EBU

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TR 054

5G FOR THE DISTRIBUTION OF AUDIOVISUAL MEDIA CONTENT AND SERVICES

TECHNICAL REPORT

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Abstract

Media organizations have evolved their content offer from a limited number of linear radio and TV channels into a rich and differentiated offering available across a range of different distribution platforms. This includes IP-based services with linear as well as nonlinear and catch-up content. Portable and mobile devices such as smartphone and tablets play an increasing role for the consumption of media content and services in the home, as well as on the move.

For the time being, the only way of delivering nonlinear services to portable and mobile devices is by means of unicast connections. However, the large-scale delivery of audio-visual content over mobile unicast networks is at present not satisfactory both from media service providers and user perspectives, due to deficits regarding QoS, coverage and costs. 5G as specified by 3GPP may offer an opportunity to bridge this gap.

This report elaborates on the potential of 5G to facilitate the distribution of the whole range of PSM services to portable and mobile devices. It is a result of collaboration between stakeholders in the media sector, including public and commercial broadcasters, broadcast and telecom network operators, equipment manufacturers, and technology providers. Hence, the views presented in the report do not necessarily reflect a formal position of the EBU or any of the contributing parties.

The report addresses 5G network deployment opportunities for the distribution of media services. Even though the media industry, led by the EBU, successfully engaged in the standardization of 5G, in particular 5G Broadcast, this does not guarantee that all standardised features will inevitably be implemented in 5G networks and devices. The scope and timing of market deployment of a particular feature are largely driven by the existing or expected market demand.

This report elaborates on those issues which need to be resolved to bring the new technology to the market. These are related to technology, network infrastructure, regulation including spectrum and business arrangements between different stakeholders. Possible actions to support the use of 5G technology in the media industry and to verify the market demand for specific features are identified.

The report starts with an overview about distribution requirements from the media industry. Then the current state of the 5G standardization is summarized followed by a chapter which contains the views of the stakeholders which were involved in drafting this report. Next, 5G deployment opportunities for the distribution of media content and services are presented, first for 5G Broadcast, then for 5G Mobile Broadband in a broader sense. The report includes an analysis looking to which extent 5G may be able to fulfil the requirements in the distribution of different types of audio-visual media services. The annexes contain more details regarding spectrum, business aspects and network design.

The main conclusions emphasise the fact that, technically, 5G may be able to meet the distribution requirements of both PSM and commercial media providers if a combination of 5G Mobile Broadband and 5G Broadcast is used. To achieve this in practice, collaboration between stakeholders across the media value chain is required. In addition, further investigations into cooperative models between broadcasters and mobile network operators in term of joint use of spectrum and site assets would be useful. Such cooperation may deliver the cost benefits and the economies of scales required to trigger the device and infrastructure ecosystem for 5G broadcast.

As the roll-out of 5G networks has widely started only recently, this report constitutes a snapshot in time. It may help media organizations though in developing their individual distribution strategy with regards to 5G technology.

List of Acronyms and Abbreviations

The following acronyms and abbreviations are used in this report.

Abbreviation/Acronym	Expansion
3GPP	3rd Generation Partnership Project
5GC	5G Core
5GMS	5G Media Streaming
5GS	5G System
ABR	Adaptive Bit-Rate
ADSL	Asymmetric Digital Subscriber Line
AES	Advanced Encryption Standard
API	Application Programming Interface
ATSC3.0	Advanced Television Systems Committee 3.0
AV	Audio-Visual
AVoD	Advertising Video on Demand
BEREC	Body of European Regulators of Electronic Communications
BNO	Broadcast Network Operator
CA	Conditional Access
CAGR	Compound Annual Growth Rate
CAS	Cell Acquisition Subframe
CDN	Content Delivery Network
CI	Common Interface
CMAF	Common Media Application Format
COTS	Commercial Off-The-Shelf
CPE	Customer Premise Equipment
D2D	Device-to-Device
DASH	Dynamic Adaptive Streaming over HTTP
DRM	Digital Rights Management
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting

DVB-HB	Digital Video Broadcasting — Home Broadcast
DVB-T	Digital Video Broadcasting — Terrestrial
DVB-T2	Digital Video Broadcasting — Second Generation Terrestrial
EIRP	Equivalent Isotropically Radiated Power
eMBB	Enhanced Mobile Broadband
eMBMS	Evolved Multimedia Broadcast Multicast Services
EnTV	Enhanced Television Services
FDD	Frequency Division Duplexing
FeMBMS	Further Evolved Multimedia Broadcast Multicast Services
FTA	Free-to-air
FWA	Fixed Wireless Access
GE06	Geneva Agreement 2006
HbbTV	Hybrid Broadcast Broadband Television
HLS	HTTP Live Streaming
HPHT	High-Power High-Tower
HW	Hardware
IMT	International Mobile Telecommunication
IoT	Internet of Things
IPTV	Internet Protocol Television
ISDB-T	Integrated Services Digital Broadcasting - Terrestrial
ITU	International Telecommunication Union
LDPC	Low-Density Parity-Check code
LPLT	Low-Power Low-Tower
LTE	Long Term Evolution
LTE-B	LTE Broadcast
mABR	Multicast Adaptive Bit-Rate
MBSFN	Multicast Broadcast Single Frequency Network
MEC	Multi-access Edge Computing
MIMO	Multiple-Input Multiple-Output
mMTC	Massive Machine-Type Communications
MNO	Mobile Network Operator
MooD	MBMS Operation on Demand
MPEG	Moving Picture Experts Group
MPMT	Medium-Power Medium-Tower
NFV	Network Function Virtualization
NR	New Radio
NSA	Non-Standalone Architecture
OFDM	Orthogonal Frequency-Division Multiplexing
OTT	Over-the-Top
PHY	Physical Layer

PPDR	Public Protection and Disaster Relief
PSM	Public Service Media
QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
ROM	Receive-Only Mode
SA	Standalone Architecture
SBA	Service-based Architecture
SDL	Supplemental Downlink
SDN	Software-Defined Network
SDO	Standalone Downlink Only
SDR	Software Defined Radio
SFN	Single Frequency Network
SIM	Subscriber Identity Module
SLA	Service-Level Agreement
STB	Set-top Box
SVoD	Subscription Video on Demand
SW	Software
TA	Targeted Advertising
TS	Transport Stream
TSM	Telecoms Single Market
TV	Television
TVoD	Transactional Video on Demand
UE	User Equipment
UI	User Interface
URLLC	Ultra-Reliable Low Latency Communication
V2X	Vehicular-to-Everything
WID	Work Item Description

Contents

5G for the Distribution of Audiovisual Media Content and Services

EBU Committee	*First Issued*	*Revised*	*Re-issued*
TC	2020		

Keywords: Programme Distribution, Broadcast, Linear, Nonlinear, 5G, Enhanced Services, 5G deployments, 5G Broadcast, Mobile Broadband.

1. Introduction

The EBU, in collaboration with several companies across the mobile and broadcasting industries have investigated how 5G may help media organisations to improve the distribution of their audio-visual (AV) content and services for their audiences.

Content and services of media organizations, in particular public service media (PSM) organizations, have evolved from a limited number of linear channels into a rich and differentiated offering across digital distribution platforms including IP-based services which, often through media players, now also provide nonlinear and catch-up content – content and services which are increasingly popular with audiences.

Audiences now widely consume media content and services (audio and video) on conventional and smart TV sets, portable and in-car entertainment systems, smartphones, tablets, personal computers, smart speakers, etc. Much of this consumption happens in the home, as well as on the move.

Conventional broadcast technologies (e.g. DVB-T/T2) could deliver linear services to portable and mobile devices. However, these standards are not widely supported in such devices. Typical HPHT broadcast networks for TV are in general not designed to support mobile use cases and will need to be adapted for such use cases, e.g. for public transport in cities. Additionally, conventional broadcasting standards are not capable of delivering nonlinear services without a complementary IP connection.

In principle it is possible to deliver linear and nonlinear media content and services to mobile and portable devices with conventional mobile broadband (e.g. unicast IP over mobile networks), however questions remain about this distribution mode, for example:

- Whether mobile networks could provide adequate quality of service to large audiences by means of unicast connections.
- Whether unicast would be affordable for consumers given data volumes consumed by media content.
- Whether distribution over mobile networks is affordable for service providers, and is compatible for example with the remit of PSM organisations.

5G has the potential to provide answers to some of the questions above, particularly for linear services which can be delivered with 5G's broadcast functionality. This may enable meeting the media industry's technical, commercial and regulatory requirements at the same time.

To date, most of the media industry's efforts related to 5G have been directed towards 3GPP standardisation. This is a necessary step, but it does not guarantee that all standardised features will inevitably be implemented in 5G networks and devices. Therefore, it is not possible to identify a reliable timeline for the availability of various standardized 5G features on the market.

The scope and timing of market deployment of a particular feature are largely driven by the existing or expected market demand. This report addresses 5G deployment opportunities for the distribution of audio-visual content and services. Issues regarding technology, networks, regulation including spectrum and business arrangements between different stakeholders are discussed. Possible actions to support the use of 5G technology in the media industry and to verify the market demand for specific features are identified.

2. AV Media Services and Requirements

Today, AV media companies offer two broad categories of content and services that are relevant for this report: linear media services and nonlinear media services. These services are now commonly being brought together into a single offer – referred to herein as an Enhanced Media Service - that builds on the strengths of each. These services, as well as the requirements that AV companies have for distributing them, are further described below.

2.1 Linear Services

Linear Media refers to conventional, curated broadcast TV or radio channels where programmes such as news, sport, entertainment and documentaries are scheduled by a service provider to be viewed at the time of transmission. Programmes in a linear channel may include live coverage of events (e.g. sports, news, cultural and entertainment) whereas others may be pre-recorded (documentaries, drama, movies etc.). The programme schedules, or sequence of programmes, are determined by the service provider and do not require, or allow, the user to interact with the programme or the service provider to view the content. Users can tune in to, or change to a different channel, but they cannot view programmes other than those being transmitted at the particular time in question, change the order of the programmes in the schedule, or the time of a programme’s transmission.

Beyond conventional broadcast TV and radio, new forms of linear service are also arising on other platforms such as the live-streaming service of Amazon Live or the use of social TV to cover, in particular, live events. These types of service, which are only meant to be available on certain occasions, are also treated under the category of linear services.

Linear services can be transmitted by platforms that do not require bi-directional communication between service provider and user to access the content – they can be broadcast with no return channel.

Linear services are conventionally delivered by broadcast platforms such as DTT, Satellite and cable. However, they may also be delivered over IP by the fixed internet e.g. ADSL and fibre, including Wi-Fi as an extension for indoor scenarios. Mobile networks (e.g. 3G/4G/5G) may also deliver linear services via unicast IP streams to compatible devices.

2.2 Nonlinear Services

Nonlinear media is a type of media content that is offered on-demand at the request of the user. Users can select content they wish to watch or listen to from a content library and control, as a minimum, the timing and sequence of the consumption. It is normally possible to rewind and replay content from libraries as desired. Particularly popular nonlinear services are catch-up and time-shifted services as well as VoD and AoD. Content may also be stored in the cloud, in personal video recorder offerings or downloaded to local storage for future consumption at times where there is no access to the network, or it is intermittent.

Nonlinear services require bi-directional communication between a service provider and user to access the content the user requests. Some content may be pushed to the user device – via a unidirectional transmission – for storage and later consumption should the functionality be enabled. However, such content is usually only pushed out to users at their request or agreement.

Nonlinear services are normally delivered over IP by the fixed internet e.g. ADSL and fibre, including Wi-Fi. Mobile networks (e.g. 3G/4G/5G) may also deliver nonlinear services, particularly to mobile devices. Note that in terms of bandwidth, the downstream is significantly more demanding than the upstream as it conveys the AV content.

2.3 Enhanced Media Services and Platforms

Enhanced media services create an enriched content proposition by combining the best of both linear and nonlinear services. Conventional curated linear services are available alongside nonlinear content, and these services may be complementary, or entirely new. Enhanced media services allow content to be personalised for users based on their viewing and listening preferences of the past as well as content genres to which they may have signed up to or previously liked.

Enhanced media services typically offer audiences/users the following:

- Access to linear stations (national and local), particularly for significant events such as international sporting matches.
- Time-shifting, pause and rewind of live services.
- Easy search of media libraries including video clips, podcast, audio books, chapters, programmes, etc.
- Downloadable programmes to watch or listen to offline.
- Additional value-added information such as targeted advertising and programme substitution (e.g. regional breakouts and regional news), and other location-aware services.
- Personalized services to match users' interests and preferences such as content recommendations.
- Possibility of user feedback and audience statistics back to the CDN or service provider.

Enhanced media services are available today and may be accessed through devices that support them. Smart TVs, for example, can receive conventional linear content through their broadcast receivers as well as nonlinear content through their IP capabilities. HbbTV services or software applications (apps) for smartphones, tablets, PCs and smart TVs also offer enhanced media services, usually delivered over-the-top (OTT), thus requiring an internet connection.

Examples of applications offering enhanced media services include the BBC iPlayer, RaiPlay, ARD Mediathek, RTL TVNOW, Atresmedia Player, etc. Several hybrid radio services are also available, or emerging e.g. Kronehit (Austrian radio application), ARD Audiothek, and BBC Sounds.

Figure 1: Linear TV and Nonlinear Video on Smartphones and Tablets. From left to right: The ARD Mediathek (PSM), RaiPlay (PSM) and Atresmedia (commercial) and RTL' TVNOW (commercial) applications.

Note that there are examples of several platforms such as waipu.tv or TuneIN Radio that aggregate content from PSM and commercial broadcasters under their own applications.

Figure 2: Radio and Podcast on Smartphone and Tablets. From left to right: The Kronehit (commercial) and BBC Sounds (PSM) applications.

These applications may also be installed on car entertainment systems provided that an internet connection is available either through the car itself or by means of pairing with a mobile phone.

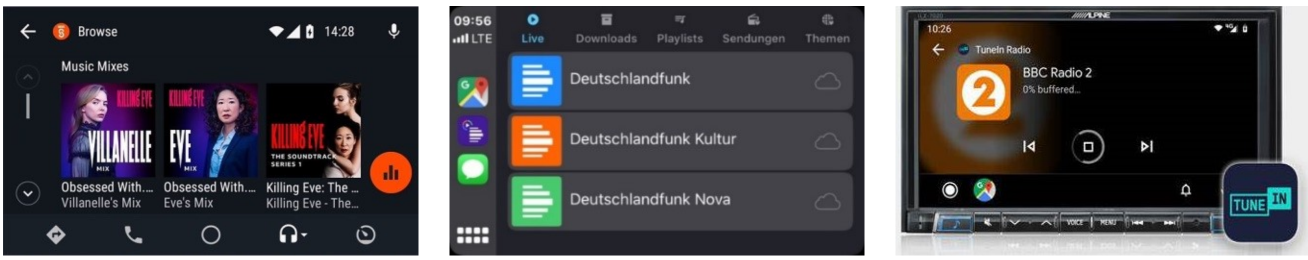


Figure 3: Radio and Podcast on Car infotainment systems. The BBC Sounds (PSM) for Android Auto, the DLF App (PSM) for Apple CarPlay and TuneIn Radio (aggregator) for Android Auto

Social networks such as Facebook, Twitter, Instagram or Snapchat, as well as YouTube, also allow live streaming of AV content alongside interaction between users by means of comments, etc. Both private users and institutional users (like TV service providers) make use of the live streaming functionalities on social media platforms. Some broadcasting companies in Europe provide live streams on these platforms from events - like e.g. a press conference held by a country's government spokesman or football matches of lower leagues. Users must subscribe to the respective social network in order to gain access to these video clips.

Figure 4: Live TV over social networks. Examples of Amazon Live and the ARD Tagesschau over Facebook.

2.4 Distribution Requirements

2.4.1 Public Service Media Organizations

Public Service Media organizations have several requirements intended to ensure the desired integrity, availability and quality of media services delivered across different platforms. Such requirements reflect the conditions in which public service media operate and their regulatory obligations and constraints. Many of the main requirements that are relevant for this document have been captured in [1], and are reproduced below:

- **Universal Coverage and Access:** Geographical availability of the service (e.g. national, regional, local) according to regulatory requirements.
- **Free-to-air Access:** users can consume content without the need to subscribe to the service provider or the network operator.
- **Defined Quality of Service (QoS):** to be defined by the broadcaster, e.g. availability of network transmissions, robustness, up-time, latency, and reliability.
- **Scalability:** QoS for each user shall be independent of the size of the audience.
- **Service integrity:** No modification of the PSM content or service by third parties. For example, TV content and additional services (e.g. subtitles) must be displayed on screen, unaltered and without unauthorised overlays.
- **Prominence:** provisions should exist for adequate prominence of several PSM services intended to be offered (e.g. position in programme guides)
- **Ease of Use:** Straightforward accessibility and prominence of the PSM offer.
- **Accessibility:** support for people with disabilities (e.g. subtitles, audio description and signing).
- **Public Warning:** Ability to reach audiences in emergency situations.
- **No Gatekeeping:** Deliver PSM content to the public without unduly constraining the service offer e.g. blocking or filtering content, restricting access to services or network infrastructure.
- **Costs:** nationwide content distribution and universal access should be affordable for PSM (including content royalty fees) and consumers alike.

Specific use cases may entail several additional requirements that need to be taken into account, for example data rate, bit error rate, targeted peak concurrent audience size, mobility, etc.

PSM requirements have been developed over many years, often with linear broadcast and fixed reception in mind. Ideally it would also be possible to meet them across all distribution platforms, including for mobile devices such as smartphones. However, it is recognized that the use of bi-directional communication – particularly IP distribution – currently involves additional implications that may require new technical enhancements or commercial arrangements to substantially fulfil these requirements.

2.4.2 Commercial Content and Service Providers

Commercial Broadcasters´ requirements are broadly consistent with the requirements of PSM organizations, especially in areas such as service integrity, access to media platforms and easy discoverability in user interfaces. These issues are also handled in the EU AVMS Directive [2].

Distinctions can however be observed regarding monetization and advertising:

- **Monetization / Encryption / Copy Protection:** Private Broadcasters and Pay TV Operators must monetize their products. In linear TV this is done in the first place by airing advertisements and selling subscriptions. In the case of nonlinear Catch-up & VoD services typical business models are SVoD, AVoD and TVoD. Industry standard Encryption and copy-protection technologies (e.g. CI+, embedded CA-System, AES-encryption, DRM-protection) allow to protect linear TV services and nonlinear content and are thus also mandatory for any new distribution technology. Here, it needs to be considered that content rights and product offerings are becoming increasingly complex.
- **Targeted Advertising (TA):** Addressable TV functionalities allowing for a personalized TV experience (e.g. regional services, customized UI and content) are essential for the market and have to be established, both for vertical (with platform operator offering services with proprietary STB) and horizontal (without platform operator) deployment scenarios. With the shift of Ad-Budgets to "addressable" also new ad products like so-called "Switch-In" display ads and dynamic ad substitution (DAS) are of growing importance.

  First DAS implementations based on HbbTV technology are currently on-air, but additional standardization is required to provide a high reach and reliability. In early 2020, DVB released its targeted advertising specification that complements the new HbbTV-TA specification for this specific use case with a standardized way of signalling the advertisement substitution opportunities in the live TV broadcast [3]. This enables broadcasters to provide specific audience groups with customized advertising during commercial breaks, where the 'normal' advertisement on the TV channel's conventional broadcast feed is replaced on a screen-by-screen basis with a specific targeted advertisement.
- **Enhanced media services**, combining interactive elements providing access to additional linear (e.g. alternative audio tracks, real-time gaming) and nonlinear content (like e.g. time-shifted viewing, video on-demand) with traditional linear TV, are an indispensable part of today's TV experience. The ability to provide enhanced TV services should be a common basic requirement of PSM and commercial broadcasters for any 5G media deployments.

3. Status of 5G Standardization and Deployments

3GPP is standardizing functionality to improve the distribution of AV media over 5G networks to mobile devices, and potentially conventional TV sets equipped with 5G receivers. The standardisation activity related to AV media distribution can be broken down into two main areas:

- 5G Broadcast, which refers to “LTE-based 5G Terrestrial Broadcast”, as defined by 3GPP in LTE Release 16, which do not necessarily require operation by a mobile network operator.
- 5G Mobile Broadband, which refers to developments in 3GPP based on the new radio access (New Radio – NR) and core (5G Core – 5GC) technologies from Release 15, which are operated and deployed in mobile networks.

Figure 5 shows the schedule of work while the following sections elaborate further on the intentions, functionalities, and capabilities of various aspects of the standardization activities that are relevant to the distribution of AV media.

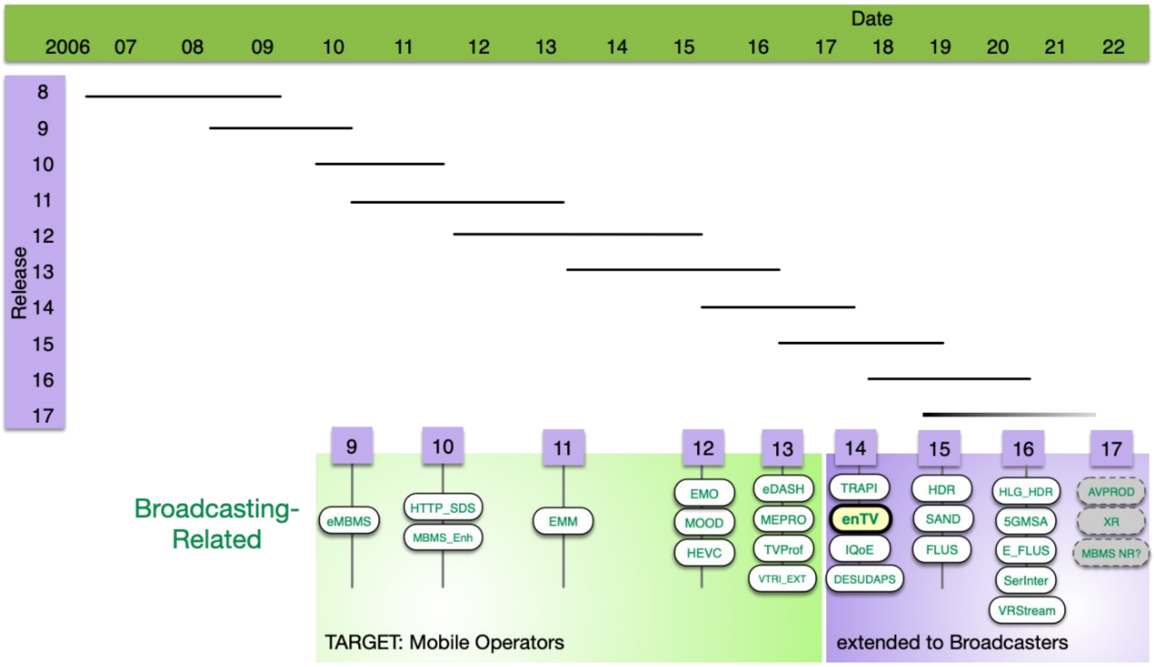


Figure 5: 3GPP timeline of work items related to media

It is worth noting that the inclusion of a feature in 3GPP specifications is a necessary step but it does not guarantee that this feature will inevitably be implemented in 5G networks and devices. The scope and timing of market deployment of a particular functionality are largely driven by the existing or expected market demand. This depends on many factors, some of which may be difficult to predict. Therefore, it is not possible to identify a reliable timeline for the availability of various standardized 5G features.

3.1 5G Broadcast

The standardization process for dedicated 5G Broadcast has now largely been completed. It started in Rel-14 under the EnTV work item based on 4G LTE networks. This first phase of the standard was completed in summer 2017, appearing in 3GPP TR 22.816 [4]. Rel-16 further enhanced the physical layer of the specification to close three main gaps that were identified in the Rel-14 [5]. Rel-16, which is named LTE-based 5G Terrestrial Broadcast [6] is expected to be complete during 2020.

The overall aim of dedicated 5G Broadcast is to provide broadcasters with the means of delivering linear TV services to mobile and portable devices, as well as conventional TV sets, with a single chipset in accordance with their requirements. The broadcast requirements are substantially based on the conventional distribution of linear TV content outlined in § 2.4.

The main features of 5G terrestrial broadcast which collectively aim to fulfil these requirements are set out below. The first six features are related to radio access enhancements while the final four are related to the system layer.

- Longer Range: 200 µs cyclic prefix (CP) for single frequency networks with inter-site distances in the order of 15km (Rel-14)
- Greater Broadcast Capacity: dedicated broadcast networks with 100% eMBMS carrier allocation (Rel-14)
- Greater Efficiency: sub-frames have reduced overhead in dedicated broadcast transmissions (Rel-14)
- Greater mobility: 100 µs CP with 2.5 kHz carrier spacing for reception at speeds up to 250 km/h (Rel-16)
- Support for HPHT Networks: 300 µs CP for single frequency networks with inter-site distances in the order of 100 km (Rel-16)
- Receive-Only Mode (ROM): Delivery of free-to-air content to devices without SIM cards or service subscription (Rel-14)
- Transport Only Mode: TV programmes can be delivered in native format without transcoding (Rel-14)
- Standardised xMB Interface: AV media can be delivered over LTE with a unified framework and standard interfaces between content providers and network operators (Rel-14)
- Shared Broadcast: multiple operators can serve users on a common broadcast carrier (Rel-14)

Physical layer time interleaving was studied in Release-16, and found to be beneficial for dedicated broadcast, but not included in the final specification.

The main use case for LTE-based 5G Broadcast requires specific hardware implementation additional to regular unicast hardware in the user device, the RAN and the core.

3.2 5G Mobile Broadband

5G technology boasts multiple capabilities for a wide range of communications, including enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC) and Ultra-Reliable Low Latency Communications (URLLC). It also includes multicast and broadcast capabilities suitable for certain applications. Corresponding network architectures are designed to address that wide range of applications with shared infrastructure in Radio Access, Transport and Core Network.

The first releases of 5G address radio access, core network and service aspects. 5G New Radio (NR) [7] is the access technology defined for the 5G System [8] and is designed to push the boundaries of mobile communications to enhancements in terms of data rates, latency, reliability, and connectivity.

The key 5G radio aspects in Rel-15 include:

- Native forward compatibility mechanisms
- New channel coding: LDPC for data channel, Polar coding for control channel
- Native support for Low Latency and Ultra Reliability
- Flexible and modular RAN architecture: split fronthaul, split control- and user-plane
- Native end-to-end support for Network Slicing
- Improved Efficiency: 5G MIMO, 5G Power and location improvements, Device Capabilities improvements

- New Features: URLLC, V2X (D2D), Enhanced Positioning, Industrial IoT, 5G Satellite, new spectral ranges

Rel-15 lays the foundation for the definition of new 5G Core Technologies, including:

- Orchestration and Virtualization (NFV) – de-couple logical function from hardware
- Slicing – logical end-2-end networks tailored to customer needs
- Multi-Access Edge Computing (MEC) – resources where they are needed (especially for URLLC)
- API Exposure – 3rd party access to 5G services
- Service Based Architecture (SBA) – stateless, open, flexible
- Harmonized Protocols & Access Agnostic – generic solutions with integrated support for fixed networking, 5G satellite access, …
- New Media (Virtual Reality, Extended Reality, …)
- Specific 'vertical industry support': Broadcasting, Mission Critical Communications, Vehicle to Everything, Industrial Automation, Future Railway Mobile Communication System, etc.

The details for several of the functions are deferred to later releases, but the basic principles of the architecture are defined in Rel-15.

Besides the development of RAN and Core architectures, a key concept in 5G is network slicing [9]. It entails the establishment of independent sub-networks for specific services and users based on a physical 5G network infrastructure. The sub-network consists of base stations, transmission functions and core network functions. The underlying technological principles are to be found in software-defined networking (SDN) and multi-tier cloud architectures for all network functions. Network slicing allows for perfect isolation of all data and operation of individual sub-networks. Each individual sub-network can have its own specific characteristics regarding 5G network parameters such as maximum throughput, end-to-end latency and data traffic density.

In content distribution, network slices can be envisaged to provide channels to broadcasters tailored to their requirements in terms of performance, reliability and content integrity.

Based on the flexibility of using network resources by applying Network Slicing, Service Level Agreements (SLA's) can be arranged between network and service/content providers. One example, in conjunction with the purposes in question - is to guarantee a certain coverage in time and geographical extent for a given throughput.

3.2.1 5G Multicast / Broadcast

Rel-17 will add support for multicast and broadcast in the 5G System, i.e. based on 5G Core and 5G New Radio (NR). The scope of the work [10] is to provide RAN support for public safety and mission critical, V2X applications, transparent IPv4/IPv6 multicast delivery, IPTV, software delivery over wireless, group communications and IoT applications. An SA2 Study Item will investigate supporting 5G multicast / broadcast in the core architecture (see TR 23.757 [11]).

The RAN work focuses on the dynamic use of multicast / broadcast in small-scale (primarily single cell) deployments with minimum RAN changes. In practical terms this means there is no support for large-scale SFNs or ROM devices, as currently enabled for LTE-based 5G Broadcast. However, developments under this work item should not prevent a future evolution to include similar features. The main use case for LTE-based 5G Broadcast requires specific HW implementation additional to regular unicast HW.

Rel-17 multicast / broadcast aims for use cases where multicast / broadcast or unicast could dynamically be selected by the MNO, depending on which mode is most spectrally efficient in a particular situation. The WID (Work Item Description) states that implementation impact should be limited, and UE complexity minimized (e.g. avoiding device hardware impact). If this is achieved, NR multicast / broadcast functionalities may later be implemented via SW upgrades. These enhancements may benefit the distribution of media content over mobile networks and may play a role for the distribution of IPTV services over Fixed Wireless Access (FWA) [12].

3.2.2 5G Media Streaming Architecture

The 5G Media Streaming Architecture in 3GPP [13] is developing an architecture to enable collaboration scenarios between a third-party content and service provider and an MNO, for potentially mutual benefits. 5G Media Streaming enables an external provider to access a subset of functions in the 5GMS system to generate complex workflows, but at the same time retain control of some aspects in its own domain.

Example of collaboration scenarios that motivate the design of such functionalities are:

- **MNO CDN:** the MNO acts as a CDN for the third-party provider. The third-party provider uses well-defined interfaces to upload streaming content to the MNO and also uses a subset of the 3GPP defined 5GMS functions (e.g., Content delivery protocol, Network Assistance, Session Management, Metrics collection) for optimized delivery. Codecs, DRM, Manifest format, etc. are all under control of the third-party provider.
- **Linear Service:** The third-party provider pushes a live service into the network. The MNO transcodes that content, if necessary, into 5GMS compatible formats and the 5G Aware application use the 5GMS Player for playback of the content. Codecs, DRM, Manifest format, etc. are all under control of the MNO. The MNO also ensures timely delivery of the service.
- **Media Processing:** The third-party provider uploads the content in a defined format as done for an origin server, but the MNO adds additional functionalities, for example it provides targeted and regional ad insertion, it does automatic captioning of the content by using network internal AI functions.

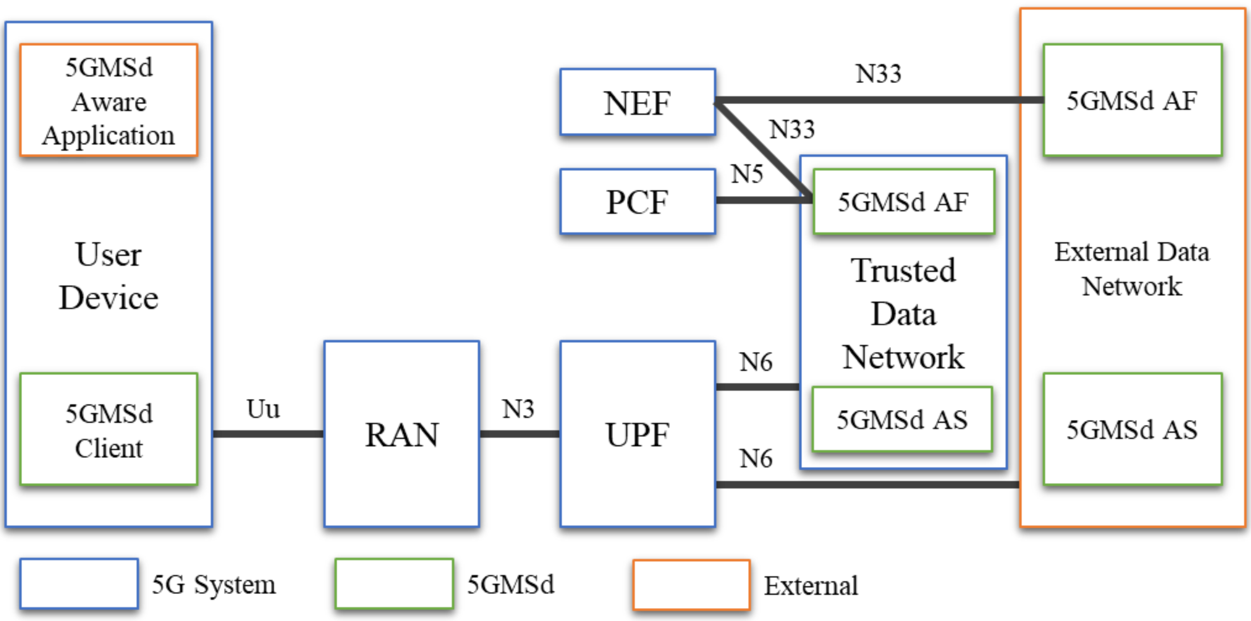


Figure 6: Basic scheme of the 5G Media Downlink Streaming architecture.

3.2.2.1 Multicast in 5G Media Streaming Architecture

Multicast / broadcast architecture has the potential to play an important role in 5G media streaming. A new study in TR 26.802 [14] will evaluate the impact of multicast / broadcast features to 5GMSA. The goal of this study item is to identify and evaluate potential enhancements to the 5G Media Streaming Architecture to provide multicast-broadcast media streaming services including scenarios for multicast ingestion or multicast distribution.

3.2.3 Hybrid DASH/HLS over eMBMS

To reach all devices, media streams must be provided in both HLS and the DASH format in parallel. Beyond the enhancements related to LTE-based 5G Terrestrial Broadcast targeting dedicated deployments, a new Rel-16 work item [15] aims at enabling the delivery of Hybrid DASH/HLS over eMBMS. Thus, Rel-16 will enable the delivery of CMAF (Common Media Application Format) fragmented formats over eMBMS to reach all devices with one format.

3.2.4 Fixed Wireless Access

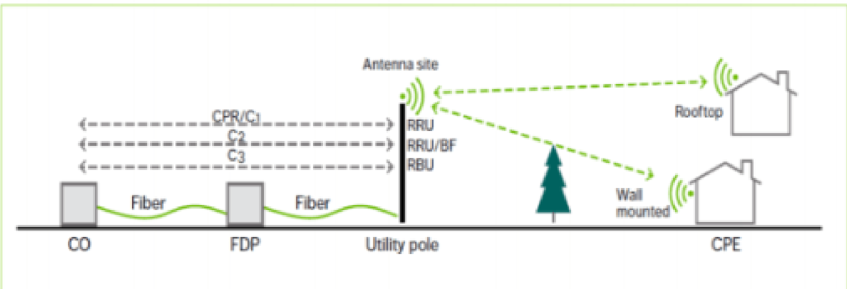
Fixed Wireless Access (FWA) [12] is a means of providing ‘last mile’ internet connections to homes and business without the need for fixed lines such as twisted pairs and fibre cables. 3GPP 4G/5G standards are well suited for FWA leveraging the 3GPP ecosystem.

FWA is primarily targeting stationary receiving devices, usually with line-of-sight visibility of the transmitter / base station. Furthermore, FWA modems may be connected to a fixed, external antenna in order to achieve the line of sight path to the transmitter and, particularly in higher frequency ranges, avoid signal attenuations due to building penetration loss, in order to establish a reliable link.

With 5G FWA, massive use of beamforming, new/more spectrum and high-frequency spectrum (e.g. mm-Wave) allow for many UEs to be connected simultaneously to the same base station (i.e. using the same spectrum simultaneously thanks to the beamforming) and with data rates comparable to many fixed line internet connections in use today.

In line with other types of broadband connections a 5G FWA connection is typically terminated at the FWA modem, which is connected to an indoor Wi-Fi network providing the indoor coverage. Any type of fixed, portable or handheld device (TV set, tablet, smartphone etc.) may then access content in the home via Wi-Fi.

Figure 7 depicts the basics of the FWA concept and key performance indicators [16].



Capability	5G Target
Peak Data Rate	20 Gbit/s
User Experienced Data Rate	1 Gbit/s
Latency	1 ms

Figure 7: Basic FWA concept and key performance indicators

4. Media Distribution Stakeholders' Views

4.1 5G Roll-out and related deployments

5G has started being deployed in various countries in 2019, based on 3GPP Rel-15 functionality, i.e. targeting primarily eMBB use cases, and based on the so called Non-Standalone Architecture (NSA), i.e. attaching 5G NR access networks to existing LTE core networks and requiring LTE Anchor coverage. The first Standalone Architecture (SA) deployments are expected during 2020.

In Q1 of 2020, the US, Korea and Japan have extensive 5G deployments, with a focus on mid band in Korea, and high band "mm-Wave", but also low band 600 MHz in US. China has started large-scale 5G deployments, while European operators have limited deployments in mid band.

The EU commission maintains an EU 5G Observatory [17] that contains up-to-date information on the status of 5G licencing and rollouts for Europe. The GSA (Global mobile Supplier Association) [18], provides recent reports and updates on the global 5G market, including for user devices. In a March 2020 report [19] the GSA counted about 250 devices (smartphones, tablets, hotspots, modules etc) supporting 5G NR.

Several manufacturers have put 5G capable handsets on the market. According to [20] several '5G phones' are available from a variety of manufacturers such as Samsung, OnePlus, LG, Huawei, Oppo and Xiaomi.

The market is, however, fast moving and it is expected that many more 5G devices will be available in due course. A press release issued by Samsung in January 2020 indicated that it has already shipped 6.7 Million 5G handsets worldwide and confirmed the launch of a 5G capable version of the Samsung tablet series Tab S6 in 2020.

Functionalities beyond those primarily adopted at a global scale are not included by default. In the particular case of media distribution, no equipment yet supports 5G Broadcast (i.e. from Rel-14 included, and onwards). Widespread support cannot be expected any time soon without visibility of large applicable markets.

So far broadcast reception support is limited to eMBMS Rel-12 in a few 4G capable handset models. The GSA report in July 2019 [21] states the following about LTE Broadcast (eMBMS i.e. Rel-12 and prior):

- Five mobile network operators have launched eMBMS services (Telstra in Australia, China Unicom in China, Reliance Jio in India, KT Corporation in South Korea, and Verizon in the USA).
- Two operators are deploying (Globe in Philippines and AT&T Mobility in the USA)
- Thirty-four operators are known to have been testing and trialling eMBMS.

On the device side, it is not always possible to know the exact capabilities of the devices available on the market as manufacturers rarely state the device capabilities beyond those for which they have been tested. Even more, the full set of capabilities contained in the specifications is not necessarily implemented in networks and devices. In general, eMBMS capabilities supported in commercial deployments include a series of mechanisms relevant for mobile network operators. These are:

- Rel-10. RAN-based counting of UEs indicating interest in an eMBMS service to allow the network to decide if it is more efficient to serve users via unicast or broadcast (Rel-10).

- Rel-12. MBMS operation on Demand (MooD), which automatically activates or deactivates the eMBMS service based on the counted number of interested UEs. This allows for example to create an eMBMS user service to deliver content which was initially delivered as unicast.
- Rel-12. MBMS PHY measurements: UEs can be ordered to perform measurements of signal power, error rates and such, which can then be used in network optimization, particularly in the MBSFN mode.

According to GSA, 69 chipsets are supporting eMBMS, with up to 59 devices able to operate it (in some instances after operator-specific upgrades). Main chipset vendors are Qualcomm, Mediatek, GCT, Intel, Sequans and Altair Semiconductor. eMBMS is widely supported in Mediatek's HelioP35, and various Qualcomm Snapdragon mobile platforms. Devices such as Samsung Galaxy Note 8 and Note 9 phones support eMBMS.

Regarding Rel-14, a series of trials have been conducted by public service broadcasters in Europe [22]. The most recent consist of a prototype software-defined radio implementation of an eMBMS Rel-14 receiver and a corresponding professional transmitter which can be deployed in traditional broadcast infrastructure. The trial has been repeated to accommodate different reception conditions including fixed and mobile scenarios in several countries such as Germany, Italy, France, Brazil, China, or Spain.

Notable developments in China include plans for 5G Broadcast with initial demos foreseen in February 2022 to be followed by large scale deployments [23].

4.2 Mobile Phone Manufacturers

Most mobile phones are typically bought either from a mobile operator (MNO/vertical model), or direct from the manufacturer without a link or contract to an individual operator (horizontal model).

Increasingly devices are being bought without a contract i.e. people are buying a device and get a SIM card independently [24] [25]. In Germany, the volume of devices sold without a contract has reached 40% - 45%.

Both routes to market have different requirements and potential. In either of them it is unlikely that devices would have features either developed or enabled that have not both been tested and have no sound commercial justification for their inclusion.

In a vertical model, it is entirely feasible that a paid-for service could be broadcast by an MNO who also has access to content. This model would be relatively simple, requiring support of LPLT LTE-B reception with a SIM card. The mobile industry is substantially based on the vertical model.

The horizontal market model – in which an MNO did not provide the broadcast service – is somewhat less well defined. It is not clear who would fund the necessary changes in hardware that would support free-to-air (FTA) reception with no SIM card, for example. Without a commercial model and a complete eco system there are extremely limited drivers to support any FTA/non-vertical capabilities.

Several billions of mobile devices are sold globally every year. The cost of any added functionality needs to be strictly justified (even cents per device translate to massive cost with such volumes) with certainty of demand in large markets, ideally global, covering at least several hundred million potential customers. Conversely, R&D for additional features can be split onto huge numbers of devices. Thus, pure software enhancements can be justified much more easily than hardware additions which may have an impact on the bill of material like e.g. support of an additional RF band.

4.3 TV Manufacturers

The business case for manufacturers to consider adding a 5G tuner directly into a consumer TV set is still at an early stage and is not yet considered to be necessary by most (particularly in DVB served areas). Several items that are taken into consideration to reach this conclusion. TV manufacturers typically work in a horizontal market space and they must find the balance between appealing features and minimising production costs.

TVs are typically developed to a core architecture that can support small adaptations for different requirements in one market compared with another. For 5G to be routinely implemented, a similar development model would be expected. A clearly defined common specification that would be suitable for use in any relevant market would be essential.

Currently most Smart TVs are connected to in-home Wi-Fi networks. Initially, device manufacturers would therefore most likely consider Wi-Fi to be the primary route to receive any new IP based services targeted at large screens within the home. Services delivered over 5G would therefore be anticipated to terminate at a Wi-Fi router. This later point itself is not yet entirely clear but may vary from market to market.

Another alternative could be the ability to “Cast” 5G delivered content from a suitably equipped mobile device to a large screen TV, although this may not be a widely used method.

Since developing new consumer products requires time and the result needs to be a reliable high performance device, equipment manufacturers would wish to see a number of changes within the wider market first – for example the formation of an end to end ecosystem bringing with it the ability for manufacturers to test and verify the operation of any such potential implementation especially as there are currently concerns around indoor reception quality.

4.4 Infrastructure Manufacturers Considerations

4.4.1 Mobile Network Infrastructure

Mobile radio access network equipment typically sells in hundreds of thousands of base stations per year with larger volumes expected in the future as small 5G cells become more widespread. While there is progress in Software Defined Radio (SDR) technology, mobile radio access networks equipment is typically non commercial-off-the-shelf (COTS) hardware, but tailored design due to the volumes involved and due to e.g. power consumption constraints. Core network equipment, however, increasingly relies on COTS hardware with tailored software. Like for mobile devices, the cost impact of additional features both in terms of R&D and in terms of hardware requirements needs to be justified by vast, ideally global markets. Many of the features required to support e.g. 5G Broadcast would be in software, but additional frequency band support would trigger hardware development impact for the RF parts.

4.4.2 Broadcast Infrastructure Manufacturers

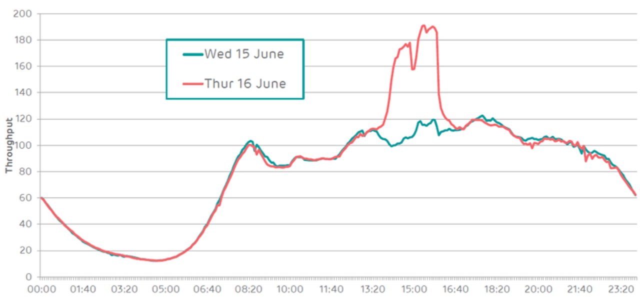
Today broadcast transmitters are operated by Broadcast Network Operators (BNO). These networks typically have transmitters with powers ranging from a few Watts to thousands of Watts. As 5G Broadcast uses OFDM – the same underlying waveform used in all modern DTT standards (DVB-T/T2, ATSC3.0, ISDB-T) broadcast transmitters can be used for 5G-Broadcast by making changes to transmitter’s modulator. Additional support for interfaces and protocols is required to integrate broadcast transmitters in a mobile core network, however, as all these enhancements are software based with almost no impact for the RF parts and the manufacturing costs of the transmitters.

4.5 Network Operators Considerations

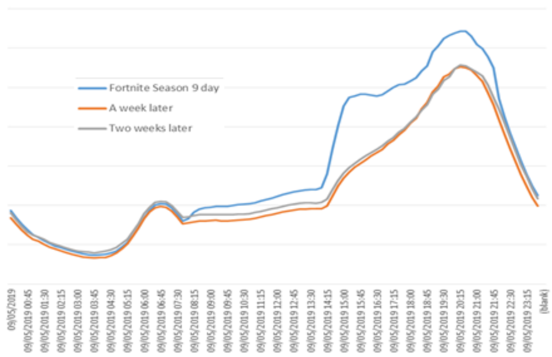
4.5.1 Broadband Network Operators

Video dominates Internet traffic today and video traffic levels are growing[1]. Consumption of live and linear services, in the form of those in § 2, sports events or e-sports are also growing as more content is available on the Internet and people are becoming accustomed to accessing it on mobiles, tablets and computers. These live events, which are nearly all delivered using unicast streams, create large peaks in synchronous network demand, with an impact on network costs.

Figure 8 shows the increase in peak traffic on a mobile network, attributable to people watching events that cause significant increases in peak traffic levels also involve multiple end points receiving the same bit streams.



Traffic levels on a UK mobile network on consecutive days showing the significantly higher traffic levels on the day when England played Wales (Thursday 16th June)



Network traffic plotted on the first day of availability of season 9 of Fortnite (blue line) compared to traffic on the same day of the week in the following 2 weeks

Figure 8: UK traffic levels

The natural solution to such a problem would be to use a point to multipoint network technology, such as multicast.

To date though, multicast is not widely used and its use for distribution is mainly restricted to network operators' own content services. Some reasons for the relative lack of success of previous generations of multicast – whether for the fixed network or the mobile are:

- The network provider is the primary beneficiary of multicast. Content service provider benefits are secondary, so the case for multicast may not be sufficiently compelling compared with normal CDN costs.
- Partial end-device support. Few end devices have been able to directly consume multicast and, even if they can, application-layer standards do not normally support it. Set top boxes have been required on fixed networks and special multicast-aware versions of applications are required for 4G.
- Limited coverage. Any individual network operator will only be able to cover a fraction of the population. A content service provider would need to buy multicast from several providers and even then, they will most likely fall short of their requirements.

[1] According to Cisco Visual Networking Index (Cisco VNI) [26] video traffic: accounts for 70% of all network traffic; is growing fast (33% CAGR) and is expected to account for 80% of all internet traffic by 2022.

- Cost of connection. Each content service provider will need to create a connection to each network operator separately.

For 4G deployment, the partial support of eMBMS by handset vendors has been a very significant issue. It is difficult to break the deadlock whereby handset vendors do not add eMBMS support because few networks deploy it, and network operators see little benefit because not all handset vendors support it.

An additional challenge is that the number of content service providers providing live content is rising. This means that, from a network operator perspective, on-boarding a new content service provider must be very straightforward.

Similarly, it is not clear which content providers will deliver the most popular content at any moment. Therefore, a flexible and dynamic approach to multicast is required, where content streams can be switched between unicast and multicast fully automatically, or at least with little manual intervention.

As a result, the requirements for the wider success of multicast are:

- It must be very straightforward to on-board any content service on the Internet. This means minimal impact on the content delivery path and minimal impact on CPE/application.
- Whilst the primary goal is efficiency of live content, other content types should also be able to benefit from multicast.
- There must be a valid business case for partial or staged roll-out, both in terms of customer/geographic coverage and end-device support.

This leads us to conclude that, from a network operator perspective, multicast should be used as an enhancement to Internet distribution of content.

To avoid historic issues around attempts to sell multicast as a service, **multicast could be deployed as an internal optimisation technology** for network operators to use as part of their internal capacity management strategy.

The requirement would be to wrap multicast in such a way as to have minimal impact on the content servers and end device applications. Technically, this is particularly challenging. CableLabs has specified a multicast ABR standard [27] which allows for the distribution of HTTP Adaptive Streaming content over multicast (specifically HLS) and 3GPP also have a similar way of supporting this in [28], [29] and [30]. DVB is in the process of producing its own multicast ABR standard, DVB-mABR (Multicast Adaptive Bitrate) [31].

There is more work to be done though to progress multicast ABR technology to a point where it can really sit transparently in an otherwise unicast content delivery path. If we were able to achieve this, it would very significantly lower the barriers to multicast deployment. Multicast would effectively become one of the tools that a network operator could use to upgrade network capacity, alongside existing techniques.

As an internal network efficiency tool, the business case for multicast is made by the network operator in terms of their own cost-savings. Such a case can be made locally, and so does not require national roll-out before any benefit can be obtained. In contrast, offering multicast as a service would require substantial roll-out before any customers could be brought on board and even then, the revenue would be uncertain.

Since the network operator will know what devices are present on their network, they can be confident of the cost savings with only partial device support. Even a 50% reduction in the volume of synchronous traffic would be extremely valuable. Again, this provides for a very low-risk business case.

4.5.2 Broadcast Network Operators

The current terrestrial broadcast networks are designed to fulfil all main requirements of Public Service Media Organisations as described in § 2.4.1.

Most requirements of commercial content providers in § 2.4.2 overlap with those of Public Service Media. However, enhanced media services like HbbTV are complements to fulfil requirements on targeted advertising, nonlinear content, time-shift etc. Also, terrestrial broadcast networks are able and used to provide Pay TV services.

In addition, the terrestrial networks are designed to meet all regulatory requirements both technical and "political" that are specific to the media sector. The technologies currently in use are specifically designed to cover all these requirements, while providing a universal coverage to an unlimited number of receivers, with state-of-the-art technical performance (e.g. DVB-T2).

Most terrestrial broadcast networks are currently designed for fixed linear TV reception with a fixed rooftop antenna, though fixed indoor antennas are also adequate in many cases. In some countries, those networks are specifically designed for fixed indoor and vehicular linear TV reception in cars. Moreover, these networks share much of infrastructure with FM radio and DAB radio with reach to virtually all European households and cars.

The terrestrial broadcasting networks are ultra-reliable and are designed for sustained operation during long power outages to be able to meet public warning requirements. This is of course especially important for radio and television in crisis and public warning situations. Also, the terrestrial broadcasting networks protect the privacy of the user and are extremely resilient against cyberattacks.

The DTT networks are used by nearly half of the European population and the number of TV sets capable of receiving DTT can be estimated to some 500 million.

The Broadcast Network Operators are currently finalising the clearance of the 700 MHz band, which entails substantial long-term investments by both BNOs and consumers. These investments and the clearance of the 700 MHz band has been made possible by EU decision DEC 899/2017 [32] stating that *"Member States shall ensure availability at least until 2030 of the 470 – 694 MHz ('sub-700 MHz') frequency band for the terrestrial provision of broadcasting services, including free television, and for use by wireless audio PMSE on the basis of national needs, ……"*. In some Member states this decision has been translated into national law.

However, current BNO's networks are not designed to provide reliable reception of linear content by hand-held devices such as mobile phones:

- The current terrestrial broadcast network infrastructures – often called "HTHP" (High Power High Tower) or MPMT (Medium Power Medium Tower) - are certainly a good basis to address outdoor and vehicular reception (see Annex C), pending necessary investments to complement the network deployment to address new needs (e.g. additional sites in HTHP networks to provide coverage for portable reception).
- For indoor reception, hand-held devices usually rely on Wi-Fi or WLAN coverage. Seamless transition between such networks is nowadays possible/manageable. Also, DVB-HB looks like a promising solution to provide indoor coverage.

Europe is diverse and AV situation differs from country to country. Any proposal needs to be flexible enough to cope with all different situations including countries with (very) high acceptance of terrestrial broadcast networks services (e.g. UK, FR, IT and ES).

The broadcast network operators would be willing to evaluate investments in future distribution technologies such as 5G in a mid or long-term perspective. Such investments would be based on using the current infrastructure. However, a prerequisite would be that there are clearly demonstrated and accepted benefits to add an alternative broadcast technology to DTT or in the longer term migrate to an alternative technology, and, in such case also a corresponding favourable "business case" for both consumers, broadcasters, regulators and network operators.

5. 5G Deployment Opportunities

§ 2 outlines three categories of content and services that media companies provide today i.e. linear, nonlinear and hybrid. All these services could, in principle, be delivered by 5G, particularly given 5G's features to distribute AV media, including unicast, multicast and broadcast.

The following discusses the ability of 5G to deliver the three service categories while fulfilling the requirements set out in § 2.4. Three different 5G deployment options are investigated: 5G Broadcast alone, 5G Mobile Broadband including multicast / broadcast and 5G Media Streaming Architecture and a combination of 5G Broadcast and Mobile Broadband.

5.1 5G Broadcast Distribution

This section investigates the ability of 5G Broadcast to deliver linear services to compatible devices including smartphones, tablets, vehicles, and conventional TV sets. As 5G Broadcast was specifically designed for this purpose, 5G Broadcast may, in general, fulfil the requirements of § 2.4 in a similar manner to conventional terrestrial broadcast technologies. The following subsections provide additional details.

Figure 9 depicts the distribution chain to model 5G Broadcast. Note the possibility for the service provider to directly interface with the network operator.

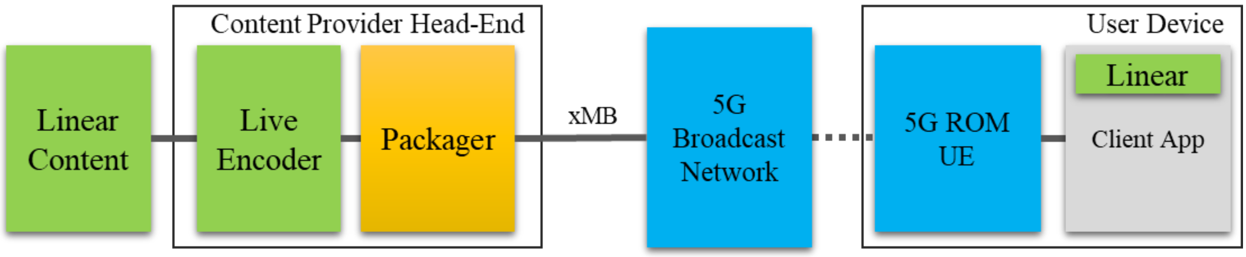


Figure 9: Distribution chain using 5G Broadcast

5.1.1 Universal Coverage and Universal Access

5G Broadcast could, in principle, enable the distribution of linear services to audiences of a national scale in the same way as existing broadcasting technologies (e.g. DVB-T2 and DAB) do today. The extent of coverage would depend on the data rate (i.e. video or audio) and quality of the content being transmitted (i.e. SD/HD), the number of programmes / channels, the audio / video codec, the receiving environment and the network, as is the case with other terrestrial broadcasting technology. 5G Broadcast networks would normally be envisaged as being configured in SFN mode, as this is a cornerstone of this technology. Removing the need of an uplink makes coverage limited by only the downlink.

5G Broadcast defines operation modes targeting fixed, portable and mobile reception. Where portable and mobile reception is possible, stationary reception is possible as well. This means that a wide range of devices (e.g. fixed TV and smartphones) could be reached from a single transmission network, should it be appropriately designed. Annex C indicates that it is much more challenging to deliver content to handheld mobile devices, particularly if they are indoors, compared to rooftop receiving antenna – the link budget to handheld devices is very onerous. Although such analyses are highly dependent on the circumstances at hand, the network simulations in Annex C reveal that universal indoor coverage to handheld devices would likely require very dense LPLT networks. Universal coverage of mobile handheld devices out of doors would also likely require an element of LPLT networks particularly in areas further from the transmitters – conventional MPMT and HPHT broadcast infrastructure alone does not appear to be adequate for near universal coverage. Car-mounted antenna reception or fixed roof-top benefit from a more favourable link budget.

LPLT sites exist for mobile networks and could be also used for 5G Broadcast transmission. In some countries, mobile network sites are owned by tower rental companies which also may have a broadcast network business.

Nevertheless, universal coverage is network dependent and could be achieved through the combination of appropriate transmission modes and network design. However, the cost of networks that may be required to provide, in particular, indoor coverage would need to be carefully considered. More intensive infrastructure sharing between BNOs and MNOs could alleviate costs related to network densification for both parties.

5.1.2 Free-to-air (FTA) Access

5G Broadcast specifies receive-only mode operation which enables content to be delivered without an uplink, SIM-card or subscription to an operator or service. Free-to-air reception without a SIM-card is thus possible. Provided that the FTA broadcast network were extensive enough to provide universal coverage, universal access could also be provided for the linear services from a single network as the 5G Broadcast signal could be received by all compatible devices regardless of the MNO network to which they subscribe (or even if they have no network subscription or SIM card). Figure 10 illustrates the concept. The FTA broadcast network could either be operated by the media content provider, or a third party (e.g. an MNO or BNO).

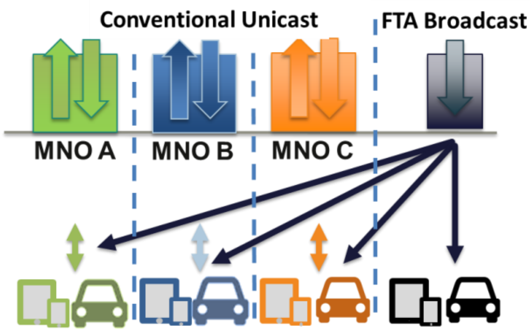


Figure 10: Universal access provided by a single FTA broadcast network

5.1.3 Defined Quality of Service (QoS)

5G Broadcast would allow the QoS for linear services to be set by the service provider, as it is done today in broadcasting networks. 5G Broadcast defines an interface (xMB) between service provider and the network. The "transport-only" mode enables service distribution without transcoding and the injection of multicast IP sources, which can be defined by the service provider together with the receiving application. The system supports external content formats defined by TV / radio broadcasting standardization organizations to be delivered over IP (e.g. MPEG-TS over IP). The system reserves capacity on the radio access for the provision of services with a dedicated and constant amount of capacity / resources. In principle the QoS could therefore be defined by the content provider and guaranteed across the network.

5.1.4 Scalability

5G Broadcast allows the delivery of linear services at a national scale with defined QoS. 5G Broadcast creates an end-to-end broadcast distribution path with reserved capacity in the core and radio access networks. An unlimited number of users may receive the broadcast content as its delivery is anonymous and independent of audience size.

5.1.5 Service Integrity

5G Broadcast allows the service integrity of the linear services to be guaranteed with the transport-only mode which passes content through the network unaltered. For example, a multiplex of linear TV programmes carried as an MPEG transport stream can be passed through the network by encapsulating the signal as an IP stream delivered over 5G Broadcast and unpacking on the receiving device.

5.1.6 Prominence

5G Broadcast would allow the prominence of linear services within an application to be guaranteed by the design of the application, particularly if designed by the service provider. However, should apps be made available through third party app stores (e.g. android and apple stores), due prominence may require additional measures, such as appropriate regulation, particularly for PSM companies.

5.1.7 Ease of Use

5G Broadcast would allow the ‘ease of use’ of linear services for consumers to be defined by the design of applications running on the end user device. For application developers, a new eMBMS Application Programming Interface (MBMS-API) was introduced primarily for developers of web and user applications to simplify access to eMBMS procedures.

However, to download and update apps, it is likely that an additional internet connection would be required.

5.1.8 Accessibility

5G Broadcast would allow accessibility content for linear services to be provided in the same format that is used for TV and radio broadcasting standards today. The display of such features on user devices may be defined by the design of the applications.

5.1.9 Public Warning

5G Broadcast would allow the reliability of linear broadcast services under emergency situations to be defined by the network design. The 5G Broadcast system use of dedicated resources for the provision of services guarantees their availability across the core and radio access networks, independent of other sources of traffic.

5.1.10 Encryption and Copy Protection

Television programmes that are encrypted and digitally transmitted using the DVB broadcast standard can classically be received by users with receivers and conditional access modules (CAM), mostly a CI+ Module. Meanwhile also TVs and STBs with embedded CA-Systems, equipped with build-in CA-System chipsets, are available for specific platform products. In this case, users do not have to purchase a CI+ Module and can register online to access the encrypted programs.

5G Broadcast is basically an IP-based System that can include an MPEG-2 TS. For 5G Broadcast devices integrating a CI-slot or CA-Systems chipsets, existing encryption technologies can also be used (up to implementation but 5G Broadcast can support signalling in the MPEG-2 TS)

Future 5G Mobile devices such as smartphones and tablets will unlikely have a CI-slot, also they might not support CAMs in different form factors, e.g. USB.

Alternative solutions for the decryption of encrypted 5G Broadcast signals are needed, some approaches could be:

- Integration of CA-System chipsets in mobile devices.
- Solutions also applicable to TS where the CA-System is applied by means of an App and connection to the internet.
- Combination of MPEG2-TS delivery with unicast DRM protection systems.

This issue requires further analysis, it might also be useful to have a look at how standards with a high degree of IP integration (e.g. ATSC3.0) deal or will deal with the issue.

5.1.11 Targeted Advertising and Personalization

Enabling commercial propositions such as targeted advertising is mandatory for future distribution networks.

In this context one major use case to be realized by 5G Broadcast is dynamic ad substitution (DAS). For this purpose, it is expected that adverts (or other types of content) can be downloaded and pre-stored on devices for later insertion and it is assumed that the following requirements are met:

- Seamless switching between broadcast and pre-stored content will be possible.
- Placement opportunities can be signalled frame accurately.
- A parallel bi-directional connection will allow for submitting ad requests and for firing ad reporting events in real-time.
- The whole substitution / insertion process can be controlled by the service provider (i.e. the broadcaster).

Further, complementing 5G Broadcast by additional unicast connectivity, using a similar model to HbbTV to enable for personalized TV services would also be attractive – see § 5.3.

5.1.12 Gatekeeping

The delivery chain of 5G Broadcast for linear services (see Figure 9) shows several areas where gatekeeping may appear. Some examples are provided below.

Network operator

A media service provider may wish to provide or procure a dedicated 5G Broadcast network. Annex C shows that to provide near universal coverage to handheld devices, either LPLT cellular networks or conventional broadcast networks supplemented by LPLT would be required in key areas. MNO operators may therefore play a role in enabling the service. This may involve granting access to mobile network sites and the support of 5G Broadcast at the RAN and core network. These may not be guaranteed; particularly if different regulatory frameworks apply to MNOs compared to BNOs, the latter often being regulated to provide fair access to network infrastructure.

Device manufacturer

§ 4.2 indicates that user devices are generally either bought from the manufacturer (directly, or through another retailer) or through a contract with a MNO. Manufacturers and MNOs are therefore able to define the functionalities that devices should support. §§ 4.1, 4.4.1 and 4.5.1 further indicate that no devices yet support 5G Broadcast, and that the case for either MNOs or manufactures to support 5G Broadcast is uncertain.

Client Application

§§ 5.1.6 and 5.1.7 indicate the need to provision services via applications. These may need to be installed and downloaded from app stores managed by third parties in case they are not pre-installed in the user equipment. Current OTT applications would require modifications to integrate 5G Broadcast functionalities, which may be granted by standardized MBMS-APIs.

5.1.13 Costs

Costs between Service Providers and MNOs

5G Broadcast (with SIM-free transmission) permits linear services to be distributed with a cost model like conventional terrestrial broadcast networks when targeting fixed reception. A direct connection between service provider and network operator is made possible through the xMB interface which means CDNs would not be necessary.

However, § 5.1.1 and Annex C indicate that the link budget for handheld devices, particularly if they are indoors, is much more onerous than for fixed rooftop reception. This indicates that more transmitter sites would likely be required to deliver services to mobile devices compared with conventional broadcast networks dimensioned for fixed rooftop antennas. The additional sites imply greater distribution cost – a factor that further work should investigate. Such investigations may consider models to cooperatively use existing mobile network infrastructure like towers, power, backhaul etc. These could be used for both 5G broadcast transmission to mobiles as well as for mobile communications. In some countries, mobile network sites are owned by tower rental companies which also may have a broadcast network business.

Costs for users

Cost for the user may involve the acquisition of an application for receiving content, which is typically provided for free by PSM organizations. When an application for tuning 5G Broadcast services is not provided by default in the user terminal it would need to be acquired (downloaded) using a broadband network.

Royalty fees

Royalty fees for rights holders can be calculated by the same model established for terrestrial broadcast distribution. More information is provided in Annex B.

5.2 5G Mobile Broadband Distribution

This section investigates how 5G Mobile Broadband (i.e. the architectures and features of 5G outlined in § 3.2 that are applicable to media distribution) may deliver both linear and nonlinear content. In the first instance the OTT delivery model has been assumed, in which media traffic is treated in the same way as any other data on the network. However, compared with OTT, the 5G media streaming architectures, or the inclusion of multicast / broadcast mechanisms may improve the distribution of media content to meet more of the requirements in § 2.4.

Figure 11 depicts the distribution chain to model 5G Mobile Broadband for OTT. Note that differences may exist when referring to architectures which can expose interfaces to CDN operators or directly to service providers as, for instance, for Figure 3.2.

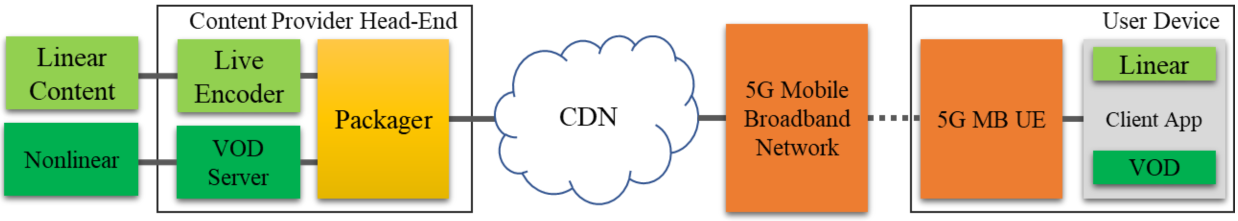


Figure 11: Distribution chain with 5G Mobile Broadband

5.2.1 Universal Coverage and Universal Access

5G Mobile Broadband connectivity is provided within a given 'home' country by a specific mobile network. Within the home country it is usually not possible to access data from a network for which the user has no subscription, i.e. intra-country roaming is usually not possible. In situations where not all mobile networks provide near-universal coverage, which is common throughout Europe, subscribers of networks with low geographic coverage may not be able to receive an adequate service throughout their journeys. Figure 12 illustrates the situation in which, out of three networks, only MNO C provides near-universal coverage. In this example, subscribers to MNO A would not be able to receive a service throughout their journey, while it would be possible for subscribers of MNO C. This situation may not be suitable for many PSM organisations who are often tasked with providing universal coverage.

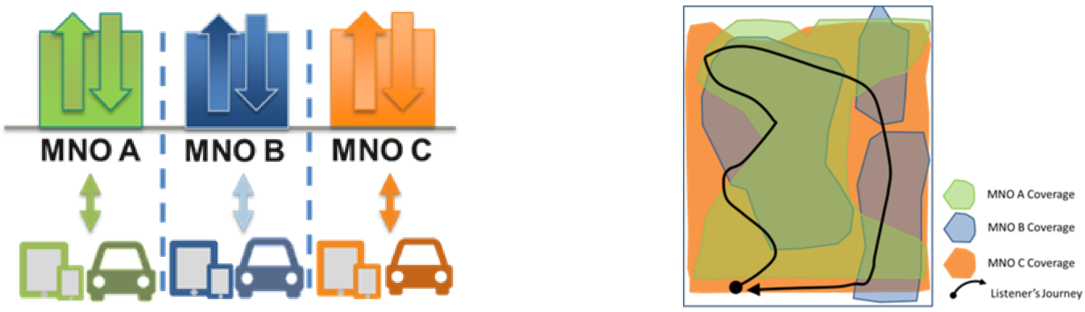


Figure 12: Conventional mobile network operation showing different coverage per operator

Options for providing universal coverage regardless of operator are:

a) Extend all networks to provide near-universal coverage. Extending all networks would require additional investment by all operators. Additionally, under this model, content concurrently requested by multiple users in the same cell, but from different home networks, would need to be replicated and transmitted across different networks, using radio spectrum inefficiently.

b) RAN sharing so that one network (e.g. MNO C) could provide coverage to all subscribers when outside the coverage area of their home network. RAN sharing may significantly reduce any additional investment compared with option I as it may not be directly necessary to extend the coverage of each network. However, RAN sharing would require at least the following aspects to be in place:

   I. A supportive regulatory environment, potentially including the ability to share spectrum across operators.

   II. Network sharing agreements between all operators in a country.

III. A governance model, potentially including a third party or joint venture to manage the shared parts of the network.

c) Use of Roaming within the 5G Media Streaming architecture. A reference architecture for roaming with local break out and home-routed scenarios is defined in [13]. Different RAN sharing and roaming models may require different degrees of cooperation between MNOs and regulatory frameworks. It is also unclear whether the technical characteristics of roaming could enable the delivery of an uninterrupted stream should a mobile device quickly need to roam from one network to another in areas of patchy coverage. Buffering content on the user device – as is now commonplace – may help overcome some of these difficulties.

The situation illustrated in Figure 12 would apply to services consumed via unicast, multicast or broadcast transmissions (except FTA broadcast). All cases call for cooperation between MNOs, which is not yet in place.

In the current situation it is unclear whether 5G Mobile Broadband could adequately provide universal coverage and/or universal access for either linear or nonlinear services.

5.2.2 Free-to-air (FTA) Access

5G Mobile Broadband requires the use of SIM cards for authentication to a network and to get access to services such as voice, text and data. Under these conditions there is typically no free-to-air access to AV services.

However, services can be made free at the point of access based on flat rate tariffs, packages with a limited cost on top of the tariff, and with zero-rating arrangements between service providers and network operators, as described in Annex B.

5.2.3 Defined Quality of Service (QoS)

At times of peak traffic, it is difficult to guarantee a defined QoS in general purpose data networks. 5G Mobile Broadband using unicast will face the same problem. The use of multicast / broadcast in the core network may decrease congestion in the case of concurrent demand of the same content. Therefore, multicast / broadcast may be useful techniques for the distribution of linear services but would be of limited help for nonlinear content. 5G Network Slicing, as described in § 3.2, may allow different QoS rules so that certain traffic receives favourable treatment (e.g. forwarding, scheduling, …) across the core network to improve its distribution.

However, in the radio access network it is unclear whether it is possible to guarantee the allocation of radio resources to maintain the QoS across nationwide coverage, especially for nonlinear content for which consumption is often non-concurrent.

5.2.4 Scalability

5G Mobile Broadband using unicast faces traffic scaling commensurately with the number of users. Meeting higher demand for unicast traffic would therefore necessarily require investing in network infrastructure to support the greater traffic. Content that is consumed concurrently may be delivered more efficiently by the provision of multicast / broadcast modes.

Unicast to broadcast switching may be provided by means of MooD in eMBMS. New approaches in Release 17 for 5G Multicast / Broadcast may also support the provision of multicast and broadcast in a dynamic fashion. Alternatively, the support of multicast within the 5G Media Streaming architecture might also be considered, as explained in § 3.2.2. Note that the use of multicast or broadcast has an impact on network protocols, architectures and the content source, which may differ from the OTT model. The integration of multicast / broadcast capabilities as a network function optimization as suggested in § 4.5.1 would allow for scalability with minimal impact on the content servers and end device applications.

Issues at the radio access network may still involve the impossibility to deploy large area SFNs (as this may not be supported in 5G Multicast / Broadcast) which may call for the need of skilful scheduling and interference coordination (frequency reuse).

5.2.5 Service Integrity

5G Mobile Broadband may not be able to guarantee service integrity for content delivered over best effort unicast as the content or its presentation may suffer modification within the network (e.g. filtering may be applied to specific content). Transcoding would also be needed at some network nodes (see § 3.2.2). Although the use of secure protocols may enhance the abstraction of content in the network, the final experience is highly dependent on the network conditions.

The deployment of specific architectures that differentiate media traffic may provide better control on the distribution chain granting a high degree of control to service providers.

5.2.6 Prominence

5G Mobile Broadband would allow the prominence of media services with the design of an application. Due prominence may require additional measures when the app is part of an app store managed by a third party.

5.2.7 Ease of Use

5G Mobile Broadband would allow the ‘ease of use’ of media services for consumers to be defined by the design of applications running on the user device. These applications generally require download and regular updates. Specific APIs may need to be provided to developers to integrate functionalities beyond the generic apps for OTT distribution.

5.2.8 Accessibility

5G Mobile Broadband using unicast grants access to a wide range of customization regarding accessibility. This is already applied in HbbTV applications which may allow changes to font size, position, background of subtitles, the introduction of customizable sign language presenter, clean audio and slowed down speech for greater audibility, etc. The integration of these options in apps is possible through implementation.

5.2.9 Public Warning

The availability of services under emergency situations mainly depends on the network availability as well as audience size. The OTT model suffers from the lack of resources in the network when networks become congested. The use of multicast / broadcast technologies may alleviate network congestion. However, without the establishment of dedicated resources, independent from other type of traffic, both at the core and radio access networks for the provision of media services, its availability may be prioritized but not guaranteed.

For example, Finnish national law (compliant with EU Net Neutrality rules [41], [42]) allows IP-packet prioritization in fixed and mobile broadband networks for PPDR (Public Protection and Disaster Relief) traffic between authorities. It would be compliant with EU Net Neutrality for Finnish national law to allow IP-packet prioritization for emergency warnings to a large audience through PSM internet publishing platforms.

5.2.10 Encryption and Copy Protection

OTT platform or content providers can use market-standard technologies to ensure that the streaming of their channels is always encrypted and protected. OTT content is typically encrypted with minimum AES 128 and protected by the usage of a DRM-system. These DRM-systems protect the content end-to-end along the complete transmission-chain to the user's display against unauthorized usage.

Common DRM systems are Google Widevine (for MPEG DASH), Apple Fairplay (for HLS) or Microsoft PlayReady (for MPEG DASH, smooth streaming), separate Security Levels must be considered. All DRM systems require a return channel. Copy protection systems can prohibit recordings, limit the outputs of devices to lower resolutions or activate “Copy never” settings on digital outputs.

Note that DRM is supported, in particular, in the architectures described in §§ 3.2.2 and 3.2.3.

5.2.11 Targeted Advertising and Personalization

5G Mobile Broadband using bi-directional communication and the use of unicast allow for the application of server-side technologies for content personalization and targeted advertising including, but not limited to, means for dynamic ad substitution (DAS).

5.2.12 Gatekeeping

The delivery chain of 5G Mobile Broadband for both linear and nonlinear services (see Figure 11) shows several areas in which gatekeeping may appear. Some examples are provided below.

Content Delivery Network (CDN)

Third-party CDNs may become gatekeepers as the intermediate point between a service provider and the MNO. Depending on the functionalities required from the CDN this may have a different impact. Content served using unicast would experience the same degree of gatekeeping as per the current OTT model. The unavailability of multicast enabled CDNs may result in the need of establishing multiple independent connections to different MNOs to provision content served as multicast. Note that the 5G Media Streaming architecture offers the possibility to by-pass the CDN as the functionality can be offered within the MNO domain.

Mobile Network Operator (MNO)

Mobile Network Operators would have control over the delivery of media towards the user. This currently involves the possibility to transcode and filter the content. Service level agreements (SLAs) could, in principle, be established between service providers, CDN operators and MNOs to agree the distribution of content with specific QoS parameters. The introduction of specific functionalities in MNO networks such as the use of multicast / broadcast or the 5G Media Streaming architecture would require corresponding business models.

Device manufacturers

Device Manufactures have the main role in integrating and requesting from chipset manufacturers the implementation of certain features in devices. For the traditional model of OTT using unicast this may not result a problem. However, the integration of additional features will need to be justified and requested to be implemented.

Client Applications

Considerations in terms of prominence of ease of use apply when the applications require to be downloaded by users. Applications currently supported under an OTT model would not require changes unless advanced functionalities of the 5G Mobile Broadband system are integrated (e.g. 5G Media Streaming Player).

5.2.13 Costs

Content Delivery Network (CDN) Costs

CDN cost is dependent on audience size and required bandwidth, what makes it difficult to predict in advance. As a rule of thumb, CDN costs scale linearly with the number of requests. Economies of scale cannot fully compensate rising costs with increasing audience. On the other hand, dimensioning CDNs for peak demand reduces the possibility for financial benefits. CDN costs are not regulated and need to be negotiated independently with the content provider.

Costs between Service Providers and MNOs

No direct cost related to mobile networks is in the OTT model although indirect cost may be passed on to users and CDN providers. The use of architectures and features that enable the establishment of special business arrangements between service providers and MNOs need to be evaluated. This may consist of costs for integrating functionalities inside MNO networks (network functions such as those described for the 5G Media Streaming architecture), for establishing SLAs or for traffic injection via specific media-related interfaces exposed from the MNO to the service provider.

It may be interesting to investigate how joint use of spectrum and infrastructure between broadcasters and MNOs can reduce the overall cost for additional broadcast and unicast DL capacity.

Cost for Users

This mainly involves a data subscription plan with potential add-ons such as tariffs including zero rating (see Annex B). Cost for using applications in their smartphones, tablets or car infotainment systems are typically free for applications of PSM organisations. Applications from aggregators or commercial service providers may be purchased (on-time payment) or offered with a subscription.

Royalty fees

Royalty fees for rights holders may be dependent on the distribution path. In general royalty fees for unicast streams may be more expensive than for broadcast distribution and increase if some sort of personalization or off-line availability is added.

5.3 Delivery of Linear, Nonlinear and Enhanced Media Services

Linear services can be distributed using either 5G Broadcast or 5G Mobile Broadband. 5G Broadcast would allow the distribution of linear content in essentially the same way as it is delivered over conventional broadcast networks today while essentially meeting all the requirements of PSM organisations and commercial broadcasters for linear service distribution.

5G Mobile Broadband may also be used to deliver linear services, however 5G Mobile Broadband would not meet all the requirements outlined in § 2.4. Universal access and guaranteed QoS, in particular, do not yet appear to be possible to achieve.

Nonlinear services can only be delivered by unicast connections as they offer bi-directional communication, which is the basis for interactivity. Additional to the challenges outlined in previous sections, nonlinear cannot benefit from multicast / broadcast modes as users do not generally request content concurrently. Scalability is therefore a major problem.

Enhanced media services – which have both a linear and nonlinear component – may make best use of all the delivery methods of 5G mobile broadband. For example, 5G Broadcast could be used to deliver linear services, free-to-air and at a national scale with defined QoS. The linear component may fulfil a minimum PSM requirement of providing free access to services for all.

Nonlinear and catch-up content could be delivered over unicast and multicast as requested through a separate unicast connection with an MNO, although content delivered in this way may only be free at the point of access and may not have guaranteed QoS. Targeted advertising and regional content could also be achieved with this model. Such functionality is enabled by the 3GPP standards and is illustrated by Figure 13.

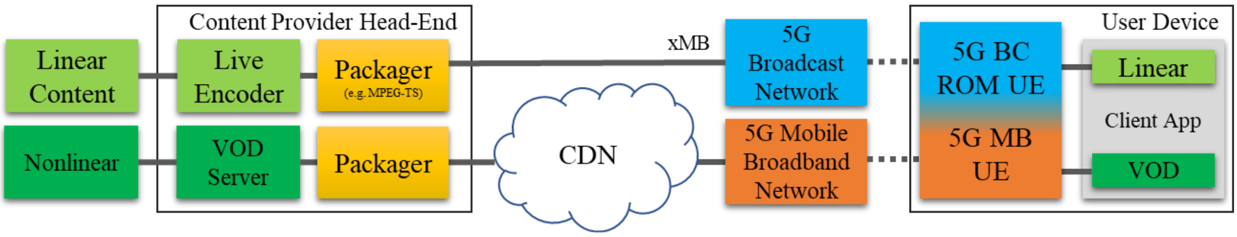


Figure 13: Combination of ROM receiver with unicast capabilities at the UE

Figure 14 shows the extent to which 5G Broadcast and 5G Mobile Broadband may fulfil the requirements of enhanced media services (linear and nonlinear) according to the analysis in the previous sections.

Service Description	Enhanced Media Service = Linear + Nonlinear		
	Linear		Nonlinear
Requirements/5G Mode	**5G Broadcast**	**5G Mobile Broadband**	
Universal Coverage & Access	Network Dependent	Network Dependent / RAN Sharing / Roaming	
Free to Air Access	Receive-only mode, SIM-free	No FTA / Subscription Required / Flat Rates / Zero-Rating	
Defined QoS	Provider-defined & Guaranteed	Network/RAN Slicing	
Scalability	Unlimited Users	MooD/Multicast/Broadcast	RAN capacity constraints
Service Integrity	Transport-Only Mode & App	Not Guaranteed / May be defined	
Prominence	Defined by App / App Store	Defined by App / App Store	
Ease of Use	Defined by App	Defined by App	
Accessibility	Defined by App	Defined by App	
Public Warning	Dedicated Resources	No guaranteed end-to-end dedicated resources	
Encryption / Copy Protection	CAS-based / To be defined	DRM-based	
Targeted Advertising	Requires Unicast / On-Demand	5GMSA / On-Demand	Possible
Gatekeeping	UE Manufacturers / Network Operators / App Stores	CDN Providers / Network Operators / App Stores	
Costs	Potential network densification / Fixed OPEX / Free for users	Variable OPEX / Tariffs for users	

Supported — Not Supported — Requires further action / relevant 3GPP technology

Figure 14: Media distribution requirements using 5G Broadcast or 5G Mobile Broadband

6. Analysis and Conclusions

Public and commercial media organizations offer a wide range of content and services across several distribution platforms. The opportunities of reaching a variety of user devices (e.g. smartphones, tablets, car infotainment systems) are limited with conventional broadcast systems. To distribute content and services to these devices, an IP delivery mechanism is required. Out of the home – where Wi-Fi is not generally available – 5G would be an obvious candidate technology.

Recent enhancements to 5G include several features which improve its ability to distribute media content and services. These has been categorized under 5G Broadcast and 5G Mobile Broadband and analysed in the context of distributing linear, nonlinear and enhanced media services. Several benefits and challenges are highlighted here.

6.1 Distribution of Linear Services

Linear services could be distributed by either 5G Broadcast or 5G Mobile Broadband.

5G Broadcast fulfils many of the requirements of media organisations for the distribution of linear services to mobile and portable devices. 5G Broadcast would also allow media organisations to operate dedicated networks (independent of MNOs) with reserved capacity for the transmission of linear services, as they do today with conventional broadcast networks, with similar operational models. Furthermore, SIM-Free FTA transmission would make linear services available to all mobile devices, regardless of the network to which they subscribe for data. The duplication of the same services by across all MNOs in parallel could thus be avoided.

However, several challenges must be overcome before this technology could be actively deployed. The most salient are summarised below:

No 5G networks nor 5G user devices today support 5G Broadcast. Now (Q2/2020) there are no signs that the operating models of MNOs and handset manufacturers will lead to support for 5G Broadcast in the future. This is most likely because user devices would require hardware modifications to be 5G Broadcast compatible – modifications that entail substantial development investments. Should broadcasters wish to make use of 5G Broadcast, they will need to actively take the steps necessary to introduce it, for example by creating a convincing business perspective for all involved market partners, ideally in large / global markets.

Furthermore, due to the challenging link budgets involved, providing near-universal coverage to portable and mobile devices would require networks with an element of LPLT transmitters. Conventional HPHT and MPMT networks alone would not be adequate. The affordability of such networks would need to be considered carefully. Models for the integration of such topologies could be further considered and would require commercial and technical cooperation with MNOs and relevant infrastructure providers.

Standalone downlink only (SDO) bands have not been defined in 3GPP, nor has spectrum been identified by the ITU. 5G Broadcast could be deployed in FDD bands defined in 3GPP. However, this would not use uplink resources, and would therefore be inefficient. Two further options are the L-Band (3GPP band 32: 1452 – 1496 MHz) and the sub-700 MHz UHF band (470 – 694 MHz). Where not assigned to MNOs, the L-Band could be used for SDO in Europe, but a request for such use would likely require wide support from many countries. The sub-700 MHz UHF band is currently heavily used by DTT and PMSE in Europe.

The sub-700 MHz band would be a candidate band for the introduction of 5G Broadcast, as it is allocated to the broadcast service. An introduction of 5G Broadcast in this band would require coexistence with the 8 MHz channel raster of DTT. This may entail the use of 5 MHz carriers within 8 MHz channels, 15 MHz carriers in a contiguous pair of 8 MHz channels or the definition of a new 8 MHz bandwidth for 5G Broadcast. Usage of 10 MHz carrier bandwidths may not be feasible because of severe adjacent channel interference issues. In all cases, ensuring compatibility with the GE06 framework in ITU Region 1 and other Regions that use 8 MHz rasters for DTT.

To create a sufficiently large device and infrastructure ecosystem for 5G Broadcast in sub-700 MHz, it is crucial that a joint effort is made globally with all stakeholders. Here, China and possibly India may deserve specific attention to align these markets with huge populations with the needs of the EBU members.

5G Mobile Broadband unicast capabilities are being deployed in networks and user devices. Unicast supports over-the-top (OTT) distribution of linear services. OTT over unicast is being increasingly used by media organizations to provide services via applications on smartphones, tables or car infotainment systems. Although OTT is very convenient and is the principle way for media organisations access to mobile devices out of the home, unicast OTT does not fulfil all the requirements of media organizations. The most relevant shortfalls are summarized below.

To date, mobile networks do not provide near-universal coverage. Furthermore, unicast coverage is dependent on the user's home network, meaning that subscribers to networks with comparatively low geographic coverage may not be able to enjoy media service throughout their travels. Universal coverage and access may therefore not be practically achievable with unicast OTT. Intra-country roaming or RAN sharing may improve the situation, but several technical and commercial hurdles would first need to be overcome. Flat-rates and/or zero-rating could enable services to be received free at the point of access, but full free-to-air access with no gatekeeping is not possible with OTT unicast.

Defining quality of service (QoS) and service integrity with unicast OTT may prove to be impractical. 5G architectures being developed in 3GPP Rel-16 such as 5G Media Streaming Architecture may improve QoS, particularly in the core network. The 5G System in Rel-17 will support multicast and broadcast capabilities, mainly driven by safety services and IoT use cases. Dynamic switching between unicast, multicast/broadcast may then more efficiently use network resources to improve the QoS of associated services.

If media may also make use of these features, multicast / broadcast could reduce traffic peaks in the core network for concurrently consumed linear and live services. Such an outcome would be particularly attractive should it be possible to implement with no hardware changes to UEs. Treating multicast as a network optimization feature (as opposed to 'as a service') would limit the impact on service providers and UEs, thus making it attractive for both MNOs and handset manufacturers. However, QoS at scale over a large coverage area may remain unguaranteed on the RAN, which would still be subject to resource contention.

Nevertheless, solutions with limited implementation impact and UE complexity and targeting requirements from different stakeholders would facilitate adoption in networks and devices.

Media distribution over 5G Mobile Broadband would imply a degree of gatekeeping given that content and services would be delivered via third party networks. CDN costs which scale commensurately with audience size would need to be further considered.

6.2 Distribution of Nonlinear Services

5G Mobile Broadband is essential to provide connectivity for nonlinear services. This makes it possible to provision on-demand services and create commercial propositions enabling monetization, targeted advertising, personalization, etc. The same considerations given in § 6.1 generally apply. However, the main challenge is to scale network resources as multicast / broadcast could not be applied to unsynchronized content consumption.

6.3 Distribution of Enhanced Media Services

5G allows for the distribution of enhanced media services, including those that integrate both linear and nonlinear components. 5G Broadcast could deliver the linear component free-to-air at a national scale with defined QoS. 5G Mobile Broadband would be used for nonlinear and catch-up content, although this may or may not be free at the point of access and may not have guaranteed QoS. The combination of 5G Broadcast and 5G Mobile Broadband would fulfil the essential requirements of PSM organisations while providing enhanced services for those with a mobile broadband connection. Commercial media organizations could also fulfil their requirements. 5G supports Fixed Wireless Access (FWA) to stationary devices in a similar way to fibre. It may thus provide linear, nonlinear and enhanced media services for stationary consumption.

In summary, the full set of requirements of PSM and private media organisations regarding enhanced media services could be met only with a combined 5G Broadcast and Broadband network.

To achieve this, further investigations into cooperative models between broadcasters and mobile network operators in term of joint use of spectrum and site assets would be useful. Such cooperation may deliver the cost benefits and the economies of scales required to trigger the device and infrastructure ecosystem for 5G broadcast.

7. References

The following are referenced in the main report and annexes.

[1] "Distribution of Public Service Media", EBU Technology Fact Sheet, available at: https://tech.ebu.ch/docs/factsheets/ebu_fs_psm_requirements.pdf (accessed in Apr. 2020)

[2] EU 2018/1808, "Directive (EU) 2018/1808 of the European Parliament and of the Council of 14 November 2018 amending Directive 2010/13/EU on the coordination of certain provisions laid down by law, regulation or administrative action in Member States concerning the provision of audiovisual media services (Audiovisual Media Services Directive) in view of changing market realities" , available at: https://eur-lex.europa.eu/eli/dir/2018/1808/oj (accessed in Apr. 2020)

[3] DVB Document A178-1, "Dynamic substitution of content in linear broadcast: interfacing an advert decisioning service and optimal preparation", Nov 2019

[4] 3GPP TR 22.816 "3GPP Enhancement for TV Service (Release 14)", Mar. 2016

[5] 3GPP TR 36.776 "Study on LTE-based 5G Terrestrial Broadcast (Release 16), Mar. 2019

[6] 3GPP TR 36.976 "Overall description of LTE-based 5G Broadcast (Release 16)", Mar. 2020

[7] 3GPP TR 38.801 "Study on NR technology: Radio access architecture and interfaces (Release 14)", Apr. 2017

[8] 3GPP TS 23.501 "System Architecture for the 5G System (Release 16)", Mar. 2020

[9] 3GPP TR 28.801 "Study on management and orchestration of network slicing for next generation network (Release 15)", Jan. 2018

[10] 3GPP WID RP-193248 "New Work Item on NR Multicast and Broadcast Services", Dec. 2019

[11] 3GPP TR 23.757 "Study on architectural enhancements for 5G multicast-broadcast services (Release 17)", Jan. 2020

[12] Håkan Olofsson et al., "Leveraging LTE and 5G NR Networks for Fixed Wireless Access", Ericsson Technical Review, Aug. 2018

[13] 3GPP TS 26.501 "5G Media Streaming (5GMS); General description and architecture (Release 16)", May 2019

[14] 3GPP TS 26.802 “5G Multimedia Streaming (5GMS); Multicast architecture (Release 17), to be published.

[15] 3GPP WID SP-190988 “New WID on support of Hybrid DASH/HLS over eMBMS (DAHOE)“, Dec 2019

[16] Fixed Wireless Access: Economic Potential and Best Practices, GSMA, available at: https://www.gsma.com/futurenetworks/5g/fixed-wireless-access-economic-potential-and-best-practices (accessed in Apr. 2020)

[17] European 5G Observatory website, available at: https://5gobservatory.eu/ (accessed in Apr. 2020)

[18] Global Mobile Suppliers Association website, available at: https://gsacom.com (accessed in Apr.2020)

[19] “5G Devices Ecosystem Report”, GSA, Mar. 2020, available at: https://gsacom.com/paper/5g-devices-ecosystem-report-with-devices-annex-march-2020/ (accessed in Apr. 2020)

[20] 5G.co.uk website, available at: https://5g.co.uk (accessed in Apr. 2020)

[21] “LTE Broadcast eMBMS Report”, GSA, Jul. 2019, available at: https://gsacom.com/paper/lte-broadcast-embms-snapshot-july-2019/ (accessed in Apr. 2020)

[22] EBU TR 044 “Trials, Tests and Projects relating to 4G/5G Broadcast supported by European PSB”, July 2018, available at: https://tech.ebu.ch/docs/techreports/tr044.pdf (accessed in Apr. 2020)

[23] “China unveils new 5G broadcast trials”, Aug. 2019, available at: https://www.ibc.org/publish/china-unveils-new-5g-broadcast-trials/4268.article (accessed in Apr. 2020)

[24] Pricing trends for communications services in the UK, OFCOM, Mar. 2017, available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0030/113898/pricing-report-2018.pdf (accessed in Apr. 2020)

[25] “Contract SIM-only continues to surge in Q317 in GB”, Growth for Knowledge, Dec. 2017, available at: https://www.gfk.com/en-gb/insights/press-release/contract-sim-only-continues-to-surge-in-q317-in-gb/ (accessed in Apr. 2020)

[26] CISCO Visual Networking Index, 2019, available at: https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/air-highlights.html (accessed in Apr. 2020)

[27] Cable Labs OC-TR-IP-MULTI-ARCH, “IP Multicast Adaptive Bit Rate Architecture Technical Report”, available at: https://specification-search.cablelabs.com/ip-multicast-adaptive-bit-rate-architecture-technical-report (accessed in Apr. 2020)

[28] 3GPP TS 23.246 “Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description (Release 16)”, Sep. 2019.

[29] 3GPP TS 26.346 “Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs (Release 16)”, Mar. 2020.

[30] 3GPP TS 26.347 “Multimedia Broadcast/Multicast Service (MBMS); Application Programming Interface and URL (Release 16)”, Mar 2020.

[31] DVB Bluebook A176: Adaptive media streaming over IP multicast, Mar. 2020, available at http://dvb.org/wp-content/uploads/2020/03/A176_Adaptive-Media-Streaming-over-IP-Multicast_Mar-2020.pdf (accessed in Apr. 2020)

[32] EU Decision 2017/899 “Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union”, available at: http://data.europa.eu/eli/dec/2017/899/oj (accessed in Apr. 2020)

[33] 3GPP TS 38.101-1 “NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone (Release 16)”, Jan 2020.

[34] 3GPP TS 38.101-2 “NR; User Equipment (UE) radio transmission and reception; Part 1: Range 2 Standalone (Release 16)”, Jan 2020.

[35] 3GPP TS 36.101 “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 16)”, Jan 2020.

[36] Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-06), ITU-R, 2006, available at: http://handle.itu.int/11.1002/pub/801af205-en (accessed in Apr. 2020)

[37] TSDSI TR 6002 “Broadcast Offload”, Sep. 2019, available at: https://members.tsdsi.in/index.php/s/pDJB4mrNzc5T38b (accessed in Apr. 2020)

[38] “Mobile Broadband Prices in Europe”, European Comission, Dec. 2019, available at: https://ec.europa.eu/digital-single-market/en/news/mobile-broadband-prices-europe-2019 (accessed in Apr. 2020).

[39] “Media Nations Report”, OFCOM, Dec. 2019, available at: https://www.ofcom.org.uk/research-and-data/tv-radio-and-on-demand/media-nations-2019 (accessed in Apr. 2020)

[40] “BingeOn Video Technical Criteria”, T-Mobile, Mar. 2016, available at: https://www.t-mobile.com/content/dam/tmo/en-g/pdf/BingeOn-Video-Technical-Criteria-March-2016.pdf (accessed in Apr. 2020)

[41] EU Regulation 2015/2120 “Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015 laying down measures concerning open internet access and amending Directive 2002/22/EC on universal service and users’ rights relating to electronic communications networks and services and Regulation (EU) No 531/2012 on roaming on public mobile communications networks within the Union (Text with EEA relevance)”, available at: http://data.europa.eu/eli/reg/2015/2120/oj (accessed in Apr. 2020)

[42] BoR (16) 127, “BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules”, Aug. 2016, available at: https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/6160-berec-guidelines-on-the-implementation-b_0.pdf (accessed in Apr. 2020)

[43] 5G-Xcast D3.1 “LTE-Advanced Pro Broadcast Radio Access Network Benchmark, Nov. 2017, available at: http://5g-xcast.eu/wp-content/uploads/2019/04/5G-Xcast_D3.1_v1.1_web.pdf (accessed in Apr. 2020)

[44] EBU TR 034 “Simulation parameters for theoretical LTE eMBMS network studies”, Dec. 2015, available at https://tech.ebu.ch/files/live/sites/tech/files/shared/techreports/tr034.pdf (accessed in Apr. 2020)

[45] T. Fautier, "Next-Generation Video Compression Techniques," *SMPTE 2017 Annual Technical Conference and Exhibition*, Hollywood & Highland, Los Angeles, California, 2017, pp. 1-12.

Annex A: Spectrum Aspects

For chipset and equipment manufactures to incorporate 5G functionalities in their devices, they would have to be convinced that there was sufficient market demand for such functionality (c.f. § 4.2). A major factor in their assessment of demand would be the availability of suitable spectrum for the potential deployment of services based on 5G Broadcast.

A1. IMT Bands for 5G Mobile Broadband

Europe has several bands harmonised for mobile communication. 2G (GSM/GPRS/EDGE) started with 900 MHz and added 1800 MHz, 3G (UMTS/HSPA) started in the 2100 MHz band, with 4G (LTE) 800 MHz and 2600 MHz have been added. 5G now further adds 700 MHz, 3400-3800 MHz [33] and 26 GHz [34]. Licences in Europe are technology neutral, i.e. licenses can freely choose the technology to best match their strategy, their terminal population and their deployed network infrastructure. Increasingly, technology allows to define the used technology in software. The table below lists the harmonised European bands, % pop use are guestimates to give a rough indication of usage.

Table A1: Harmonized European bands

Band	Hz]		Technology	available	
700 MHz	2x 30	FDD	4G 5G	~2020	European-wide
700 MHz	15-20	SDL	4G 5G	?	?
800 MHz	2x 30	FDD	4G 5G	~2010	European-wide, >90% pop use
900 MHz	2x 35	FDD	2G 3G 4G 5G	~1990	European-wide, >95% pop use
1400 MHz	40 (90)	SDL	4G 5G	~2015	few countries
1800 MHz	2x75	FDD	2G 3G 4G 5G	~1995	European-wide, >80% pop use
2100 MHz	20	TDD	(3G) 4G	~2000	unused, new uses discussed in CEPT
2100 MHz	2x 60	FDD	3G 4G 5G	~2000	European-wide, >80% pop use
2100 MHz	15	TDD	(3G) 4G	~2000	unused, new uses discussed in CEPT
2600 MHz	2x 70	FDD	4G 5G	~2010	European-wide, >60% pop use
2600 MHz	50	TDD	4G 5G	~2010	European-wide, some use
3.6 GHz	390	TDD	(4G) 5G	~2020	European-wide
26 GHz	3125	TDD	5G	~2020	European-wide

Bands below 1 GHz are ideal for covering large areas with limited amounts of sites. The 800 MHz band is considered “the workhorse” for wide area MBB coverage with 4G. Bands below 6 GHz are less useful for covering wide areas as the number of sites required increases rapidly with the carrier frequency. The 3400 - 3800 MHz range is the European mid pioneer band and allows for substantially wider carrier bandwidths for 5G New Radio in combination with adaptive antennas. 26 GHz is the EU high pioneer band for 5G and will allow for double digit Gbit/s peak data rates but with limited cell ranges, not expected to be deployed nation-wide any time soon.

MNOs increasingly face substantial coverage obligations with spectrum licenses like the recent 100 Mbit/s per antenna sector target in Germany to 98% pop. Most of the available RF bandwidth is in higher bands well suited for densely populated areas. In rural areas, primarily bands below 1 GHz are used. With network load primarily driven by AV content, networks would soon typically exceed a ratio of 10:1 between downlink (DL) and uplink (UL).

A2. IMT Bands for 5G Broadcast

As described above, in Europe the bands in 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2600 MHz, 3400 - 3800 MHz, and 26 GHz are identified for IMT systems. Some frequency bands are used by legacy mobile systems (2G, 3G and 4G) while others will be used for 5G. Being licensed on a technologically neutral basis, all of these frequency bands may, over time, be repurposed for 5G. All these bands are regionally or globally harmonised

5G Broadcast technology relies on the LTE frequency bands as defined in [35], which provides many options for the deployment of such technology. MNOs are likely to prefer a mixed mode where broadcast is used in addition to unicast for local bandwidth optimisation and this is in principle possible in any of the above-mentioned frequency bands.

However, for standalone 5G Broadcast networks the number of spectrum options is rather limited, especially if near-universal coverage is required. Such coverage may be best provided by lower frequency bands as opposed to high frequencies such as 26 GHz. Standalone, wide area 5G Broadcast networks may not be commercially viable in the bands owned by MNOs as they would likely derive higher revenues from mobile unicast services.

A3. Supplemental Downlink (SDL) bands for 5G Broadcast

Possible alternatives for stand-alone 5G Broadcast services could be SDL bands that are currently underused (the central gap in the 700 MHz band and the L-band) and, under certain conditions, the sub-700 MHz band. SDL is a form of carrier aggregation. It is not possible to aggregate all combinations of carriers together – only the combinations set out in [35] are permitted.

There are several challenges associated with a possible deployment of 5G Broadcast networks in these SDL bands, including standardisation, device support, regulatory conditions, and ensuring commercial viability.

Table A2 contains an example of potential FDD allocations in the 700 and 800 MHz bands as well as the allocation intended to be used to realize SDL.

Table A2: Examples of FDD bands

Band	Uplink (UL)			Downlink (DL)			Duplex Mode
	F_{UL_low}		F_{UL_high}	F_{DL_low}		F_{DL_high}	
20	832 MHz	-	862 MHz	791 MHz	-	821 MHz	FDD
28	703 MHz	-	748 MHz	758 MHz	-	803 MHz	FDD
32		N/A		1452 MHz	-	1496 MHz	FDD*
67		N/A		738 MHz	-	758 MHz	FDD*

*Restricted to Carrier Aggregation, where the downlink band is paired with the uplink of another carrier.

It should be noted that potential allocations to downlink-only transmission with unpaired uplink, Standalone Downlink Only (SDO) are not defined in 3GPP. Further consideration is therefore required of which bands may be suitable for 5G Broadcast deployment, including the technical/regulatory considerations associated with them.

A3.1 UHF SDL Band 67 (738 - 758 MHz)

TR 36.101 only permits the aggregation of the 700 MHz duplex gap (LTE SDL band 67) with the 800 MHz FDD band 20. In other words, SDL in band 67 is not permitted to operate while band 700MHz (LTE FDD band 28) is in use. This is presumably because the uplink in band 28 from a UE would interfere with an SDL downlink signal in band 67.

Should an SDO service be deployed in band 67, it would also suffer interference (within UEs) that were simultaneously using the uplink in band 28. The SDO service would therefore be impaired by the UE's own uplink when band 28 were in use. The effect would be a smaller coverage area for the SDO service than otherwise expected.

The use of band 67 for an SDO service would therefore require careful thought, should it be practical at all.

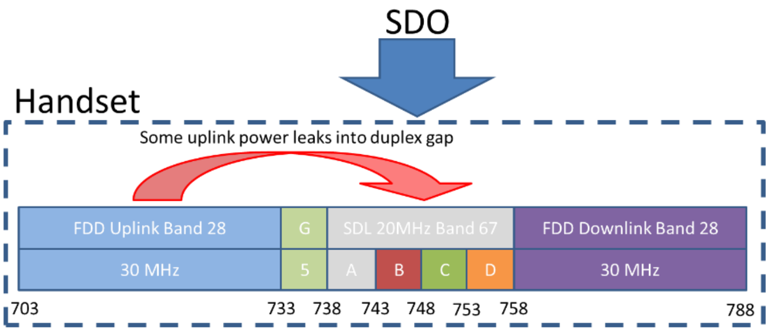


Figure A1: Potential self-interference from handset uplink to SDO service.

A3.2 L-band SDL Band 32 (1452 – 1496MHz)

TR 36.101 permits the aggregation of the LTE SDL Band 32 with the 700 MHz FDD Band 28 and with the 800 MHz FDD Band 20.

The L-band is not currently intended for use by SDO. In Europe it has been set aside for SDL. In principle the L-Band could be used for SDO in Europe, but a request for such use would likely require wide support from many countries.

A4. Broadcast bands for 5G Broadcast

The main terrestrial broadcasting bands in Europe include VHF Band II 87.5 - 108 MHz (FM radio) and Band III 174 - 230 MHz (T-DAB) and part of UHF Bands IV/V, 470 - 694 MHz (DVB-T/2); the UHF Bands predominately targeting fixed rooftop reception from HPHT networks.

HPHT transmissions require careful coordination between countries, particularly in the border areas between one country and another. The use of broadcasting Bands V/V, in ITU Region 1, are subject to the Geneva 06 (GE06) Agreement [36]. This agreement provides a framework to manage the rights to use the UHF Bands, which are subdivided into 8 MHz UHF channels, in associated countries. All transmissions in the 470 - 694 MHz band must conform to the framework of GE06 which ensures compatibility between services.

Two options have been considered for the operation of 5G Broadcast in the 470-694 MHz range. The first of these is co-existence whereby 5G Broadcast would operate within the band at the same time as HPHT DTT broadcasting. The second is a clean sheet in which 5G Broadcast would not have to consider compatibility with DTT.

A4.1 Coexistence

The first option, co-existence, would require that the 5G Broadcast transmissions were compatible with the existing DTT transmissions, and vice versa. Two further sub-options for co-existence are:

a) using the interleaved spectrum that is locally unused by DTT, the so-called 'white spaces'.

b) Using existing planned DTT assignments for 5G Broadcast. In ITU/Region 1 this corresponds to using the envelope concept of the GE06 Agreement which allows plan entries to be used for other purposes if they conform with the GE06 envelope concept. In other Regions, this corresponds to bilaterally or multilaterally coordinated DTT assignments.

Option a) does not seem to be viable as in most cases within Europe the UHF spectrum is heavily used for both DTT and PMSE. The available white spaces are therefore considered to be insufficient for the deployment of 5G Broadcast at a scale sufficiently large for content distribution. Therefore, option b) is the remaining opportunity.

Under option b), some countries may be able to use their planned, yet unused, DTT assignments, for 5G Broadcast. Others may need to replace some of their existing DTT transmissions with 5G Broadcast.

In any event, for option b), the frequency raster (i.e. channel bandwidths and centre frequencies) of 5G Broadcast would have to be considered alongside the 8 MHz frequency raster of DTT. 5G Broadcast – as used in this context – is based on LTE carriers. LTE defines carrier bandwidths of 1.4, 3, 5, 10, 15 and 20 MHz i.e. 5G Broadcast does not currently have an 8 MHz bandwidth.

Unless the specifications are further modified, any deployment of 5G Broadcast would therefore need to use one of these non-8 MHz bandwidths. Option b) therefore involves the use of mismatching DTT and 5G Broadcast frequency channel rasters. Should this be done, several compatibility issues would arise. The most obvious of these issues are outlined below for 5 MHz, 10 MHz, and 15 MHz LTE carriers.

Figure A2 illustrates two possibilities for the 5 MHz carrier whereas Figure A3 illustrates two possibilities for the 10 MHz carrier.

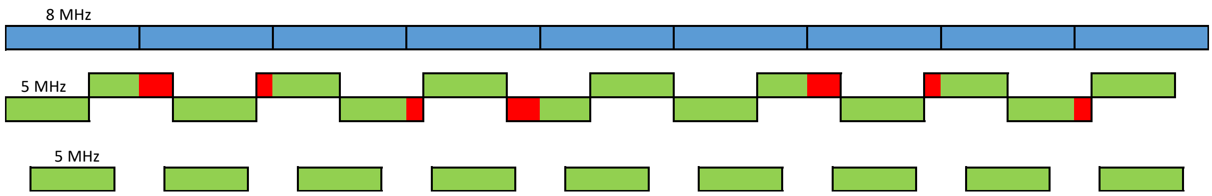


Figure A2: Position of a 5 MHz channel bandwidth in an 8 MHz raster with off-centred (middle) and centred allocations (bottom).

A 5 MHz carrier, effectively occupying 4.5 MHz, could be aligned relative to an 8 MHz DTT channel as shown in Figure A2. Should the 5 MHz channels be centred on the 8 MHz channels (lower line in Figure A2), they can be directly used under 8 MHz GE06 plan entries.

In case they are not centred (middle line of Figure A2) several of them would overlap with adjacent DTT channels and mutual interference would occur.

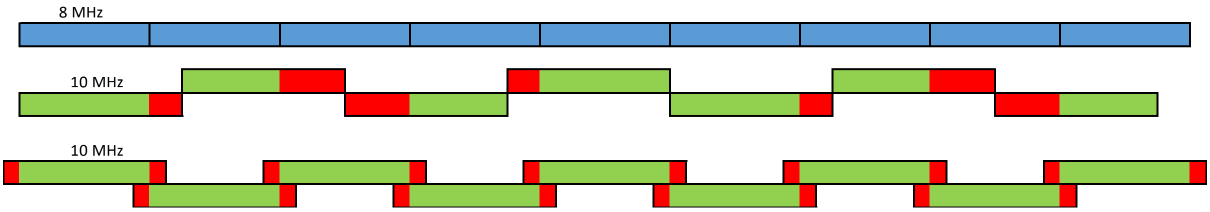


Figure A3: Position of a 10 MHz channel bandwidth in an 8 MHz raster with off-centred (middle) and centred allocations (bottom), in the latter case with overlapping carriers

A 10 MHz carrier, effectively occupying 9 MHz (the active portion of the occupied bandwidth), could be centred on an 8 MHz channel with an (active) overlap of 0.5 MHz into each of the adjacent channels (see the lower illustration in Figure A3). It can also be off-centred (see middle illustration in Figure A3). However, in both cases the LTE carrier would overlap with adjacent DTT channels and mutual interference would occur.

The only option which could be implemented straightforwardly under the GE06 envelope concept is the centred 5 MHz variant. However, as only 5/8 of the available spectrum would be employed this would not be an efficient use of the spectrum. All other options would have to cope with adjacent channel interference. The question whether this could be mitigated, for example by means of specific network designs, including power reduction, use of lower antenna heights with directive antenna patterns, requires further study.

Another possibility for 5G deployment in the sub-700 MHz band could be to use a 15 MHz LTE block which would be positioned such to occupy two adjacent DTT channels. Figure A4 shows such a layout.

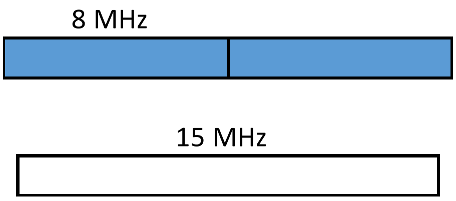


Figure A4: Position of 15 MHz channel bandwidth in an 8 MHz raster placed at the centre of 2 adjacent 8 MHz channels

However, the availability of two adjacent channels in the same geographical area is not prevalent in the GE06 plan in Region 1 or within any bilaterally coordinated plan based on 8 MHz raster elsewhere. While modification of existing plans is always possible, generalising the above-mentioned solution would require substantial re-planning and coordination efforts. It should also be noted that this option would not strictly meet the GE06 requirements in terms of envelope concept and spectrum mask.

A4.1.1 Potential of 8 MHz carrier bandwidth

An LTE 8 MHz carrier bandwidth would fit into the existing 8 MHz raster and co-exist with current deployments in large part of the world. Use of 8 MHz bandwidth maximizes spectrum use and minimise interference. The potential to standardise such an 8 MHz bandwidth should therefore be considered.

A4.2 Clean Sheet

A clean sheet – in which compatibility with DTT was of no concern – would have significantly more freedom and could potentially use any of the non-8MHz carrier bandwidths defined today.

However, at present, such a clean sheet does not exist and implementing it would require significant national planning and cross-border coordination effort and would require a long transition time. During this transition, co-existence solutions with DTT would still be required to avoid viewer disruption in areas/countries where DTT may remain a primary distribution platform in the future. Such a transition might also be eased by the introduction of an 8 MHz channel for 5G Broadcast as mentioned above.

A4.3 Global Harmonisation of sub-700 MHz Usage for 5G Broadcast

Taking Europe alone, it may be difficult to create sufficient market demand for 5G Broadcast devices, given the wide diversity of member states and their policy objectives. Thus, activities in economies outside Europe deserve some attention.

Notable developments in China include plans for 5G Broadcast with initial demos foreseen in February 2022 to be followed by large scale deployments. The Chinese Academy of Broadcast Science has shown plans to reserve the 700 MHz band for mobile communication with an FDD global Band 28 band plan and consider 5G Broadcast on a HPHT topology below the 700 MHz band. One discussed option is a band split with the range 470 - 606 MHz dedicated to conventional DTMB in an 8 MHz raster and the range 606 - 702 MHz planned for 5G Broadcast deployments based on 3GPP Rel14/Rel16 5/10/15/20 MHz carrier offering. This band segmentation seems to be motivated by the non-availability of an 8 MHz carrier bandwidth solution from 3GPP, which would allow for a degree of sharing of the band between DTT and 5G Broadcast. If China's current plans materialize in a 5G terminal ecosystem, this would be of limited use in Europe where 5G Broadcast would need to fit into the existing 8 MHz raster of GE06 and all current DTT deployments. However, should China choose a 5G Broadcast band plan with an 8 MHz raster, a wider ecosystem could be created with better prospects of device implementation in Europe.

In India, proposals have been discussed to offload eMBMS broadcast traffic from spectrum licensed to MNOs into UHF spectrum below 700 MHz. In the report [37] from the Telecommunications Standards Development Society India (TSDSI), there are competing proposals for ATSC3.0 and for 3GPP 5G Broadcast technology in user terminals. While India is not expected to set the pace for a device ecosystem, it could greatly enlarge a 470 - 694 MHz ecosystem perspective when choosing the 3GPP path.

A4.4 Summary

The most straightforward option for 5G Broadcast to co-exist with DTT, is for 5G Broadcast to use 5 MHz channels with the same channel centres as the 8 MHz DTT raster. However, as this option would use only 5/8 of the available spectrum and it would be spectrally inefficient. A newly defined 8MHz bandwidth would be more efficient while also being compatible with the GE06 framework in ITU Region 1 and with coordinated plans in other Regions that use 8 MHz channel raster for TV broadcasting.

A clean sheet approach – in which compatibility with DTT was of no concern – could potentially use any of the existing 5G Broadcast channel bandwidths. However, transitioning to this situation may still require a solution for co-existence with DTT. An 8 MHz channel bandwidth for 5G Broadcast would also help with this in large parts of the world.

The potential for standardizing an 8 MHz channel bandwidth should be further investigated as it has clear advantages in all the options considered in this document.

It would also be useful to investigate several other areas such as:

- Whether techniques, such as specific network designs, including power reduction and the use of lower antenna heights with directive antenna patterns may help compatibility between DTT and 5G Broadcast using existing LTE channel bandwidths.
- The extent to which contiguous pairs of adjacent 8 MHz channels are available in the existing DTT frequency plans (to allow 15 MHz LTE channels to co-exist with existing DTT)

Whatever paths may be considered potentially successful for the introduction of 5G Broadcast in the band 470 - 694 MHz, it is absolutely crucial that a joint effort is made globally, i.e. all stakeholders around the world need to agree to follow the same direction. Different proposals from different regions of the world will diminish the chances of global 5G Broadcast uptake.

Annex B: Mobile Broadband Commercial Aspects

B1. Distribution Costs

Operation costs are a decisive factor for broadcasting, especially if these costs are related to the number of clients or consumers where economies of scale cannot sufficiently compensate for rising operational expenses.

Media distribution over IP is directly affected by such costs. CDN distribution costs and royalty fees add on top of the expenses connected with programme production and linear distribution. Both types of costs are not new to broadcasters and have already in the past been a significant factor in content production and distribution. The difference in the IP world is that the way these costs are calculated is different to the way they are calculated in the classic broadcast world.

B1.1 CDN cost

Broadcast programmes are distributed through a full-time operational broadcast network, which is well known and established and is mostly operated by the broadcasters or BNOs. The costs for these networks are based on the expenses necessary for investment and operation to guarantee reliable operation. These costs are independent of the number of potential or actual listeners and may be, to the greatest extent, easily calculated for years in advance.

With CDNs, a per-use approach is applied. Media companies might benefit from lower costs in times when fewer people or even nobody consumes the programme, but costs drastically increase when the number of consumers and with the required bandwidth rises. The calculation of these costs is not purely based on investments and operational costs, but also on demand and availability. Therefore, economies of scale cannot fully compensate rising costs with a rising number of consumers. Sometimes maybe even on the contrary. Furthermore, this approach makes it impossible to calculate future distribution costs as reliable as in classic broadcast networks. Every (unplanned) major event may significantly change the demand for bandwidth and therefore the related costs. Savings in times of low consumption cannot compensate for peaks as there are still minimum fees to be paid for keeping the network and the option for having dynamic, additional bandwidth available.

Broadcasters or broadcast-network-operators may invest in their own CDNs to keep control of availability and costs. Though the necessity to keep bandwidth for the maximum necessary use available reduces the possibility to gain significant financial benefits. The costs for CDNs are, as of today, not regulated by any form of legislation and are therefore to be negotiated by every market participant himself. Which, again, increases the effects of demand and availability.

B1.2 Royalty fees

Royalty fees for rights holders are not regulated and need to be negotiated directly with the rights holders, which results in completely different contracts, calculation models and therefore costs, for the same rights, for different media companies.

Even more, calculation models as well as calculation bases differ for linear distribution and for on-demand distribution as well as for point-to-multipoint distribution versus point-to-point distribution. The difference between the costs per thousand users may vary even by a factor of ten and above. Based on today’s usage the costs for the royalty fees for a music-radio programme could easily reach up to more than 100% of the station's total revenue if the programme were distributed solely via point-to-point or unicast IP-connections.

Exact figures are difficult to compare as prices and the calculation models vary widely between different countries as well even as between different broadcasters within a nation. In general royalty fees for unicast streams (point-to-point connections) are far more expensive than for point-to-multipoint, broadcast distributions. The difference may even exceed a factor of ten.

Prices increase even more as soon as some type of personalization (which 'nowadays is key to up-to-date streaming applications) is applied. Such personalization could be as simple as rewinding, pausing or skipping a playing track. Even more expensive are services that include offline availability. Extended buffering, such as is required to compensate for poor download speeds in mobile applications often count as download in the eyes of the rights-holders. Therefore, even higher rates are applied if the application enables such features.

Although there are some license-models that allow broadcasters to calculate their respective royalty fees upon a fixed percentage of their revenue, the music industry tends to per-track fees. Percentage related calculation models can also only work for programmes that mainly consist of content which may be licensed through rights-holders' platforms; music-radio or –television programmes for example, whereas nearly all other programme-formats need to calculate on a per-item basis.

As technology changes and new forms of media consumption are introduced and are demanded by the market, contracts and the underlying calculation formulas between broadcasters must be re-evaluated and adapted. Therefore, regulatory steps would be needed, to ensure reasonable and calculable costs for broadcasters.

B2. Mobile Communication Tariffs in Europe

The results of the EU Mobile broadband prices in Europe 2019 [38] survey is contained in Table B1. It shows, for example, that the average cost across the EU28 countries of a 2 Gbyte data tariff would be around €10 per month, while a 50 Gbyte tariff would cost €46. The least expensive tariffs would be €2.05 and €3.88, respectively. The final column in the table indicates that the cost of these tariffs has fallen compared with the previous year – a trend that is continued from reports from previous years. These figures and trends are a snapshot of the current situation (2020) and may change in the future.

Table B1: EU28 average and least expensive prices for data-only baskets, VAT included

Basket	Least expensive (EUR/PPP)	EU28 average 2019 (EUR/PPP)	EU28 average 2018 (EUR/PPP)	Variation 2018/19
500 Mbyte	1.99	7.11	7.75	-8.3%
1 Gbyte	1.99	8.06	9.20	-12.4%
2 Gbyte	2.05	9.96	11.15	-10.7%
5 Gbyte	3.88	13.87	16.02	-14.0%
10 Gbyte	3.88	17.52	20.56	-14.8%
20 Gbyte	3.88	23.81	27.76	-14.2%
50 Gbyte	3.88	46.27	53.36	-13.3%

At the beginning of 2020, an increasing number of mobile service providers were offering unlimited data tariffs on the back of greater 4G capacity. Examples of costs for these packages are shown below:

- Austria €14
- France €16 (requires specific IPTV subscription)
- Germany €30 (but no free roaming within EU connected to this tariff)
- Italy €40
- Spain €41
- Switzerland 40 CHF
- UK £20

Some unlimited data packages may be subject to lower speeds after a certain volume of data has been downloaded in each month.

As an example, the Ofcom Media Nations report [39] indicates that in 2019, people in the UK listened to an average of 20.9 hours of radio content a week. At 128 kbit/s, 4.8 Gbyte of data would be required each month, costing around €4 to €14 per month of a conventional data plan, or more with an unlimited package.

The same report indicates that people in the UK watch an average of 3 hours and 12 minutes of broadcast television a day. At 2.5 Mbit/s, 102 Gbyte of data would be required each month, costing around €90 per month with a conventional data plan. Unlimited data plans may cost around €20 to €40 per month.

A further aspect considered in the report is FWA. This is being commercially rolled out in some countries, particularly to cover rural and remote areas where fibre is not viable. The use of FWA involves a subscription to a mobile network operator.

Initial deployments, based on 4G will normally offer downlink capacity up to 100 Mbit/s, with a minimum guarantee of 30 Mbit/s. This may be migrated to 5G at some later time. The service involves an installation cost and a monthly broadband connection. A TV package may be added on top depending on the operator.

B3. Zero-Rating

Zero rating may permit the consumer to access content without having to pay for its delivery, that is, content may be made free at the point of access. Zero-rating usually requires a business arrangement between the content provider and the mobile service provider, with one or both often meeting the cost of delivering the content.

Technical arrangements and functionality (e.g. BingeOn by T-Mobile [40]) may help to reduce the costs of delivery while increasing the quality of the service. Several degrees of integration are possible, from letting the network optimize video delivery on a best-effort approach without zero rating up to enabling the correct identification of the provider’s video traffic and therefore being able to apply and participate in the zero-rating offer. This optimization, which requires the insertion of video detection signatures, is done in cooperation with the network operator.

Typically, zero-rated content does not count toward data plans. Several mobile service providers are now offering content from different media providers, including PSM. Examples of zero-rating schemes with consumer branding are shown in Figure B1, where video quality is typically 480p or better at 1.5 Mbit/s.

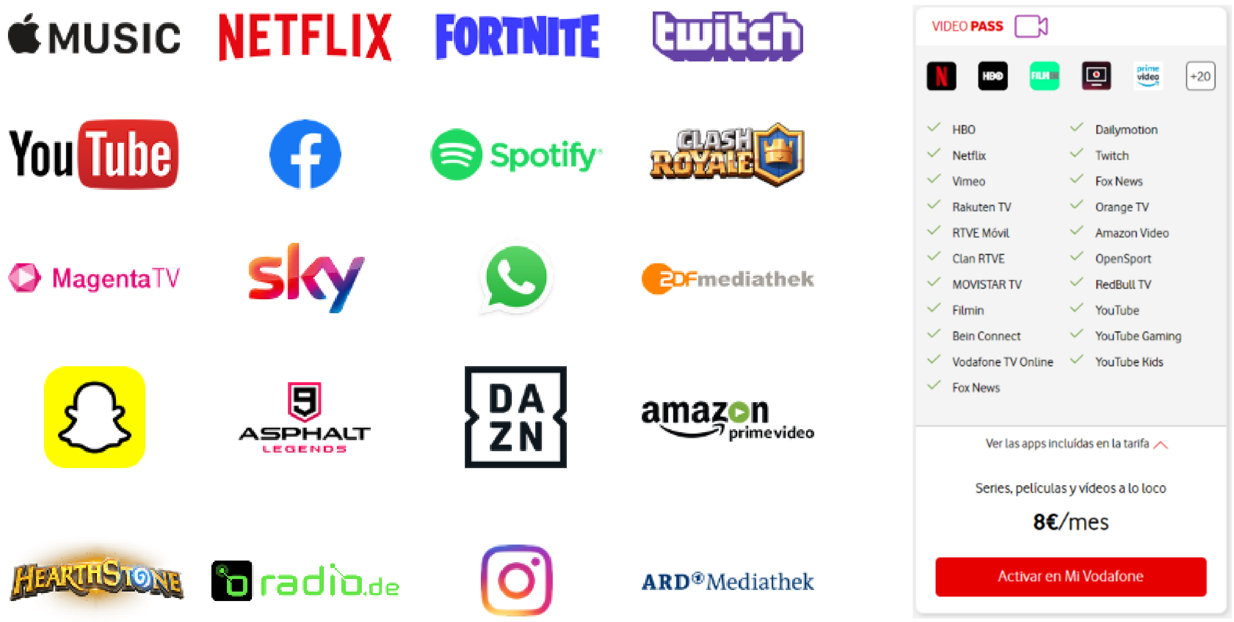


Figure B1: T-Mobile StreamOn in Germany and Vodafone Pass offers in Spain

In the UK, EE Video Data Pass (200 Mbyte of data per month for £8.99/month) is offering Netflix, Amazon Prime Video, BT Sport, MTV Play, TV Player, BBC iPlayer, or YouTube.

In Finland, unlimited 4G data plans are available in the price range of €20 – €25 monthly. 85% of all mobile consumer subscriptions have unlimited data plans. The dominance of unlimited data plans makes zero-rating irrelevant and thus, zero-rating does not exist in Finland.

In markets where unlimited data plans are predominant, OTT may be a viable option for delivering content to audiences, particularly if an acceptable quality of service can be maintained or guaranteed.

Zero-rating is a practice that exempts internet traffic generated through certain applications or access to certain websites from usage charges.

Net neutrality regulation in Europe (specifically the Telecoms Single Market (TSM) regulation [41] in combination with the BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules [42]) permits zero-rating (under certain conditions).

Zero-rating is a relatively new practice. There was limited zero-rating in Europe prior to 2012, but it is now becoming increasingly common. The recent rise of zero-rating may potentially be attributed to greater clarity being provided about its use - the TSM regulation and the BEREC Guidelines, published in August 2016.

Competition law runs in parallel with these regulations and competition authorities can assess zero-rating practices under competition law. The competition aspects are therefore a significant factor that also need to be considered alongside net-neutrality.

Zero-rating, irrespective of how the practice is to be assessed from a net neutrality perspective, is capable of affecting competition amongst ISPs and CAPs. However, it appears to be little reason to believe that zero-rating gives rise to competition concerns.

Annex C: Network Infrastructure Aspects

C1. Introduction

This annex reports on and is intended to indicate which types of transmission networks (i.e. LPLT, MPMT and HPHT) may be suitable for delivering linear radio and TV services using 5G Broadcast in a number of different indoor and outdoor receiving environments ranging from reception with fixed rooftop antennas to reception with portable/mobile and in-car mounted devices. The assessment has been undertaken for single frequency networks in the UHF band (circa 700 MHz).

C2 Link Budgets for Common Reception Environments

In this context, link budgets set out the differences in relative gain of the receiving system from the receiving antenna to the terminals of a receiver. Link budgets are essential for dimensioning the network topology (e.g. LPLT, MPMT or HPHT) needed to deliver a particular type of content (e.g. audio or video), with its associated capacity requirement, for a given receiving environment.

For this report the link budgets of five receiving environments were considered, as shown in Figure C1. Fixed rooftop reception refers to reception by stationary receivers connected to external rooftop antennas. Indoor portable reception refers to reception of stationary receivers (i.e. set top boxes or TV sets or radios) connected to a low gain external antenna such as ‘rabbit ears’.

Portable Handheld reception refers to reception on portable devices with integrated antennas such as smartphones. Car mounted reception describes reception by receivers mounted inside cars connected to well-designed receiving antenna system integrated into the vehicle. All values shown in the diagrams have been sourced from [5], other values may be more appropriate in circumstances where the receiving environment is more clearly defined.

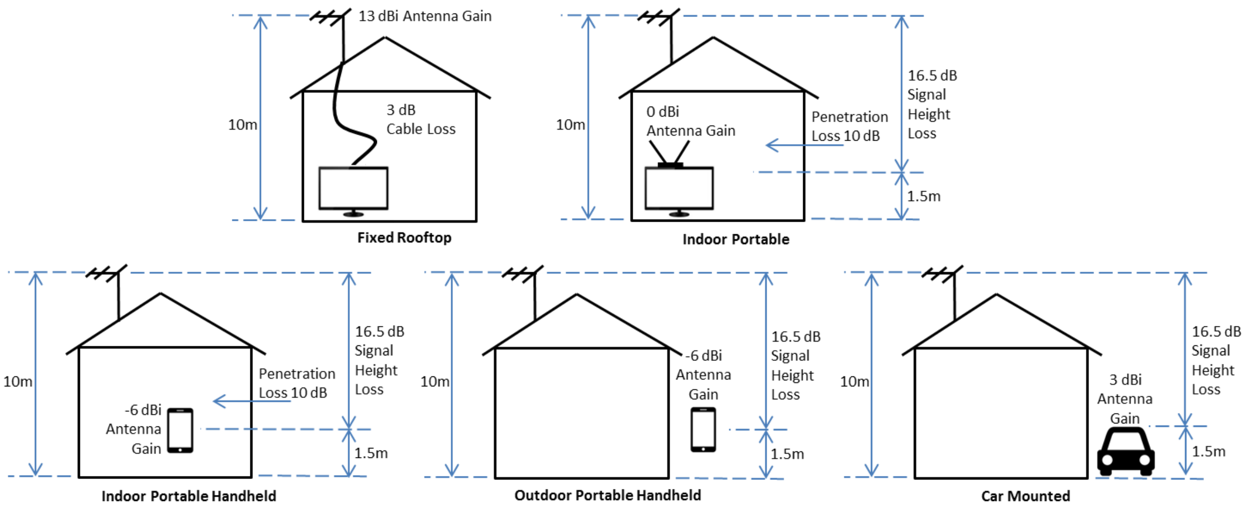


Figure C1: Receiving environments.

Figure C1 indicates that, of the environments considered, fixed rooftop would provide the highest signal level at the receiver terminals. In this environment a high gain (typically 13 dBi) receiving antenna is located at, or above, rooftop level (typically 10 m), providing the least obstructed view of the transmitting antenna to receive the highest field strength possible. A low loss cable (typically 3 dB) then connects the receiving antenna to the receiver terminal. In contrast, the three remaining environments are all at 1.5 m above ground level where measurements reveal that, due to local obstructions such as housing and trees, the field strengths are around 16.5 dB lower than the same signal measured at 10 m a.g.l. Additionally, handheld devices such as smartphones have much lower receiving antenna gains (circa -6 dBi) compared with fixed rooftop antennas – a 22 dB difference. Furthermore, indoor reception is subjected to an additional building penetration loss (typically 10 dB) as the signal propagates from outdoors to indoors.

The differences in each of the link budgets, relative to the fixed rooftop case, are shown in Table C1, where, as expected, the portable and car mounted environments are significantly more challenging than fixed rooftop reception. For example, for a given field strength at 10 m above ground level, the wanted signal power at the receiver terminals for an indoor handheld UE would be some 42.5 dB lower than the signal power at the terminals of a receiver connected by a low loss cable to an external rooftop aerial.

Table C1: Link Budgets

System Aspect	Fixed Rooftop	Indoor Portable	Outdoor Portable Handheld	Indoor Portable Handheld	Car Mounted
Receiving Antenna Gain	13 dBi	0 dBi	-6 dBi	-6 dBi	3 dBi
Cable Loss	3 dB	1 dB	0 dB	0 dB	0 dB
Height Loss 10 m vs 1.5 m	0 dB	16.5 dB	16.5 dB	16.5 dB	16.5 dB
Outdoor to Indoor Penetration Loss	0 dB	10 dB	0 dB	10 dB	0 dB
Link Budget Difference	Ref	-37.5 dB	-32.5 dB	-42.5 dB	-23.5 dB

The next section further explores the ability of different types of network to deliver broadcast content to these receiving environments.

C3. Representative Terrestrial Networks and Capabilities

Terrestrial networks can broadly be classified according to the power, height and achievable coverage area of the transmitters that comprise them. In general, High Power High Tower (HPHT) and Medium Power Medium Tower (MPMT) networks normally provide conventional broadcast TV and Radio services while cellular Low Power Low Tower (LPLT) networks provide mobile telephony and broadband multimedia communications.

HPHT and MPMT networks generally have a limited number of high-power transmitters with large effective antenna heights (high transmitter masts on hills and mountain tops) and effective radiated powers (EIRP) in the range of some kW to a hundred kW or more. Even using a few transmitters, these networks allow the coverage of large service areas, and linear TV content is easily delivered to nationwide audiences with roof-top antennas used for reception. Conversely, the LPLT architecture is characterized by a dense network of transmitters, with comparatively low power levels and antenna heights, which are optimised for wireless unicast communication for handheld user devices.

Table C2 outlines the main parameters of four different types of terrestrial network. The detail of real networks will invariably be quite different to the parameters set out in Table C2, which are characterised by singular values (e.g. the transmitter heights and spacing between any two transmitters in real networks will not have a single, uniform value and HPHT networks will be supplemented by lower power sites in areas where they are needed). However, the values in the table help to characterise the physical layout and of different types of network in use today.

Table C2: Representative network parameters

Network Topology	Illustrative Inter-site Distance (km)	Illustrative Transmitter Effective Height (m)	Illustrative Effective Radiated Power (kW EIRP)
HPHT	100	400	100
MPMT	50	200	20
LPLT Rural	15	30	1
LPLT Urban	2	30	1

C4. Services

The main context of this report is to investigate the delivery of services to mobile and portable devices. At the time of writing, spectral efficiency figures for 5G Broadcast in different receiving environments were not widely available. Table 34 in [43] indicates that a 5G Broadcast mode with a 10 dB SINR requirement would provide a spectral efficiency of around 1 bit/s/Hz for portable outdoor reception and for reception in the region of 120 km/h (assuming two receiving antennas provides a 5 dB improvement [44]).

Table C3 illustrates how many audio or video channels may be transmitted in a given bandwidth.

Table C3: Representative Service Description

Service	SINR Requirement (dB)	Bandwidth (MHz)	Capacity (Mbit/s)	Indicative Content
Linear TV	10	10	10	4 - 5 HD Programmes (HEVC) [45]
Linear Audio	10	1.4	1.4	20 - 30 Programmes (AAC)

C5. Simulations

System level simulations – which take into account the network configuration, the link budgets and the cyclic prefix/guard interval of the physical layer - have been performed in order to determine the proportion of the service area that may be covered with the target SINR by 5G Broadcast throughout each combination of the networks in Table C1 and the reception environments in Figure C1. The simulations of a 61-site regular hexagonal network have been done in accordance with [5] with an improved receiving antenna gain of mobile devices of -6 dBi. Random dropping was used.

C5.1 Linear TV

The results of the simulations are summarised in Table C4 which shows the percentage of the service area that might be covered by each network.

Table C4: Percentage of service area covered with ≥10 dB SINR. 10 MHz Carrier Bandwidth

	Fixed Rooftop	Indoor Portable	Indoor Portable Handheld	Outdoor Portable Handheld	Car Mounted
CP (µs)	200				
HPHT	>98%	55%	30%	65%	93%
MPMT	>98%	65%	25%	75%	>98%
LPLT Rural	>98%	34%	15%	45%	>98%
LPLT Urban	>98%	>98%	45%	>98%	>98%

C5.2 Linear Radio

The results of the simulations are summarised in Table C.5.2.1 which shows the percentage of the service area that might be covered by each network.

Table C5: Percentage of service area covered with ≥10 dB SINR. 1.25 MHz Carrier Bandwidth

	Fixed Rooftop	Indoor Portable	Indoor Portable Handheld	Outdoor Portable Handheld	Car Mounted
CP (μs)	200				
HPHT	>98%	85%	65%	90%	>98%
MPMT	>98%	>98%	75%	>98%	>98%
LPLT Rural	>98%	90%	40%	>98%	>98%
LPLT Urban	>98%	>98%	>98%	>98%	>98%