uniquely referred to by the abbreviation for the use case plus its number. For example, requirement "M&E1_R10", refers to requirement "10" for the use case "M&E1".

2.3 Media and Entertainment (M&E) use cases

The following M&E use cases have been defined:

M&E 1. Hybrid broadcast service
M&E 2. Virtual / Augmented reality broadcast
M&E 3. Remote live production

2.3.1 Use case M&E 1 – Hybrid broadcast service

Table 2 – Use case M&E 1: Definition

Description	Users have access to any combination of linear and non-linear audio-visual content in addition to social media. The content is diverse and includes multiple media types such as video, audio, text, and data, possibly coming from various sources, including different content providers as well as the members of the public (user-generated content). Audio-visual services can be personalised and combined with different other functionalities, such as social media, location-based features, interactivity, interpersonal communications, and more. Access to content and services is enabled on different user devices and in different environments, across large geographical areas (possibly the whole country). Content and services may be delivered over a combination of several networks and types of network simultaneously. Continuity of the users' experience should be preserved when switching between different access networks, possibly operated by different operators. The population of concurrent users may be very large (i.e. millions of viewers of a popular live event) and may substantially change over short periods of time. This use case covers a number of different scenarios, such as: • distribution of audio-visual media content over large areas, possibly country-wide • venue coverage, e.g. at live sport events, concerts, public gathering • digital signage, possibly with interactive capabilities
Services	• Linear and on-demand video content (e.g. TV programmes, VoD, user generated content) • Linear and on-demand audio content (e.g. radio programmes, podcasts, streamed music) • Social media content • Interactive advertising • Personalised and/or regionalised advertising
User devices	• Fixed TV sets • Portable and mobile devices • Vehicle mounted devices (e.g. in cars, couches, trains)
Environment	• Home / indoor • Out of home / outdoor, including both stationary and mobile conditions and reception in vehicles

Benefits	*End users* have seamless access to audio-visual content both at home and on the move including seamless mobility between access networks, and across different types of devices. The user's device is able to automatically connect to the best available network to give the highest QoE to the user (including multiple connectivity to several networks). Users have a single set of credentials in order to access a consistent set of content, services and policies across different access networks. *Content and service providers* deliver audio-visual content to a range of user devices, whether the users are at home or on the move, over the 5G infrastructure (possibly including fixed and mobile broadband as well as broadcast networks) to which they connect via standardized interfaces. This enables substantial reduction of complexity and costs compared to the currently available distribution options, without compromising on flexibility and the quality of user experience. The possibility to utilise different types of infrastructure allows content and service providers to extend the overall audience reach. At the same time, new types of services can be offered, for example multi-screen/angle of sporting events with interactive features and in high quality. *Network operators* can benefit from a more efficient use of network resources, be it radio resources or backhaul as well as optimal use of different network topologies. Customer QoE is improved as seamless network handover allows customers to remain connected longer. As customers remain connected, they will be consuming data longer which may result in increased revenues. Technology convergence allows operators to achieve cost efficiencies by choosing the most efficient method of delivery. *Equipment manufacturers* are able to provision better quality of service and experience to end users with the flexibility of hybrid access. *Network equipment vendors* have higher flexibility in terms of resource management to provision the traffic flows through the best possible access technology available. Through efficient signalling between the access technologies, seamless connectivity could be provided to the end user. User device vendors can also use the flexibility of hybrid access to enable better user experience through implementation specific access selection techniques. Different business models can be supported, including both OTT and managed services with guaranteed QoS.

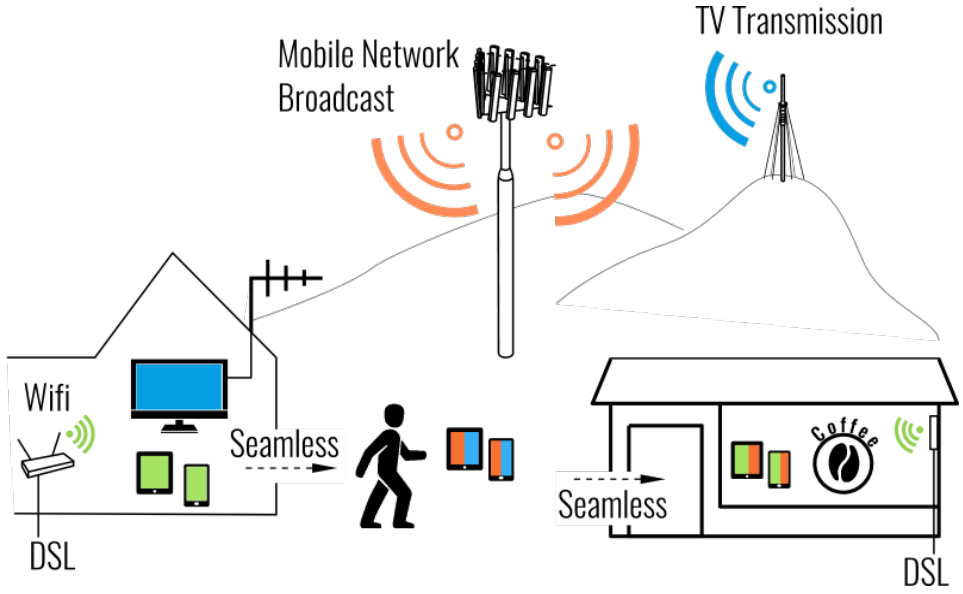

Figure 1 – Use case M&E 1: Hybrid broadcast service; combinations of networks and technologies give a seamless experience as the user moves between different locations

Requirements for the use case M&E 1

Table 3 – Use case M&E 1: Requirements

No.	Requirement	Role
1	End users have seamless access to audio-visual content both at home and on the move including seamless mobility between access networks, and across different types of devices (stationary, portable/ mobile, mounted in a vehicle). • The user's device is able to automatically connect to the best available network/s to give the highest QoE to the user, including simultaneous access to multiple networks. • It is desirable to allow using multiple network types together to increase QoS/QoE to any segment of the population that can support this.	User
2	End users have a single set of credentials (e.g. single user name and password) in order to access a consistent set of content, services and policies across different access networks.	User
3	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. • An audience may be concentrated in a limited geographical area or distributed • Minimising the distribution costs for the content service provider	Content service provider Network operator
4	It should be possible for different network types to carry different content elements that constitute the user experience. • It is desirable that networks operated by different operators can carry different content elements that constitute the user experience.	Content service provider Network operator

No.	Requirement	Role
5	If multiple networks are used it should be possible to offload the traffic between them. • e.g. fixed, mobile and/or broadcast networks	Network operator
6	It is desirable that content delivery can use multiple networks at the same time and switch between networks including when operated by different operators.	Content service provider Network operator
7	It is desirable that the network supports dynamic optimisation of resource allocation based on individual operators' policies, e.g. automatically initiating the switching between unicast, multicast and broadcast. • Means should be given to allow implementation of various deployment and optimization policies of network resources vs QoE of the population as a whole or segments of.	Network operator
8	It is desirable that a user can easily discover an existing audio-visual service, including free-to-air.	User
9	It is desirable that the user at any time is able to use basic network services associated with the UE (e.g. voice, data, SMS) concurrently with the hybrid broadcast service. • At any time, a PW message may occur pre-emptively on the user's device.	User
10	Allow the UE to receive content via a broadcast/multicast radio carrier while a concurrent non-broadcast data session is ongoing.	The user Network operator
11	Parallel delivery of a given content at different QoS/QoE levels to different portions of the population in the same geographical area should be supported.	Content service provider
12	Transition between unicast and broadcast and multicast should be allowed during service, without impact on viewers and other users, and within a minimized transition time (in the order of seconds).	Network operator
13	Both, conventional and object-based delivery should be enabled	Content service provider Content producer
14	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.	Content service provider Network operator Public authority
15	User (device) density: • high: ≥ 10000 devices per km^2 (crowded venues, hotspots) • medium: 1000-10000 devices per km^2.	Content service provider Network operator
16	The system should be scalable to serve very large concurrent audiences while maintaining the required Quality of Service for each user irrespective of the size of the audience. The number of concurrent users can be very high, i.e. >10^6 for the most popular content. The system should support variations in the number of concurrent users (e.g. driven by the changing popularity of content).	Content service provider Network operator
17	The 5G-Xcast solution should allow indoor, outdoor and in-vehicle coverage.	Content service provider Public authority

No.	Requirement	Role
18	The 5G-Xcast solution should be applicable for all mobility classes defined by ITU-R [9] in terms of velocity as: - Stationary: 0 km/h - Pedestrian: 0 km/h to 10 km/h - Vehicular: 10 km/h to 120 km/h - High speed vehicular: 120 km/h to 500 km/h • Including the case of multiple access networks	User Content service provider
19	Must support lawful intercept, where required. • For public broadcasted traffic, such as BBC news and sporting events, no lawful intercept is needed. • However, if an individual can initiate a broadcast session and starts to broadcast their own user generated content to many people, then this needs to be subject to Lawful Intercept for voice, and Internet Watch Facility for data.	Public authority
20	End-to-end (i.e. from content service provider to end user) transport layer security of multicast traffic must be equivalent to that of unicast traffic. • Content integrity, confidentiality, availability and non-repudiation should be ensured in transit.	All
21	The 5G-Xcast solution should support authentication of the content origin	User
22	The 5G-Xcast solution should support authentication and authorisation of the user, where required.	All
23	The 5G-Xcast solution should be able to provide a sufficient data rate to deliver content up to UHD quality. • As an indicative figure, the current state-of-the-art would typically require 50 Mbit/s per video stream. It can be expected that with further advance in coding technologies this figure would go down for a given image quality level. Lower picture quality requires substantially lower data rates.	Content service provider
24	Latency: • End-to-end latency is allowed to be in the order of 50 ms or even higher o 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	User Content service provider Network operator
25	Quasi error-free reception: • 1 uncorrected error event per hour	User Content service provider

No.	Requirement	Role
26	The solution should not be restrictive to service / application related requirements, such as: • audio or video formats* • codec* • transport containers* • multiple languages* • subtitle formats* • access services* • ad insertion • EPG data • metadata transport • protection of content rights • location based features (e.g. local weather forecast, directions on the map, targeted ads) • combining content from different sources (e.g. multiple media types such as video, audio, text, and data) • time availability of content (e.g. live, time-limited access in a library, unlimited) *Examples of typical values are given in Annex 1.	Content service provider
27	Content should be delivered to the user device as designed by the content service provider, i.e. without undesired alterations (e.g. interruptions, overlays, distortions, reduced image quality).	Content service provider Network Operator
28	Geographical availability - the service provider should be able to define in which territory the content / service should be made available, i.e.: • globally • in one or more individual countries • regional • local • one or more specific venues	Content service provider
29	Spectral efficiency for the point-to-multi-point should be at least as good as current state-of-the-art systems.	Content service provider Network operator Public Authority
30	The system shall be flexible to support different network topologies including existing High Power High Tower and Low Power Low Tower deployments	Network operator
31	The system should be as flexible as possible regarding which frequency bands it supports	Network operator Public authority
32	The interface between the content provider and different networks should be as simple as possible and it should be consistent across different network types.	Content service provider Network operator

No.	Requirement	Role
33	The system should have the possibility to provide audience metrics (e.g. number of users, duration, location, QoS experienced), including behavioural and QoE reporting in real-time. • The system should enable monitoring of the performance of the service (session established, content flow as expected) • It should be possible to report audience metrics anonymised or non-anonymised.	Content service provider Network operator
34	The 5G-Xcast solution should be designed in a way as to minimise the need for excessive updates to the hardware capabilities of consumer equipment, including UEs. • Support of the 5G-Xcast solution can be different in different types of UEs. • The UEs should also be able to use the capabilities used for unicast for broadcast / multicast such as existing media player components.	Network operator
35	It is desirable that the networks support different business arrangements (e.g. free-to-air, subscription, pay-per-view, usage deducted from a subscriber's data allowance) including both OTT and managed services with guaranteed QoS. • Whilst 5G-Xcast would not develop a billing mechanism, the solution should provide sufficient information to feed a billing system.	Content service provider Network operator
36	The radio access networks in 5G-Xcast system should maximize the system's spectral efficiency when unicast and multicast/broadcast services are deployed in the same frequency.	Network operator Public authority
37	The 5G-Xcast solution should provide a simplified interface for content being delivered over point-to-point and point-to-multipoint bearers: • The system should provide information about PTM processes delivering specific content. • The system should provide interfaces to tag content as eligible for being delivered in a PTP and/or PTM fashion	Content service provider Network operator User

Note 1:

For the requirements listed below the values already defined for point-to-point (see [9]) are assumed to be valid also for the point-to-multipoint solution to be developed in 5G-Xcast:

- Reliability;
- Availability;
- Retainability;
- Energy efficiency / battery life; and
- Storage capacity.

Note 2:

Unless specified otherwise, the requirements apply to all transport modes (i.e. unicast, multicast and broadcast).

2.3.2 Use case M&E 2 – Virtual / augmented reality broadcast

Table 4 – Use case M&E 2: Definition

Description	*Virtual Reality* (VR) is a technology that creates a perception of a user's physical presence in a rendered environment, real or imagined, leading to an immersive experience and may allow for user interaction. Virtual realities artificially create sensory experience, which in principle can include sight, touch, hearing, and smell. *Augmented Reality* (AR) is a technology that composites multimedia or other types of content on top of a user's view of the real world. *Mixed Reality (MR)* is the combination of several realities in one experienced 'reality'. VR/AR/MR applications are usually experienced through head-mounted displays. The quality of user experience is influenced by a number of parameters such as field of view, visual acuity, stereoscopic or flat image, image quality (e.g. resolution, contrast, colour range), frame rate, degrees of freedom or head tracking latency. With respect to connectivity requirements, the most demanding ones are high sustained throughput, low latency, and high reliability. In this use case a multitude of users should be able to receive high-quality VR /AR content over the air.
Services	Linear and nonlinear Virtual / Augmented Reality content, including live
User devices	• Wearable devices, i.e. AR / VR headsets • Portable and mobile personal devices • Vehicle mounted devices (e.g. in cars, couches, trains)
Environment	• Home/indoor • Out of home / outdoor, including both stationary and mobile conditions and the reception in vehicles
Pre-condition	The network operator has deployed a 5G unicast point-to-point network supporting high data rates
Post conditions	The network operator would be able to provide immersive video content to a mass audience
Benefits	Enhanced user experience, new business verticals in media and entertainment, faster 5G technology adoption

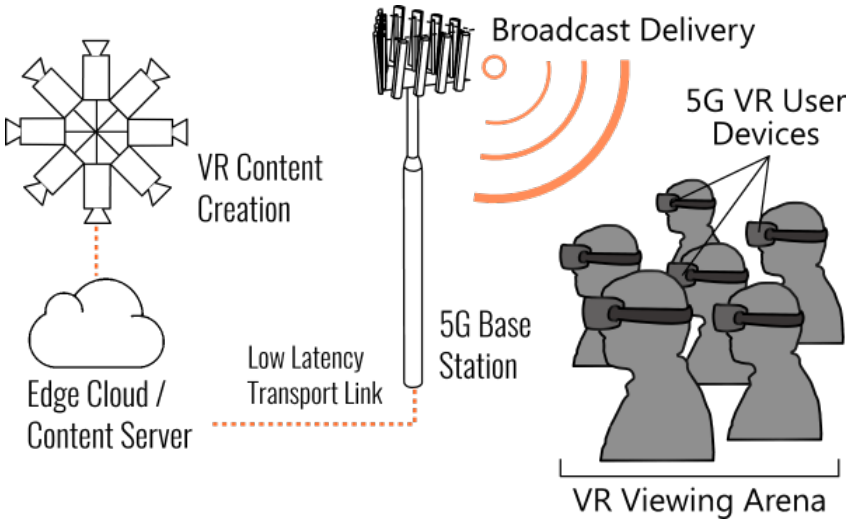

Figure 2 – Use case M&E 2: Virtual/augmented reality broadcast

Requirements for the use case M&E 2

The following requirements for this use case are in addition to (or supersede if specified) the requirements listed for M&E 1:

Table 5 – Use case M&E 2: Requirements

No.	Requirement	Role
1	The 5G-Xcast solution should support high data rates to allow high quality VR experiences: • The current state-of-the-art (which could be called pre-VR) would require several 10s of Mbit/s. Here the content could be clearly distinguishable from reality. • Fully immersive VR content delivery would require in the order of several Gbit/s, e.g. 5 Gbit/s. *Note: This requirement supersedes requirement M&E1_R23*	Content service provider Network operator
2	The system shall support a low end-to-end latency. • A typical value would be under 7 milliseconds *Note: This requirement supersedes requirement M&E1_R24*	User Content service provider Network operator
3	User (device) density: • low: Several 100s per cell (e.g., crowded venues, hotspots, theatre) *Note: This requirement supersedes requirement M&E1_R15*	Content service provider Network operator

2.3.3 Use case M&E 3 – Remote live production

Table 6 – Use case M&E 3: Definition

Description	In order to support the workflows in a typical production environment, it is often required that different people have access to the same video feed at the same time (e.g. directors, editors, commentators, those that create metadata). Given the potentially very high bit-rates in use, it is not practicable to carry multiple unicast copies of content. Instead, a feed from the production equipment such as cameras and microphones is carried over a unicast uplink connection (e.g. multilink) to the infrastructure access point and distributed via multicast to enable concurrent viewing by multiple users. These different users are normally not at the same place, hence there is a need to have access to the feed from multiple different locations whether on-site of remotely. Multiple cameras (up to 20 for large events) and microphones (up to 100 or more for complex stage performances) are commonly used. It is common to use one or more telecom providers and/or modems/links from the same provider combined together, i.e. bonded, as needed to transmit the video to the production studio. The most important capability is to receive the video feed continuously, without breaks, freezes, artefacts or other issues.
Services	Raw audio video production feeds, uncompressed or lightly compressed.
User devices	• 5G-enabled wireless cameras, microphones, in-ear monitors and other production equipment • Multi-link devices connected to cameras and production equipment
Environment	Outdoor or a venue, e.g. a stadium.
Pre-condition	The presence of a 5G network on-site and a high capacity connectivity (e.g. fibre) between the venue and the studio centre.
Post conditions	The ability to efficiently deliver remote live content to an intended audience
Benefits	*Broadcasters, content producers, events producers* With high capacity connectivity in place, it would be possible to produce live broadcasts with high quality at a distance from the studio facilities without the need for large production vehicles (OB Vans). Innovative production applications might be enabled, such as mobile journalism, mobile production office, unmanned production equipment or tracking individual athletes. For content producers, there is a potential for cost savings and for reducing the complexity of the workflows. *Network operators:* • Improve efficiency, especially for local broadcast • Enable new business models for guaranteed QoS for video streaming • Offload between a number of different networks, technologies, and operators according to real time usage *Network equipment vendors:* New services and business models based on guaranteed QoS for video, on network slicing, NFV/SDN

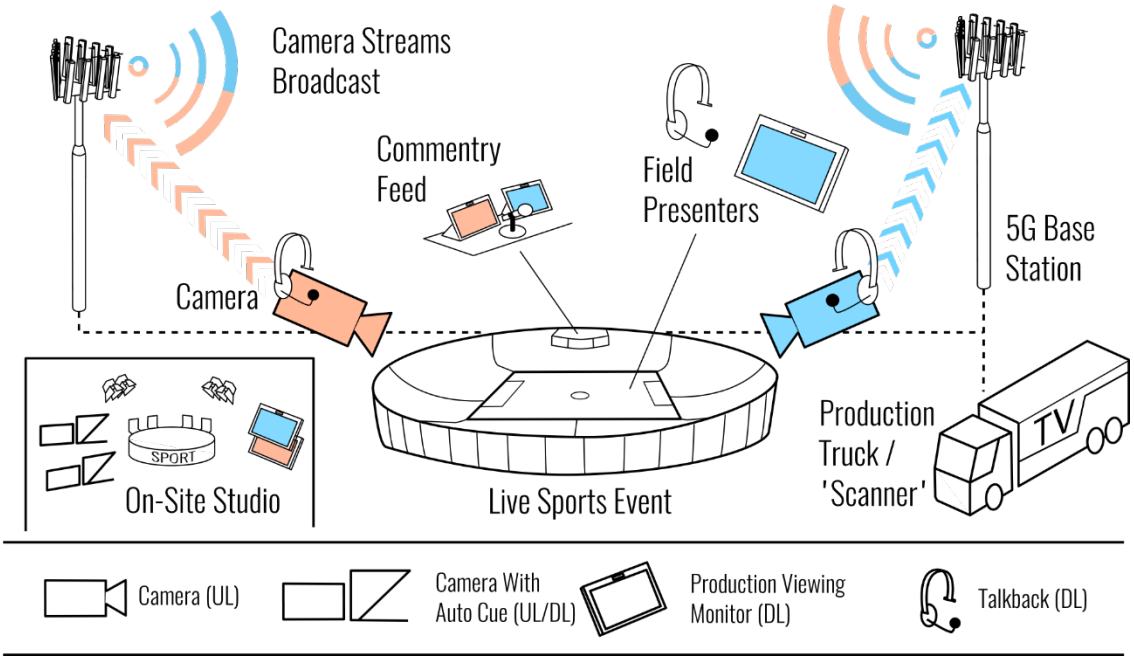

Figure 3 – Use case M&E 3: Remote live production; multiple users often require the same feed, making the use of point-to-multipoint more efficient than point-to-point

Requirements for the use case M&E 3

The following requirements for this use case are in addition to (or supersede if specified) the requirements listed for M&E 1:

Table 7 – Use case M&E 3: Requirements

No.	Requirement	Role
1	5G-Xcast solution should support sufficient bit-rate to enable very high-quality audio and video to be transported such that it is suitable for later processing within the production chain: • ca. 100 Mbit/s for mezzanine quality (i.e. lightly compressed) per video stream; and • ca. 9 Gbit/s for uncompressed quality (UHD p50) per video stream *Note: This requirement supersedes requirement M&E1_R23*	User Network operator
2	Latency: • The system shall support low end-to-end latency of the order of a few milliseconds *Note: This requirement supersedes requirement M&E1_R24*	User Network operator
3	The system shall support very high Quality of Service delivery: • ca. 10^{-11} Bit Error Rate	User Network operator
4	5G-Xcast solution should be applicable to the ITU-R [9] mobility class in terms of velocity as: - Stationary: 0 km/h *Note: This requirement supersedes requirement M&E1_R18*	User Content service provider

2.4 Public Warning (PW) use cases

The following PW use case has been defined:

PW1. Multimedia public warning alert

2.4.1 Use case PW 1 – Multimedia public warning alert

Table 8 – Use case PW 1: Definition

Description	In the *Multimedia public warning alert,* users are notified with alerts carrying multimedia and manifold information, which improves the effectiveness and reactivity of the users' responses. Alerts include: • a description of the type of alert; and • multimedia data giving instructions, advices and additional information to users (e.g. instructing them on how to better react to the alert). The digital structure of a message encompasses several types of alerts. For example, in Amber alerts users are informed about a missing child in the area of the child's last known whereabouts. Apart from textual information, a picture of the child is also included in the message along with telephone numbers and URLs that reach the relevant authorities. Also, a map of the area could be distributed which could include information of the latest known whereabouts (e.g. route, play areas). Information can be encoded in several formats (e.g. textual, audio-visual). Multimedia data carries the kind of information which is difficult to squeeze in the limited amount of text an alert typically has, such as: • pictures; • audio and videos (e.g. audio for visually impaired and video with sign language for hearing impaired, speech in several languages); • telephone numbers, URLs; • recommended actions; and • geographical information (e.g. the map of the area of the alert, recommended crowd-steering routes and latest known whereabouts for Amber alerts, like play areas). Every message includes at least a minimal set of multimedia components used to convey the message to both able-bodied and disabled people, in particular: • textual information for able-bodied individuals; • audio content for visually impaired persons; and • video with a sign-language interpreter for deaf people. Depending on the type of alert, this use case can be time critical; ability to quickly receive input from the community contributes to a timely and hopefully positive outcome. The alert is send to a targeted location. Within that targeted location, all users need to be notified promptly.
Services	Community or Government services.
User devices	Portable and mobile devices, devices for home usage, read-only devices.

Environment	Indoor and outdoor. In case the alert is raised due to some large disaster, the environment may additionally experience: • significantly increased traffic due to users contacting each other; and • network outage in case the disaster also affected the network itself.
Pre-condition	The user has configured the preference for the type of alert that will be presented (e.g. disaster alerts, Amber alerts, etc.) as well as the modality to present the content (e.g. audio messages for blind people, visual media for deaf people, any type of multimedia format for able-bodied persons, etc.).
Post conditions	Users in the affected area have received the alert and taken appropriate actions. The Alert is no longer in effect.
Benefits	Direct benefits depend on the type of conveyed alert. For example, in the case of Amber alerts [10], they include: • for the affected child and family, a potential faster and positive outcome; • for the authorities having the support of the community on this subject can support the investigative process; • for the community and authorities improved communication between these two parties; and • the operator has the opportunity to contribute and engage with the community and thereby demonstrating his/her social responsibility. Both able-bodied and disabled people can benefit from the PW messages; users with deficiencies would otherwise have not access to the service. More contextual information delivered for PW, like maps of area, instructions for shelter, evacuation route.

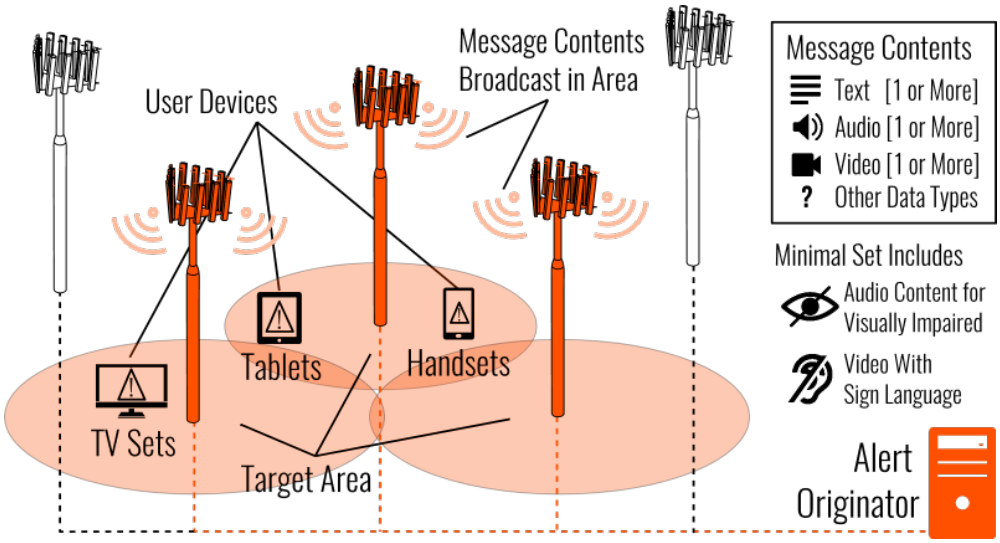

Figure 4 – Use case PW 1: Multimedia public warning alert

Requirements for the use case PW 1

The following requirements for this use case are in addition to (or supersede if specified) the requirements listed for M&E 1:

Table 9 – Use case PW 1: Requirements

No.	Requirement	Role
1	The system shall support ad-hoc (unplanned) Alerts that must be sent as soon as possible once executed and typically within 10s from the issue of the alert.	Public authority
2	It shall be possible to send multiple types of content, including: • Pictures; • Text; • URLs; • Videos; • Audios; and • Geographical information.	Public authority User
3	Only designated authorities shall be allowed to send the Alert. • Requiring authentication and authorization	Public authority Network operator
4	It shall be possible to target messages to groups of users with a cell granularity.	Public authority Network operator
5	The solution shall be designed such that it does not cause a noticeable increase in battery consumption in devices.	User
6	The Alert shall be automatically received by each device for which the user has opted-in within the target area and the message is reproduced immediately without any manual user intervention.	Public authority User
7	In-bound roamers who opt-in for the service shall also be capable of receiving the Alert.	User Network Operator
8	The Alert shall only be notified once to the user.	User
9	Where a subscriber is roaming, the system shall allow an Alert to be sent in two languages: • the language of the country where an incident has taken place; and • the language of the country where a subscriber has come from.	User Public Authority
10	The internal components of the alert message can be delivered separately, in order to speed up its diffusion (e.g. textual components before additional geographical information). • Multimedia components such as videos and audios conveying messages to disabled people have the same priority of textual information for able-bodied persons.	Public Authority Network Operator
11	The system shall support multimedia components of an alert according to the modality (priority) specified by the user.	User
12	The system shall deliver multimedia components according to the priority levels defined by the Public authority. Is shall be possible for Public authority to set the priority for delivering alert content that is higher than other types of content to increase the probability that Public Warning content will arrive without undue delay to the end-users.	Network Operator Public Authority
13	An alert shall support a severity level (e.g. warning, severe, extreme, presidential).	User Public Authority

2.5 Automotive (Auto) use cases

The following automotive use case has been defined:

Auto 1. V2X broadcast service

2.5.1 Use case Auto 1 – V2X broadcast service

Table 10 – Use case Auto 1: Definition

Description	Various V2X applications like road safety, signage, mapping and autonomous driving would require information delivered from the Intelligent Transport System (ITS) infrastructure (such as ITS roadside units and sensors) to the vehicle. The delivery of information that would benefit multiple recipients concurrently could utilize a point-to-multipoint service. Various types of Alerting One important aspect is that alerts need to be delivered well in advance to the vehicles to allow for proper manoeuvring or even allow alternative routes to be selected. One example of an alert is a broken-down vehicle, blocking a lane on a road. Approaching vehicles need to change lane in order to avoid a collision. The broken-down vehicle transmits its status to a Road Side Unit (RSU) and the RSU broadcasts this information in an area up to a few kilometres to warn approaching vehicles. Signage information Signage could be provided from the RSU to the vehicle. This could be both static signage like dangerous curve ahead as well as dynamic information such as the current speed limit in operation. The information could be highlighted to the driver but also be used in autonomous driving. Mapping data Autonomous vehicles will require high definition mapping. These maps will typically comprise a large data volume and could be delivered more efficiently to multiple vehicles simultaneously using point-to-multipoint. Vehicle and other object positions. To enable Autonomous Driving, vehicles would need to be aware of each other's positioning and headings. Besides using on-board sensors and direct vehicle to vehicle communication to achieve this, the Autonomous Driving application could benefit from having a larger horizon as well as inclusion of other objects like pedestrians and bikes. This would require updated and very accurate positioning capability by all participants. This aspect is not addressed as part of 5G-Xcast.
Services	Road safety and traffic services, Signage, Mapping, Autonomous Driving
User devices	Vehicle unit
Environment	Outdoor environment, high speed
Benefits	For *road users* increased safety through improved awareness. Increased information can further enable Autonomous Driving which also claims increased safety as well as convenience. There is also potential to reduce energy consumption and reduce emissions as well as traveling time. For *road operators* or *authorities* improved safety means less disruption of traffic and fewer emergency vehicle callouts. The various sensors and distribution of positioning information can provide the additional benefit of ability to monitor road conditions in real-time. For *network operators,* automotive use cases provide a new market segment and opportunities.

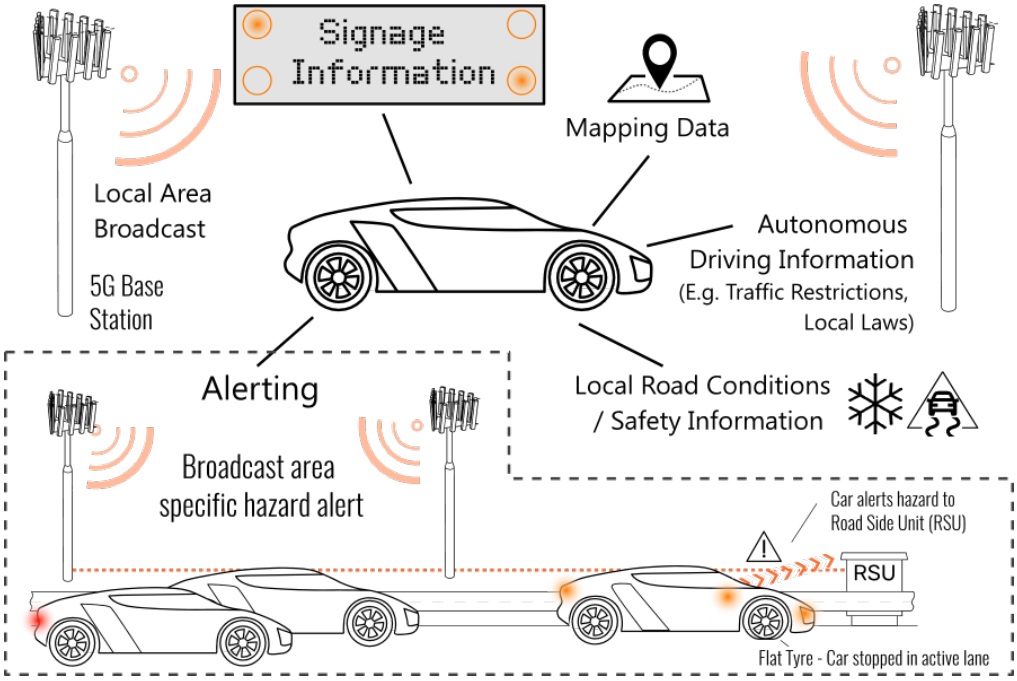

Figure 5 – Use case Auto 1: V2X broadcast service

Requirements for the use case Auto 1

The requirements for the Auto 1 use case are those set down within 5GCAR [11]. However, for reference, the principal requirements that have been identified by 5GCAR as not met by today's networks and that are of most relevance to 5G-Xcast are reproduced in the table below.

The following requirements for this use case are in addition to (or supersede if specified) the requirements listed for M&E 1:

Table 11 – Use case Auto 1: Requirements

No.	Requirement	Role
1	Low end-to-end latency • A typical time for packet transit through the radio network below 5 milliseconds. *Note: This requirement supersedes requirement M&E1_R24*	Network Operator User Content Service Provider
2	Ultra-high reliability: • A typical packet loss rate of less than 10^{-5}.	Network Operator User Content Service Provider
3	A very large density of connected vehicles across different environments: • Urban: 1000 – 3000 vehicles/km^2; • Sub-urban: 500 – 1000 vehicles/km^2; and • Highway: 100 – 500 vehicles/km^2. *Note: This requirement supersedes requirement M&E1_R15*	Network Operator User Content Service Provider

2.6 Internet of Things (IoT) use cases

The following IoT use cases have been defined:

IoT 1. Massive software and firmware updates

2.6.1 Use case IoT 1 – Massive software and firmware updates

Table 12 – Use case IoT 1: Definition

Description	IoT devices such as smart water-metering are installed deep indoors and wake up once or twice a day to send the consumption reports to the water-metering network that is regularly extended. Based on the growing amount of data, the system configuration is adjusted, requiring the delivery of small configuration updates to all metering devices. Moreover, the water-metering manufacturer regularly provides non-critical software updates.
Services	Massive file delivery for IoT devices
User devices	Devices with a long battery life, low cost NB-IoT or eMTC
Environment	Indoors, outdoors
Pre-condition	
Post conditions	The IoT device provider receives the report on successful software update. Upon successful update, IoT devices go back to their normal operation by either going to sleep or sending the consumption report.
Benefits	The *IoT device provider* benefits from a single broadcast session to deliver the software update to a large number of IoT devices. The *network operator* optimizes its bandwidth usage for the software update event. *IoT devices* are informed to wake up at the right moment to receive the software update and then go back to sleep mode to save the battery. *IoT devices* perform simple procedures for the required operations on file reception to save the battery.

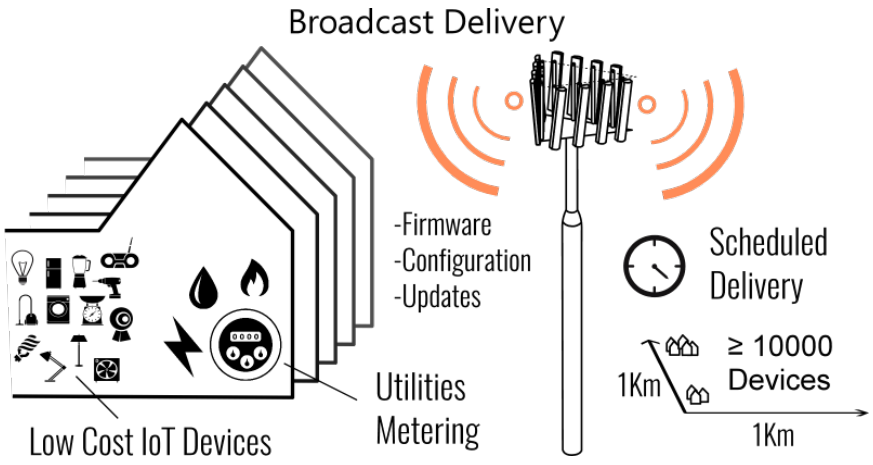

Figure 6 – Use case IoT 1: Massive software and firmware updates

Requirements for the use case IoT 1

The following requirements for this use case are in addition to (or supersede if specified) the requirements listed for M&E 1:

Table 13 - Use case IoT 1: Requirements

No.	Requirement	Role
1	The system shall be designed such that it is possible for devices to: • have a long battery life (typically 15 years); • have limited processing capabilities; • have limited storage facilities; and • to wake from standby up at a scheduled time to receive a file delivery.	User (IoT device)
2	The system shall support reports on successful delivery from each receiving device.	Content service provider Network provider User (IoT device)
3	The system shall support a mechanism to inform the device about future schedule delivery sessions. • e.g. indicating the IoT devices' wake up time for software updates.	Content service provider Network operator
4	User (device) density: • high: ≥ 10000 devices per km^2 (crowded venues, hotspots) *Note: This requirement supersedes requirement M&E1_R15*	Content service provider Network operator

3 Discussion on use cases

3.1 Analysis of the 5G-Xcast use cases

Chapter 2 described the 5G-Xcast use cases classified in four categories. The most relevant category belongs to the Media and Entertainment vertical defined within the 5G framework. Other use cases are located in the area of Public Warning, Automotive and Internet of Things. At a first glance, these four categories seem to be somewhat divergent. This is due to the fact that different requirements have to be fulfilled for each single use case.

Looking at the use case definitions from various organisations such as ITU-R (IMT2020) [12], 5G-PPP [13], 3GPP [14] or NGMN [15], a divergence in one or more sectors is apparent. The spectrum efficiency varies according to the conditions that are applied concerning the network performance, the service composition, the device arrangement and the behaviour of the user. Furthermore, almost all requirements are related to a unicast transmission, such as the user experienced data rate derived from the user throughput. For a broadcast-oriented scenario this value will be all the same for all users and is only dependent on the network capability.

A closer view nevertheless discloses some similarities among the proposed use cases. The basic principle of the 5G-Xcast project is the delivery of information to a large number of users or devices at the same time and in the same format. This applies for the Hybrid Broadcast Service use case, the Multimedia Public Warning Alert use case and the V2X Broadcast Service use case. Out of these use cases synergy could be derived to facilitate the development of the respective demonstrators and the examination of the achieved results.

These three use cases have in common the rather high data rate, the flexibility of using different data rates, a high trustworthiness and a large geographical availability. During the course of 5G-Xcast it could not be expected to fulfil all the KPIs of the spider diagrams defined by the organisations mentioned above. The main elements to improve and realize for the proposed use cases are the area traffic capacity, the reliability and the service flexibility. One common factor among the three use cases under discussion is the container and the format of the transmitted information. Also, the priority of different pieces of information has to be established. Thereafter the reliability of the data delivery has to be very high for the Hybrid Broadcast Service, the Public Warning and Automotive Use Cases. In respect to the foreseen services not only the technical parameters and interfaces have to be developed and tested, but also the workflow between the content providers, the public authorities, the broadcasters and network operators must be designed. To understand and coordinate the procedures of all the players in the information chain will be challenging for the on-going project.

One additional aspect is the available performance of the UEs. As far as possible one carefully designed end user device should serve for all proposed use cases. Indeed, there will be some adaptations for specific environments e.g. external antennas while using a smartphone in a vehicle.

As a general design principle, the technologies within 5G-Xcast should be developed with forward compatibility in mind, i.e. they should be designed in a way that allows a smooth introduction of future services and features with no impact on the access of earlier services and UEs.

3.2 Implementation scenarios / convergence issues

There are a number of possible implementation scenarios for the 5G-Xcast system, including:

- a fixed and a mobile network operated by a single telecom provider;
- a 5G mobile-only network including unicast/multicast/broadcast;
- a dedicated broadcast 5G network; and
- a scenario combining the three different networks, i.e. fixed, mobile and terrestrial broadcast.

Decoupled networks often result in fragmented views, designs, deployments and content formats. This rarely delivers the best experience for end customers and often results in network operators, content providers and vendors not working together efficiently. For example, encrypting data may ensure content is secure for a content provider, but makes it hard to produce detailed reporting which could lead to optimising a network to deliver content more efficiently for a network operator.

A formal converged approach may lead to cost efficiencies and new cost models. If users, whilst viewing content, experience seamless handovers between networks and an uninterrupted service whilst moving between environments, they are more likely to watch more content on a particular session because of a lack of service interruptions. It also encourages more general content viewing due to a general uplift in quality of experience. More data consumed may result in increased revenues for operators, who may in turn purchase more content from content providers.

Convergence brings down the cost and complexity of delivering Media and Entertainment to multiple devices for operators. Currently there are different distribution networks for fixed IPTV, mobile, DTT and cable. This means that the same content needs to be produced in multiple formats being distributed by multiple physical solutions which could be expensive. A converged solution to deliver a stream of content to multiple devices in different environments would reduce costs for content providers and network operators as there will be fewer physical solutions to design, deploy and operate.

3.3 Potential demonstrations

The 5G-Xcast solution has the potential to enable different business models, spectrum deployments and new regulation frameworks through convergence. One such aspect of convergence is the switchover between different network technologies and networks. This can occur as the end-user context changes and/or as the popularity of content changes such that it is appropriate to switch between PTM and PTP mechanisms for efficiency reasons. From a user perspective, this handover process should be completely seamless.

A potential demonstration that could showcase this is illustrated in Figure 7. It would be based on a user watching a live video on a mobile device at home (1) using a fixed network connection. The user subsequently leaves to an outdoor location where the home connection is out of range (2) but wants to continue watching the video without interruption using their mobile connection. Later, the user moves to another area covered by the TV network (3). During the use case, the content can become more or less popular and be switched between PTM and PTP delivery and the user may move in or out of the coverage

area of different networks. Throughout the whole period the video should continue to play smoothly and without interruptions.

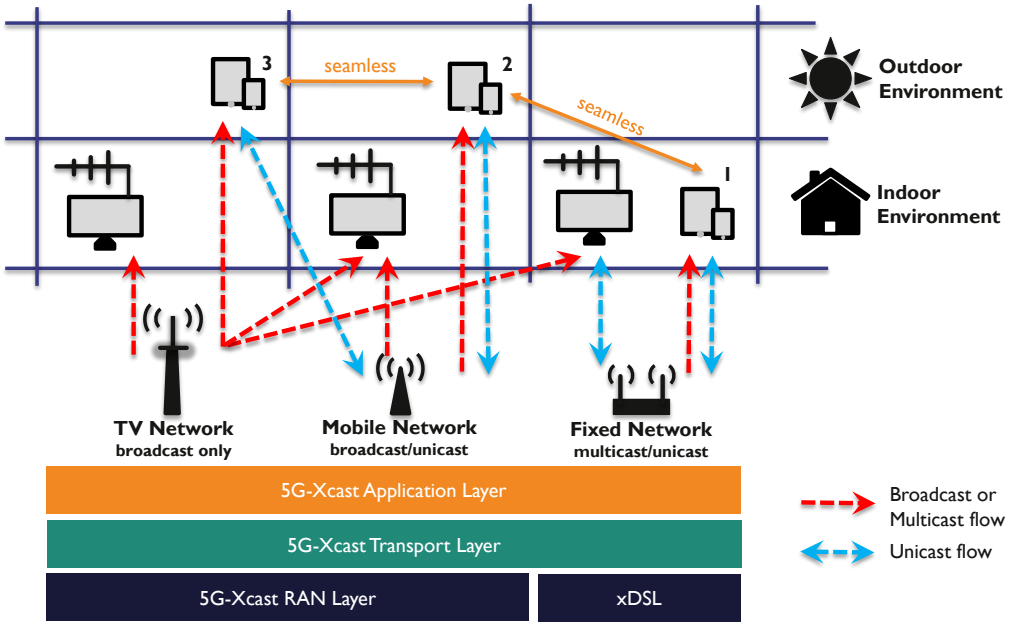

Figure 7 – Combinations of technologies and access networks work together in 5G-Xcast to give a seamless experience as the user moves between locations 1, 2 and 3

3.4 State-of-the-art

The current LTE eMBMS RAN is configured with rigid OFDM numerology parameters that limit the type of network deployment. More specifically eMBMS, including MBSFN and SC-PTM, is characterised by a limited set of waveform configurations, e.g. cyclic prefix length in LTE Release 14. The limitations on the waveform flexibility hinder the current technologies of LTE eMBMS to support the different network deployments with the aforementioned requirements in Chapter 2, e.g. high coverage and high mobility in a large area deployment for the Hybrid Broadcast Service. Note that some of the requirements can even be challenging for current unicast transmission technologies in PTP scenarios, e.g. the extremely high data rate and low end-to-end latency required in the virtual/augmented reality broadcast or in the remote live production.

In addition to the limitations on the waveform flexibility, the lack of a feedback channel in LTE eMBMS means that features such as dynamic optimisation of resource allocation or the provision of useful audience metrics are not supported. Furthermore, compared with the DTT system ATSC 3.0, where MIMO techniques and high constellation size are enabled, the limitations on spatial multiplexing and available modulation order in eMBMS in Release 14 can limit support for certain types of network deployment, e.g. large area deployment with a high spectral efficiency requirement.

From a network architecture perspective, mobile and fixed/broadband networks are considered as separate entities at the present time (i.e. 3GPP Release 14). End users are not able to have a seamless experience when moving from home, where Wi-Fi through a broadband connection is a preferred choice, to outdoors where a mobile connection is usually used. This challenge is also applied in the reverse direction where the end users

move from outdoor to the home. In addition, a seamless experience when switching between unicast and multicast/broadcast can be achieved in each isolated network type (e.g. multicast ABR in broadband/fixed network and MBMS operation on-Demand (MooD) in a mobile network). However, the autonomous and seamless transition is not possible from converged network point of view where the end users have a seamless experience regardless of whether they are using a fixed/broadband and/or mobile connection and regardless of transitions between unicast and multicast/broadcast.

Within 5G-Xcast, the Content Delivery Framework focusses on the means to exploit a point-to-multipoint network capability to deliver content in an efficient way and which can respond to dynamically changing demand. The goal is to define a means to do this which is the common over fixed, mobile and possibly other, network types.

There are some existing technologies which seek to exploit a point-to-multipoint network capability for delivering otherwise unicast traffic, though none yet in a way that meets all our requirements. Candidate existing technologies would include the 3GPP MooD specification [16] and the CableLabs Multicast ABR specification [17]. In addition, there is a standardisation activity currently underway in DVB to consider a new specification for Multicast ABR [18].

The main limitation of current approaches is that they each address a specific network type. That is, the CableLabs specification only considers the requirements of cable operators in the specific market conditions found in the USA. The 3GPP specifications only apply to 3GPP networks. In the 5G-Xcast project, a solution will be developed which is re-usable over different network types.

A further limitation of current approaches is the degree to which the network operator must understand the content that they are delivering. Another goal of 5G-Xcast is to simplify the relationship between the content service provider and the network service provider. This will encourage the exploitation of point-to-multipoint networks by simplifying integration.

Annex 1: Examples of service related requirements

Audio formats	• Stereo • Multichannel • Next generation (immersive) audio * loudness control * multiple audio descriptors may be required
Audio codecs	• MPEG1, Layer 2 audio • MP3 • AAC
Image formats	• SD, HD, UHD • Video profiles in 3GPP TS 26.116 [19]
Video codecs	• H.264/AVC • H.265/HEVC * other codecs might be required for legacy / archive material. ** future codec (i.e. beyond HEVC) may need to be supported. ** distinguish between two cases: 1. pre-encoded content, possible adaptation for transport 2. content encoded/transcoded in the delivery system
Transport containers	• RTP/MPEG Transport Stream • MPEG-4 Part 14 (MP4) • MPEG-DASH
Multiple languages	• Any number of languages may potentially be required. • Users should be able to choose a particular audio language version.
Subtitle formats	• Textual • Bitmap * Users should be able to choose a particular subtitle language.
Access services	• Subtitling (closed caption) • Signing (e.g. picture in picture) • Audio description • Audio subtitling

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