INDUSTRY STUDY REPORT

Future Broadcasting Technology

Preface

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0. Executive summary

The study into the future of broadcasting is essential and a clear implementation roadmap should be a subset of the national telecommunications policy. By definition, broadcasting is the act of the dissemination of information to a large number of listeners and viewers in a real-time and cost-effective manner. In many countries, broadcasting services serves as an important element in the daily lives of its citizens. Broadcasting, especially television (TV) and radio have undergone a variety of challenges which is mainly due to the usage of a strategic part of the electromagnetic spectrum. Broadcasting spectrum is also worth billions of Malaysia ringgit in monetary value[1]. Proper and 'well thought' spectrum management, strategy and re-allocation are vital for Malaysia as it moves into the next telecommunications era. This report reviews all promising technologies for the future broadcasting in Malaysia; applications for broadcast remote production and post-production using 5G New Radio (5G NR), distribution using 5G broadcast. This report also concludes with a recommendation of a further trials to select the appropriate market use case and cross check with regulatory, technical, and business findings.

1. References

Please refer to Annex A for a list of references used in this report.

2. Abbreviations

Please refer to Annex B for a list of abbreviations used in this report.

3. Terms and definition

3.1 5G Broadcast

5G Broadcast is a global terrestrial broadcast standard for a standalone terrestrial broadcast standards specified by Third Generation Partnership Project (3GPP) and based on 3GPP device silicon and ecosystem. 5G Broadcast is a profile of 3GPP specifications that addresses the 5G requirements for broadcast in clause 6.13 of ETSI TS 122 261.The profile is documented in the ETSI JTC Broadcast specification ETSI TS 103 720 and addresses radio and service layer aspects. 5G Broadcast is designed to operate on top of broadcast networks including High-Power High-Tower (HPHT), Free-to-Air (FTA), Ultra-High Frequency (UHF) spectrum, Single Frequency Network (SFN)/ Multi Frequency Network (MFN) and broadcast channel bandwidths. It is viewed by the industry as an alternative or successor to Digital Video Broadcasting (DVB) standards.

3.2 5G New Radio (5G NR)

5G NR is a global standard defined by 3GPP describing the air interface of the 5G wireless communication system. It is designed to provide faster data rates, lower latency, increased capacity, and improved connectivity for a wide range of applications and devices. 5G NR is designed to operate in a wide range of radio frequency ranges across both sub-6 GHz and millimetre Wave (mmWave).

[1] https://www.stout.com/en/insights/article/sj17-tuning-in-to-spectrum-valuation

The technology incorporates and builds on 4G Long Term Evolution (LTE) systems with features such as Massive Multiple-Input Multiple-Output (MIMO), beamforming, and dynamic spectrum sharing, enabling more efficient use of spectrum and better performance across a range of application scenarios including broadcasting.

3.3 5G Non-Public Network (NPN)

Non-Public Networks (NPN) are intended for the sole use by enterprise, and can be deployed in a variety of configurations, utilising both virtual and physical elements. Specifically, they can be deployed as completely standalone networks, they can be hosted by a Public Land Mobile Network (PLMN), or they can be offered as a slice of a PLMN. The further description of NPN can be found in 3GPP TS 22.261.

3.4 5G Media Streaming (5GMS)

5G Media Streaming (5GMS) is built on the idea of enabling third-party media distribution beyond the Mobile Network Operator (MNO) and the 5G network acting not only as a bit pipe but to provide technical and commercial opportunities for collaboration. 5GMS is documented in ETSI TS 126 501 and derived stage-2 specifications. The framework is aligned with modern over-the-top media distribution practices. The specifications support MNOs and third-party media services to easily access 5G System (5GS) and 5GMS features.

3.5 5G Multicast Broadcast Service (MBS)

In contrast to 5G Broadcast, 5G Multicast Broadcast Service (MBS) is a technology developed and designed to operate in MNOs network using operator spectrum, integration with unicast network and reuse of low power cellular infrastructure. It predominantly allows to support Point-to-Multipoint (PMP) in a single cell, but not SFN. Initial use cases of MBS are for Internet of Things (IoT), public safety and other verticals, not necessarily media distribution. The specification work was carried out in different 3GPP working groups to address all aspects of the radio, core, and service layer.

4. Introduction

4.1 Objective

This report serves as an overview of the 5G implementation and the impact it has on broadcasting as a service in Malaysia. This report also focuses on broadcasting and content services in retrospect, and it shall provide a better understanding of 5G Broadcasting and its related services.

This report does not intend to provide a definitive decision on whether 5G broadcast and its related services are to be implemented in Malaysia. Instead, this report provides the basis of further deliberation and discussion points for the regulators to intellectually decide on future policies of 5G Broadcasting implementation in Malaysia.

4.2 Overview

This clause outlines the way this report is structured.

The report begins with the general background of Digital Broadcasting in Malaysia.

Clause 4.5 onwards narrows down the discussion into 5G Broadcasting and its technologies.

Clause 5 discusses issues, which are being faced by broadcasters in general with specific emphasis on content creators and producers alike. It is hoped that this clause will create an understanding as to what are the possible solutions which could be offered by five key Broadcasting Technologies. This clause also looks at what are the potential issues faced by the various service providers in the country.

Remote production as stated in 5.2.1 is being actively used by broadcasters today in Malaysia. This production is an interesting case study where 5G New Radio (NR) could be an excellent platform in order to improve the capacity of the broadcasters in creation of new types of content.

Several examples are provided and some of them includes as follows.

(a) Venue - casting

The ability for live content which are being streamed by a large number of viewers to be sent via a broadcast method hence freeing up the data bandwidth for more needful services.

(b) Remote production

The ability for multiple camera production which are captured at a remote site to be sent live through a high bandwidth and low latency linkages to the main production centre where live editing and camera switching is done without having to be present at the actual site.

(c) Large scale computing resource sharing

Most production systems require the usage of large-scale computing resources which may be shared remotely through high bandwidth wireless networks enabling video editing and storage to be done anytime/anywhere and shall no longer be location dependent and enabling significant cost savings.

Clause 6 examines the technical requirements and the ecosystem readiness to implement 5G broadcast. During a recent seminar, delegates also deliberated on the possibility of conducting a proof-of-concept (PoC). This is also an interesting proposition whereby a simulated environment is constructed, and physical experiments are done in order to gauge whether a full-scale implementation is possible or not. The details of the cost and other technical components are outlined and discussed in 6.9.

Clause 7 introduces 5G Media Streaming (5GMS) and multimedia broadcast services which could potentially be offered by MNOs. 7.1 deals a lot into the technicalities of 5G broadcasts implementation issues. It looks specifically into the standards the radio network facilities as well as all the other requirements which should be offered by the service providers. Various business potentials and use cases for 5G broadcasts. It also looks into the issues of regulatory environment and the planning of a PoC.

Clause 8 and Clause 9, concludes and suggests the regulators and policymakers to introduce in the country in order to facilitate the implementation of 5G broadcasts and its related technical requirements.

4.3 History of Mobile Broadcast (DVB-H, MFLO, MBMS)

4.3.1 Digital Video Broadcasting (DVB)

From a broadcast market point of view, Digital Video Broadcasting-Handheld (DVB-H) and MediaFlo (MFLO) were the two most promising broadcasting technologies designed to directly reach mobile phones, more than 20 years ago. The concept was very innovative but unfortunately the technology was too early for the ecosystem where the support in receiver devices was limited to one or two models with the consequent lack of business case. Hence, it was considered as a failure.

While taking a closer look at the existing terrestrial broadcasting solutions, Digital Video Broadcasting-Second Generation Terrestrial (DVB-T2) is a very mature technology with widescale deployments in Europe, Middle East and Africa (MEA) region, Columbia, as well as in Association of Southeast Asian Nations (ASEAN) countries, primarily designed for fixed reception. DVB created another variant, addressing the mobile reception mode, DVB-T2 Lite, but this never achieved significant adoption by mobile device manufacturers. Even though, its underlying physical layer was optimised for the mobile environment, the changing consumer behaviour with the advent of smartphones, internet connectivity and video streaming technology, the technology never took off. This reminds us of the DVB-H and MediaFlo era, where efficient technologies were especially created for mobile reception environments but never took off, despite significant investments made into the development by the broadcasting industry.

While connecting the DVB-H or MediaFlo cases with Digital Video Broadcasting-Terrestrial (DVB-T) or DVB-T2, the main learning is that the success of a technology is not necessarily linked to its technical performance, but rather to the readiness of the overall ecosystem to provide support to its End-to-End (E2E) implementation, so that several use cases, coupled with critical mass of availability of receiver devices is achieved.

4.3.2 Advanced Television Systems Committee (ATSC), Integrated Services Digital Broadcasting-Terrestrial (ISDB-T), and Digital Terrestrial Multimedia Broadcast (DTMB)

The Advanced Television Systems Committee (ATSC) developed the ATSC 3.0 standard that was first deployed in South Korea in 2015 and in the United States (US) since 2016. Recently, Jamaica has also considered ATSC 3.0 as their future Digital Terrestrial Television (DTT) technology. ATSC 3.0 is one of the powerful and promising technologies equipped with a high-end physical layer to primarily deliver superior in-home TV experiences. With similar performance and efficiency to DVB-T2, ATSC 3.0 provides an Internet Protocol (IP) delivery and can also target reception by mobile devices through an additional silicon either added inside the devices or via external dongles to accommodate a non-3GPP standard in existing and future planned smartphones. Furthermore, ATSC 3.0 is one of the possible candidates for Direct-to-Mobile (D2M) services in India.

Integrated Services Digital Broadcasting-Terrestrial (ISDB-T) with its 1-seg scheme offered a mobile broadcasting service in Japan and Brazil. Some mobile phone models introduced ISDB-T 1-seg since 2002 onwards. This offered low resolution video of 320 x 240 pixels (due to limited bit rate) carried within the same broadcast transmission used for fixed rooftop reception. However, the advent of the smartphone, with higher resolution displays, and internet connectivity combined with video streaming technology (Dynamic Adaptive Streaming Over HTTP (DASH) and HTTP Live Streaming (HLS)) has replaced 1-seg which only offered live broadcast compared to current on-demand and live streaming.

While using the same concept, Digital Terrestrial Multimedia Broadcast-Advanced (DTMB-A) and Advanced ISDB-T are also aiming at supporting broadcasting mobile reception.

4.3.3 3GPP based broadcast solutions

It seems to be crucial that for a successful broadcast technology must leverage on a well-established mobile ecosystem like 3GPP, evolved Multimedia Broadcast Multicast Service (eMBMS), and International Mobile Telecommunications (IMT)-based broadcast/multicast solution designed with LTE did not generate the expected economical results. eMBMS was successfully deployed by selected MNOs by Reliance Jio in India and Telstra in Australia between 2015 to 2018 to address Radio Access Network (RAN) congestion created by large audiences watching live sporting events which usually where the MNO held the rights to the sporting event, but these services have now ceased operation due to a combination of lack of support by the major handset manufacturers alongside the absence of a concrete business case. eMBMS is, however, used in Mission Critical (MCx) LTE-based networks to provide synchronised audio and video streaming within limited capacity emergency networks.

It is essential that spectrum is used efficiently, so that equitable access could be available to different users for operation of radio communication networks in an interference free environment.

It is therefore imperative that the topic of convergence is holistically considered and confirm the availability of broadcast support the end user device ecosystem, alongside any discussion on the technology choice to be made. Incrementally, it is evident that a broadcast technology inspired from the mobile ecosystem is certainly a pre-requisite but not sufficient for its success. The latter should have also lower complexity in order to facilitate its implementation, with a totally different consumer behaviour where barrier-free access, interactivity (combined broadcast and broadband) and seamless service continuity (switch between broadcast and broadband) are defining the main headline for new service offerings.

The march of technology continues to move at a faster pace and therefore the definitions of services should consider the success of broadband streaming. It has shown that user-interactivity is an essential value for modern media and entertainment industries as consumers these days prefer to be an active participant rather than remaining as a passive recipient. The media broadcasting, in the new convergence era, will find its momentum from interactivities among various platforms and systems. Based on those interactions, the broadcast DTT is expected to be able to distinguish itself through real-time programs enriched in broad dimensions, enhanced qualities of experience, and service. Quality of Service (QoS) and Quality of Experience (QoE) are now important metrics indicating the level of satisfaction of the consumers.

Faced with declining viewership, the global broadcasting industry has increasingly turned to diversification, exploring new revenue streams beyond traditional TV advertising. Based on that, a new terrestrial broadcast technology named LTE-Based 5G Terrestrial Broadcast, known as 5G Broadcast, appeared in the industry specification since 2017 for operation in the Broadcast UHF spectrum.

Since 2019, several countries including China, Brazil, and some countries in Europe, have started to shift their focus into 5G Broadcast as their next terrestrial broadcast standard. Since 5G Broadcast merge the terrestrial broadcast and mobile reception under the same specification, the support of such feature in some of the existing and upcoming smartphones and tablet models is often a matter of software and middleware adjustment and upgrades. In other terms, there should be no need for additional silicon or any hardware changes within the same mobile devices or even vehicles.

This technology has been inspired from the telecommunication world via 3GPP under the lead of the European Broadcast Union (EBU) and has been endorsed as a standalone terrestrial broadcast system in Europe via the European Telecommunications Standards Institute (ETSI) standard (ETSI TS103 720) labelling the capability of mobile reception in multiple European countries. On top, Study Group 6 (SG6) within International Telecommunication Union - Radiocommunication Sector (ITU-R) recently endorsed 5G Broadcast as worldwide DTT standard within UHF band, labelled as System-L, in order to facilitate local and regional future DTT regulations.

4.4 Unicast challenges and Broadcast & Multicast benefits

4.4.1 Introduction

Unicast allows traffic, which is the streams of IP packets, to move across networks from a single transmitting point to another single receiving point. One-to-one bidirectional communications is the foundation of cellular networks, from Global System for Mobile Communications (GSM) right up to the current 4G, LTE, and 5G technologies.

In broadcast mode, traffic flows from a single point to all possible endpoints that can be reached within the network. This is the easiest and most efficient way to ensure traffic reaches its destination. This distribution mode has been used for many years for free-to-air analogue TV and radio distribution. Today it is mainly used in digital television and video and audio distribution networks.

Multicast enables traffic to exist between the boundaries of unicast (one-to-one) and broadcast (one-to-all). Literally, multicast is a one source to many destinations approach to traffic distribution. In other words, it only involves the destinations that openly choose to accept the data from a specific source and receive the traffic stream. For example, by purchasing a subscription, holders of vouchers or scrambling codes can decrypt the encrypted signal and enjoy the content.

4.4.2 Network operators' technical and business challenges

Network operators are classified into two distinct groups: MNOs that provide mobile services, and Broadcast Network Operator (BNO)s involved in terrestrial TV and radio distribution.

It is quite clear that the mobile telecommunications era is here to stay. As part of our everyday lives, a world without mobile phones is difficult to imagine. The ease of communications has changed and is still changing the entire way we do things. Despite these good times, MNOs are still finding it tough to bring this to their subscribers.

4.4.2.1 Inability to combat the growing Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) burden

Today, increases in data traffic and network complexity are leading to continuously growing operator Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). MNOs across the world are facing a new wave of network investment, ranging from 5G and low-power wide area networks to gigabit fibre. Yet, the returns on this CAPEX remain uncertain with many 5G use cases still in their infancy.

Moreover, the perception of broadband as a utility is threatening the premium pricing of fibre connectivity. Therefore, it is important for operators to develop new business models and cost structures in order to remain competitive and survive ongoing budget cuts. As operators grapple with an increasingly diverse network asset portfolio, therefore making the right choices about infrastructure switch-off, spin-off and even sharing will become vital.

Moreover, CAPEX is not the only upcoming issue. The power consumption of a 5G base station can be as high as three times that of its predecessor, 4G LTE. It is important to consider that power consumption is about 20 % of MNO OPEX.[2]

4.4.2.2 Keeping customer satisfaction at a high level

In the face of increasing customer requirements related to new products and services combined with continuous growth in the subscriber base, it is a herculean task to keep customers satisfied at all times. Outstanding customer service, trouble-free network operation and flawless delivery of promised services are key competitive advantages for operators that drive customer satisfaction.

Customers will stay satisfied with the latest applications and services at their fingertips in combination with network uptime. Especially when it comes to on-demand and live streaming services, mobile users expect higher quality of service than is delivered today. They are not willing to accept standard definition anymore and do not have the patience to tolerate high network latency and longer buffering times. In short, customers want a continuously satisfactory experience to meet their changing tastes.

4.4.2.3 Coverage outages

Coverage outages represent a significant pain point for mobile network operators. While some large MNOs may have backup systems in place, the vast majority do not and are at continual risk of failure. Coverage outages can halt services and bring MNO operations to a standstill. Cellular network congestion is a major pain point, which includes as follows.

a) Too many devices simultaneously accessing the same network.

b) Requesting high bandwidth services like video or live streaming cause a digital traffic jam.

Network congestion is the leading cause of cellular coverage problems today. This pushes cellular networks to their limits and can lead to network outages. In addition, due to design constraints, cellular networks have relatively smaller cells and more costly. This limits the ability of MNOs to expand coverage nationwide due to factors such as rising CAPEX and OPEX but also the lack of frequencies that would allow implementation of greater coverage.

a) Intelligent and reasonable use of network resources

[2] Rohde & Schwarz – 5G Broadcast/Multicast: Redefining the future of content delivery

BNOs have a huge asset related to the use of broadcast and multicast distribution models, such as spectrum efficiency. Public and private content is reaching millions of consumers simultaneously with huge coverage, timely synchronisation and unprecedented video and audio quality. However, this resource is wasted most of the time because the content is continuously on air, regardless of the presence of an audience, affecting energy efficiency and more.

In addition, the majority of terrestrial broadcast content is available in three other ways: satellite, cable and Over-the-Top (OTT). The use of terrestrial broadcast resources (infrastructure and frequencies) could be better managed and optimised while expanding free-to-air services, defining diversified business models and achieving advanced energy and spectrum efficiency. Deployment of broadcast and multicast over 5G applications in the UHF bands is definitely not a precondition. Technically speaking, other possibilities exist, such as the L-band, which is also a good option for the technology. However, when using such frequencies, the coverage will not be as effective as sub 1 GHz.

b) Network infrastructure under and over provisioning

Before cellular network deployment, MNOs perform network planning and dimensioning based on expected data traffic volume. MNOs will continue the network expansion based on consumer demand.

In order to fulfil these demands, operators still need to invest in the network. Some of these investments may not be justified by a business case since they would involve preparing the cellular network for traffic peaks that only rarely occur.

c) Potential to create diversified business models

BNOs strived for several years until 2010 with DVB-H and MFLO to expand and further diversity their traditional business models while reaching a larger audience with a greater number of devices. Unfortunately, they have not been successful. Nevertheless, BNOs are still hoping to achieve this goal with the help of new technologies like 5G Broadcast.

d) Control distribution costs

One of the main benefits behind utilising broadcast and multicast modes is to keep the distribution and transmission costs under control. Nowadays, content providers/owners provide live and linear multimedia content over OTT streaming services. This is the only possible way to be able to reach out to mobile and portable devices since the existing terrestrial transmission solutions does not primarily support the functionality.

In doing so, the traditional broadcasters and content owners need to use content delivery networks, not only for live streaming but mainly for Subscription Video on Demand (SVoD) services, the is also called as Content Delivery Network (CDN). The billing model of the latter is primarily based on measuring the size of the audience and make the charging based on volume of data delivered. That leads in many cases to very high distribution costs, narrowing the margins for content providers and broadcasters as well as impacting the audience experience, since the content is in the end only delivered using unicast so is susceptible to network congestion.

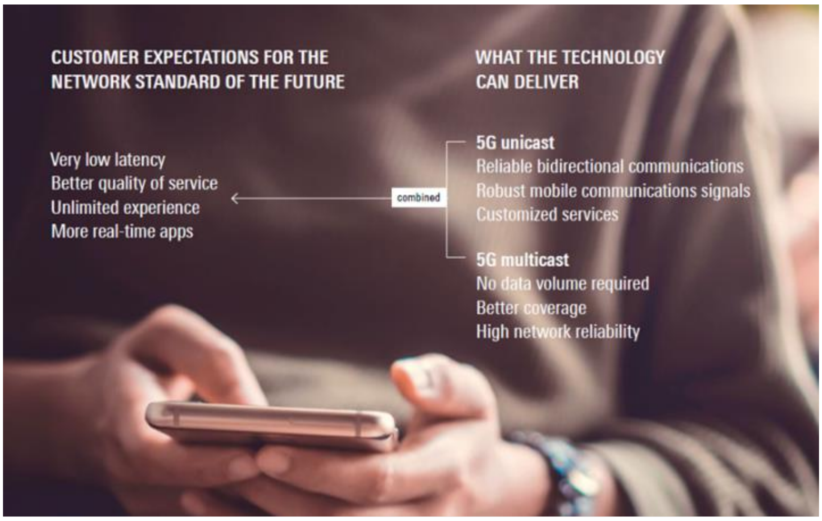
With the broadcast and multicast mode, like, 5G Broadcast, the content providers will have a flat distribution cost for live content, no matter how many people are consuming the content at the same time while potentially reaching a wider audience via a mixture of HPHT, Medium-Power Medium Tower (MPMT), and Low Power Low Tower (LPLT) infrastructure. In addition, the audience will be able to have the same quality of experience, no matter the size of the audience. The on-demand services will still be distributed via CDN as a best fit solution.

4.4.3 Consumer's experience

For years, mobile cellular networks have been based primarily on a unicast communications model to provide various services to their end users. However, nowadays consumers enjoy watching a huge amount of premium content, including a large percentage of live media services.

Moreover, mobile user behaviour and expectations are trending increasingly in the direction of higher quality of service, more features and better accessibility from the service providers. This puts network resources under pressure while pushing mobile networks to the limits of the unicast paradigm. Refer to Figure 1.

This preliminary report aims at exploring the possibility of broadcast and multicast to complement unicast.



(source: Rohde & Schwarz)

Figure 1. Customer expectations for the network standard of the future

4.5 Overview of 5G-based Technologies for Broadcasters

4.5.1 Introduction to 5G

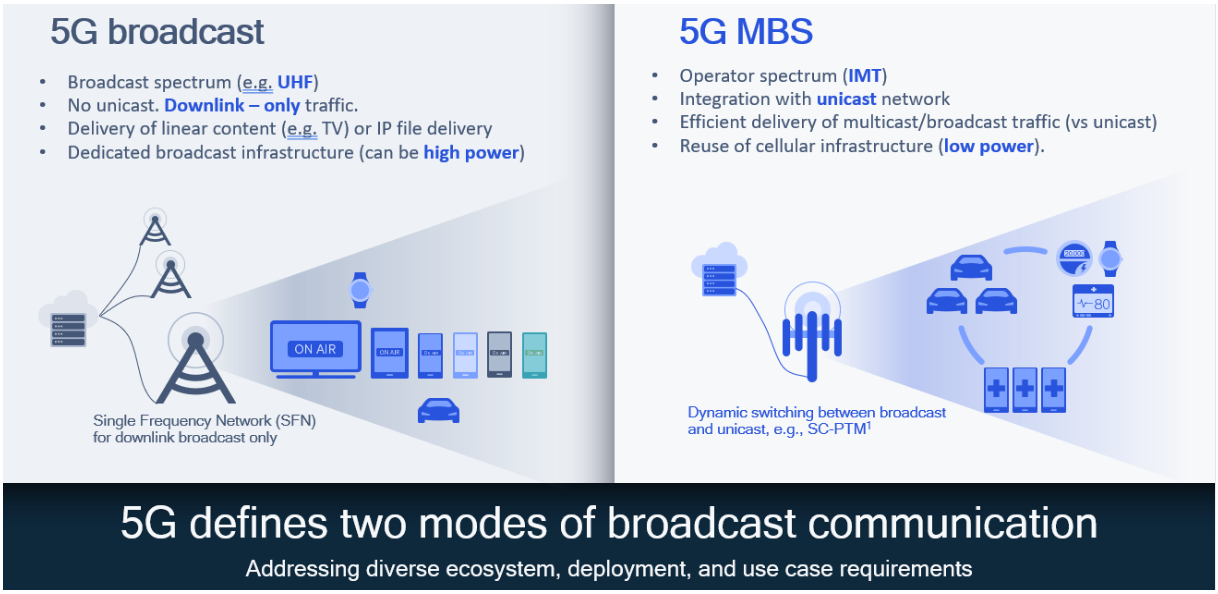
In only a quarter of a decade, the TV and media landscape has changed tremendously. Whereas until the end of the last century, premium media access and distribution was limited to broadcast TV and radio targeting dedicated end devices via dedicated distribution networks. Nowadays, a variety of different media experiences are distributed over many different networks to various types of devices. Broadcasters and media companies face challenges reaching different device types such as smart TVs, personal computers, smartphones, tablets, vehicular receivers as well as new classes of devices such as Virtual Reality Head-mounted Displays (VR HMD) and Augmented Reality (AR) glasses. Furthermore, innovative media types and experiences are now being produced and distributed. Modern media assets are more interactive, more social, more gaming-like, short and long-form, location-dependent, targeted, personalised, live, on-demand, immersive, and monetised. Broadcasters and media companies are highly motivated to use IP-based, mobile, and cellular distribution technologies to enable users to get access to their latest and greatest media services - independent of the location and the device of the user. Vertical service platforms, for example linear TV services distributed over terrestrial broadcast systems using a fully self-contained Moving Picture Experts Group-2 (MPEG-2) transport stream, are meanwhile becoming less and less attractive. New media and TV services leverage and build on top of commonly available data networks - the Internet as well as wireless and mobile access networks and systems including 5G. This combination provides a broadly accessible and unified distribution platform, can reach many devices and users, and can deliver significant innovation in much shorter cycles compared with vertical service platforms. 3GPP as the organisation defining the core parts of the 5G technologies has invited verticals to integrate their services into the 5G distribution platform. In the ongoing standardisation process of 5G, media companies, technology providers, device manufacturers, broadcasters, and mobile network operators come together to agree on technologies that support collaboration opportunities across different stakeholders and provides new services and experiences for consumers.

5G NR opens up an entire horizon of possibilities for the broadcasting industry. The concept of provision of high bandwidth and low latency connectivity sits very well with the broadcast basic requirements. As many people are aware, the purist in the broadcasting industry would insist that all video exchange within a broadcast environment is done at the highest possible quality. High quality could only be achieved using low compression video streaming and encoding techniques.

Live broadcast requirements would add low latency to the above requirements. Switching between cameras and video sources are normally done at 1 or 2 frame delay at most; even less in most professional environments.

For recorded or postproduction materials, extremely high specification editing machines are almost synonymous in the broadcasting industry. Owning and maintaining these machines can be expensive and only the largest TV station can normally afford such machines. Lately, server sharing, and networked systems are being introduced. The only problem is that high bandwidth connectivity was only possible within the same infrastructure. If editors were to use them off-site (outside the broadcast stations), usage is extremely limited or even sometimes not possible at all. However, with high bandwidth connectivity over 5G networks, these remote editing facilities are now within reach of most small and medium scale production houses.

This clause reviews some specific technologies related to 5G based media distribution. A first set of 5G specifications has been completed in Release 15 and Release 16, summarised in an overview in 4.5.2. Specifically introduced are, 5GMS in 4.5.3, 5G Broadcast in 4.5.4, and 5G MBS in 4.5.5.



(source: Qualcomm)

Figure 2. 5G defines two modes of broadcast communication

As shown in Figure 2, 5G defines two modes of broadcast communication.

5G Broadcast pre-dominantly addresses the following.

a) Broadcast spectrum (e.g., UHF).

b) No unicast. Downlink-only traffic (but can be combined with unicast services).

c) Delivery of linear content (e.g., TV) or IP file delivery.

d) Dedicated broadcast infrastructure (can be high power).

e) Single Frequency Network (SFN) for downlink broadcast only.

5G MBS predominantly addresses the following.

a) Operator spectrum (e.g., IMT).

b) Integration with unicast network.

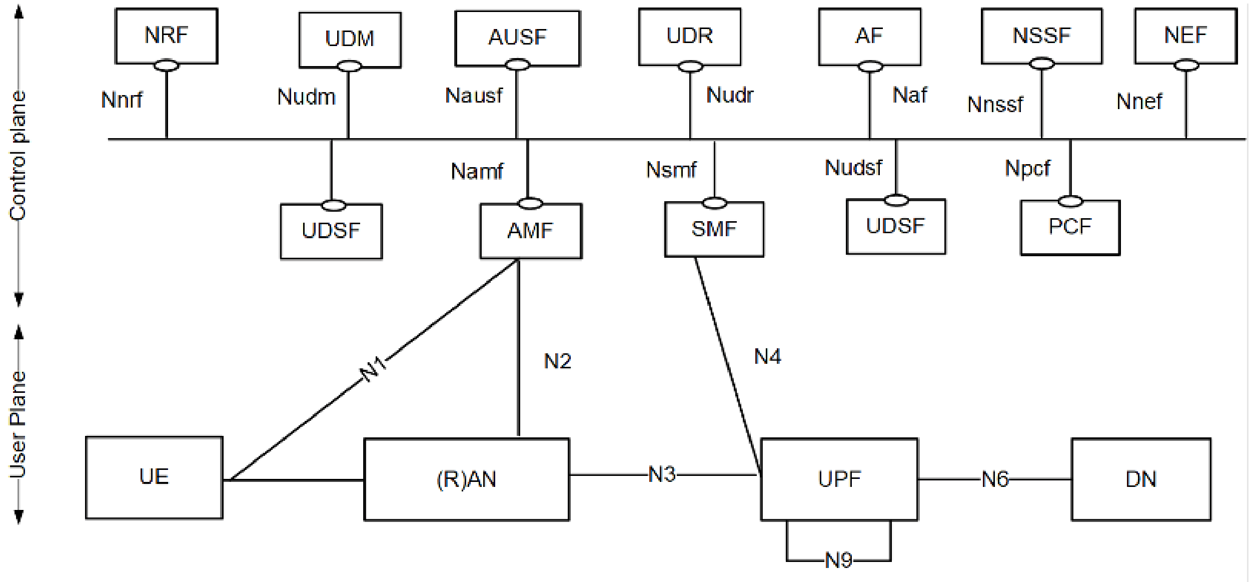
c) Efficient delivery of multicast/broadcast traffic (vs unicast).

d) Reuse of cellular infrastructure (low power).

e) Dynamic switching between broadcast and unicast, for example using Single Cell Point-to-Multipoint (SC-PTM).

4.5.2 5G Principles

Figure 3 shown the 5G system architecture, as defined in 3GPP TS 23.501, lays out the core of a 5G network, detailing the various network functions that build the 5G core.



(source: 3GPP TS 23.501)

Figure 3. 5G system architecture

The following principles have guided the design of the above architecture.

a) Separation of user plane from control plane functionality.

b) A service-based architecture, where network functions offer services to other network functions and consumers.

c) Support for stateless network functions, optimised for speed and large load.

d) Scalability through virtualisation and distribution, allowing for multiple instances of each network function to be created.

The 5G System introduces the concept of network slicing, allowing the creation of dedicated and isolated networking infrastructures that are suited for the service needs. The 5G Core (5GC) network applies QoS rules on QoS Flows. As part of a Packet Data Unit (PDU) session, a QoS Flow is identified by a unique QoS Flow ID (QFI) in the 5G System. All User Plane traffic within a PDU session with the same QFI will receive the same QoS treatment, i.e., traffic forwarding, scheduling, and admission control. All QoS Flows are controlled by the Session Management Function (SMF). A QoS Flow can be pre-configured, established during the PDU session establishment procedure, or by the PDU session modification procedure.

4.5.3 5G Media Streaming

4.5.3.1 Overview

5GMS is built on the idea of enabling third-party media distribution beyond the MNOs and the 5G network acting not only as a bit pipe but to provide technical and commercial opportunities for collaboration. MNOs and content providers are generally highly interested in such collaboration models that permit monetising video traffic on 5G and sharing revenue. MNOs are also interested in addressing the dilemma of ever-growing demand for media consumption on their networks, whereby it is expected that in 2026, 50% of the mobile data will be on 5G, and 77% of this data will be video. [3]

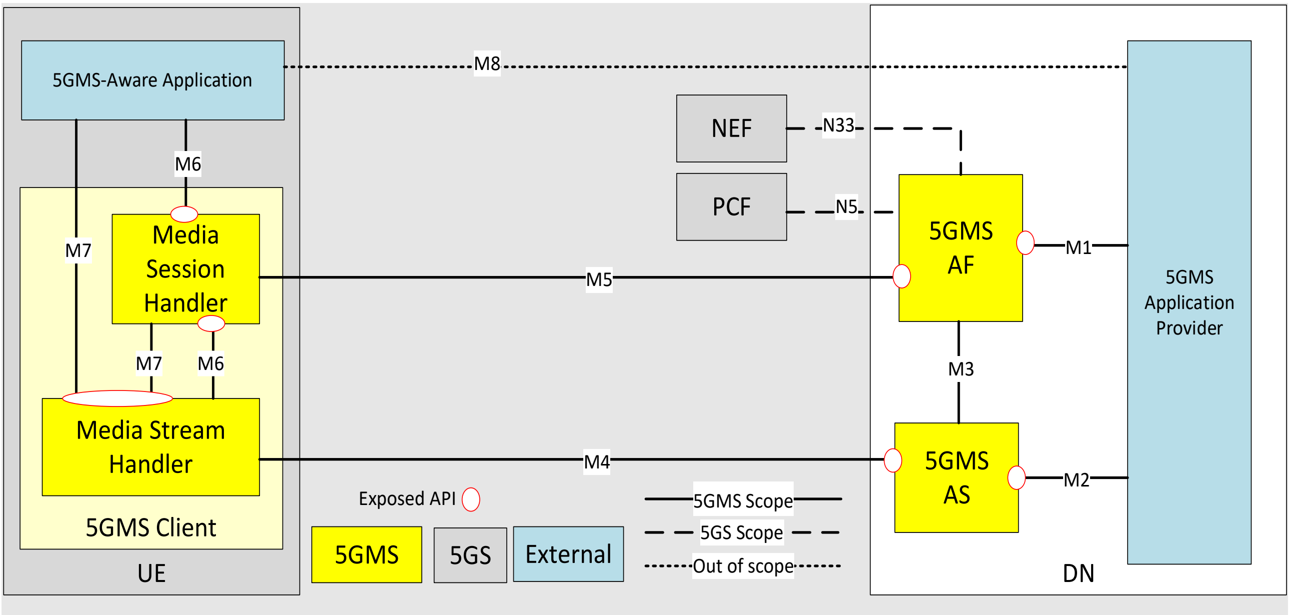
Challenges for pure OTT distribution include the following.

a) Quality of experience issues (rebuffering and stall events) that are associated with the operator in the end user's mind.

b) Obscuring of traffic by E2E encryption using HyperText Transfer Protocol Secure (HTTPS).

c) Unidentified content eating into users' data caps.

d) The increasing demand for higher quality, new formats, new immersive and interactive experiences.



(source: 3GPP TS 26.501)

Figure 4. 5GMS architecture

[3] https://www.ericsson.com/en/reports-and-papers/mobility-report/reports/november-2023
https://www.statista.com/chart/27664/mobile-data-traffic-by-application-category/

The approach taken for 5GMS is documented in 3GPP TS 26.501 and shown in Figure 4.

a) The framework is aligned with modern OTT media distribution practices.

b) The specifications support MNOs and third-party media services to easily access 5G System and 5GMS features.

5GMS stage-3 specifications, 3GPP TS 26.512, and 3GPP TS 26.511 provide an instantiation of 5GMS for one or a small subset of recommended technologies including codecs, formats, protocols, and other functionalities.

4.5.3.2 Reference Tools for 5GMS

5G-MAG also supports reference tools for 5GMS. An overview is provided in Figure 5. Among others, the following developments are ongoing.

a) 5GMS components for downlink.

    i) Application server and application function.

    ii) Media stream and media session handlers.

b) Reference points and Application Programming Interface (API).

    i) Retrieval of service access information from 5GMSd Application Function (5GMSd AF) via M5d using baseline via M8d.

    ii) M3 Link (5G Media Downlink Streaming - Application Server (5GMSd AS) and 5GMSd AF client).

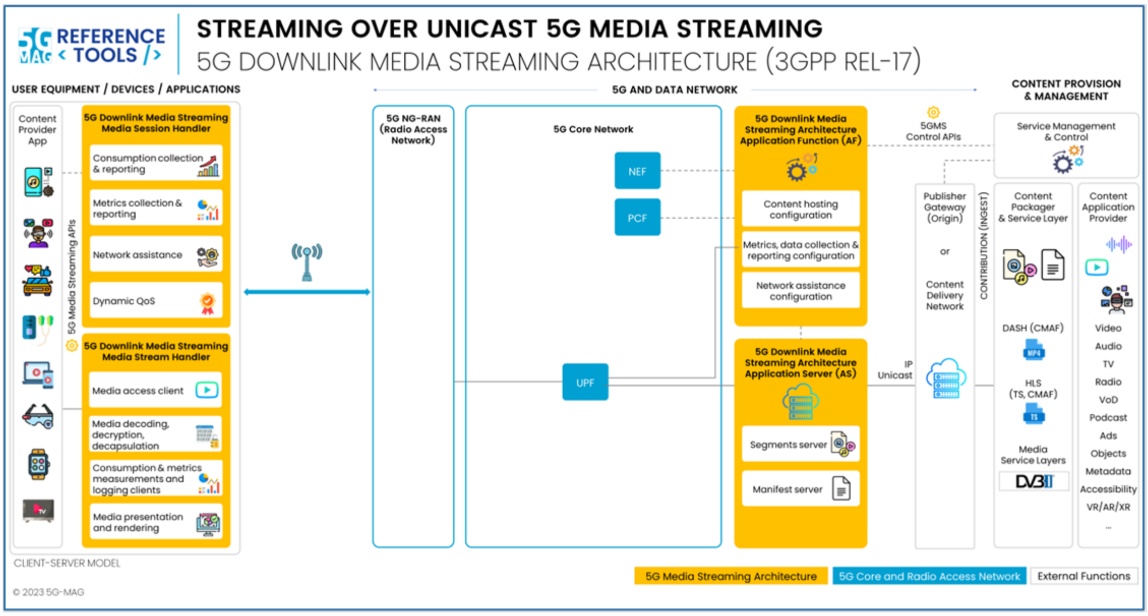
    iii) M1 Provisioning Sessions API.

    iv) M1 Content Hosting Configuration.

    v) M1 Server Certificates Provisioning API.

c) Android-based clients and applications

    i) Integration of DVB-I service lists with ExoPlayer.



(source: 5G-MAG)

Figure 5. 5GMS downlink - reference tools in 5G-MAG

The following repositories and functionalities exist.

a) 5GMSd Application Function

The 5GMSd AF is a Network Function that forms part of the 5G Media Services framework as defined in 3GPP TS 26 501. The AF is a logical function which embodies the control plane aspects of the system, including provisioning, configuration, and reporting, among others.

b) 5GMSd Application Server (5GMS AS)

The 5GMS AS is a Network Function that forms part of the 5G Media Services framework as defined in 3GPP TS 26 501. This logical function embodies the data plane aspects of the 5GMSd System that deals with proxying media content (similar to a Content Delivery Network).

c) 5GMSd Media Session Handler

The 5GMS Media Session Handler is a 5GMS Client component that forms part of the 5G Media Services framework as defined in 3GPP TS 26 501. A Media Session Handler first retrieves its configuration ("Service Access Information") from the 5GMSd AF at reference point M5d and then uses this configuration information to activate and exploit the currently provisioned 5GMSd features.

d) 5GMS Examples

Example projects that make use of other 5G-MAG repositories or provide additional functionality to test and implement new features for 5GMS.

e) 5GMS Common Android Library

The 5GMS Common Library is an Android library that includes models and helper classes used within the different client-side Android applications such as the 5GMSd-Aware Application, 5GMSd Media Stream Handler and the 5GMSd Media Session Handler.

f) 5GMS Media Stream Handler

The 5GMS Media Stream Handler is a 5GMS client component that forms part of the 5G Media Services framework as defined in 3GPP TS 26 501. A Media Stream Handler (Media Player) enables playback and rendering of a media presentation based on a media player entry and exposing some basic controls such as play, pause, seek, stop to the 5GMSd-Aware Application.

g) 5GMS-Aware Applications

Each folder within the repository contains a different application with its own code, documentation and license file. This is a list of the current applications available: 5GMSd-Aware Application. Exo DVB-I Player, and a Sample 5G-MAG Player.

4.5.4 5G Broadcast

While Multimedia Broadcast Multicast Services (MBMS) had been part of 3GPP specifications since Release 6 in 2005 based on Universal Terrestrial Radio Access Network (UTRAN), and since Release 9 based on LTE (the evolution to LTE is also referred to as eMBMS), the dedicated requirements of broadcast service providers were only taken into account in 3GPP Release 14 some ten years later. Requirements for 3GPP enhancements for TV service support were developed in 3GPP Release 14 and are documented in ETSI TS 122 101, Clause 32. Based on these requirements, 3GPP specifications have gradually evolved to meet the use cases and requirements in order to support broadcasting of linear television and radio services. In 3GPP TR 23.746, a significant set of key issues relevant for the usage of MBMS for broadcast services is identified and these issues are subsequently addressed in 3GPP Release 14 specifications:

a) Support of Free-to-Air (FTA) service over 3GPP.

b) Broadcast-only service for UEs with no MNO broadcast subscription.

c) Support of shared eMBMS functions.

d) Decoupling of content, MBMS service and MBMS transport functions.

e) Exposure of eMBMS service and transport capabilities to third parties.

Beyond the service layer enhancements, also in 3GPP Release 14 the use cases and scenarios for eMBMS services based on LTE were expanded to include terrestrial broadcasting (the feature also referred to as EnTV). This included new requirements:

a) Network dedicated to TV broadcast via eMBMS.

b) SFN deployments with Inter-Site Distance (ISD) significantly larger than a typical ISD associated with typical cellular deployments.

c) Support for Receive-Only Mode (ROM) services and devices.

With the development of 5G from Release 15 onwards, 3GPP formulated requirements for the system and Radio Access Technology (RAT) in 3GPP TS 22.261 as part of the initial release for 5G, namely Release 15. In particular, broadcast is addressed in Clause 6.13 of 3GPP TS 22.261. Whereas the requirements are generic for a flexible broadcast multicast system, only a subset of the requirements apply to broadcasting linear television and radio services, in particular those for 5G dedicated broadcast networks. Several 3GPP specifications have been extended or newly developed over several releases to address the use cases and requirements for 5G dedicated broadcast networks. While it is expected that 3GPP will continue to address all the requirements for a flexible broadcast/multicast system in Clause 6.13 of 3GPP TS 22.261 in future releases, with the completion of the Release 17, a comprehensive set of 3GPP specifications is available that fulfils the use cases and requirements for a 5G Broadcast System.

The progress in improving TV technology within 3GPP is outlined in ETSI TR 136 976. This laid the groundwork for the specification efforts in ETSI JTC Broadcast, resulting in the publication of ETSI TS 103 720 in December 2020, v.1.1.1.

In June 2023, ETSI TS 103 720 v1.2.1 outlines the fundamental aspects of a 5G Broadcast System for carrying traditional TV and radio services. It documents these as an implementation profile derived from a subset of 3GPP specifications, covering key features and functionalities such as follows.

a) Support of FTA service.

b) Broadcast-only service for UEs without an MNO broadcast subscription.

c) Support of shared network functions across multiple 5G network operators.

d) Decoupling of content, user service and transport functions.

e) Exposure of broadcast service and transport capabilities to third parties.

f) Support for client APIs for simplified access to broadcast services.

g) Network dedicated to linear television and radio broadcast, for example transmitted using supplemental downlink channels and spectrum.

h) SFN deployments with ISD significantly larger than those associated with typical cellular deployments, with ISD > 100 km to support receivers with high-gain rooftop directional antennas, low mobility, and a predominantly line-of-sight channel.

i) Support for mobility scenarios including speeds of up to 250 km/h to support receivers in moving vehicles, with external omni-directional antennas.

j) Support for ROM services and devices.

k) Support for user service announcement through broadcast.

l) Support for common streaming distribution formats such as DASH, HLS, and Common Media Application Format (CMAF).

m) Support for IP-based services such as IPTV or Multicast Adaptive Bitrate (MABR).

n) Support for different file delivery services such as scheduled delivery or file carousels.

o) Support for services that use unicast and broadcast delivery methods.

p) Support for typical broadcast channel bandwidths of 6/7/8 MHz.

q) Support for public warning and emergency alerts based on cell broadcast services.

Note that these features are independent of the access or core network technology.

4.5.5 5G MBS

4.5.5.1 Overview

3GPP Release 17 has some extensive efforts to add multicast and broadcast capabilities to the 5G System, NR, and 5GMS under the umbrella of 5G MBS. Among others, the following aspects are addressed:

a) Support of Multicast Services with autonomous RAN-based switching between point-to-point and point-to-multipoint transmission modes.

b) Reuse of physical (PHY) channels and signals, without new numerologies.

c) Support Broadcast Services, always using point-to-multipoint transmission.

d) Only SC-PTM supported in NR RAN, i.e., no support from Single Frequency Networks.

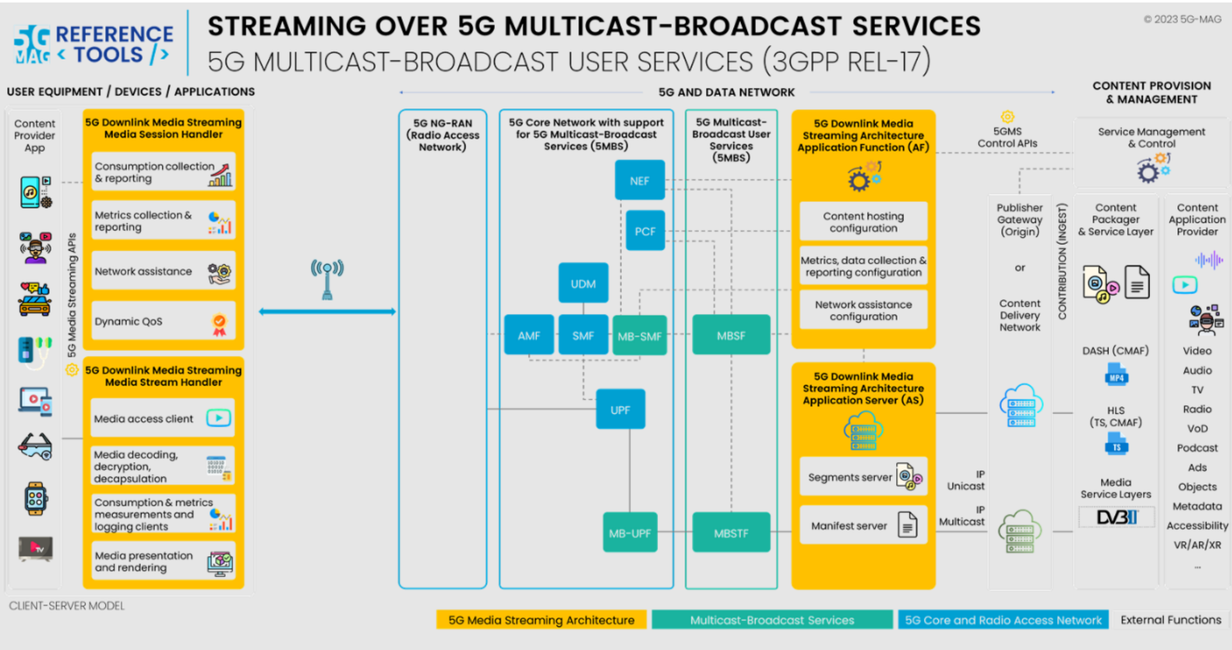
e) Delivery and service layer aspects.

f) APIs on the network and client sides.

The specification work is carried out in different working groups to address all aspects of the radio, core and service layer.

4.5.5.2 Reference Tools for MBS

Planning of support for MBS in 5G-MAG Reference Tools has just started. An overview of the expected implementation architecture is provided in Figure 6.



(source: 5G-MAG)

Figure 6. Implementation Plan for Media Distribution using MBS

No tools have yet been released from 5G-MAG.

5. 5G NR for broadcasting

5.1 Problem statement

The problem statement for live production and post-production has been identified across the people, process, and technology dimensions.

5.1.1 Live production

a) Deployment cost of live production.

i) Remote site or venue deployments traditionally require a team of 20 to 40-man crew, including camera operators, riggers, floor managers, and technical managers.

ii) Production team deployment to site is time consuming and requires large scale preparations and planning. These elements may deter some production plans due to cost factors.

iii) Personnel resource allocation for remote sites often faces limitations, driven by both cost and time pressures.

b) Limited resources to perform concurrent live production.

c) Multiple service providers are required to provide the service.

d) Limited bandwidth on visual radio broadcast.

5.1.2 Post-production

a) Service provider

Multiple service provider required to provide the services. More Subscriber Identity Module (SIM) cards are required.

b) Data management

Managing and transferring large, high-resolution video, and multimedia files efficiently over a 5G network without bottlenecks, data loss, or security vulnerabilities.

c) Collaboration and real-time editing

Enabling seamless collaboration among remote post-production teams in real time while ensuring a consistent and efficient workflow.

d) Resource optimisation

Leveraging cloud-based post-production tools and services effectively, maximising the potential of 5G for remote rendering and resource-intensive tasks.

e) Quality control

Ensuring that high-quality video and multimedia content can be reviewed and edited on various devices while maintaining content integrity.

f) Security

Implementing robust security measures to protect sensitive post-production assets and intellectual property when using 5G for data transfer and remote collaboration.

5.2 Solution

5.2.1 Live production

5.2.1.1 Remote production

Remote production is an alternative to the current traditional production methods used by the content industry today.

5.2.1.1.1 How remote production can improve the traditional production method

a) Compared to traditional Outside Broadcasting (OB) van, Digital Satellite News Gathering (DSNG), and Electronic News Gathering (ENG) deployments.

i) Optimisation of manpower to be deployed within the remote site or venues

Only required to deploy camera crew, riggers, floor managers, and technical managers. From a traditional 20 to 40-man crew down to only 5 to 15 crew depending on production requirements.

ii) Reduction of deployment time

Deployments setup at remote site simplified as it only requires ensuring that the content acquisition equipment (cameras systems, microphone systems), intercoms, and network facilities are fully deployed with line tests done with the Headquarters (HQ).

iii) Remote production within the cloud now provides the possibility of working with a global pool of talent resources without the need for them to travel to HQ to be part of the production.

Talent pools such as producers, switcher operators, replay operators, audio operators, and commentators, can be sourced from anywhere they are. As long as they have an IP connection to allow them to remotely access the production resources.

iv) Economics

Increased savings due to the reduction of travel compensation from the following.

1) Increased efficiencies of manpower deployed.

2) Increased efficiencies of on-venue deployment turnaround time.

3) Increased efficiencies and flexibilities in remote venue manpower and equipment scheduling allows productions to be able to increase on-venue production slots.

b) Caveats from traditional remote production setups

i) Due to remote production latencies concerns and equipment availability at site. It only supports highly templatised production formats.

5.2.1.1.2 How 5G NR can expand the remote production

a) Improved network latencies

i) 5G can achieve landline Internet Service Providers (ISP) network latencies. Reducing total overall production latencies to increase coordination of on-venue crew to the studio production crews.

ii) The reduction of network latencies and total production latencies allows increased flexibility to also provide content feedback, distribution or monitoring possibilities at site.

b) 5G Multi-access Edge Computing (MEC)

i) Allows for deployment production resources (i.e., switcher, graphics, replay, audio mixing, processing, intercom or AI production) within the MEC. The deployment can include either on-prem or virtualised production systems.

ii) Reduces production latencies that are typical of remote production setups.

c) Increased bandwidth capacities

   i) The increased bandwidth capacities allow for transmission of more content acquisition, distribution, monitoring channels. (i.e., increased camera channels).

   ii) The increased bandwidth capacities allow for transmission of higher quality video (High Definition (HD), Ultra-High Definition (UHD), or High Dynamic Range (HDR).

   iii) Availability of 5G network slicing functionalities on the public 5G will be able to better guarantee higher service priority during public 5G cell tower congestion.

d) Improved remote production architecture flexibilities

   i) Apart from the typical ground-to-ground, it also allows for ground-to-cloud, cloud-to-ground, and hybrid ground or cloud remote production system deployment possibilities.

   ii) Post-production processes which are increasingly utilising 'cloud infrastructure' are increasingly dependent on good connectivity and low latency connections in remote and normally inaccessible places over fibre or physical infrastructure. Here 5G connectivity seems to offer solutions which were not available before.

5.2.1.1.3 How 5G Non-Public Networks (NPN) can replace traditional Radio Frequency (RF) camera systems

Traditional Radio Frequency (RF) camera systems operate within the Very High Frequency (VHF) or UHF frequency bands with the frequency capacity of up 1 x HD camera chain within a 5 MHz channel with High Efficiency Video Coding (HEVC). The video transmission is only one-way without camera control return or video return possibilities. To provide for camera control return and video return monitoring, operators will be required to allocate more RF channels and very careful RF deployment planning to cater for such functions to the camera crew.

Due to the recent advancements of low latency encoding and 5G or 4G transmission kits, it has been considered as a possible replacement for traditional RF Camera systems with the following.

a) Increased camera channels within a 5G frequency band and reduced complexities of RF allocation planning.

b) The video transmission data channel is inherently IP-based. Allows for 2-way video transmission and with camera control and tally integrations.

c) Ease of deployment within all-in-one kit. 5G video transmission devices are now typically pre-integrated with video transmission, camera controls, video return within a single equipment.

d) Reduces the requirement for dedicated hardware to set up the wireless camera transmission system, e.g., VHF or UHF RF antenna systems, IP mesh kits, etc. The possibility of reusing the same 5G video transmission kit for wireless camera usage.

e) Traditional RF camera systems require dedicated equipment chains for each of the camera functionalities (RF camera transmission chains, RF camera control indoor unit, outdoor unit and receivers, etc.).

f) Increased field coverage size and capability of roaming in between 5G cells towers.

g) 5G NPN provide the possibility for broadcasters to operate outside of public 5G frequency bands.

5.2.1.2 Case study from local industry

5.2.1.2.1 Introduction

A case study has been conducted by Media Prima Berhad in-collaboration with Digital Nasional Berhad on the feasibility of live remote production using a 5G network.

Figure 7 shows the existing OB infrastructure relies on the following three technologies.

a) Mobile signal antennas.

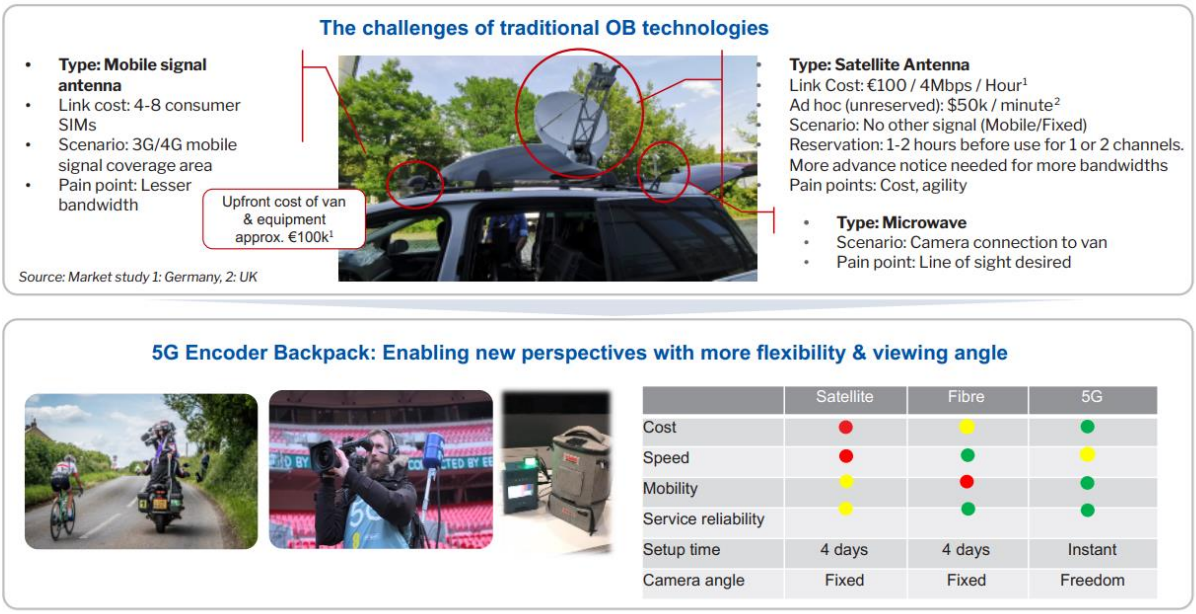
b) Satellite antennas.

c) Microwave transmission.

However, these technologies present notable challenges, including high operational costs, limited signal coverage, exhibits noticeable latency, restricted mobility, moderate reliability, prolonged setup times, constrained camera angles, and restricted bandwidth.

In response to these challenges, the industry needs innovative technology solutions. Fibre optic technology has partially addressed issues related to speed and service reliability. Nonetheless, problems such as cost implications, mobility limitations, setup duration, and restrictions on camera angle adjustments persist, demanding for further solution.

Extensive testing and analysis have affirmed that 5G technology introduces a new dimension of possibilities. It offers flexibility and expands viewing angles through the utilisation of the 5G encoder backpack. This solution not only proves to be more cost-effective but also greatly enhances mobility, expedites setup procedures, and provides a broader spectrum of camera angle options.



	Satellite	Fibre	5G
Cost	Red	Yellow	Green
Speed	Red	Green	Yellow
Mobility	Yellow	Red	Green
Service reliability	Yellow	Green	Green
Setup time	4 days	4 days	Instant
Camera angle	Fixed	Fixed	Freedom

Figure 7. Overview of 5G implementation in existing outside broadcast system

The primary objective of the PoC is to evaluate the feasibility of live remote production using a 5G public network and to discover the requisite bandwidth for real-time video transmission.

In theory, the minimum speed requirement for 5G devices stands at 4 x Full HD (1920 x 1080 pixels at 50 frames per second) with a 5.5 Mbps uplink video bit rate, and 1 x 4K (3840 x 2160 pixels at 50 frames per second) with a 20 Mbps uplink video bit rate.

Table 1 depicts the speed requirement for 5G broadcast system.

Table 1. Minimum speed requirement for PoC

Devices	Number of channels	Video codec	Output resolution	Video bit rate
5G Encoder	4 x Full HD (FHD)	H.265	1920 x 1080 P50	5.5 Mbps uplink
5G Encoder	1 x 4K	H.265	3840 x 2160 P50	20 Mbps uplink

5.2.1.2.2 System configuration

Table 2 provides the details of the tested 5G network environment and its associated equipment parameters. The components subjected to testing encompass the network operating mode, designated as 5G NR enterprise network in a Standalone (SA) mode. Additionally, the evaluation considers the frequency band employed, with specific reference to N78 operating at 3.5 GHz. The channel bandwidth parameter, characterised by the utilisation of a single carrier spanning 100 MHz, is also within the scope of testing. Furthermore, the assessment considers the network signal quality, denoted by Reference Signal Received Power (RSRP) values ranging from -73 dBm to approximately -61 dBm.

Table 2. 5G network equipment parameters

Item	Description
Network operating mode	5G NR, SA, NPN
Frequency band	N78, 3.5 GHz
Channel bandwidth	1 carrier, 100 MHz
Network signal	RSRP: -73 dBm ~ -61 dBm

5.2.1.2.3 Findings

Following the comprehensive evaluation of all components within the 5G Test environments, two distinct test scenarios and their corresponding results are obtained in Table 3.

The first scenario refers to the encoding of 4 x Full High Definition (FHD) (channel, utilising the H.265 codec. In this context, a minimum uplink speed of 5 Mbps per channel is deemed necessary to ensure the delivery of a high-quality, seamless video stream. Notably, this configuration ensures that video content becomes viewable within a mere 3 seconds from the initiation of video capture, maintaining an undistorted viewing experience.

The second scenario revolves around the encoding of 1 x 4K channel, employing the H.265 codec. In this instance, a more substantial uplink speed of 20 Mbps is needed to sustain the delivery of a smooth, high-quality video stream. Just like the previous scenario, this setup also guarantees that viewers can enjoy undistorted video content within a brief 3-second timeframe from the commencement of video capture.

Table 3. Tested scenarios and results for video quality with no distortion

Devices	Number of channels	Output resolution	Speed capped per channel via setting on encoders (Uplink)	Channel bonding features activation	E2E Latency below 3s (from video capturing to stream on TV)
5G Encoders	4 x FHD	1920 x 1080 P50	5 Mbps	Yes, 2 SIM cards	Yes
5G Encoders	1 x 4K	3840 x 2160 P50	20 Mbps	No	Yes

5.2.1.4 Immersive camera for live event

Production values are normally measured by the ability of viewers to have a positive experience during consumption. In order to provide the experience, camera position and capture angle is important. Multiple camera position and options will ensure that the producers are able to choose the best shots to be aired. A large selection of camera angles will enable a more immersive experience for the viewers. Typically, a high bandwidth and low latency connectivity will enable these options.

5.2.1.4.1 Eco-system readiness and global trends in 5G content production for broadcasters

The transition to 5G content production for broadcasters is not just about the technology itself but also about the ecosystem readiness and global trends that shape its adoption. Below is the exploration of both aspects.

a) Ecosystem readiness

i) Network infrastructure

The readiness of 5G networks is a pivotal factor. Many countries and regions have been rolling out 5G infrastructure, but the extent of coverage, network density, and reliability can vary widely. Broadcasters require comprehensive and high-quality 5G coverage to leverage its potential fully.

ii) Hardware and devices

Ecosystem readiness depends on the availability of 5G-enabled devices and equipment. Broadcasters need access to cameras, transmitters, and other hardware that can transmit and receive 5G signals efficiently. The availability of consumer devices capable of receiving 5G broadcasts is also crucial.

iii) Content Creation Tools

Broadcasters must have access to content creation tools and software that are compatible with 5G workflows. This includes video editing software, production equipment, and content management systems tailored to the high-speed, low-latency requirements of 5G.

iv) Skill development

The broadcasting industry needs to invest in training and upskilling its workforce to understand and harness 5G technology effectively. Engineers, content producers, and technicians should be proficient in 5G-specific workflows.

b) Global trends

i) Increased Immersive Content

Global trends in content consumption show a growing appetite for immersive experiences, including Augmented Reality (AR), Virtual Reality (VR), and 360-degree video. Broadcasters are aligning their strategies with these trends to create more engaging and interactive content.

ii) Sustainability

Sustainability is a global trend affecting all industries, including broadcasting. Broadcasters are exploring ways to make their 5G content production more energy-efficient and environmentally friendly.

iii) Monetisation diversification

The traditional advertising revenue model is evolving. Broadcasters are diversifying their revenue streams through subscription models, premium content, e-commerce integration, and targeted advertising, leveraging the capabilities of 5G to deliver personalised content.

iv) Edge computing

Edge computing is gaining momentum as a global trend, especially in 5G content production. By processing data closer to the source, broadcasters can reduce latency and enable real-time analysis and enhancements, enhancing the viewer experience.

v) Security focus

As content production and distribution become more reliant on 5G networks, cybersecurity becomes paramount. Global trends emphasise the importance of robust security measures to protect content and data integrity. Implementing strict Digital Rights Management (DRM) measures enhances security, preventing unauthorised access and ensuring the safe handling of digital assets.

5.2.2 Post-production

Real-time remote post-production is the process of editing and completing audio or video projects with a team of professionals who are geographically dispersed. It involves leveraging technology and workflows to enable collaboration and communication as if all team members were in the same physical location. Real-time remote post-production is typically done as follows.

a) Network slicing

5G file-based post-production through a network slicing.

b) High-speed internet connection

A fast and reliable internet connection is essential for a real-time remote post-production. This can be a wired broadband connection, a dedicated fibre optic line, or a high-speed 5G mobile connection, which depends on the specific needs of the project and the remote locations of the team members.

c) Cloud-based collaboration tools

The cloud-based collaboration tools are video conferencing, collaborative editing software, and file sharing and storage, which explains as follows.

i) Video conferencing

The team use video conferencing platform for the communication which allows screen sharing, making it easier to discuss and demonstrate the edits.

ii) Collaborative editing software

Cloud-based editing tools provide accessibility to all team members, enabling simultaneous collaboration on the same project, with real-time updates reflecting changes made by editors.

iii) File sharing and storage

Cloud storage services and dedicated media asset management systems offer a centralised repository for project files, media assets, and deliverables.

d) Secure access control

Security is crucial, especially when working with sensitive post-production materials. Implement user access controls, encryption, and secure authentication methods to protect the integrity and confidentiality of the content.

e) Colour calibration

To ensure colour accuracy, colour calibration tools to align the colour profiles of different monitors are used by team members. This helps maintain consistent colour grading.

5.3 Cost optimisation and production efficiency

Cost optimisation represents a crucial advantage that content creators can achieve by adopting 5G technology in their content production workflows. These cost-related benefits play a significant role in enhancing the overall efficiency and sustainability of content creation.

5G technology contributes to cost-savings for content creators, as below.

a) Remote production efficiency

5G low latency and high-speed data transmission allow content creators to embrace remote production workflows. This reduces the need for extensive on-site crews and equipment, leading to significant cost reductions in travel, accommodation, and logistics.

b) Reduced transmission equipment costs

Content creators can optimise their equipment costs by using 5G-enabled devices and cameras, eliminating the need for expensive hardware specifically designed for content transmission. This simplifies equipment requirements and lowers capital expenditures.

c) Lower content delivery costs

5G enables more efficient content distribution, reducing the costs associated with traditional delivery methods. Content creators can benefit from faster and more cost-effective content uploads and distribution to various platforms and streaming services.

d) Optimised production time

The real-time collaboration facilitated by 5G reduces production time. Content creators can complete projects faster, saving on labour costs and streamlining the overall content production process.

e) Global collaboration

Content creators can collaborate with talent and teams from around the world without the need for physical presence. This eliminates travel expenses, accommodation costs, and visa-related expenses associated with international collaborations.

f) Real-time data analytics

Content creators can harness real-time data analytics provided by 5G to make decisions about content production and audience engagement. This minimises the risk of investing resources in less effective content strategies.

g) Scalability

5G infrastructure and workflows are scalable, allowing content creators to adapt to changing production demands efficiently. They can scale up or down as needed, optimising resource utilisation, and avoiding unnecessary costs.

6. 5G Broadcast for broadcast network operators

6.1 Background

Even though 5G Broadcast is a common nomenclature in the broadcasting industry, LTE-based 5G Terrestrial Broadcast is the technical naming of the underlying technology which is a broadcast system designed and standardised by 3GPP. As this broadcast system is part of the 3GPP family of standards, it can be fully integrated into 3GPP compliant devices and complemented by conventional mobile broadband data.

According to 4.5.4, 5G broadcast brings the following technical highlights.

a) SIM free mode of operation for ROM.

b) FTA reception requiring no uplink.

c) Flat architecture with simplified broadcast/multicast core and broadcast multicast RAN.

d) Designed to re-use the existing terrestrial broadcasting infrastructure e.g., HPHT, MPMT, and LPLT.

e) Intended to use the UHF spectrum or part thereof.

f) Can also be deployed in addition using Supplementary Downlink (SDL) bands coupled with an uplink channel.

g) Services that require authentication, including encrypted services.

h) SFN and/or dedicated broadcast networks using MFN.

i) Fixed reception with up to 100 km ISD.

j) Portable and mobile reception with up to 250 km/h.

k) Service providers can define the desired QoS.

l) Utilising standard APIs for easy design and integration in applications and devices.

By deploying the previously mentioned technical highlights, 5G BNOs get direct-to-mobile services.

6.2 5G Broadcast standards

6.2.1 Introduction

This clause focuses on the architecture, services, and core aspects of the 5G Broadcast standard.

The evolution until the end of 2023 for the 5G Broadcast standards are provided in Figure 8. The work in 3GPP since Release 14 is supported with work in the ITU to adopt 5G Broadcast as an official broadcast standard. Furthermore, ETSI JTC Broadcast and 5G-MAG jointly addressed the profiling of 3GPP specifications towards a stand-alone 3GPP-based broadcast standard with ETSI TS 103 720.

In June 2023, a version ETSI TS 103 720 was published addressing the following core functionalities.

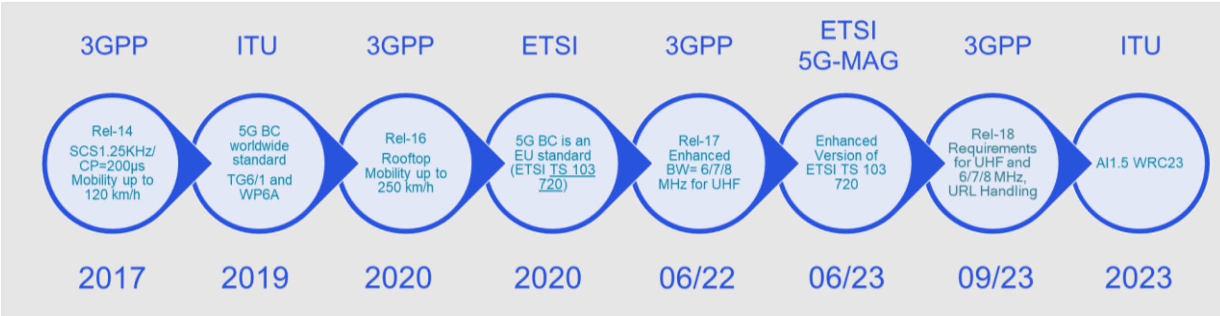
a) Bug fixes and clarifications from trials and Release 17.

b) Adding bandwidth information, including 6/7/8 MHz.

c) 5GMS, integrated unicast and broadcast.

d) Consistent codecs and formats.

e) Support of Public Warning System (PWS) and emergency alerts.



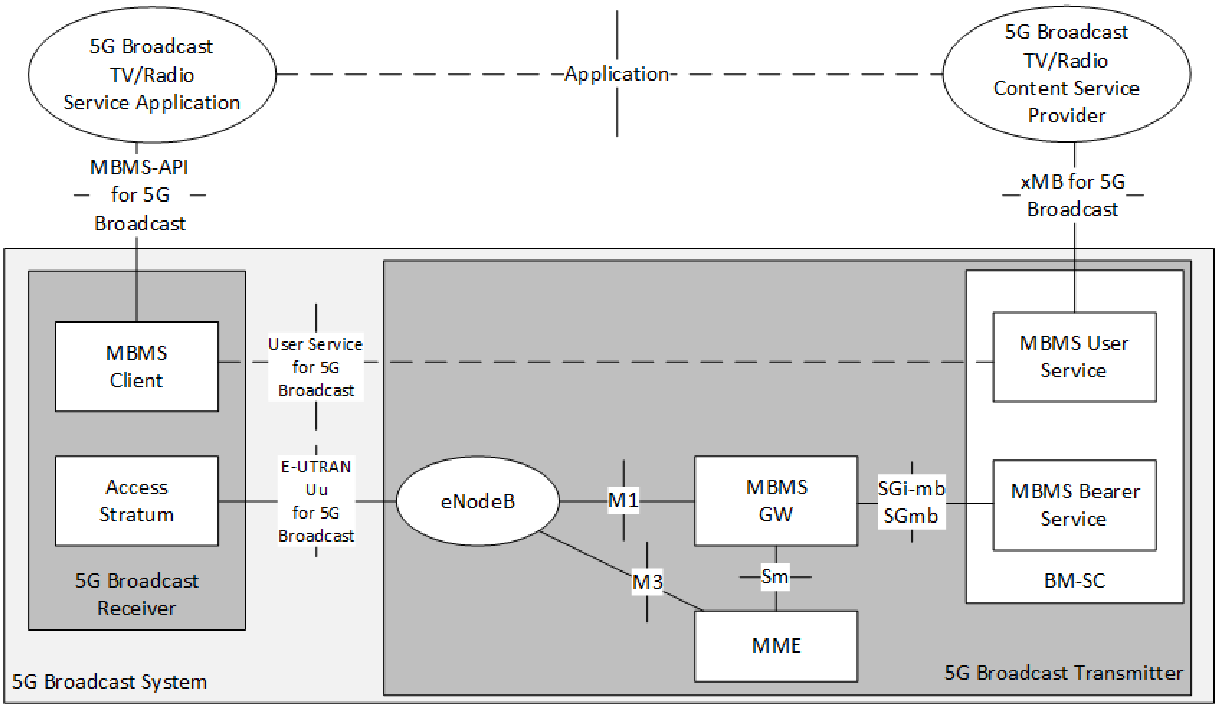
(source: Future TV+ For Everyone, Qualcomm)

Figure 8. 5G Broadcast standards evolution, towards World Radiocommunication Conferences (WRC) 2023

6.2.2 Reference architecture

Several 3GPP specifications have been extended or newly developed over several releases to address the use cases and requirements for 5G dedicated broadcast networks. ETSI TS 103 720 summarises the basic features of a 5G Broadcast System for the carriage of linear television and radio services, and documents these as an implementation profile of a subset of 3GPP specifications. The LTE-based 5G Broadcast System is an instantiation of a 5G Broadcast System addressing the basic features that is based on a profile of 3GPP specifications available in Release 16, with extensions provided in Release 17 and Release 18.

Figure 9 depicts the reference architecture for the LTE-based 5G Broadcast system as defined in ETSI TS 103 720.



(source: ETSI TS 103 720)

Figure 9. Reference architecture for 5G Broadcast System for linear TV and radio services with LTE-based 5G Broadcast instantiation

According to Figure 9, the reference points and protocols for the LTE-based 5G Broadcast System instantiation are as follows.

a) For the northbound network API for 5G Broadcast, a profile of xMB (extended MBMS interface) (the name of the northbound interface between the BM-SC and the content provider) as defined in 3GPP TS 26.348 and 3GPP TS 29.116 is defined in 5.5.2 of ETSI TS 103 720.

b) For the user service for 5G Broadcast, a profile of the MBMS user service as defined in 3GPP TS 26 346 is specified in 5.5.3 of ETSI TS 103 720.

c) For the RAN for 5G Broadcast, a profile of Evolved Universal Terrestrial Radio Access Network (E-UTRAN) as defined in 3GPP TS 36.300, 3GPP TS 36.211 and 3GPP TS 36.331 is specified in 5.5.4 of ETSI TS 103 720.

d) For the client API for 5G Broadcast, a profile of the MBMS-API as defined in 3GPP TS 26 347 is specified in 5.5.5 of ETSI TS 103 720.

The core network is a central part of the 5G infrastructure that handles tasks such as authentication, data routing, and connection management. It is responsible for routing broadcast content and interactive data to and from the appropriate devices.

As depicted in Figure 9, the followings are the core network function elements required for LTE-based 5G broadcast.

a) Mobility Management Entity (MME)

Serving the main control plane on mobility and session management.

b) MBMS gateway

Handling the multicast or broadcast traffics by forwarding to eNB and managing MBMS session control via MME.

c) Broadcast-Multicast Service Centre (BM-SC)

Provisioning MBMS user service and delivery and responsible for areas such as group membership, content collection, QoS management, announcement of multicast/broadcast sessions and security.

6.2.3 5G Broadcast services

According to 5.3.2 of ETSI TS 103 720, the following types of 5G Broadcast service are defined.

a) 5G Broadcast Service Announcement

A 5G Broadcast service that provides service announcement and originates in the BM-SC (or in the 5G Broadcast transmitter) and terminates in the MBMS client (or in the 5G Broadcast receiver).

b) 5G Broadcast User Service

A 5G Broadcast service that provides user data, for example a linear television or radio service. The user service originates in the content provider and terminates in the application. Based on the delivery modes available for MBMS user services, the following user service types are defined in the present standard.

i) User Datagram Protocol (UDP) Proxy, supported by the transport-only proxy delivery mode.

ii) IP Packet Routing, supported by the Transport-only Forward-only Delivery Mode.

iii) File delivery, supported by the download delivery mode and non-real-time file delivery in order to distribute files on a scheduled basis or in carousels.

iv) Segment streaming, supported by the download delivery mode and real-time segment delivery in order to distribute segment streaming services such as DASH, HLS, and hybrid DASH and HLS.

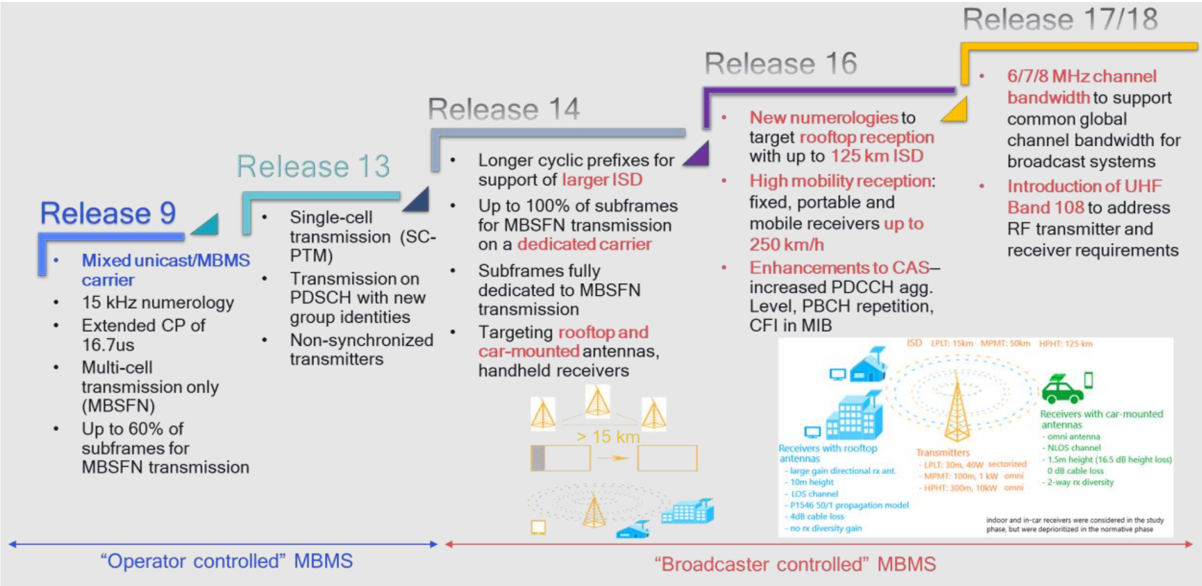
For service discovery, details are provided in 5.12 of ETSI TS 103 720. For discovering all available 5G Broadcast services, a 5G Broadcast receiver identifies all PLMNs that carry 5G Broadcast services. Then, for each identified PLMN carrying at least one 5G Broadcast Service, a 5G Broadcast Receiver finds the 5G Broadcast SA services in the range of associated Temporary Mobile Group Identities (TMGI) as defined in clause 5.11.2 of ETSI TS 103 720. Finally, for each service announced in the 5G Broadcast SA service a 5G Broadcast receiver finds the 5G Broadcast user services in the range of associated TMGI as defined in 5.11.3 of ETSI TS 103 720 based on the received service announcement.

5G Broadcast Services impose no requirements on the support of a unicast connection. However, a UE may choose to support unicast in addition to 5G Broadcast Services as introduced in clause 9 of ETSI TS 103 720. This permits hybrid broadcast service operation. According to ETSI TS 103 720, the 5G Broadcast TV or Radio application itself makes use of unicast to provide an improved service. Examples for this may be in the context of Hybrid broadcast broadband TV (HbbTV) or DVB-I service information.

This may, for example, include an Electronic Program Guide (EPG) or an Electronic Service Guide (ESG).

6.2.4 RAN functionalities

As mentioned, 5G Broadcast is built on as an evolution from Release 9 eMBMS, a technology built for operators as shown in Figure 10. Over several releases, additional functionalities were added addressing the requirements defined by the Broadcasters as part of their engagement in 3GPP, in particular from Release 14 onwards.



(source: Rode & Schwarz)

Figure 10. Radio Access Network evolution from MBMS to 5G Broadcast

For RAN, in Release 14, in order to address the features:

a) Network dedicated to TV broadcast via eMBMS.

b) SFN deployments with ISD significantly larger than those associated with typical cellular deployments.

c) Support for ROM services and devices.

The following key RAN enhancements were made to the specifications to enable LTE terrestrial broadcast.

a) MBMS-dedicated cell in 3GPP TS 36.300.

b) Multicast-Broadcast Single-Frequency Network (MBSFN) subframes using Df = 1.25 kHz in 3GPP TS 36.211, with a cyclic prefix duration of 200 µs and a symbol duration of 1 ms.

c) New information blocks on Physical Broadcast Channel (PBCH) and Physical Downlink Shared Channel (PDSCH) of Conditional Access Systems (CAS) (see 3GPP TS 36.300 and 3GPP TS 36.331).

d) MIB-MBMS is transmitted with a 40 ms periodicity and updated every 160 ms; and

e) SIB1-MBMS is transmitted with an 80 ms periodicity and updated every 160 ms, containing information relevant for receiving MBMS service and, optionally, the scheduling of other system information blocks.

f) MBMS Interest Indication RRC signalling procedure.

In Release 16, a gap analysis was carried out and documented in ETSI TR 136 976 that compared the Release 14 LTE terrestrial broadcasting capabilities (i.e., what is specified by the "enTV" work item) with the requirements for 5G dedicated broadcast networks in 9.1 of ETSI TR 138 913C As a result of this analysis, the following two requirements were deemed unfulfilled by Release 14 LTE eMBMS, as follows.

a) Support for service over large geographic area, including SFN with ISD > 100 km for fixed reception.

b) Support for mobility scenarios including speeds of up to 250 km/h for high velocity (e.g. high-speed trains)

The first requirement is associated with receivers with high-gain rooftop directional antennas, low mobility and a predominantly line-of-sight channel. The second requirement is associated with receivers in moving vehicles, with external omni-directional antennas.

Based on this, in Release 16 the following RAN enhancements were made to address the use cases described in Clause 3.2:

a) MBSFN subframes using Df = 0.37 kHz, with a cyclic prefix duration of 300 µs and a symbol duration of 3 ms, for the support of large ISD.

b) MBSFN subframes using Df = 2.5 kHz, with a cyclic prefix duration of 100 µs and a symbol duration of 0.5 ms, for the support of high mobility.

c) The following enhancements on the CAS:

    i) Physical Downlink Control Channel (PDCCH) enhancements: CFI indication in MIB 3GPP TS 36 331 to avoid the need to decode Physical Control Format Indicator Channel (PCFICH); and new aggregation level 16.

    ii) Repetition of PBCH to increase its robustness.

As part of Release 17, the following RAN enhancement was introduced to enable deployment in broadcast UHF spectrum, where the channelisation is 6/7/8 MHz (depending on regional channel spacing), Physical Multicast Channel (PMCH) bandwidth of 30, 35 and 40 Physical Resource Block (PRB)s (corresponding to 6/7/8 MHz), applicable for CAS bandwidth of 15 or 25 PRBs (corresponding to 3 and 5 MHz).

In Release 18, the support of the full UHF Band 108 was enabled. In September 2023, 3GPP formally published the technical specs for 5G Broadcast in version 18.3.0 of the specs for ETSI TS 36.101 (Evolved Universal Terrestrial Radio Access, or E-UTRA). The updated specs show approval for LTE based 5G terrestrial broadcast to operate in a new 108 band (470MHz - 694MHz).[4]

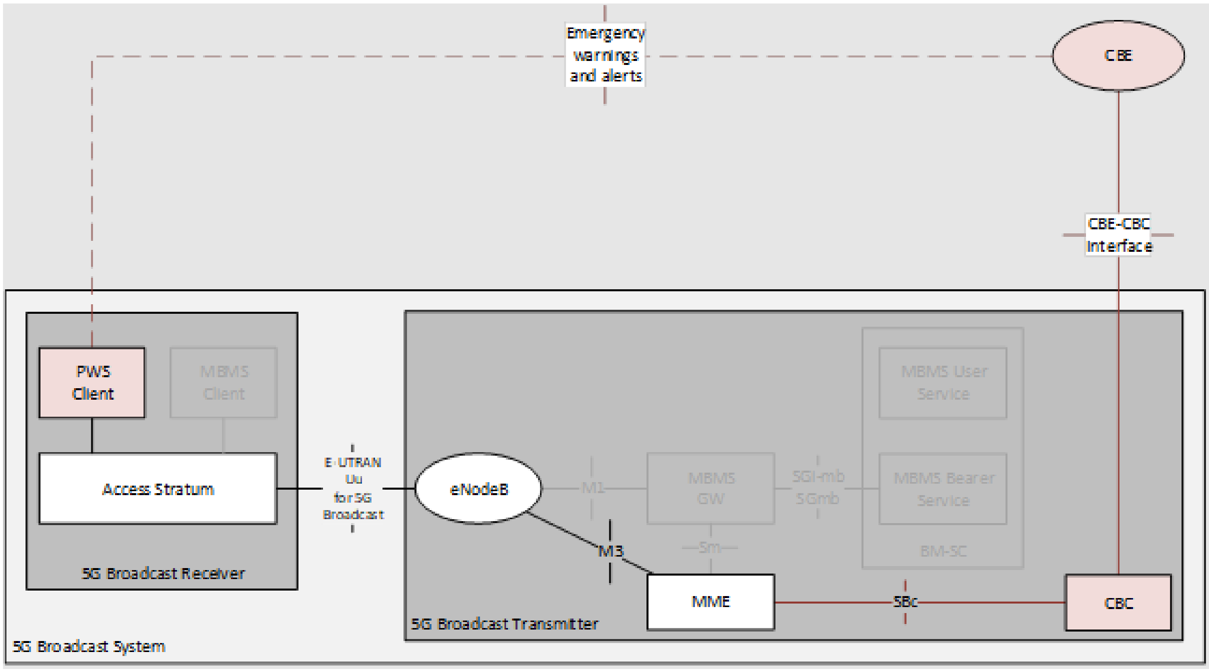
[4] https://www.mcmc.gov.my/skmmgovmy/media/General/pdf/SRSP-BS-DTT-470_Jan-2023.pdf

6.2.5 Public Warning System (PWS) over 5G Broadcast

ETSI TR 122 968 is the output of a 3GPP feasibility study for a PWS service capable of sending emergency alerts and public warning messages via the 5G System to a UE-hosted message reception function. The EMTEL specification ETSI TS 102 182, ETSI TR 102 444, requirements from Japan for ETWS and requirements from the USA for the Commercial Mobile Alert System (CMAS) were used as input. From this study, 3GPP specified its general requirements for the PWS in 3GPP TS 22.268. The Earthquake and Tsunami Warning System (ETWS), Wireless Emergency Alert (WEA) and CMAS, EU-Alert, and Korean Public Alert System (KPAS) are considered regional adaptations of the PWS service. Based on these requirements, relevant specifications in 3GPP have been created and updated to address these requirements, in particular the system specifications for the Cell Broadcast Service (CBS) 3GPP TS 23.041 and 3GPP TS 29.168 as well as the extension of several RAN specifications. Based on these specifications, for example ETSI published a specification that defines the system requirements for a European Public Warning Service using the Cell Broadcast Service in ETSI TS 102 900 as a means of message distribution and delivery to User Equipment (UE). Other regions in the world, such as the US, Korea and Japan have developed similar specifications based on the Cell Broadcast Service.

The CBS does not require authentication with a PLMN. Hence, a network that is accessible in ROM is inherently compatible with the Cell Broadcast Service as defined in 3GPP TS 23.041. This aspect is leveraged in the present document to support public warnings and emergency alerts in the 5G Broadcast System.

ETSI TS 103 720 extends the basic reference architecture in Figure 11, adding the Cell Broadcast Service to support the PWS. Figure 11 depicts the extended reference architecture for the LTE-based 5G Broadcast System including PWS. This architecture is a simplified version of the Evolved Packet System (EPS) architecture for E-UTRAN only, as defined in 3GPP TS 23.246 and considers the PWS architecture in E-UTRAN as defined in 3.3 of 3GPP TS 23.041.



(source: ETSI TS 103 720)

Figure 11. PWS supported by 5G Broadcast

For the PWS architecture in E-UTRAN, the following reference points are present in addition to those listed in 5.2 for the E-UTRAN MBMS Broadcast Mode only.

a) CBE-CBC: Between Cell Broadcast Entity (CBE) and Cell Broadcast Centre (CBC).

b) SBc: Between the CBC and the MME, as defined in 3GPP TS 29 116.

The scenario for 5G Broadcast based emergency alert is considered to provide a robustness and resiliency layer on top of MNO-based emergency alerts. Typically, it is assumed that MNO PLMNs distribute the same emergency alerts in a region where emergency alerts are also distributed through 5G Broadcast.

Nevertheless, there are different scenarios for which a UE with an integrated 5G Broadcast Receiver may receive PWS warning messages from the 5G Broadcast network and not from the MNO PLMN.

In one scenario, the UE consumes a service from a 5G Broadcast network. By this, the UE is already receiving system information and data in the broadcast carrier. In case of an emergency alert received through the Cell Broadcast Entities - BCC (CBE-CBC) interface, the CBC in the 5G Broadcast network triggers a system information update, generates a CMAS notification and starts scheduling and sending System Information Block 12 (SIB12) messages. The UE decodes the SIB12 messages and processes the CMAS message.

In a second scenario, the UE does not consume a service from a 5G Broadcast network but at the same time no other network than the 5G Broadcast network is available. Reasons for such a scenario may be that:

a) the UE is in a remote area outside of coverage of any regular PLMN;

b) due to a disaster the cellular infrastructure is not working and no regular PLMN is accessible; or

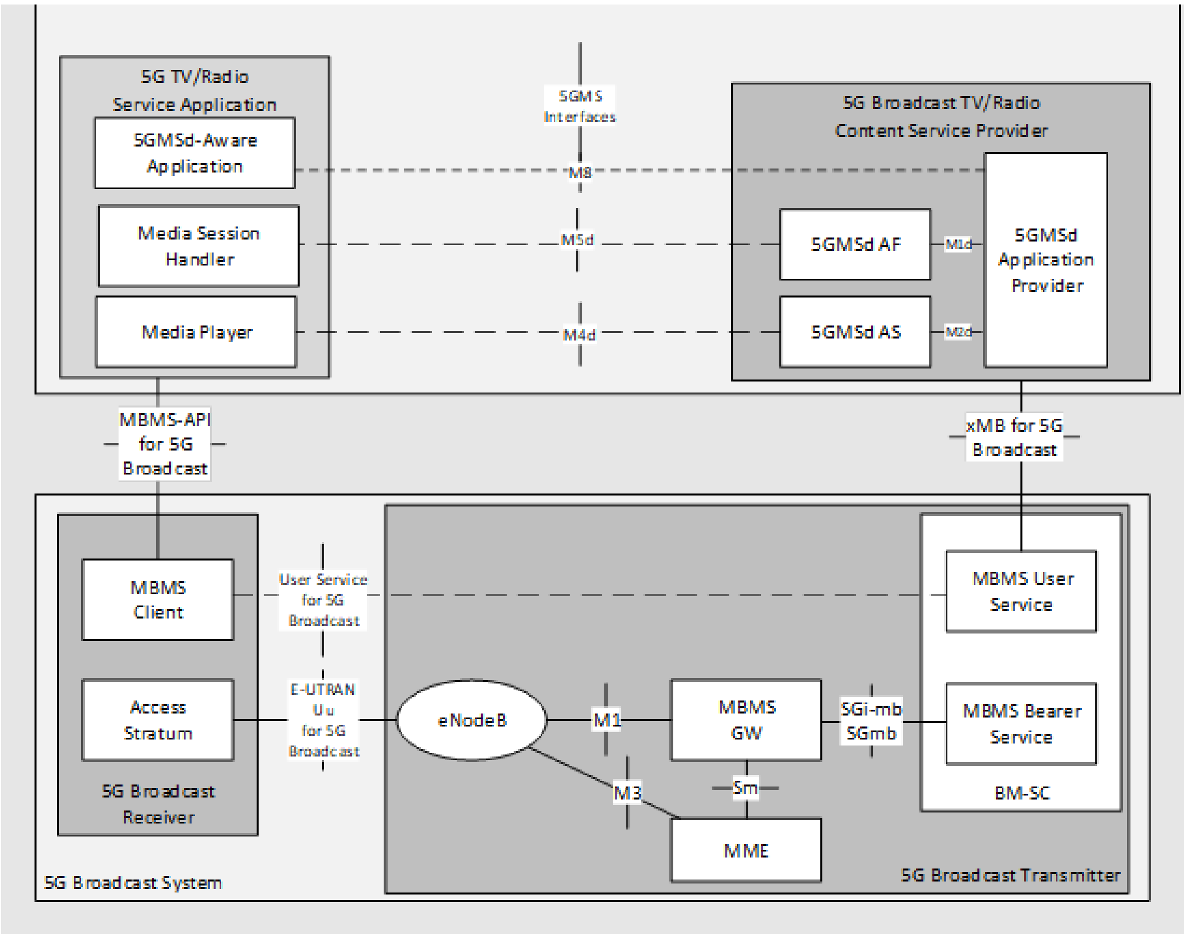
c) the device does not support any regular MNO PLMN, but only supports 5G Broadcast reception.

In this case, the UE is expected to process at least System Information Block Type 1 (SIB1) and SIB12 messages received from the 5G Broadcast network and to monitor paging and/or SIB1 to detect scheduling of SIB12 messages containing CMAS warning messages.

6.2.6 Combinations with IP-based Applications and Service Layers - Hybrid Services

While 5G Broadcast allows deployments independent of the availability of unicast (which may be a necessity in some areas, or in some situations), generally the full benefit comes from the combination and integration with existing unicast applications and existing TV Service layers. From a standards perspective this is addressed in several activities.

5GMS on top of LTE-based 5G Broadcast using MBMS User services was completed in Release 17 by updating 3GPP TS 26.501. The harmonised architecture is shown in Figure 12. This arrangement allows 5GMS-based downlink MS to be deployed as an MBMS-aware Application on top of eMBMS as defined in 3GPP TS 23.246, ETSI TS 126 346, ETSI TS 26 347 and ETSI TS 26 348. Details on procedures and implementations are provided in ETSI TS 103 720.



(source: 3GPP TS 26.501)

Figure 12. Harmonised architecture for 5GMS over 5G Broadcast

As can be seen from the Figure 12, the 5GMS Media Player is served by a Media Server that is part of the MBMS Client and which acts as a proxy for the 5GMSd AS when media objects are transmitted via MBMS. The Media Session Handler acts as an MBMS-Aware Application and initiates service acquisition. In order to fully support this functionality, some of the reference points need extensions to fully support different scenarios.

5G promises the delivery of media services via different transport means. Examples provided in the paper are 5GMS, LTE-based 5G Broadcast or 5G MBS. This permits media services to be offered that use multiple delivery options simultaneously, referred to as hybrid services. A hybrid service is defined as a service that fulfils at least one of the following aspects.

a) The same service is available on different delivery systems, for example on multicast, on broadcast or on unicast.

b) A service available on one delivery system may be enhanced by additional resources available on a different delivery system.

c) The service includes sufficient information such that a client can synchronise or seamlessly replace the content acquired from one delivery system with that from another.

In Release 17, as an add-on to support 5GMS over eMBMS as introduced several use cases and scenarios for hybrid services are identified and supported as follows.

a) Usage of 5GMS consumption reporting and metrics reporting for delivery of 5GMS content via eMBMS.

b) 5GMS session continuity when multicast or broadcast service is temporarily unavailable, for example when the UE is out of broadcast coverage and creating an experience that is transparent to the 5GMS-Aware Application.

c) To support time-shifted viewing, the service is made available via both 5GMS and eMBMS delivery networks, but only one Representation of each Adaptation Set is provided via eMBMS. The content is retained by the 5GMS AS for a period of time to support time shifted access.

d) Enhanced service quality, for which the user experience is enhanced by additional unicast delivery components, which for example, through scalable or layered coding or equivalent means.

e) Targeted ad insertion, for which certain UEs that are in broadcast coverage receive a targeted advertisement via unicast replacing the main event for a short period of time.

f) For dynamic provisioning of 5GMS content delivery via eMBMS, the same content is distributed via eMBMS (for example using a broadcast network in receive-only mode) and via a 5GMS System. The resources of the broadcast system are statistically configured. eMBMS-based distribution may, for example, be used only for services in high demand, and the resources and quality of the service distributed through broadcast may be adjusted according to demand. Demand may be identified through 5GMS Consumption Reporting.

Release 17 specifications support such use cases, leveraging the basics from MBMS User services and combining with modern 5GMS.

The combination with unicast also for example allows to operate the distribution of content protected services. Typically, a common encryption format as defined in DASH or CMAF is used, and the licence acquisition is done via unicast. Once retrieved, the content distributed over broadcast is decrypted using the key.

6.2.7 DVB services via 5G Broadcast

The DVB Project is well known for specifying conformance profiles of codecs for use on digital broadcasting systems. The DVB-DASH specification in ETSI TS 103 285 additionally profiles MPEG-DASH segment-based packaging to support Adaptive Bit Rate streaming over HTTP with a high degree of compatibility. DVB-MABR builds on this, specifying how linear DVB-DASH services can be carried simultaneously to large audiences using multicast packet replication in IP routers.

DVB-I service discovery as in ETSI TS 103 766 specifies the means to describe and discover both broadcast- and IP-delivered instances of linear services by means of a common XML metadata format. It also profiles the XML-based TV-Anytime metadata description in order to provide a content guide for these services as well as related on-demand content.

In order to address the delivery of DVB services via 5G Broadcast and other DVB delivery methods, the DVB Project convened a task force of experts to collect more detailed use cases and commercial requirements for DVB-I over 5G and produced Bluebook DVB Document C100, July 2021 providing the description of key use cases to realise on the following.

a) DVB-I services over 5G Broadcast and unicast.

b) Standalone DVB-I Service using 5G Broadcast.

c) DVB-I Service using 5GMS.

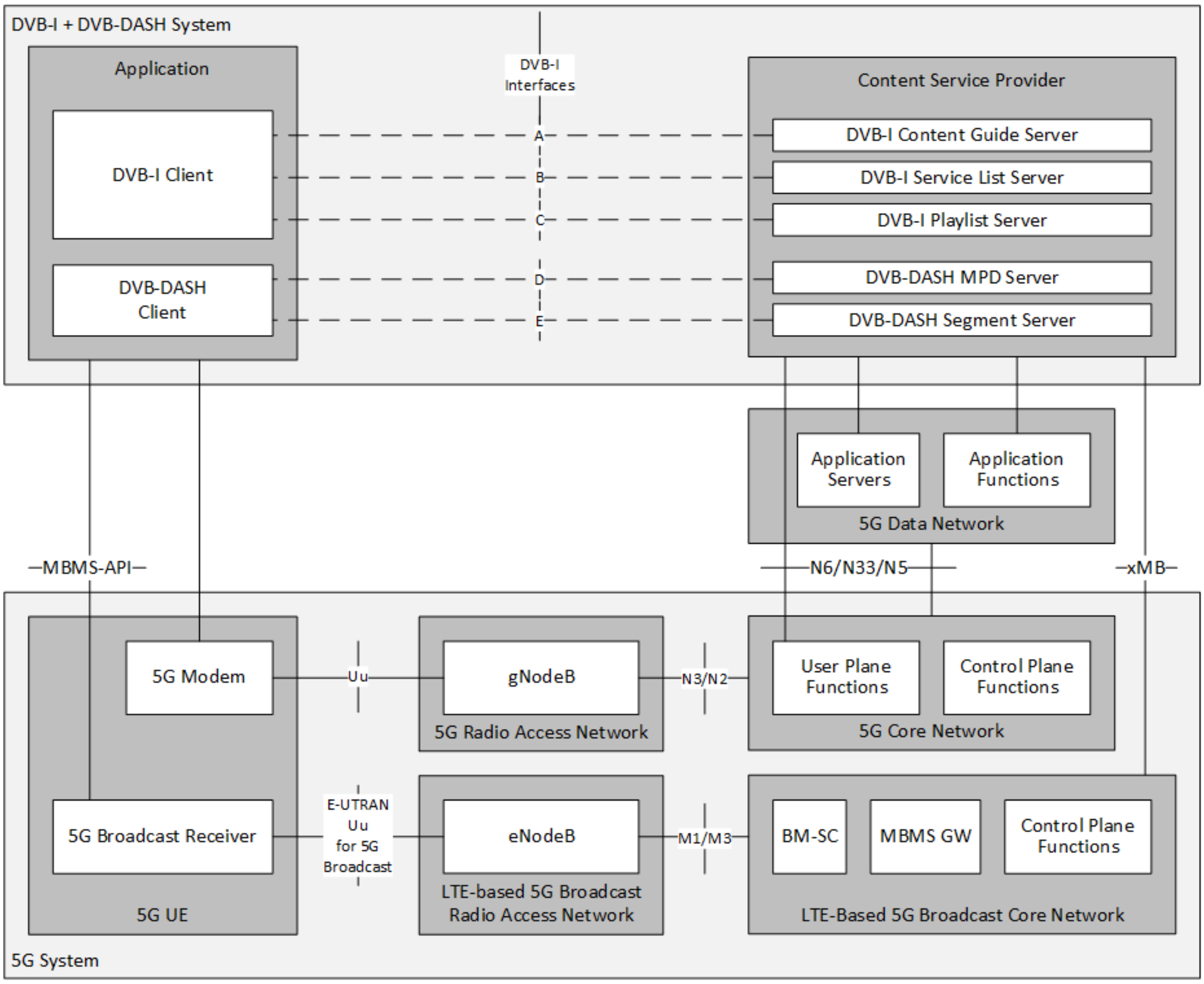
d) DVB-I services offering simultaneously over broadcast and unicast.

From the commercial requirements it was obvious that more detailed technical evaluation was needed before embarking on specification work in 3GPP. This is why 5G-MAG had gained significant experience in the implementation of 5G-based technologies as part of the 5G-MAG Reference Tools initiative. It was an obvious partner for DVB to collaborate with as a proxy for 3GPP on the development of a technical analysis and deployment guidelines.

To that end, a Joint Task Force was created in 2022 by DVB and 5G-MAG to carry out this work and it was quickly agreed to produce a joint technical report providing deployment guidelines for delivering DVB-I services over 5G, initially addressing the three most relevant commercial use cases identified above as guiding scenarios.

The Joint Task Force produced a technical report in ETSI TR 103 799 including a DVB-I over 5G Reference architecture to support all service scenarios and requirements. The architecture references existing architecture specifications and leverages standard interfaces.

Figure 13 illustrates the principal system approach for running DVB-I services over 5G Systems. The approach is to leverage existing and well-defined interfaces, reference points, and APIs as defined in DVB as well as 5G to connect and establish the services.



(source: ETSI TR 103 972)

Figure 13. DVB-I over 5G reference architecture

From Figure 13, DVB-I and DVB-DASH system comprises an application running on a 5G-connected device (left) and the Content Service Provider's back-end servers in the network (right) that support the Application. The Application includes a DVB-I Client for discovering DVB-I services, and DVB-DASH Client for consuming DVB-I services. In general, case depicted in the Figure 13, the Application can consume DVB-DASH content via the 5G mobile broadband and/or from LTE-based 5G Broadcast. In the latter role, it acts as Broadcast TV or Radio Service application as defined in ETSI TS 103 720.
The client is connected via DVB-I logical interfaces to the Content Service Provider's DVB-I and DVB-DASH servers. The logical interfaces are carried over the 5G System which is depicted in the bottom part of the figure.

The DVB-I Client and DVB-DASH Client are connected via client APIs to the broadcast-capable 5G UE (i.e., 5G device). The UE interfaces to the 5GC network via 5G RAN and to LTE-based 5G Broadcast Core Network via LTE-Based 5G Broadcast Radio Access Network.

The Core Network functions interfaces towards the Content Service Provider's DVB-I and DVB-DASH servers via two reference points whose interfaces are defined by 3GPP.

a) xMB API for LTE-Based 5G Broadcast.

b) N6 for direct user plane IP Connectivity, or via Application Functions and Application Servers for 5GMS.

The 5GMS AF interfaces towards the 5G Core's Control Plane Functions (PCF and NEF) via reference points N33 and N5.

Based on the reference architecture, the technical report ETSI TS 103 799 details workflows for the following service scenarios identified in the Commercial Requirements:

a) DVB-I over 5G broadcast,

b) DVB-I over 3GPP 5GMS, and

c) DVB-I services offered simultaneously over broadcast and unicast.

Each of the workflows includes references to relevant specifications to assist implementation. Recommended configurations are documented. Gaps identified in existing specifications are documented as recommended changes to the relevant specifications under the control of DVB, 3GPP or ETSI, as appropriate.

An innovative step forward when using 5G-based delivery systems is the expected simple ability to operate and receive DVB-I Services over broadcast and unicast in parallel which also referred to as Hybrid Services. Based on the commercial requirements, the technical report details different flavours of unicast and broadcast mixed services exist. A subset of potential use cases is documented in more details in the following.

a) DVB-I via unicast and DVB-DASH via 5G Broadcast

DVB-I Service metadata is retrieved via unicast and DVB-DASH content is transmitted via 5G Broadcast. Such a setup would for example allow creating a DVB-I compatible service offering, but only popular channels are delivered over broadcast, whereas long-tail or on-demand channels are provided via unicast. It may also be the case that the content service is provisioned at the same time over 5G Broadcast and regular unicast, modelled as two different DVB-I service instances. Based on the capabilities of the device, the Application Client may decide to select one or the other service instance using information provided in the DVB-I service list.

b) Hybrid broadcast - unicast services with session continuity

The same DVB-DASH service may be available via both unicast and 5G Broadcast delivery networks, but only one Representation of each Adaptation Set in DVB-DASH is provided via 5G Broadcast. When the receiver is in 5G Broadcast reception, it consumes the broadcast content. When out of coverage, it uses unicast with DASH adaptive streaming. The technical report describes different options on handling this case, which namely as follows.

i) Unicast-broadcast switch it is managed by the 5G Broadcast receiver that proxies also unicast requests from the DVB-DASH client to the network.

ii) DVB-DASH client smartly selects the delivery network, possibly supported by information provided from the 5G Broadcast receiver.

iii) DVB-I client provides information on two equivalent and time-aligned service instances and transition between service instances is supported on DVB-I level.

c) Hybrid broadcast - unicast services for time-shifted viewing

The service is made available via both unicast and 5G Broadcast delivery networks. The content is retained on unicast for a period of time to support time shifted access. Hence, if content is consumed at the live edge, broadcast reception may be chosen, whereas in case of time-shifted viewing, the content is accessed via unicast.

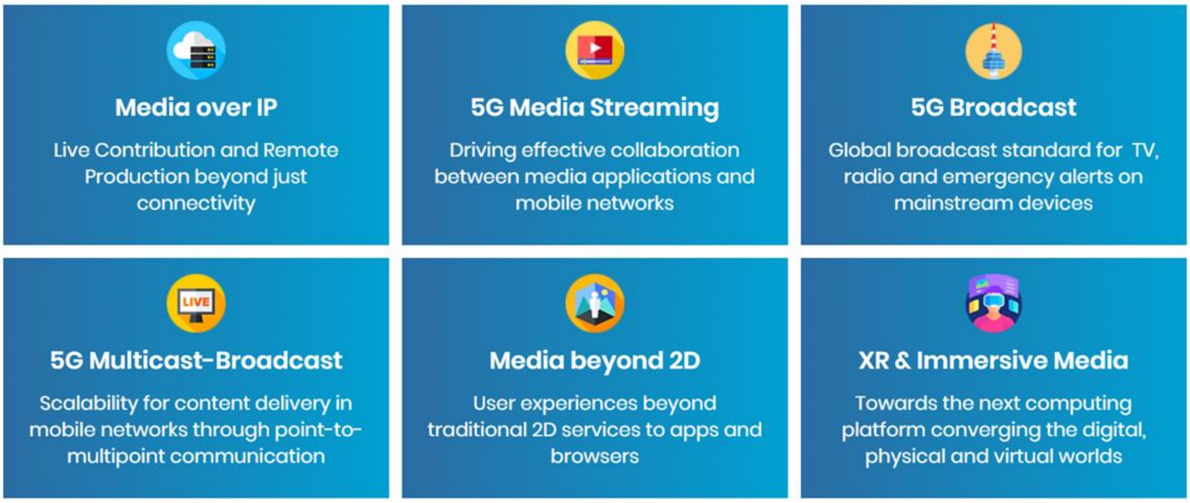
d) Hybrid broadcast - unicast services with content or component replacement

The service is made available via both unicast and 5G Broadcast delivery networks. However, some content components are only available via unicast, for example an alternative language, an enhanced video version in HDR, or a subtitle. In another case, two or more content alternatives may exist for a period of time, but only one alternative is provided over 5G Broadcast. This may for example address cases for which a common advertisement provided in the broadcast stream is replaced by a targeted ad received over unicast. Based on the selection of the client, the receiver collects the content from broadcast, if available or otherwise from unicast.

6.2.8 Reference Tools for 5G Broadcast

The 5G Media Action Group (5G-MAG) has recently been established as a Market Representation Partner (MRP) for 3GPP. In this role, 5G-MAG supports the transition from media companies' requirements into 3GPP as well as the transition of 3GPP technologies for use in new media services. In this context, 5G-MAG sponsors a program, open-source reference tools for multimedia applications to develop and maintain a set of reference tools supporting 5GMS and 5G Broadcast.

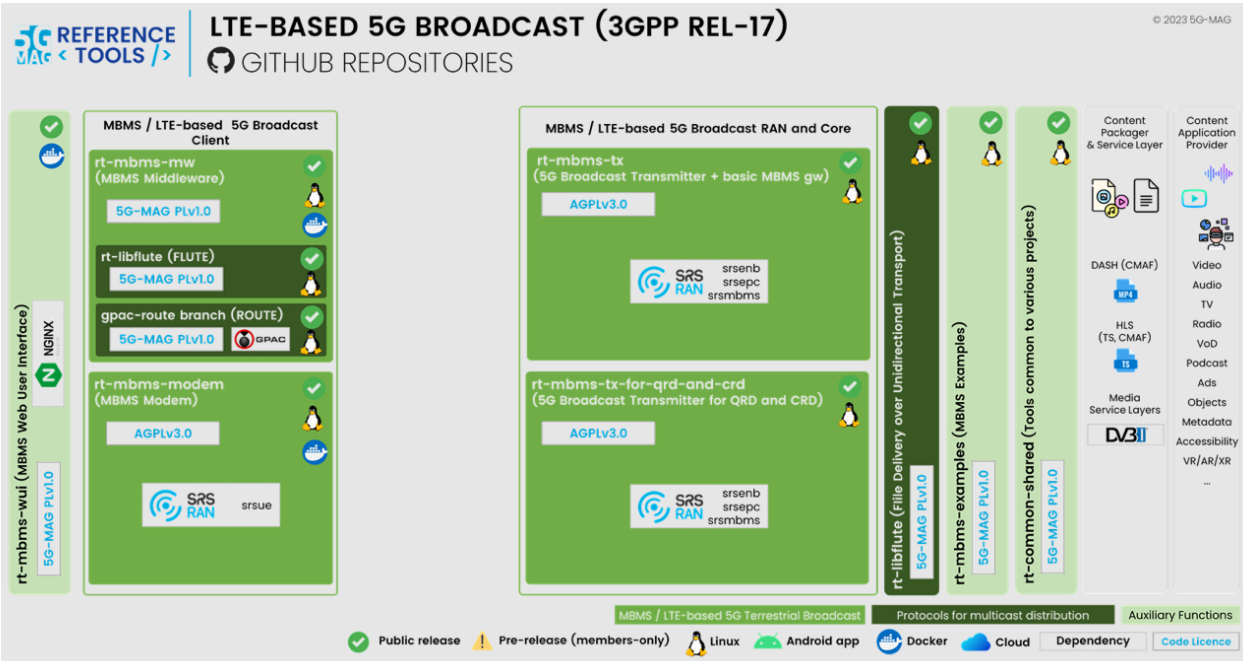
An overview of the currently established work topics is provided in Figure 14, including a 5G Broadcast workstream.



(source:5G-MAG)

Figure 14. Work topics in 5G-MAG

In particular, 5G-MAG provides a set of open-source tools for 5G Broadcast and 5GMS related topics. An overview is provided in Figure 15.



(source:5G-MAG)

Figure 15. Work topics in 5G-MAG

Selected repositories are provided below.

a) LTE-based 5G Broadcast Transmitter

b) MBMS Middleware

c) MBMS Modem

d) Web User Interface for MBMS Modem, Middleware & Application

e) MBMS Examples

6.3 Main benefits of 5G Broadcast

6.3.1 Summary

5G Broadcast is a broadcasting technology designed with hardware re-use of cellular modems in mind.

a) 5G Broadcast supports essential features required by broadcasters, including high-power deployments, operation without SIM card, UHF spectrum support (470MHz - 694MHz), and fixed reception support.

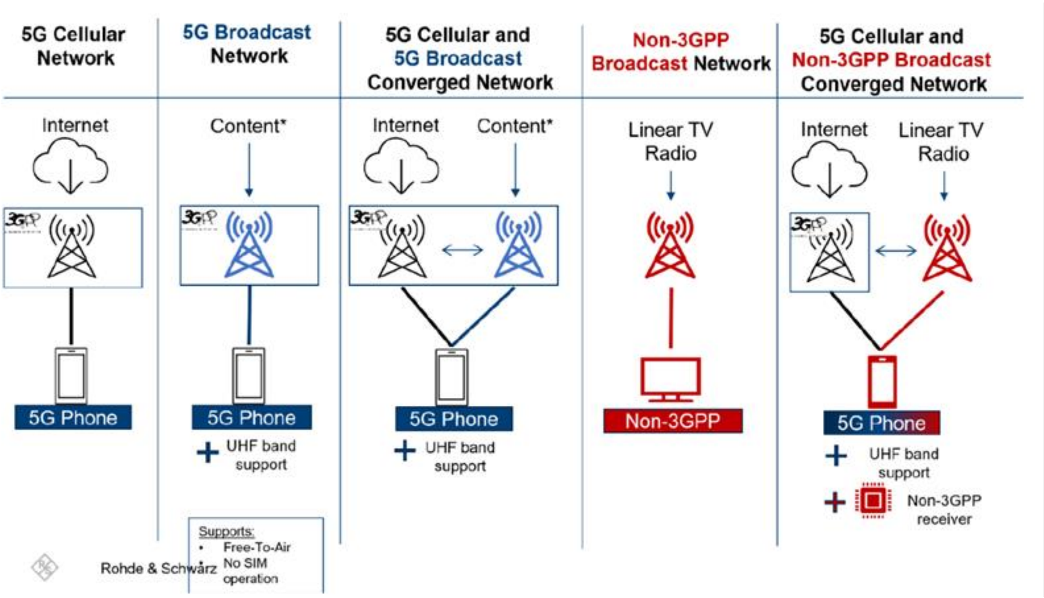
b) Integration with the 3GPP stack allows for advanced features such as emergency notifications, interactive broadcast, etc.

c) The 5G Broadcast system, apart from its ease of integration in handsets, inherits features of cellular systems such as support of multiple antennas, carrier aggregation, etc.

d) New band definition work already closed in 3GPP for Introducing 6/7/8MHz channel bandwidth and the full UHF for the exclusive deployment of 5G Broadcast under a new band 108 and a new type named Standalone Downlink-Only (SDO). This is a Release 18 independent WID.

e) 5G Broadcast system has seen continuous evolution during the last few releases and may be further enhanced if new use cases or requirements arise.

Figure 16 provides benefits of 5G Broadcast over traditional DTT systems.



(source: Rohde & Schwarz)

Figure 16. Benefit of 5G Broadcast over traditional DTT systems

6.3.2 For Television (TV) and radio broadcaster

The following main benefits for TV broadcasters are identified as follows.

a) Efficient content delivery

5G broadcast enables TV broadcasters to efficiently distribute high-quality video content to a large number of mobile users simultaneously. This is particularly beneficial for live events, sports broadcasts, and other time-sensitive live content that requires real-time delivery to a mass audience.

b) Improved scalability

Traditional TV broadcasting relies on one-to-many broadcast transmission. 5G broadcast's multicast capabilities allow broadcasters to reuse the traditional TV broadcast distribution model and transmit the same content to multiple users using the same amount of spectrum, ensuring consistent quality even during peak demand.

c) Enhanced quality and resolution

5G Broadcast can deliver a superior QoE as all viewers receive the same highest quality profile of content. Unicast streaming is subject to network congestion resulting in switching to lower quality profiles, buffering, and latency.

d) Personalised and interactive content

5G broadcast enables broadcasters to offer more personalised and interactive content experiences. Viewers could choose camera angles, access additional information, participate in polls, and interact with content in real time, creating a more engaging and immersive viewing experience.

e) Targeted advertising

5G broadcast allows for targeted and location-specific advertising for BNOs, which can increase the effectiveness of advertising campaigns and provide advertisers with better insights into their audience.

f) Lower distribution costs

Traditional TV broadcasting uses HPHT infrastructure for content distribution. With 5G broadcast, broadcasters can leverage existing broadcast infrastructure, reducing the need for additional transmission towers.

g) Faster content delivery

5G Broadcast's low latency and high data rates enable broadcasters to deliver content to viewers more quickly, reducing buffering and lag time, and ensuring a smoother and more enjoyable viewing experience.

h) Emergency alerts and public safety

5G broadcast could be crucial for broadcasting emergency alerts and public safety information to a wide audience, ensuring that critical information reaches viewers in a timely manner, even during network congestion.

i) Flexibility and agility

5G broadcast offers broadcasters more flexibility in terms of content scheduling and delivery. It is easier to adapt to any changes in programming or schedule adjustments, ensuring that viewers to receive the up-to-date content.

j) Content monetisation

The improved capabilities of 5G broadcast can open up new revenue streams for broadcasters. They can explore subscription-based models, pay-per-view options, or partnerships with content providers to offer premium content packages.

k) Global reach

Mobile nature of 5G broadcast allows broadcasters to reach viewers beyond traditional broadcasting coverage areas. This is especially beneficial for international events or content that needs to reach a global audience.

6.3.3 For Mobile Network Operator (MNO)

The following main benefits for MNO are identified as follows.

a) Efficient content delivery

5G broadcast enables MNOs to efficiently deliver popular content to multiple users simultaneously, reducing network congestion and providing a consistent quality of service. This is especially beneficial for high-demand events and live streaming.

b) Optimised spectrum usage

Through multicast technology, 5G broadcast allows MNOs to optimise spectrum usage by transmitting the same content to multiple users using the same frequency, freeing up network resources for other network activities.

c) Monetisation of broadcast services

MNOs can monetise their 5G broadcast capabilities by partnering with content providers to offer premium content packages, pay-per-view events, and other value-added services.

d) Enhanced QoE

5G broadcast’s ability to deliver high-quality content with low latency contributes to an improved quality of experience for users, increasing customer satisfaction, and loyalty.

e) Over-The-Air (OTA) Updates

5G broadcast can be utilised to efficiently deliver common data a large number of IoT devices and sensors over a wide area, supporting applications such as, software update and upgrade.

f) Stadium and event coverage

5G broadcast can enhance coverage and capacity during large events, such as sports games or concerts, where a high number of users congregate in a specific location.

g) New business model

Offering 5G broadcast services opens up new revenue streams for MNOs, such as charging content providers for access to their broadcast capabilities or collaborating on targeted advertising initiatives.

h) Innovative services

MNOs can explore innovative services that leverage 5G broadcast, such as immersive broadcast virtual reality experiences, interactive gaming events, and augmented reality applications.

i) Differentiation and market leadership

Implementing 5G broadcast can help MNOs differentiate themselves in the market by offering unique and compelling content delivery experiences that set them apart from competitors.

j) Wider reach

5G broadcast can extend the reach of MNOs beyond traditional cellular services, allowing them to deliver content and services to a global audience.

k) Network offloading

By using 5G broadcast for live broadcast content delivery, MNOs can offload data traffic from their regular data networks, freeing up capacity and reducing network congestion while enhancing their consumer's quality of experience.

6.3.4 For public

The following main benefits for the public are identified.

a) Enhanced content consumption

5G broadcast enables the public to enjoy high-quality content, such as live events, sports, and entertainment, with minimal buffering and lag. This leads to a more immersive and satisfying content consumption experience.

b) Improved access to information

Public alerts, emergency notifications, and critical information can be rapidly disseminated through 5G broadcast, ensuring that citizens are informed about important events and situations in real time.

c) Interactive and personalised experiences

With 5G broadcast, the public can engage with content interactively by participating in polls, choosing camera angles, and accessing supplementary information related to what they are watching or listening to.

d) Connected vehicles and transportation

The public can benefit from 5G broadcast's role in connected vehicles, receiving real-time traffic updates, navigation assistance, and safety alerts, leading to safer and more efficient transportation.

e) Distance learning and education

5G broadcast can enable high-quality remote learning experiences, offering students access to virtual classrooms, educational videos, and interactive content from anywhere.

f) Crisis communication

The public can receive timely information during crises, natural disasters, and emergencies, allowing them to make informed decisions to protect their safety and well-being.

g) Global access to events

5G Broadcast can help individuals around the world access and participate in international events, conferences, and cultural experiences in real time.

h) Personal safety applications

Wearable devices and personal safety applications can leverage 5G broadcast for sending alerts and location information to emergency responders or trusted contacts.

i) Access to uncovered areas

5G broadcast can help extend connectivity to rural and underserved areas where traditional broadband infrastructure is limited.

j) Global Positioning System (GPS)

The GPS is a network of satellites and receiving devices used to determine its location on earth.

6.4 5G Broadcast - business potentials and use cases

a) Content delivery and media

5G broadcast can provide an efficient way to deliver high-quality video and multimedia content to a large number of users simultaneously. This is particularly useful for live events, sports broadcasts, concerts, and other real-time content that requires high bandwidth and low latency to reach a mass audience.

b) Emergency alerts and public safety

5G broadcast can be used to disseminate emergency alerts, public safety information, and critical communications to a wide area quickly. This ensures that important information reaches the intended recipients without being affected by network congestion or individual device limitations.

c) Connected vehicles and transportation

5G broadcast can enhance communication in connected vehicle environments, enabling real-time updates on road conditions, traffic congestion, and other relevant information. This can contribute to improved road safety and traffic management.

d) Distance learning and remote education

5G broadcast can support remote education initiatives by delivering educational content, classes, and lectures to students in various locations simultaneously. This can help bridge the digital divide and provide equal educational opportunities.

e) VR and AR

High-quality VR and AR experiences often require large amounts of data to be transmitted in real time. 5G broadcast can enable immersive experiences by efficiently delivering content to multiple users without straining the network.

f) Stadiums and event venues

In crowded venues such as stadiums and event spaces, 5G broadcast can ensure that attendees have access to high-bandwidth content, such as live video feeds, instant replays, and interactive experiences, without overloading the cellular network.

g) Retail and advertising

Retailers can use 5G broadcast to deliver targeted advertisements, promotions, and product information to customers' devices in a specific geographic area, enhancing the shopping experience.

h) Tourism and hospitality

Tourist destinations and hotels can use 5G broadcast to provide tourists with multimedia guides, interactive maps, and other relevant information to enhance their experience while visiting.

i) Crisis communication

During crisis situations, such as natural disasters or public health emergencies, 5G broadcast can be instrumental in disseminating critical information to the affected population, that helping them in making the informed decisions.

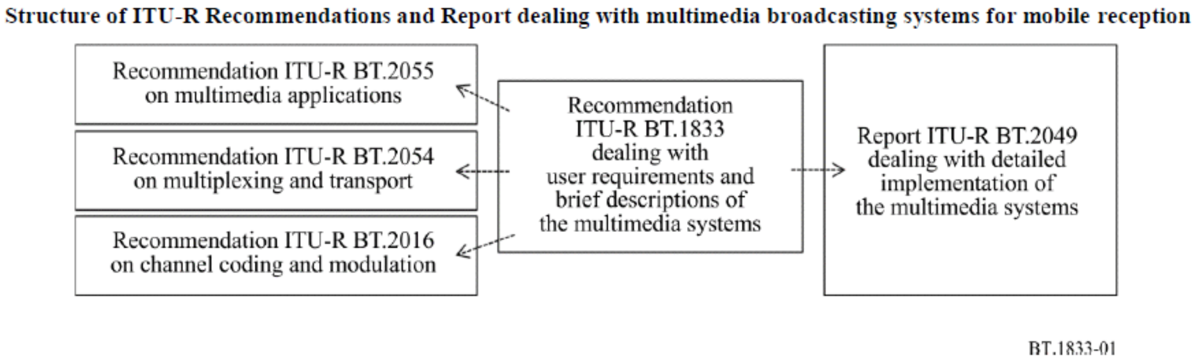
6.5 5G Broadcast - ITU regulatory environment

In addition to 3GPP as a main technology standardisation body, going through ITU-R was a necessity since 5G Broadcast is a new terrestrial broadcast standard. The latter is directly linked to existing broadcast UHF frequency bands, 470 - 694MHz.

For that, new studies started under ITU-R TG 6/1 and WP6A aiming at reaching a universal consensus in defining 5G Broadcast as a worldwide terrestrial broadcast standard while operating within UHF bands and coping with GE06 requirements.

After more than four years of extensive work and collaboration, ITU-R endorsed the designation of 5G Broadcast as a next generation terrestrial broadcast system, primarily addressing mobile and hand-held reception. As a results, the ITU-R recommendation has been published in 2023, which is the Recommendation ITU-R BT.1833-5 (05/2023), BT Series: Broadcasting service (TV), Broadcasting of multimedia and data applications for mobile reception by handheld receivers.

This Recommendation gives big-picture information on multimedia broadcasting systems for mobile reception. It describes the user requirements of multimedia broadcasting systems for mobile reception and overviews of each system. There are three other Recommendations and one Report related with this Recommendation. The structure of a suite of Recommendations and Report is shown in Figure 17.



(source: Recommendation ITU-R BT.1833-5)

Figure 17. 5G Broadcast - ITU regulatory environment

a) Recommendation ITU-R BT.2055

Content elements in multimedia broadcasting systems for mobile reception, deals with technologies for the application and presentation layers in multimedia broadcasting systems for mobile reception. It describes signal formats, source coding of audio, video, and other signals that constitute content. It also describes the technologies used for content navigation and interactivity.

b) Recommendation ITU-R BT.2054

Multiplexing and transport schemes in multimedia broadcasting systems for mobile reception, deals with technologies for the multiplexing and transport layers in multimedia broadcasting systems for mobile reception.

c) Recommendation ITU-R BT.2016

Error-correction, data framing, modulation, and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands, gives information on the channel coding and modulation layers in multimedia broadcasting systems for mobile reception.

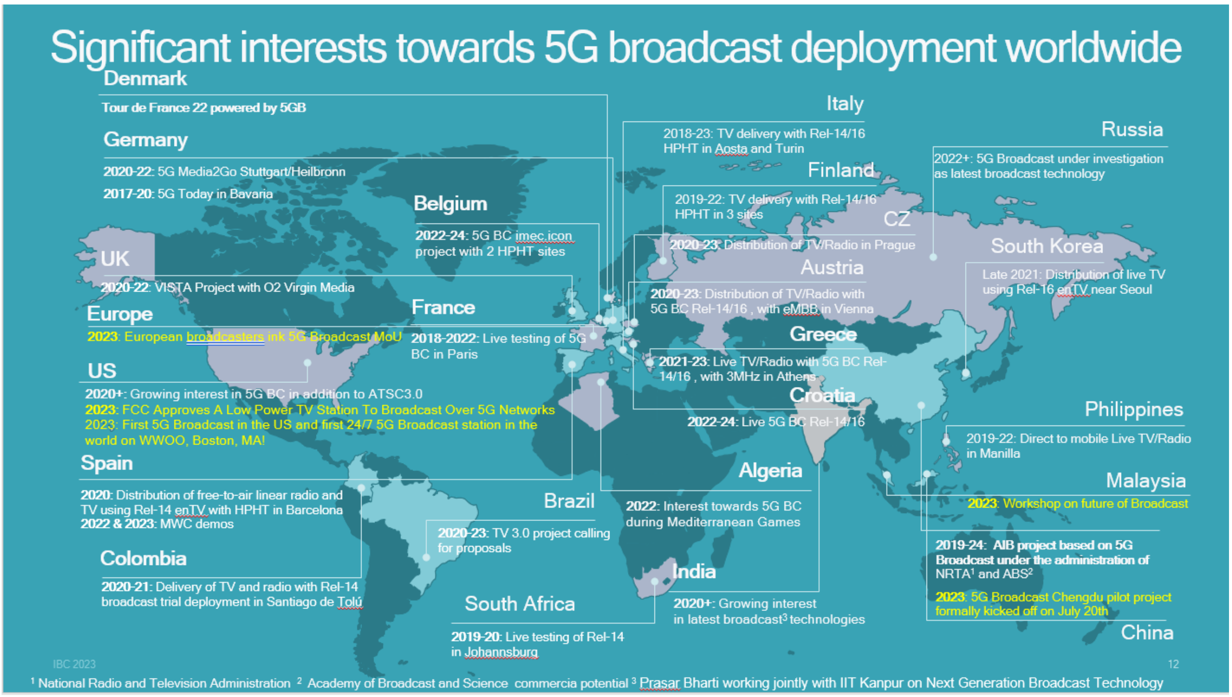
d) Report ITU-R BT.2049

Broadcasting of multimedia and data applications for mobile reception, gives detailed information on the implementation of multimedia broadcasting systems for mobile reception.

6.6 Worldwide 5G Broadcast activities

3GPP is the industry group responsible for defining global cellular technical standards. In the last few years 3GPP has expanded to new verticals (e.g., broadcast, automotive, satellite, etc.) hence it should not be regarded as a surprise that a broadcasting tech is coming out of 3GPP. What is ultimately important that 3GPP technologies are globally unified to support of the same technologies and features across the world and to enable economy of scale for a highly innovative and dynamic equipment and device market. Hence, 5G Broadcast is tested and trialled globally, in basically all regions of the word.

An overview is provided in Figure 18.



(source: Rohde & Schwarz)

Figure 18. Significant interests on global 5G Broadcast trials

6.7 Ecosystem readiness and trends

To plan a commercial deployment of 5G Broadcast, many elements need to be checked and proven. The first element is the business model which will be defined with a clear cash flow between the right stakeholders. As the economic model is the first element to start with, it is the most important one which will lead to the self-resolution of the other technological-oriented items. From an E2E network chain perspective, there is a need for encoding solutions, on top of the network infrastructure. In addition, consumer devices shall be widely available within the commercialisation timeline.

a) Network Equipment

The 5G Broadcast flat architecture is composed of a 5G Broadcast Core Network, 5G Broadcast RAN with three power classes, HPHT, MPMT, and LPLT and optionally, an orchestration layer for network automation.

b) Service integration and interoperability testing

Once a network planning is performed (e.g., for trial purposes) while the transmission sites are being ready, the 5G Broadcast Network core can be connected to one or multiple transmitters at the same time for SFN or MFN or both operations. Besides, the encoding solution should be placed before the core network, and the interoperability testing procedure may begin.

On the receiver side, a solution on end-to-end 5G Broadcast was tested in multiple trials that interoperable with Software Defined Radio (SDR) solution for 3GPP Release 14, 16, and 18.

For RF parameter testing purposes, there are a range of network drive testing solutions used in the trials such as SDR form TU Braunschweig, Kathrein Signal Analyser (KSA) and R&S® ROMES.

c) Example of test devices used

i) QRD based on the Snapdragon 8 Gen 1 initially, now Gen 2 (8450 / 8550).

ii) Modified (non-commercial) changes to enable a subset of 5G broadcast features. Qualcomm has also enabled 5G Broadcast trials on Commercial devices by applying some firmware upgrades to CRD.

iii) ENENSYS provide a cross-hardware platform middleware to support FeMBMS functionality on multiple semiconductor chipsets to enable 5G Broadcast support.

iv) Additional trial features are expected in the next release of QRD and CRD. Depending on spectrum allocation for 5G broadcast, current "Test Device" is available to operate in band 71 UHF.

d) Commercial devices

i) Commercial devices are not yet available or announced. However, 5G Broadcast was developed with the cellular modem architecture in mind. The new features added to the physical and higher layers were carefully designed to be compatible with the cellular modems that are in the smartphones today. To support reception from broadcast networks, such as HPHT downlink-only infrastructure and existing hardware in smartphones can be entirely reused. With this integration, typical commercial assessments before adding a new modem technology to a mainstream mobile chipset can be cut short or completely bypassed. For example, a detailed analysis of the technology in terms required area size, hardware availability, power consumption, integration with the applications and operating systems, global harmonisation, development timescales, co-existence and re-use of existing functions, testing and interoperability testing, and many more.

ii) Based on all these considerations, 5G Broadcast can be viewed as a modem feature. Like many other technology enhancements in 3GPP, 5G Broadcast reuses the basic building blocks of a cellular modem. Hence, many new opportunities may arise. For example, this could almost instantly expand the reach that broadcasters can have, in terms of access to the millions of 3GPP standards' compliant smartphones all over the world, which will be in people's pockets now and for the years to come.

iii) Conducting ongoing system trials and engaging in collaborative field trials to monitor standards development are crucial steps in preparing for commercialization. Persistent and intensified efforts establish a clear path toward commercialisation in the upcoming generations of mobile devices. Typically, from the time a commitment to a feature is completed, it takes an additional 2 to 3 years before a commercial device becomes available in the market.

6.8 Co-existence with existing DTT systems

5G Broadcast, as developed and specified as part of the general mobile communication technology of 3GPP, and per ITU-R Recommendations mentioned earlier, is a broadcast mode of operation that seems to be a promising candidate for finally allowing all Public Service Media (PSM) services, both linear and nonlinear, to reach smartphones and tablets.

Many PSM organisations around the world are considering 5G Broadcast (see Figure 18). However, prior to the adoption, a thorough study has to be conducted in order to fully understand the implications of such as decision. This refers to the potential and pitfalls of this new audio-visual distribution option in terms of technology, regulatory constraints, and business implications.

The EBU TR064 sheds some light on frequency planning of 5G Broadcast networks, including sharing and compatibility between 5G Broadcast and DTT in the spectrum range 470 – 694 MHz. The network planning aspects, including studies on coverage and capacity offered by different network topologies for 5G Broadcast are dealt with in a separate EBU Technical Report, TR 063.

The main findings of the studies carried out show that the use of coordinated yet unused GE06 DTT entries by 5G Broadcast seems to be the most practical way for early introduction of 5G Broadcast in the sub-700 MHz band. The compatibility between 5G Broadcast and DTT in this scenario, including at border areas between neighbouring countries, is manageable with mitigation measures and solutions currently applied to DTT networks. This might include filtering out 5G Broadcast frequencies in the DTT installations surrounding 5G Broadcast sites, when possible, and as needed. It might also include implementing additional constraints, such as Equivalent Isotropic Radiated Power (EIRP) reduction, polarisation, and antenna adjustments on 5G Broadcast sites, as needed.

7. 5G Media Streaming (5GMS) and MBS for MNO-based Media Distribution

7.1 Introduction and challenges

In contrast to 5G Broadcast as introduced in Clause 4 that targets the deployments for BNOs, Clause 7 reviews technologies defined in 3GPP that are targeted for MNO to support media distribution of third-party media service providers, including broadcasters providing their content to applications. Technologies introduced in this clause predominantly address collaboration models between BNOs and MNOs.

7.2 5G Media Streaming (5GMS)

7.2.1 Principles and architectures

5GMS is built on the idea of enabling third-party media distribution beyond the MNO and the 5G network acting not only as a bit pipe but to provide technical and commercial opportunities for collaboration. MNOs and content providers are generally highly interested in such collaboration models that permit monetising video traffic on 5G and sharing revenue. MNOs are also interested in addressing the dilemma of ever-growing demand for media consumption on their networks, which by 2026 50 % of mobile data will be on 5G and 77 % of this data will be video.

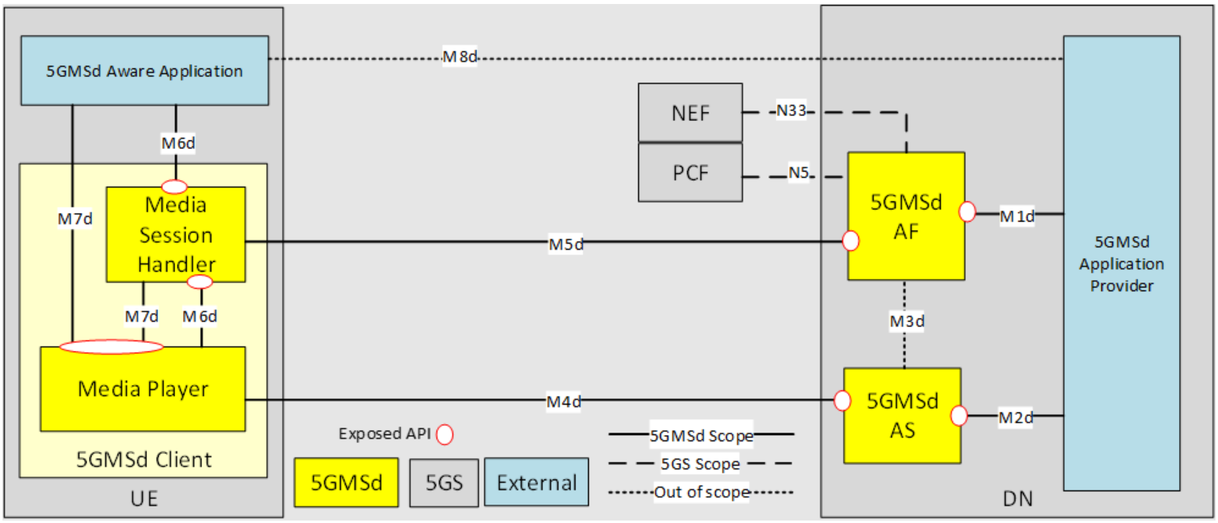
Challenges for pure OTT distribution includes the following.

a) QoE issues such as rebuffering and stall events, that are associated with the operator in the end user's mind.

b) Obscuring of traffic by end-to-end encryption.

c) Unidentified content eating into users' data caps.

d) The increasing demand for higher quality, new formats, new immersive and interactive experiences.

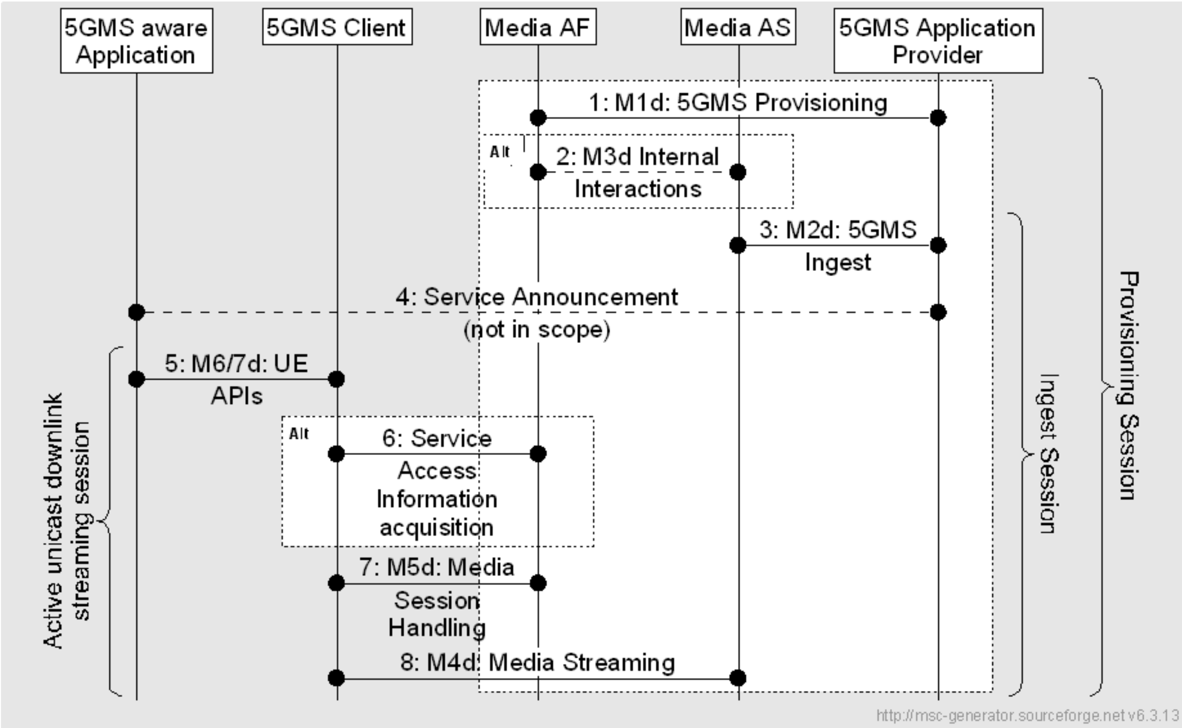


(*source: 3GPP TS 26 501*)

Figure 19. 5GMS downlink architecture

The approach taken for 5GMS is documented in 3GPP TS 26 501 is shown in Figure 19. The framework is aligned with modern OTT media distribution practices. The specifications support MNOs and third-party media services to easily access 5G System and 5GMS features. 5GMS as defined in 3GPP TS 26 501 which includes downlink and uplink streaming. However, only downlink streaming is considered.

The basic procedures are shown in Figure 20, provisioning, ingest, service announcement, and MS session along with media session handling. It should be noted that while step 4 is considered out of scope for 5GMS, it is expected that DVB-I (in the role of 5GMS-Aware Application) defines service announcement.



(Source: 3GPP TS 26.501)

Figure 20. 5GMS Downlink – Basic call flows

5GMS stage-3 specifications 3GPP TS 26.512 and 3GPP TS 26.511 provide an instantiation of 5GMS for one or a small subset of recommended technologies including codecs, formats, protocols, and other functionalities. These specifications are introduced below in 7.2.2.

7.2.2 5G Media Streaming (5GMS) protocols, APIs, and codecs

The interfaces and protocols that realise the 5GMS system are defined in 3GPP TS 26.512. The 5GMS AF manages a 5GMS system that deployed in the 5GC network of the MNO or in an external Data Network (DN). This logical function embodies the control plane aspects of the system, such as provisioning, configuration, and reporting with the following.

a) A 5GMS application provider provisions 5GMS functions using a RESTful HTTP-based provisioning interface at reference point M1.

b) Another RESTful HTTP-based configuration and reporting interface is exposed to UE-based 5GMS Clients at reference point M5.

The 5GMS AS, deployed in the 5GC or in an external data network, provides 5GMS services to 5GMS clients. This logical function embodies the data plane aspects of the 5GMS system that deals with media content of the following.

a) Content is ingested from 5GMS application providers at reference point M2. Both push and pull based ingest methods are supported, based on HTTP.

b) Content is distributed to 5GMS clients at reference point M4 (after possible manipulation by the 5GMS AS). Standard pull-based content retrieval protocols (e.g. DASH) are supported at this reference point.

A 5GMS client deployed in the UE consumes 5GMS services. The 3GPP specifications are silent on whether this logical function is realised as shared UE middleware components or provided piecemeal by individual applications of the following.

a) A media session handler subcomponent first retrieves its configuration (service access information) from the 5GMS AF at reference point M5 and then uses this configuration information to activate and exploit the currently provisioned 5GMS features. The 5GMS-Aware Application controls the media session handler via a UE-internal API defined at reference point M6. This reference point could be realised as a JavaScript API in a web browser.

b) A media player subcomponent consumes media from the 5GMS AS at reference point M4. The 5GMS-Aware Application controls the media player via a UE-internal API defined at reference point M7. This reference point could also be realised as a JavaScript API in a web browser.

5GMS also specifies the use of segment formats that are based on the CMAF in ISO/IEC 23000-19. By using this format, 5GMS is compatible with a broad set of segment-based streaming protocols including DASH and HLS. For example, ISO/IEC 23009-1 defines a detailed DASH profile for delivering CMAF content within a DASH media presentation using a converged format for segmented media content.

5GMS media profiles for video, audio, and subtitles based on the general constraints of ISO/IEC 23000-19 are defined in 3GPP TS 26.511. However, downlink 5GMS is not restricted to the media profiles defined in 3GPP TS 26.511. Any CMAF media profile, for example for codecs defined in DVB specifications, may be distributed within downlink 5GMS.

7.2.3 Deployment opportunities for 5G Media Streaming (5GMS)

5GMS permits value-added services. Examples are provided as follows.

a) CDN, where the MNO acts as the distributor.

b) Content-aware and device-aware streaming.

c) Premium QoS which is activating a QoS bearer or using a dedicated network slice with specific transport characteristics.

d) Standardised and extended (conditional) zero rating provides following policies.

   i) A: notify the player or client that throttling is applied.

   ii) B: instruct the player to not exceed certain bitrate policies.

e) Different charging policies.

f) Dynamic policies.

In order to support advanced 5GMS, different features are supported in the 3GPP specifications, as follows.

a) Content hosting.

b) Network assistance.

c) Consumption and metrics reporting.

d) Dynamic policies using either as below.

i) Service operation point as a network slice. The concept of Network Slice-as-a-Service (NsaaS) is defined in 3GPP TS 28 530.

ii) Service operation point as a QoS flow using flow description(s) of the transport session (see 3GPP TS 23 502).

e) 5GMS and edge.

f) Event exposure.

g) 5GMS via 5G broadcast and hybrid unicast broadcast.

7.3 5G MBS

7.3.1 Introduction

For introduction of 5G MBS, please refer to 4.5.5.

Note that MBS is a technology addressing support of mobile network operators to enhance their network operation. MBS is expected to operate fully within an MNO operation.

Key aspects for MBS are provided in Figure 21.

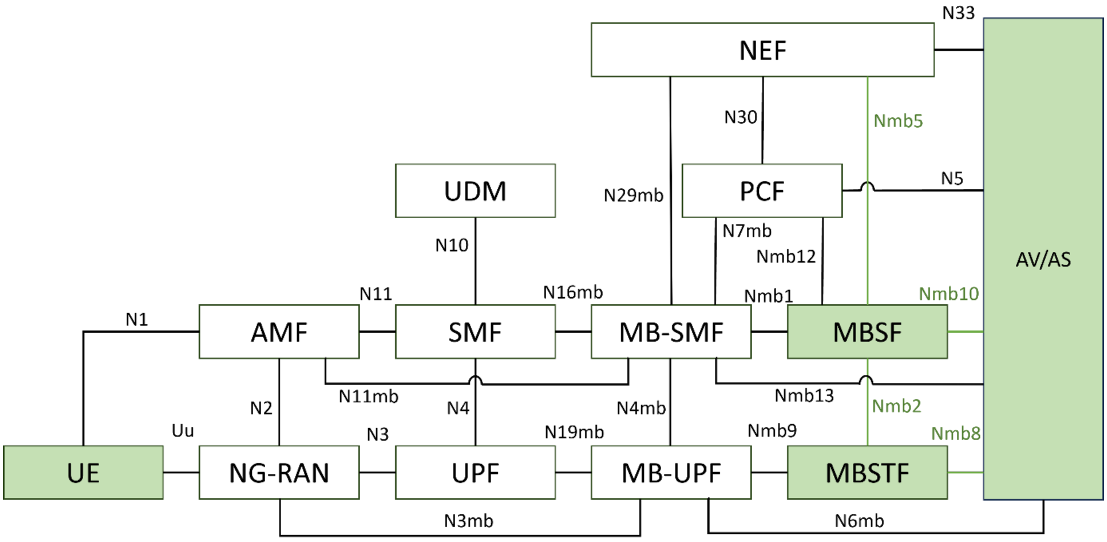
(source: 5G-MAG)

Figure 21. Key takeaways about the scope of 5G Multicast or Broadcast Services (MBS)

7.3.2 5G system architecture

5G system architecture for MBS leverages the unicast 5G system architecture wherever possible with the goal of having a better integrated offering of 5G unicast, multicast and broadcast services.

Figure 22 shows at high level the 5G system architecture impacts for 5G multicast and broadcast services. 5G MBS system architecture provides a fully separate MBS service layer, provided by new functions Multicast Broadcast Service Function (MBSF) which is a control plane service function and Multicast Broadcast Service Transport Function (MBSTF) which is a user plane service function, and MBS transport layer, provided by new core network functions MB-SMF (session management) and MB-UPF (user plane transport) and enhancement to existing 5G functions SMF, UPF, AMF, NG-RAN, NEF, PCF, and UE.



(source: 3GPP TS 26.502)

Figure 22. System architecture for 5G MBS

At the transport layer, the MB-SMF provides session management and control of MBS transport, including QoS determination, MBS session ID (TMGI) assignment, handling of UE join or leave procedures, as well as RAN and MB-UPF configuration of MBS data tunnelling. The MB-UPF is the user plane transport functionality for 5G MBS data, via shared tunnel or unicast delivery (e.g., to non-supporting RAN nodes). Individual delivery may be routed over unicast UPFs. The AMF transfers MBS signalling between MB-SMF and NG-RAN and manages paging procedures for Ues in multicast mode during service activation. The NG-RAN provides support of 5G MBS N3 shared tunnel, and Point-to-Multipoint (PTM) or Point-to-Point (PTP) delivery of MBS data.

At the MBS Service layer, when present, the MBSF provides control plane functionality to configure 5G MBS sessions, including interacting with the AF and the MB-SMF for MBS session operations, determination of transport parameters, and session transport, selection of MB-SMF to serve an MBS Session, control of MBSTF and determination of sender IP multicast address for the MBS session if IP multicast address is sourced by MBSTF. On the user plane, the MBSTF provides generic packet transport functionalities available to any IP multicast enabled application such as framing, multiple flows, packet Forward Error Correction (FEC) (encoding) and multicast or broadcast delivery of input files as objects or object flows. The MBSTF may act as the media anchor for MBS data traffic if needed and may provide sourcing of IP Multicast.

For Multicast service, the MBS service layer is optional, and an Application Function (AF) can request configuration and activation of a multicast session via Network Embedded FEC (NEF) in that case. For Broadcast service, MBSF, and MBSTF are required.

3GPP Release 17 introduces multicast or broadcast transmission in the physical layer. The main design principles are as follows.

a) One of the key principles adopted for the design of PTM transmission is to ensure that the specified techniques can be implemented at the UE without the need to incorporate additional hardware to minimise the changes on top of legacy processing blocks. Due to this principle, no new channels, including new subcarrier spacings or signals are introduced with respect to Release 16 NR. Note that this principle is different from the one followed in Release 9 MBMS, which required the introduction of new channels or signals and numerologies.

b) Another key aspect is flexible scheduling of unicast and multicast from the network perspective. One of the main drawbacks of LTE MBMS was that it required reserving some cell resources in a static way (MBSFN subframes), which were not able to be reused for unicast.

c) For NR multicast mode, flexible switching between PTM and PTP by the NG-RAN node is allowed even supporting a Hybrid Automatic Repeat Request (HARQ) retransmission by PTP of an initial packet delivered via PTM. This allows the network to dynamically adjust the usage of PTM depending on a variety of factors such as number of users, required reliability, and etc.

d) Due to the above design principles, NR MBS introduces light modifications in the physical layer, to reuse the current NR specifications as much as possible but enabling the use of multipoint transmissions.

Between 5GC and NG-RAN, there are two delivery methods to transmit the MBS data, which are as follows.

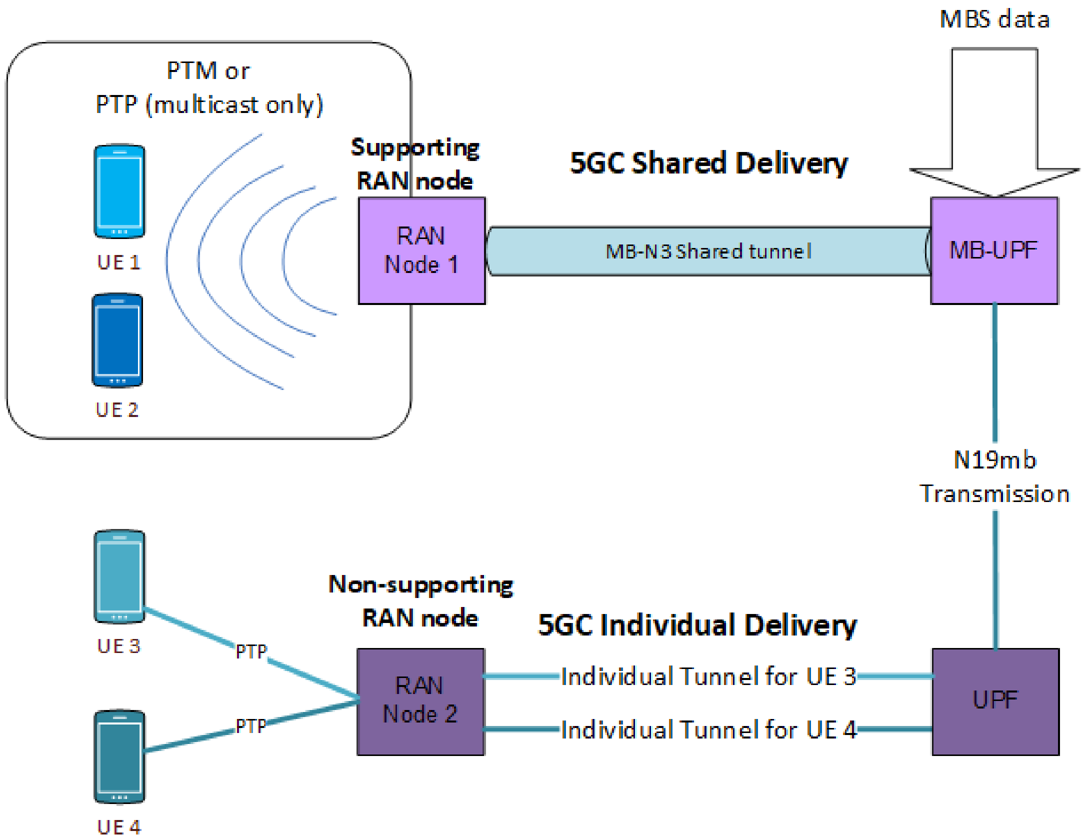
a) 5GC shared MBS traffic delivery method

This method may be applied to both broadcast and multicast MBS session. 5GC receives a single copy of MBS data packets and delivers to NG-RAN node. The packets will then be delivered to one or multiple Ues.

b) 5GC individual MBS traffic delivery method

This method is mostly intended for delivery of MBS data packets over RAN nodes that does not support MBS and is only applied for multicast MBS sessions. 5GC receives a single copy of MBS data packets and delivers separate copies of those MBS data packets to individual UEs via per-UE PDU sessions. Hence, each UE one PDU session is required to be associated with a multicast session.

Figure 23 depicts the high level the 5G diagram for 5GC shared MBS traffic delivery and 5GC individual MBS traffic delivery.



(source: 3GPP TS 26.502)

Figure 23. 5G MBS delivery model

The MB-UPF acts as the MBS Session Anchor of an MBS session, and if the MBSTF is involved in the MBS session, then the MBSTF acts as the media anchor of the MBS traffic. The MB-UPF receives only one copy of MBS data packets from the upstream source or MBSTF.

The user plane between MBSTF and MB-UPF, or between AF and MB-UPF (see Figure 22), may use either multicast transport or a unicast tunnel for the MBS session, depending on application and capabilities of control interface. If the transport network does not support multicast transport, the user plane uses a unicast tunnel for the MBS Session. The user plane between MBSTF and AF may use a unicast tunnel, multicast transport or other means (e.g., HTTP download from external CDN). Unicast is used for the MBS Session. After receiving the downlink MBS data, the MB-UPF forwards the downlink MBS data without the outer IP header and tunnel header information.

The user plane from the MB-UPF to NG-RAN(s) for shared delivery and the user plane from the MB-UPF to UPFs (for individual delivery) may use multicast transport via a common GTP-U tunnel per MBS session or use unicast transport via separate GTP-U tunnels at NG-RAN or at UPF per MBS session. If the user plane uses unicast transport, the transport layer destination is the IP address of the NG-RAN or UPF. Each NG-RAN or UPF allocates the tunnel separately and multiple GTP-U tunnels are used for the MBS Session. If the user plane uses multicast transport, a common GTP-U tunnel is used for both RAN and UPF nodes. The GTP-U tunnel is identified by a common tunnel ID and an IP multicast address as the transport layer destination, both assigned by 5GC.

7.3.3 User Service Architecture

The 5G MBS architecture as shown in Figure 22 not only includes new functions on radio and core network layers, but also on User Service layer. Similar to the design goals for 5GMS and the lower layers of 5G MBS, the 5G MBS User Service definition follows similar principles according to the findings in a feasibility study documented in 3GPP TR 26.802.

The resulting work item on the 5MBS User Service Architecture as documented in 3GPP TS 26.502.

a) Support of operator and third-party applications using 5G MBS for media distribution.

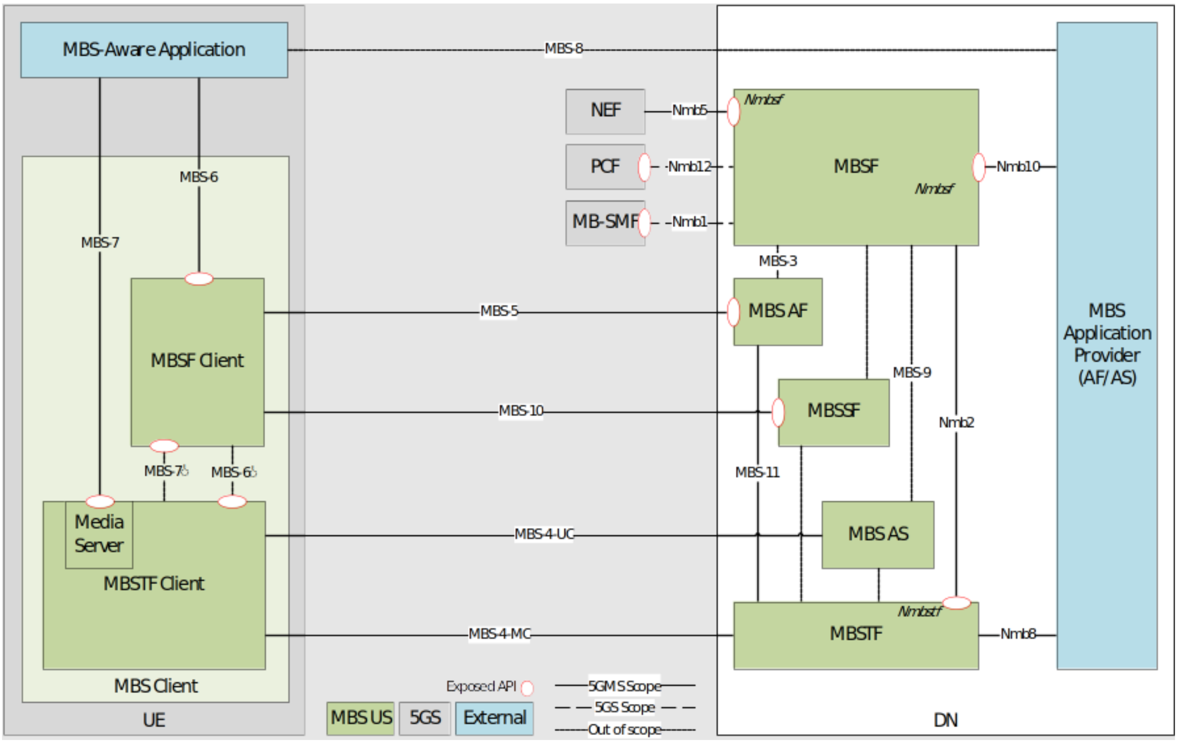
b) Separation of user and control plane functions.

c) Support of collaboration models between third-party content providers and MNOs offering a 5G MBS system.

d) Enable seamless and transparent delivery of existing 5GMS content via 5G MBS.

e) Re-use of existing and deployed MBMS user plane delivery services and data models but modernise the control and signalling.

For this purpose, an initial 5G MBS User service architecture is defined as shown in Figure 24. The architecture addresses the design goals in the following manner. An MBS Application Provider may communicate with the MBSF through reference point Nmb10 to establish a 5G MBS User Service. The MBSF deals with all internal logic and communicates with the 5G System to establish QoS and 5G MBS delivery. The MBSF also provisions MBSTF through reference point Nmb2 in order to accept user plane data from the Application provider and to deliver it to the UE using the MBSTF, in particular to the MBSTF Client. The User Service is announced to the UE and the MBSF Client discovers the announced User Services and sets up the relevant delivery functions in order to receive the data of the MBS User service through reference point MBS-4. Typically, and most prominently the MBSTF client accesses the multicast- or broadcast-delivered data on reference point MBS-4-MC. However, in certain circumstances, the MBSTF client may also use unicast reference point MBS-4-UC, for example for file repair.



(source: Qualcomm)

Figure 24. User Service Architecture for Multicast and Broadcast Service (MBS)

In terms of multicast delivery methods, it is expected that based on the functionalities in MBMS, 5G MBS will offer object as well as packet delivery methods. Whereas the latter method permits transparent packet delivery from application providers all the way to the application, for example of RTP streams. The former addresses the delivery of large files, object carousels or segment streaming such as DASH or HLS. Appropriate reference points (Nmb-8) and APIs (MBS-7) in the network and client, respectively, support the delivery of regular unicast-based applications on top of efficient multicast and broadcast modes of 5G MBS.

A concrete example is the delivery of 5GMS formats using 5G MBS to create an efficient multicast delivery of 5GMS content and services. This may for example be attractive for popular live services to create scale.

8. Proof-of-Concept (PoC)

8.1 Objective

a) Showcase on 5G remote live production.

Table 4. 5G remote live production

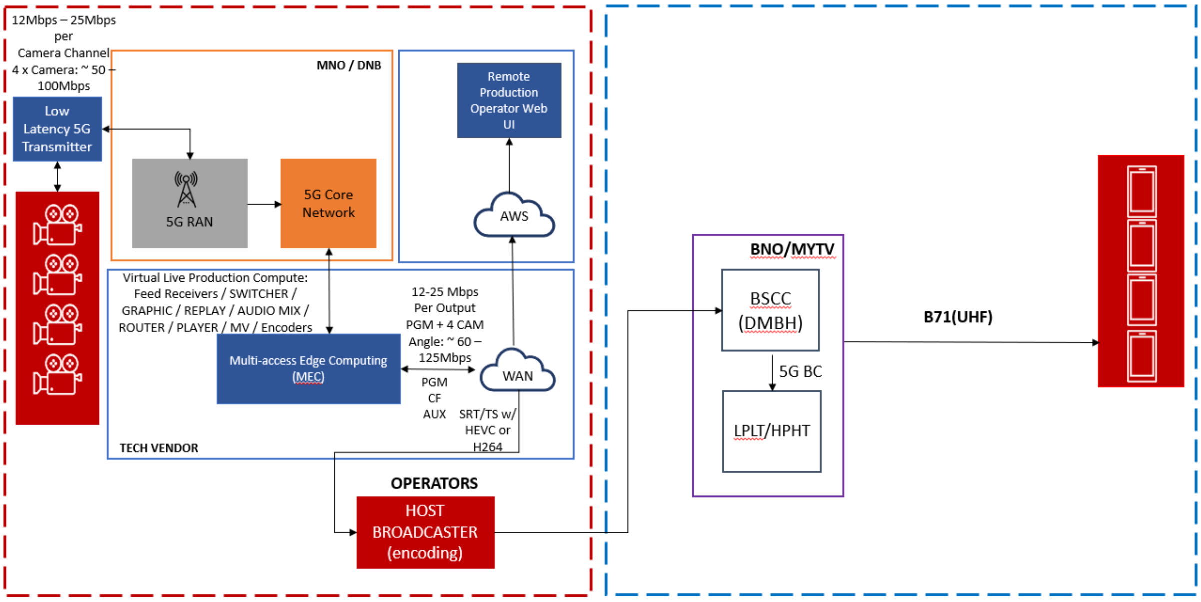
Phase	**Phase 1** Laboratory demonstration (maximum 3 months)	**Phase 2** On-site PoC trial	**Phase 3** On-site PoC actual
Objective	To demonstrate remote live production in a controlled laboratory environment.	To demonstrate remote live production in an actual 5G RAN site.	To perform PoC on use cases for remote live production during the identified event.
Test criteria	i) Content acquisition over public 5G with best effort networks ii) Low latency content acquisition over public 5G with network slicing iii) virtual remote live production system from within a 5G Mobile Edge Computing (MEC)	i) Content acquisition over public 5G with best effort networks ii) Low latency content acquisition over public 5G with network slicing iii) Virtual remote live production system from within a 5G Mobile Edge Computing (MEC)	i) Low latency content acquisition over public 5G with network slicing ii) Virtual remote live production system from within a 5G Mobile Edge Computing (MEC)

b) Showcase on 5G Broadcast distribution.

Table 5. 5G Broadcast distribution

Phase	**Phase 1** Laboratory demonstration (maximum 3 months)	**Phase 2** On-site PoC trial (HPHT and LPLT)	**Phase 3** On-site PoC actual
Objective	To demonstrate the following use-cases in controlled lab environment with test UE.	To demonstrate transmitter coverage and use cases from the actual 5G Broadcast transmission site.	To perform PoC on use cases for 5G Broadcast during the identified event.
Test criteria	i) Early Warning System (EWS) or multimedia warning system ii) Targeted advertisement iii) Really Simple Syndication (RSS) feed iv) Software update v) Consumption reporting or viewership analytic	i) Multi angle live audio and video content ii) EWS or multimedia warning system iii) Targeted advertisement iv) RSS feed v) Software update vi) Consumption reporting or viewership analytic	i) Multi angle live audio or video content ii) EWS or multimedia warning system iii) Targeted advertisement iv) RSS feed v) Software update vi) Consumption reporting or viewership analytic

8.2 Scope



5G remote live production **5G Broadcast distribution**

Figure 25. PoC block diagram

The live production will involve the usage of the broadband connectivity between the portable streaming devices (e.g., wireless cameras). These data are sent back to the MEC processors which will send the individual devices into the main production switcher. This is where the production team will control and select shots which will be aired. The production team shall also be capable of selecting the various audio source which are also sent through the streaming devices.

The final output shall be aggregated and sent to the Broadcast Server and Control Centre (BSCC) as well as the terrestrial TV encoders. Both terrestrial digital TV as well as 5G Broadcast can be simultaneously accessed using the appropriate receiving devices by the public.

The 5G Broadcast frequencies proposed are within the LTE band B71.

8.3 Preliminary criteria

a) 5G remote live production

i) Content acquisition over 5G networks

1) Sustained uplink bandwidth and network latencies: Round-Trip Time (RTT).

2) Video transmission latencies or data packet drop rates.

3) 5G virtualised RAN (vRAN) or 5GC diversity access: Redundancy.

4) Cell tower hopping or roaming capabilities.

ii) Virtual remote live production system within a 5G MEC

1) Remote live production and post-production workflow.

2) Overall production turnaround latency or output quality.

3) Remote operator ease of access.

4) Production output to 5G Broadcast system.

b) 5G Broadcast distribution

The coverage area are as follows.

i) RF parameters (ETSI TS 103 720)

1) Signal to Noise Radio (SNR).

2) Modulation Error Ratio (MER).

3) Reference Signal Received Power (RSRP).

4) Reference Signals Received Quality (RSRQ).

5) Modulation Coding Scheme (MCS).

6) Antenna gain.

7) EIRP.

8) Output power.

9) Field strength.

ii) Channel capacity

iii) Use cases

1) Multi angle live audio or video content.

2) EWS or multimedia warning system.

3) Targeted advertisement.

4) RSS feed.

5) Software update.

6) Consumption reporting or viewership analytic.

9. Conclusion

In summary, 5G technology not only enhances the quality and interactivity of content but also offers substantial cost-savings opportunities for content creators. These cost-efficiencies contribute to a more sustainable and financially viable content production process, allowing creators to allocate resources more strategically and focus on producing engaging and high-quality content.

9.1 Readiness of 5G broadcast

5G Broadcast can be considered as a potential future terrestrial broadcast solution in Malaysia. However, it is yet to be explored and proven, both technically and business-wise.

In view of the extensive investment which has been made by various organisations including the government in the implementation of the 5G platform in Malaysia, 5G broadcasting would be an ideal addition to the list of services that could be done within the 5G infrastructure. It would further optimise the investment that the government and various organisation have made and would strengthen the justification of 5G infrastructure in the country.

9.2 Readiness of 5G Media Streaming (MS) and MBS

5GMS is a technology initially standardised in Release 16. Parts of the technology are already available in devices and networks and gradually more will be added. The reference tools in 5G-MAG support the introduction is the technologies, and the combination with 5G Broadcast will foster the deployment of 5GMS to allow seamless unicast or broadcast services.

5G MBS is a technology initially standardised in Release 17 addressing multicast or broadcast service leveraging the existing 5G NR networks. The technology targets MNOs that see the need to enhance capacity in their networks. From a market perspective, the technology is not being studied and explored yet by the main stakeholders such as MNOs, content providers, CDN, etc., at the time of developing the current report. This particularly holds for media distributions, MBS may initially be used for other type of services, for example for mission critical services, or for IoT devices. Media delivery is not the primary scope of MBS at the time when this report is completed.

10. Recommendations

Based on the discussion presented in this paper, we shall therefore conclude and recommend the following.

a) The standardisation committee shall remain active in engaging all stakeholders in order to ensure that we keep up to date on the various developments in 5G broadcasting. The committee shall regularly discuss on global and international developments in this area of 5G broadcast. This engagement process shall be intensified with the inclusion of 5G Media Action Group and 3GPP.

b) Based on the discussions presented in this paper, there are interest in 5G Broadcast as an alternative means to deliver broadcast materials to the masses.

c) 5G NR is seen as a way forward for broadcaster and content producers alike in achieving a more optimal production process which will eventually lead to better cost management and hence higher quality content which may improve the content industry in Malaysia. This shall eventually benefit the 'rakyat' and perhaps even spur the local content industry as more opportunities are made available as production process becomes more affordable while improving quality.

d) A PoC is seen as an essential way forward in order to provide better understanding and a catalyst in encouraging the use of 5G infrastructure as an effective tool for large scale production. We also believe that a PoC shall also enable industry player to provide greater clarity on some issues such as bandwidth and delay issues which needs to be verified physically.

e) 5G broadcast has the potential to replace specialised broadcast infrastructure if used properly and hence reduce monopoly in the supply of certain production equipment.

f) The committee also recommends that policies should be put in place to enhance collaboration between the industry players such as between service providers and broadcast network operators and broadcasters.

Annex A

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Annex B

Abbreviations

3GPP	Third Generation Partnership Project
5GC	5G Core
5GMS	5G Media Streaming
5G NR	5G New Radio
5GS	5G System
5G-MAG	5G Media Action Group
5GMS AF	5GMS Application Function
5GMSd AF	5GMS Downlink Application Function
5GMS AS	5GMS Application Server
5GMSd AS	5G Media Downlink Streaming - Application Server
AF	Application Function
AI	Artificial Intelligence
AMF	Access and Mobility Management Function
API	Application Programming Interface
AR	Augmented Reality
AS	Application Server
ASEAN	Association of Southeast Asian Nations
ATSC	Advanced Television Systems Committee
BM-SC	Broadcast-Multicast Service Centre
BNO	Broadcast Network Operator
BSCC	Broadcast Server and Control Centre
CAPEX	Capital Expenditure
CAS	Conditional Access Systems
CBC	Cell Broadcast Centre
CBE	Between Cell Broadcast Entity
CBE-CBC	Cell Broadcast Entities - CBC
CBS	Cell Broadcast Service

CDN	Content Delivery Network
CMAF	Common Media Application Format
CMAS	Commercial Mobile Alert System
CRD	Commercial Reference Device
D2M	Direct-to-Mobile
DASH	Dynamic Adaptive Streaming over HTTP
DN	Data Network
DRM	Digital Rights Management
DSNG	Digital Satellite News Gathering
DTT	Digital Terrestrial Television
DTMB-A	Digital Terrestrial Multimedia Broadcast-Advanced
DVB	Digital Video Broadcasting
DVB-I	Digital Video Broadcasting-Internet
DVB-H	Digital Video Broadcasting-Handheld
DVB-T	Digital Video Broadcasting-Terrestrial
DVB-T2	Digital Video Broadcasting-Second Generation Terrestrial
E2E	End-to-End
EBU	European Broadcast Union
EIRP	Equivalent Isotropic Radiated Power
eMBMS	evolved Multimedia Broadcast Multicast Service
ENG	Electronic News Gathering
EPG	Electronic Program Guide
EPS	Evolved Packet System
ESG	Electronic Service Guide
ETSI	European Telecommunications Standards Institute
ETWS	Earthquake and Tsunami Warning System
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
EVS	Enhanced Voice Service
EWS	Early Warning System

FEC	Forward Error Correction
FHD	Full High Definition
FM	Frequency Modulation
FTA	Free-to-Air
GPRS	GSM Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GTP - U	GPRS Tunnelling Protocol
HARQ	Hybrid Automatic Repeat Request
HbbTV	Hybrid broadcast broadband TV
HD	High Definition
HDR	High Dynamic Range
HEVC	High Efficiency Video Coding
HLS	HTTP Live Streaming
HPHT	High-Power High Tower
HQ	Headquarters
HTTPS	HyperText Transfer Protocol Secure
IoT	Internet of Things
IP	Internet Protocol
ISP	Internet Service Providers
ITU-R	International Telecommunication Union - Radiocommunication Sectors
ISD	Inter-Site Distance
ISDB-T	Integrated Services Digital Broadcasting-Terrestrial
KPAS	Korean Public Alert System
KSA	Kathrein Signal Analyser
LPLT	Low-Power Low Tower
LTE	Long Term Evolution
MABR	Multicast Adaptive Bitrate
MB - SMF	MBS Session Management Function

MB - UPF	MBS User Plane Function
MBS	Multicast-Broadcast Services
MBSFN	Multicast-Broadcast Single-Frequency Network
MCx	Mission Critical
MBMS	Multimedia Broadcast Multicast Service
MBS	Multicast-Broadcast Services
MBSF	Multicast Broadcast Services Function
MBSTF	Multicast Broadcast Services Transport Function
MCS	Modulation Coding Scheme
MEA	Middle East and Africa
MEC	Multi-Access Edge Computing
MER	Modulation Error Ratio
MFN	Multi Frequency Network
MFLO	MediaFlo
MIB-MBMS	MasterInformationBlock - MBMS
MIMO	Multiple-Input Multiple-Output
MME	Mobility Management Entity
mmWave	millimetre Wave
MNO	Mobile Network Operator
MPEG-2	Moving Picture Experts Group-2
MPMT	Medium-Power Medium Tower
MPN	Multiple Frequency Networks
MRP	Market Representation Partner
MS	Media Streaming
NEF	Network embedded FEC
NG - RAN	Next Generation Radio Access Network
NPN	Non-Public Networks
NR	New Radio
NSaaS	Network Slice-as-a-Service

OB	Outside Broadcasting
OPEX	Operational Expenditure
OTA	Over-The-Air
OTT	Over-The-Top
PBCH	Physical Broadcast Channel
PCF	Policy Control Function
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PDU	Packet Data Unit
PLMN	Public Land Mobile Network
PMP	Point-to-Multipoint
PMCH	Physical Multicast Channel
PoC	Proof-of-Concept
PRB	Physical Resource Block
PSM	Public Service Media
PTM	Point-to-Multipoint
PTP	Point-to-Point
PWS	Public Warning System
QFI	QoS Flow ID
QoE	Quality of Experience
QoS	Quality of Service
QRD	Qualcomm Research Devices
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
ROM	Receive-Only Mode
RRC	Radio Resource Control
RSRP	Reference Signal Received Power

RSRQ	Reference Signal Received Quality
RSS	Really Simple Syndication
RTP	Real-time Transport Protocol
RTT	Round-Trip Time
SA	Standalone
SC-PTM	Single-Carrier Point-to-Multipoint
SDL	Supplementary Downlink
SDO	Standalone Downlink-Only
SFN	Single Frequency Network
SIB1	System Information Block Type 1
SIB12	System Information Block 12
SIM	Subscriber Identity Module
SMF	Session Management Function
SNR	Signal to Noise Radio
SVoD	Subscription Video on Demand
TM	Technical Managers
TR	Technical Report
TMGI	Temporary Mobile Group Identities
TV	Television
UDP	User Datagram Protocol
UE	User Equipment
UHD	Ultra-High Definition
UHF	Ultra-High Frequency
UPF	User Plane Function
US	United States
UTRAN	Universal Terrestrial Radio Access Network
VHF	Very High Frequency
VR	Virtual Reality
vRAN	Virtualised RAN

VR HMD	Virtual Reality Head-mounted Displays
WEA	Wireless Emergency Alert
WRC	World Radiocommunication Conferences
xMB	extended MBMS interface

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