2020·广州
世界5G大会
WORLD 5G CONVENTION

5G BROADCAST SOLUTION

WHITE PAPER V7.0 P
2020.11

N xie

5G Broadcast Solution

Version 1

FuTURE Forum 5G Broadcast and Video WG

2020/11/27

Table of Contents

1. Summary

Great thanks to the evolution of mobile communication, 4G LTE greatly improves and changes the user experience of watching the video content on a smartphone. With affordable charges people is now used to watch live video contents via mobile internet without waiting for a WiFi or cable connection. While smartphone is with tens of Mbps user experienced throughput, OTTs created more and more interesting live video streams.

Via some remarkable changes, we observed the live video audience grew fast in the past 15 years and the average audience number now reaches 30 million for top shows which is roughly same as a top TV soap opera. Moreover, the numbers of the top OTTs shows are much larger than the TV soap opera as it’s accessible by 7*24 hours while TV set isn’t.

In general, we observed couples of interesting trends of live video streams in China. From 2006, OTT provides live show via internet to catch audience’ eyeball and people accepted the laptops & pads as the 2nd screen beyond TV. Later on, live electronic gaming became popular and expanded the users’ screen to smartphones. On 2018, live sports (NBA, World Cup and etc) provided by OTT achieved more than 50 million audience. From 2019, live commerce achieved 10 million live audience as well. Top seller of Taobao – Viya successfully sold more 1 billion CNY in a 4-hour live commerce show with >30 million audience on Nov. 11th, 2019. The research institute – IIMEDIA summarized the scale of live video audience is around 504 million and the number will reach 526 million in 2020.

5G broadcast, which is a 3GPP feature, is recognized as the best solution to serve the live videos for smartphone users. Compared with traditional, it can provide seamless coverage by converged broadcast and unicast transmission, where High Tower deployment could largely reduce the cost, and unicast could provide indoor coverage and enable interactive user experience. Meanwhile, 5G broadcast provides enough flexibility to support contents in different formats, with unified transmission protocols. 5G broadcast allows user to access without a USIM (a.k.a. ROM), which is an important requirement of public service.

In the rest of this whitepaper, we summarize the 5G broadcast technical solutions which includes

- Chapter 2: Use cases, deployment scenarios and KPIs
- Chapter 3: high-level overviews and standard status
- Chapter 4: transmission protocol stacks
- Chapter 5: system architecture, procedures, transmission and reception configurations
- Chapter 6: a landscape of 5G broadcast and other broadcast solutions
- Chapter 7: considerations on 5G broadcast deployment

2. Use Case and Requirements

As summarized in the use case whitepaper [1], the use cases for 5G broadcast includes

- Linear TV, targets to extend the TV service from large screen to small screen including smartphone, pad and etc.
- OTT live stream, offloads the traffic from unicast link to broadcast link to save the cost;
- Venue cast: enable live, interactive broadcast for on-site audience. Exemplary use cases are free view-point, low latency play back, and etc.
- Emergency broadcast, reaches out everyone with emergency content as a public service;
- Software download: distributes the software for massive IOT, or other wireless terminals;
- Other data transmission: advertisement, complementary data transmission.

To accommodate the above the scenarios, we can further derive the following requirements where most of them were already documented in 3GPP TR38.913.

- Network dedicated to TV broadcast via eMBMS. The new RAT shall support static and dynamic resource allocation between Multicast/Broadcast and unicast; the new RAT shall allow support of up to 100% of DL resources for Multicast/Broadcast (100% meaning a dedicated MBMS carrier).
- Receive Only Mode [2]: As the public service, audience should be assumed without a operator's subscription. A UE configuration option that allows a UE to receive only eMBMS broadcast service without the need to access and register with the PLMN offering the eMBMS service. A UE configured to operate in Receive Only Mode receives MBMS service only on a standardized TMGI value range. The UE uses the acquired system information to receive MBMS broadcast. Use of Receive Only Mode does not require USIM for the UE.

- Large coverage. The new RAT shall make it possible to cover large geographical areas up to the size of an entire country in SFN mode with network synchronization and shall allow cell radii of up to 100 km if required to facilitate that objective. It shall also support local, regional and national broadcast areas.
- High Mobility. To enable the car mounted, portable, and mobile UEs. Mobility up to 250 km/h shall be supported.
- Flexible content: The new RAT shall support dynamic adjustment of the Multicast/Broadcast area based on e.g. the user distribution or service requirements.

3. Solution overview and Standard Status

3.1 CDN based converged broadcast and unicast design

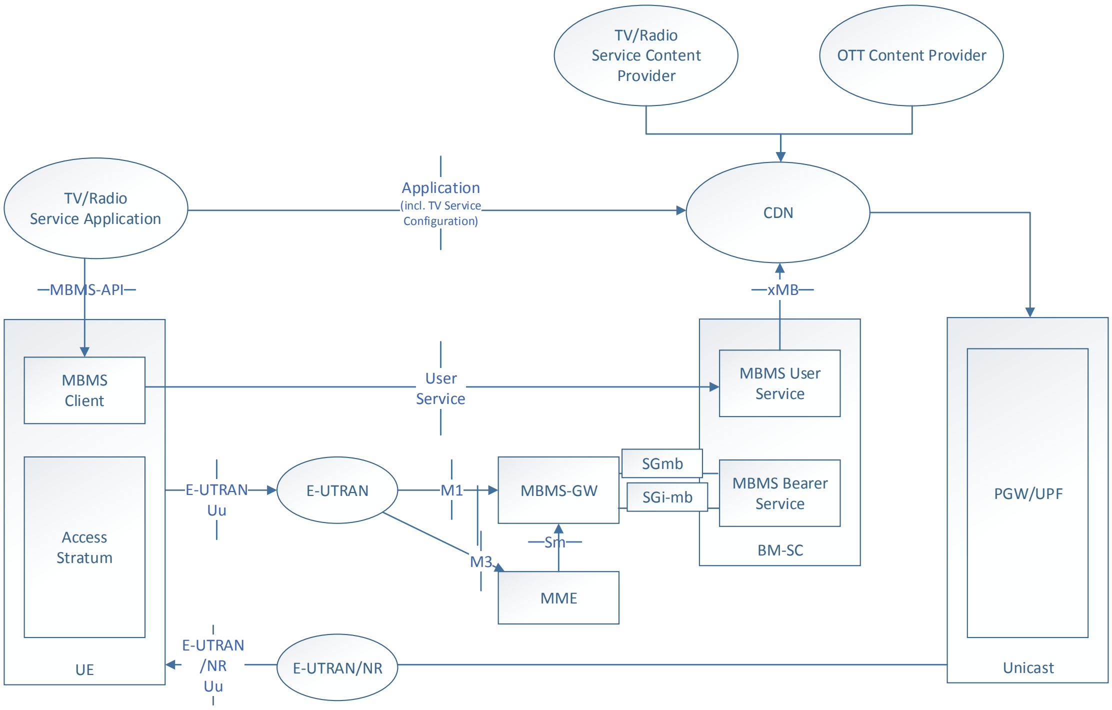


Figure 1 converged broadcast and unicast architecture

CDN serves as an anchor point for the convergence of unicast and broadcast services. The broadcast service obtains the content on the CDN through the xMB interface, and the unicast connects the UPF/PGW with the CDN through the network interface. Taking 3GPP as an example, the corresponding unicast protocol is TS 23.501 [5], and the broadcast protocol is TS 23.246 [2] and TS 26.346 [4].

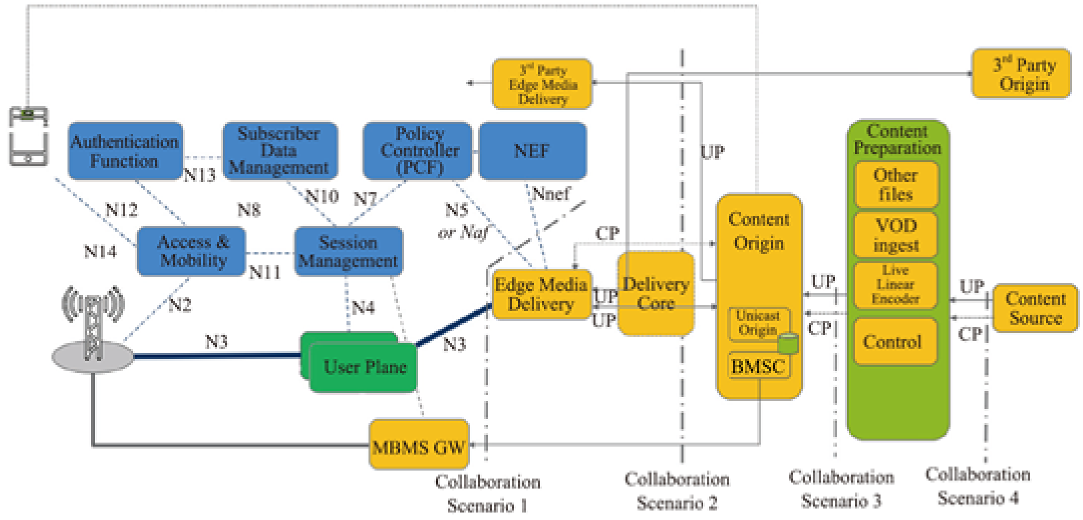


Figure 2 Media on 5G System Architecture [6]

Even though the unicast can be 5G NR, LTE, or other unicast techs, we would like to use 5G NR as an example to illustrate the protocol. The Figure 2 provides a potential extension to the 5G reference architecture (as defined in TS 23.501) with media delivery related functions like CDN edge and origin functions.

Most media distribution on 5G is based on Adaptive Bit Rate streaming with HTTP 1.1 to deliver file-based video content. The most popular video container format is fMP4 (a.k.a. ISO-BMFF) and MPEG2-TS. To unify the packaging format and reduce the cost of CDN provider, MEPG defined the new CMAF format which can be used for different manifest formats.

Edge Media Delivery is part of a CDN facing the clients and connects to 5G packet core UPF through the N6 reference point. The function is typically a HTTPS Reverse proxy/cache serving the UEs with content pulled from the CDN. It also caches content and functions as a HTTPS server when serving UEs from the pre-cached store.

User Service Architecture (Stage 2) is defined in TS 26.346. [4]

The Figure 3 starts decomposing the MBMS User Service Architecture and the PSS Architecture into smaller functions.

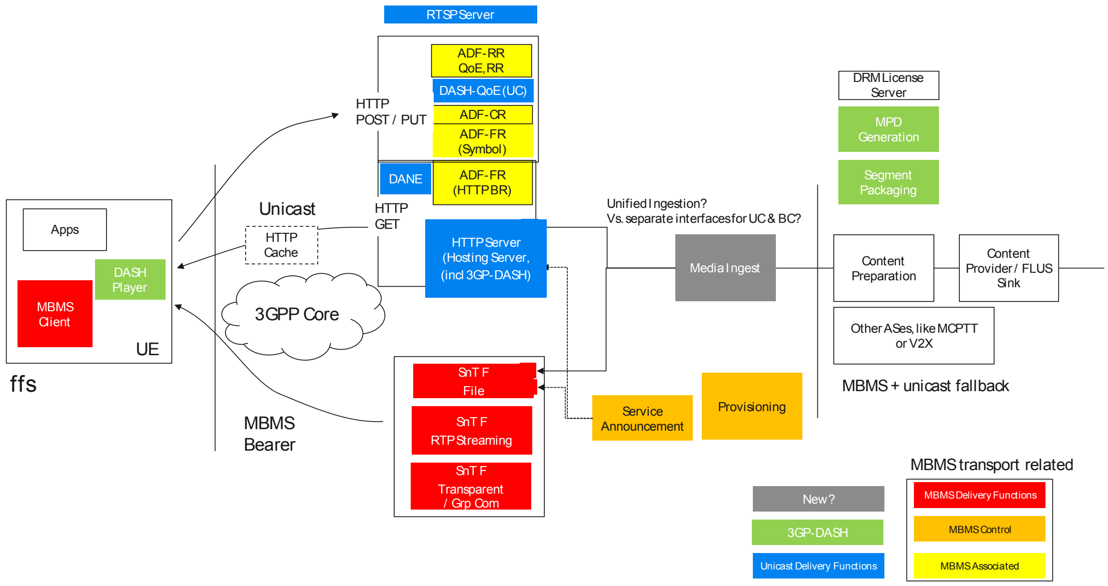


Figure 3 Decomposing MBMS and PSS functions [6]

The MBMS related transport functions are drawn in red, orange and yellow.

The xMB reference point considers content preparation on the content provider side, so that 3GP DASH formatted segments and MPDs are provided by the content provider. In PSS, the PSS server receives 3GP-DASH format from a content preparation function.

MBMS and PSS support QoE reporting. In case of MBMS, the QoE reporting is part of the associated delivery function (ADF).

MBMS supports Byte Range File Repair as part of the associated delivery function (ADF-FR HTTP-BR). Such a function can be hosted together with 3GP DASH unicast segments and MPDs on an HTTP server.

Unicast and MBMS Session and Transmission Function (SnT F) for file delivery can be used to offer Service Announcement to clients.

3.2 Standard Status

Mobile broadcast was specified in 3GPP for quite a long time which even can be traced to 3G era. LTE introduced broadcast (eMBMS) in R9 on both service architecture and radio access network.

- R9, which is the 1st release of LTE broadcast, includes the following features
  - Mixed unicast/MBMS carrier
  - 15 kHz numerology
  - Extended CP of 16.7μs
  - Multi-cell transmission only (MBSFN)
  - Up to 60% of subframes for MBSFN transmission
- R13, enable single cell to multiple cell (SCPTM) to small area multicast/broadcast, includes the following features
  - Single-cell transmission (SC-PTM)
  - Transmission on PDSCH with new group identities
  - Non-synchronized transmitters
- R14, enable key feature for traditional broadcasters, includes the following features
  - >30KM ISD: Longer cyclic prefixes
  - Dedicated broadcast carrier: up to 100% of subframes for MBSFN transmission
  - ROM: UE only receives broadcast services on a standardized or configured TMGI value range, to acquired system information. Use of Receive Only Mode does not require USIM for the UE.
  - Targeting rooftop and car-mounted antennas, handheld receivers
- R16, enable larger ISD and high mobility for mobile terminals
  - >100Km cell radius with 300μs CP
  - Up to 250m/h with 100μs CP
  - CAS enhancement for reliability: higher PDCCH aggregation level, PBCH repetition and etc.

In ITU-R WP5D #35e meeting, as a component in the whole package, 5G broadcast (a.k.a. 5G Terrestrial broadcast) was formally approved as 5G solution. To help broadcasters and others who might be interested on deep dive on technologies, 3GPP provides a technical report to briefly summarize the 5G broadcast key features in [19].

4. Protocol Stack

The core part of 5G converged broadcasting is the converged communication of broadcast and unicast. The converged protocol stack design in this chapter is the core of converged technology. This chapter will introduce broadcast and unicast protocol stacks separately and merge them into a converged protocol stack. Among them, the broadcast and unicast protocol stacks all come from the 3GPP SA4 specification.

4.1 Broadcast protocol stack

The content distributed by broadcast transmission could be live streaming media files or data files. Mainstream broadcast networks usually use a unified protocol architecture to transmit and distribute different broadcast content. Streaming media file distribution requires a media transmission protocol for file packaging, and then transmission through the FLUTE protocol. Text, software or other data services can be directly transmitted. The broadcast protocol is usually transmitted by the UDP protocol and carried by the MBMS broadcast type.

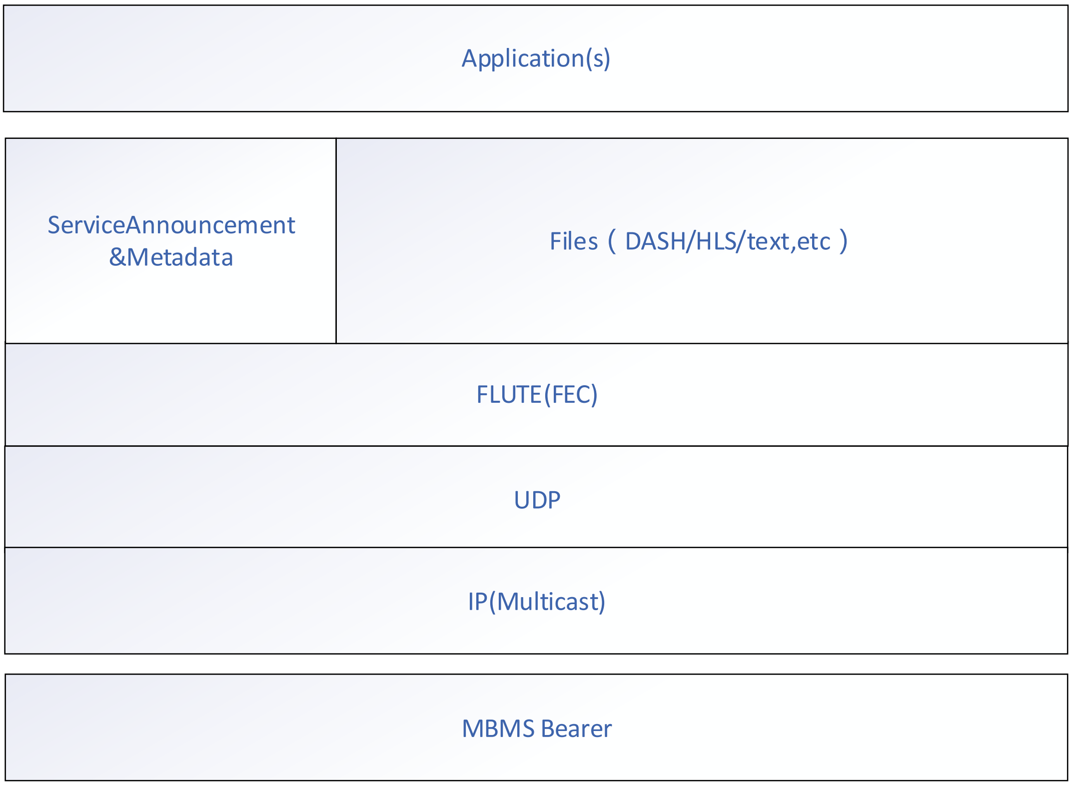


Figure 4 5G broadcast protocol architecture

4.2 Unicast protocol stack

The structure of the unicast protocol stack for 5G applications is relatively intuitive, and data or video transmission basically uses traditional IP transmission, as follows:

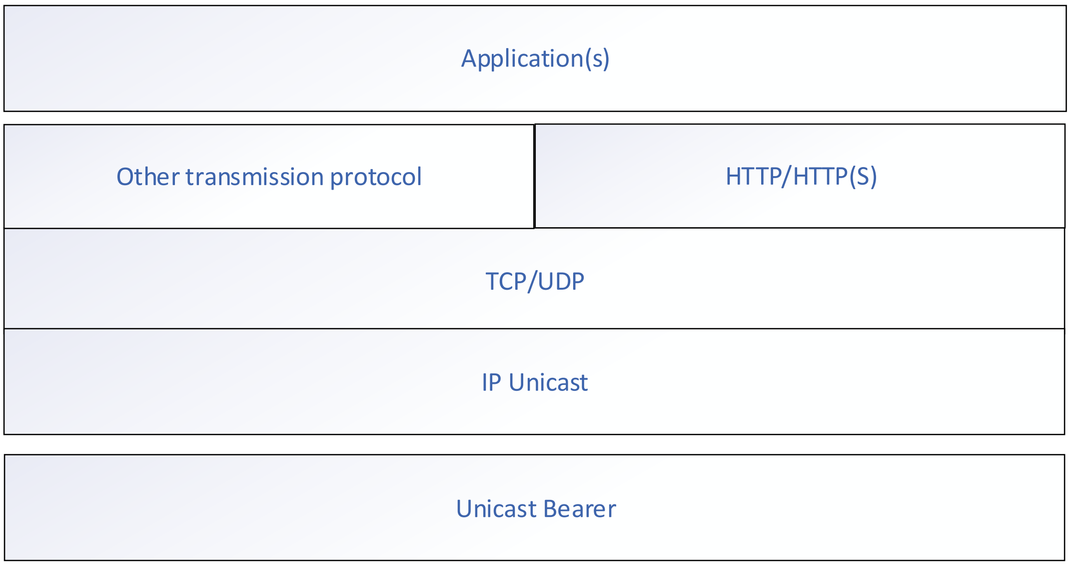


Figure 5 Unicast protocol architecture for media streaming

Since it covers a variety of different services, here is mainly divided into two application scenarios for video-related services to classify the upper layer video transmission protocol stack:

- Content production/production field (upload mainly)
- Distribution/redistribution field (download-based)

More details as figure below:

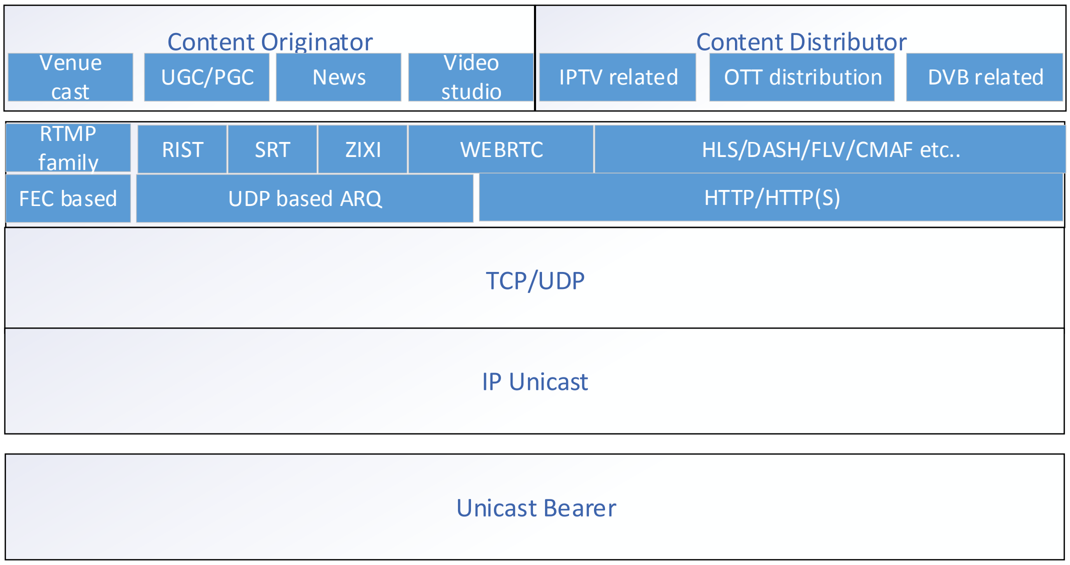


Figure 6 illustration of different traffic and media protocol

All unicast IP data are carried on the 5G unicast service. On top of the traditional TCP/UDP protocol, file-based video applications will directly use HTTP/HTTPs-based data services for data upload and distribution. In addition, FTP or transfer protocols based on cloud service providers such as S3/OBS/COS/OSS can be used to reliably and efficiently transfer large video files. In the live broadcast business, the mainstream protocol composition can be divided according to application scenarios, such as RTMP, RIST, SRT, ZIXI and WEBRTC suitable for live broadcast production backhaul, or HLS, DASH, CMAF suitable for distribution/redistribution application scenarios (although FLV has been gradually eliminated, it is still used a lot) and so on.

Through the above-mentioned transmission protocols, content manufacturers can use the large bandwidth and low latency of 5G networks to send videos in time, while service distributors can quickly deliver content to 5G users. At the same time, 5G can also serve as existing supplement to IPTV or DVB services.

4.3 Converged protocol stack

From the perspective of smart phones and other terminals, application layer data may be transmitted by unicast and broadcast channels according to the transmission type. Data is transmitted at the bottom layer through different protocols and bearers, and finally converged at the application layer.

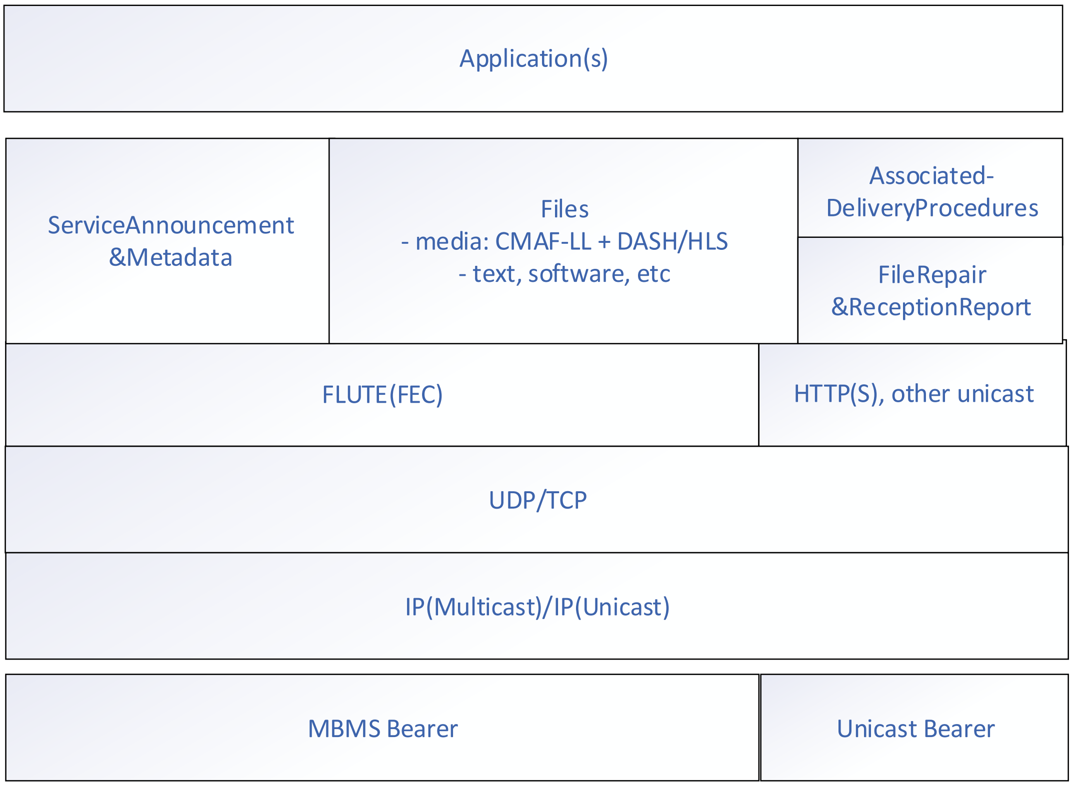


Figure 7 converged broadcast and unicast protocol architecture

The figure above shows the converged unicast and broadcast protocol stack. Compared with the broadcast protocol stack, the converged protocol stack supports CMAF-based low-latency encapsulation. File repair is still carried out at the protocol layer through HTTP, QUIC or other unicast protocols, and the bottom layer can be transmitted through unicast bearers. The service announcement can be sent in the broadcast band or unicast.

5 Broadcast

5.1 System architecture

5.1.1 Architecture

The converged architecture here includes the broadcast and unicast link on the transmission side. CDN as the anchor point, provides large flexibility and the unicast link could be 4G, 5G or even WiFi.

At the content provider side, both linear TV and OTT are supported, and the ingested content could be converged at the CDN for further streaming via broadcast and/or unicast.

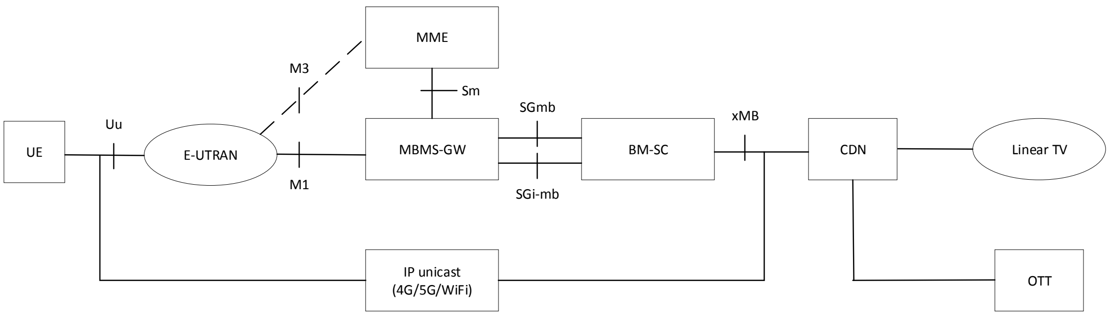


Figure 8 system architecture

5.1.2 BMSC

The BM-SC for a 5G Broadcast System for linear TV and radio services shall provide the following functions:

- Northbound Application Programming Interface (API) for Multimedia Broadcast/Multicast Service (MBMS) at the xMB reference point are defined in TS 26.348 [7] with the restrictions as described in clause 5.1.5.
- MBMS User Service Interface with the restrictions as described in clause 5.1.4.
- The EPS MBMS Procedures as defined in clause 5.2.1.

5.1.3 MBMS-GW

MBMS GW includes the function entities for broadcast. It provides an interface for entities using MBMS bearers through the SGi-mb (user plane) reference point and SGmb (control plane) reference point, allocate IP multicast address, and IP multicast distribution of MBMS user plane data to RAN. The detailed functions of the MBMS-GW in the 5G Broadcast System for linear TV and radio services are specified in TS 23.246 [2].

5.1.4 Interface, reference point, MBMS-API

MBMS User Service protocols and codecs are documented in TS 26.346 [4] and defines the reference point between the BM-SC (origin of an MBMS User Service) and the MBMS client. Only a subset of the MBMS User Service protocols and functionalities are applicable to 5G Broadcast Services.

In order to support 5G Broadcast SA and User Services, MBMS Profiles for MBMS User Services are defined in Annex L of TS 26.346 [4].

For Service Announcement the MBMS User Service Discovery / Announcement Profile 1b as documented in clause L.3 of TS 26.346 [4] shall apply.

For File Delivery or Segment Streaming mode, the MBMS Download profile as documented in clause L.4 of TS 26.346 [4] shall apply with the following restrictions:

- RTSP Control of FLUTE Sessions as defined in clause L.4.6 shall not be used.

For the Transport-Only mode, the Transparent Delivery Method as defined in clause 8B of TS 26.346 [4] shall apply with the following restrictions:

- MBMS transparent delivery sessions only operated strictly in Proxy mode, whereby the transport protocol and session description as described in clauses 8B.2 and 8B.3 of TS 26.346 [4] shall apply.
- The transport framing protocol is not used.
- In the case of Delivery Mode Configuration for user plane is set to

  - Forward Only, the Content Provider acts as the source for multicast traffic
  - Proxy, the BMSC acts as the source for the multicast traffic.

- ROHC as defined in clause 8B.4 of TS 26.346 [4] is not used.
- FEC as defined in as defined in clause 8B.5 of TS 26.346 [4] is not used.

5.1.5 xMB

Northbound Application Programming Interface (API) for Multimedia Broadcast/Multicast Service (MBMS) at the xMB reference point are defined in TS 26.348 [7] and TS 29.116 [8].

The functions and related procedures could be referred to the specifications for more details.

5.2 Broadcast system configuration

5G Broadcast protocol support both OTT broadcast transmission and traditional TV broadcast.

One of the most obvious differences between Internet broadcasting and TV broadcast is that content service providers of Internet broadcasting can trigger the switch between unicast and broadcast through APP based on network measurement results, the geographic area where the user is located, and the content to be played.

APP triggering can usually broadcast network information through network configuration, including key information such as TMGI. At the same time, the APP on the mobile phone can initiate an HTTP Get request to obtain Service Announcement information in the manner defined below.

The presentation of traditional TV broadcasts on smart terminals is also considered to be an APP based on the operating system. There is no essential difference from OTT live broadcasts, but the APP interface may be designed to try to restore the user's experience on traditional TVs according to traditional viewing habits

5.2.1 procedure

5G Broadcast protocol supports multicast and broadcast services. The overall process of broadcasting service is described as follows:

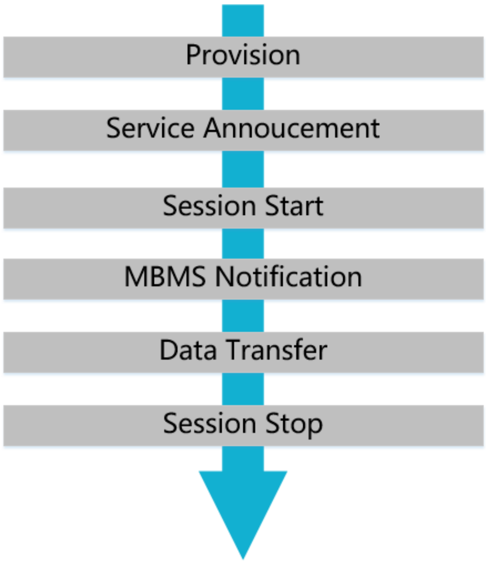


Figure 9 Overall flowchart of 5G broadcast

The Figure 9 describes the strict sequence relationship between the different steps of the broadcast service. In order to ensure that new users receive broadcast services, Service announcement and MBMS notification may be executed multiple times: Service announcement should be executed repeatedly between Provision and Session Stop; MBMS notification should be executed repeatedly between Session Start and Session Stop. The overall process is defined in 3GPP TS23.246 [3].

5.2.2 Broadcast procedure

5.2.2.1 Provisioning

Broadcast content providers may broadcast different content in different regions, in different time periods, and have different video quality in different access modes. Broadcast content providers should configure this information to BM-SC in advance.

Content providers communicate with BM-SC based on REST interface and execute two steps to configure broadcast service: Service and Session.

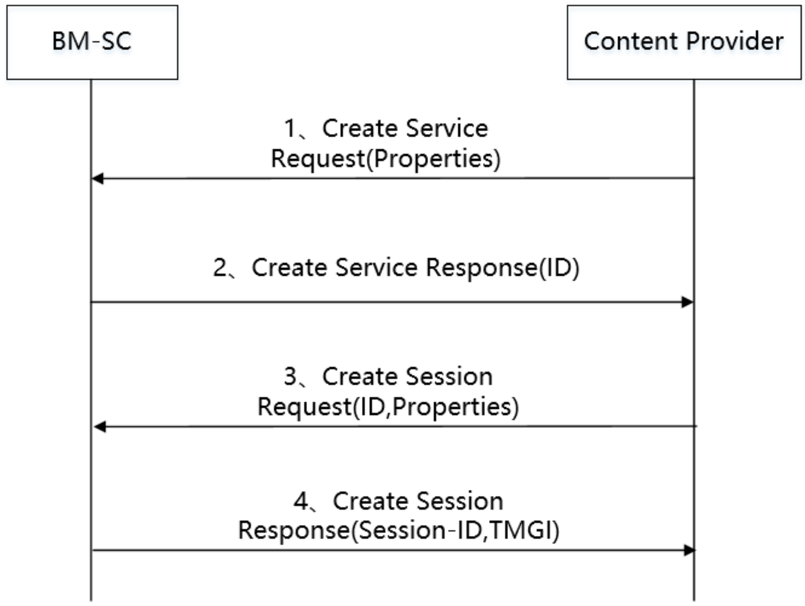


Figure 10 session pre-start - provisioning

Content providers send a Create Service Request message to BM-SC, including information such as Service Class, Service Languages, Service Name, Service Announcement Mode, Consumption Reporting Configuration, Push Notification URL, Push Notification Configuration, etc. There are two types of Service Announcement Mode: SACH and Content Provider. The details description is defined in 3GPP TS26.348.[7]

BM-SC returns a successful response, including information such as ID. BM-SC generates a unique ID for each service.

Content providers can create, delete, query and modify services. Content providers use the ID as the unique identity of the service except create service request.

Once the service is successfully created, the content providers begin to create the session. The content providers send a Create Session Request message to BM-SC, including information: ID (service), Start Time, End Time, Max Bitrate, Max Delay, Announcement Start Time, Geographic Area, QoE Reporting, QoE Report URL, Session Type, FEC, etc. There are four types of Session Type: Streaming, Files, Application and Transport-Mode.

If the session type is set to Transport-Mode, information such as Delivery Mode Configuration for user plane should be included. The Delivery Mode includes two options: Proxy and Forward-only. In Proxy mode, BM-SC receives the message and converts to the broadcast address for forwarding; in Forward-only mode, BM-SC receives the broadcast message and forwards it directly.

BM-SC returns a successful response, including information such as Session-ID, TMGI, etc. BM-SC returns TMGI only when Service Announcement Mode is Content Provider.

Content providers can create, delete, query and modify sessions. Content providers use Session-ID as the unique identifier of the session except create request. Content providers can create multiple sessions for one service. The details description is defined in 3GPP TS26.348. [7]

5.2.2.2 Service Announcement /Service Discovery[4]

Service Announcement / Service Discovery refers to methods for terminal / user to obtain available broadcast services, which can be passive notification or active query. Through the Service Announcement / Service Discovery, users can obtain the scheduling parameters (start time, etc.) and service activation parameters (such as TMGI, multicast address) of broadcast service. Only when the terminal receives the Service Announcement information can the terminal receive the broadcast correctly.

There are many ways to implement Service Announcement / Service Discovery, which is defined in 3GPP TS26.346.[4]

- Content Provider
- MBMS Bearer
- Interactive Announcement Function
- Point2Point Push Bear

These four methods are introduced as follows：

- By Content Provider

Content providers provide service description files that can be obtained by users through HTTP. Users access the portal to get the URL of the service statement via app, and the communication network does not perceive the service announcement process.

- Over MBMS Bearer

BM-SC provides service description files that can be downloaded through the download session defined by BM-SC. In order to complete the download, user should obtain the download session parameters first. Generally, there are several ways to obtain download session parameters: terminal preset; APP preset; SMS push; get parameters through URL. The URL format is recommended as follows:

http://mbmsbs.mnc<MNC>.mcc<MCC>.pub.3gppnetwork.org/bootstrap.multipart.

Once the download session parameters are obtained, user can download the service description files by the download session, and then correctly accept the broadcast data.

- Using Interactive Announcement Function

BM-SC provides service description files that can be obtained through HTTP. Generally, there are several ways to obtain URL: terminal preset; app preset; SMS push; FQDN. FQDN are recommended as follows:

mbmsbs.mnc<MNC>.mcc<MCC>.pub.3gppnetwork.org, the URL is http://mbmsbs.mnc<MNC>.mcc<MCC>.pub.3gppnetwork.org/unicastUSD.

The unicastUSD is a complete service description file, including download session parameters, service description information, scheduling parameters, and feedback parameters, etc.

- Over Point2point Push Bearer。

BM-SC provides service description files that would be pushed by communication network using Push Bear based on user location.

5.2.2.3 Session Start

For sending broadcast data correctly, BM-SC informs the network to reserve resources first. The network elements such as MME and MBMS GW establish the bearer contexts and reserve resources for broadcasting services after receiving session start message. When one service is transmitted via multiple bearers, BM-SC should send Session Start for each bearer service, and the terminal needs to receive the broadcast data from each bearer service.

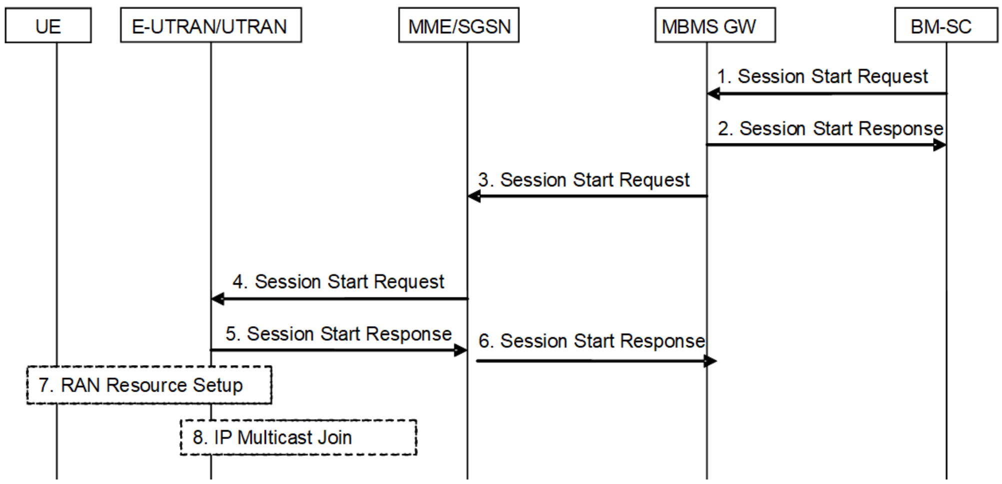


Figure 11 session start

5.2.2.4 MBMS Notification

BM-SC sends MBMS Notification message to inform terminal about forthcoming (and potentially about ongoing) MBMS broadcast data transfer.

During data transfer, BM-SC can also send MBMS Notification messages.

5.2.2.5 Data Transfer

The content provider pushes the broadcast data to the terminal.

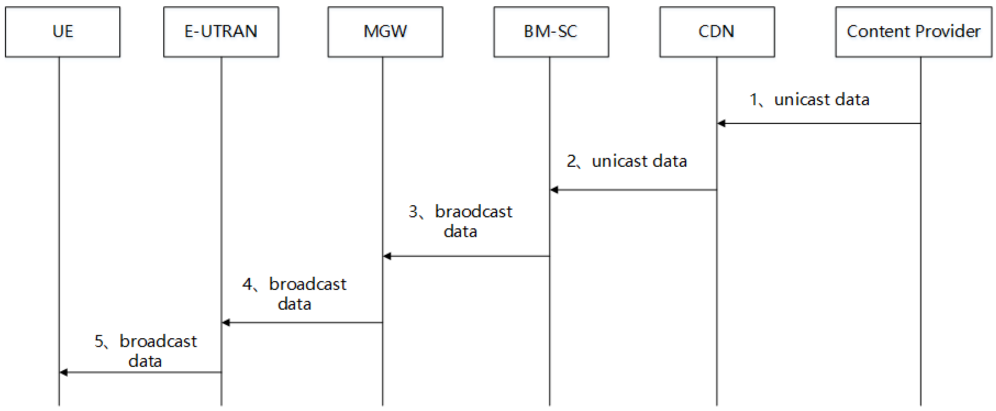


Figure 12 data transmission

There are several transmission modes used by BM-SC to transmit data, which includes transparent mode, proxy mode, files mode and streaming mode.

The end-to-end protocol stack for transparent mode shows as follows:

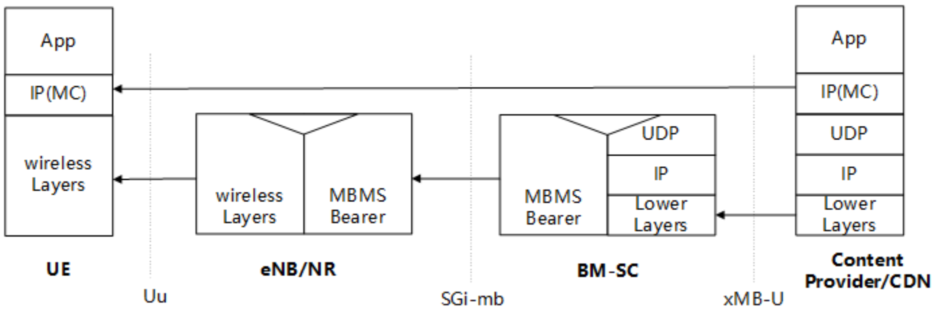


Figure 13 transparent mode

The end-to-end protocol stack for proxy mode shows as follows:

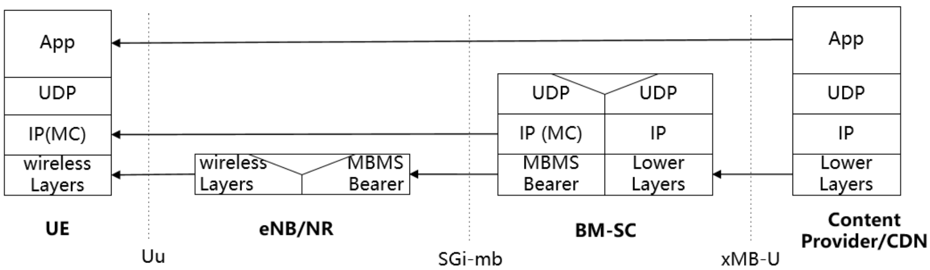


Figure 14 proxy mode

The end-to-end protocol stack for files mode shows as follows:

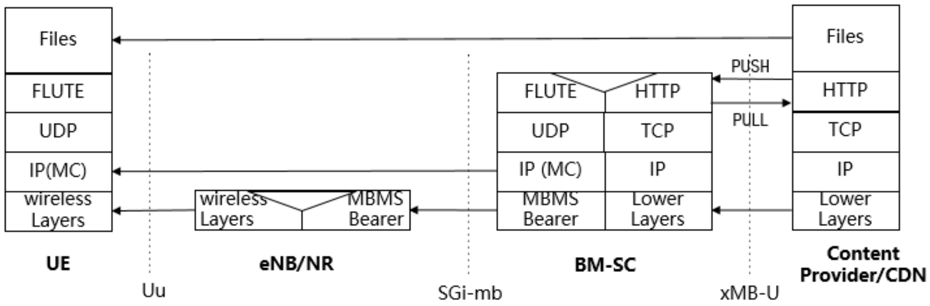


Figure 15 file delivery protocol stack

The end-to-end protocol stack for streaming mode shows as follows:

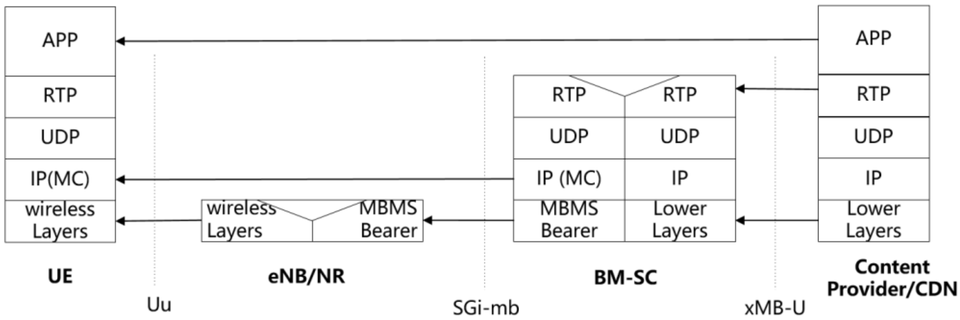


Figure 16 live video stream delivery protocol stack

5.2.2.6 Session Stop

Once sending broadcast data completely, BM-SC sends Session Stop message to inform that the broadcast service is stopping. After receiving the message, the network element releases the bearing resources, and the terminal can no longer receive broadcast data.

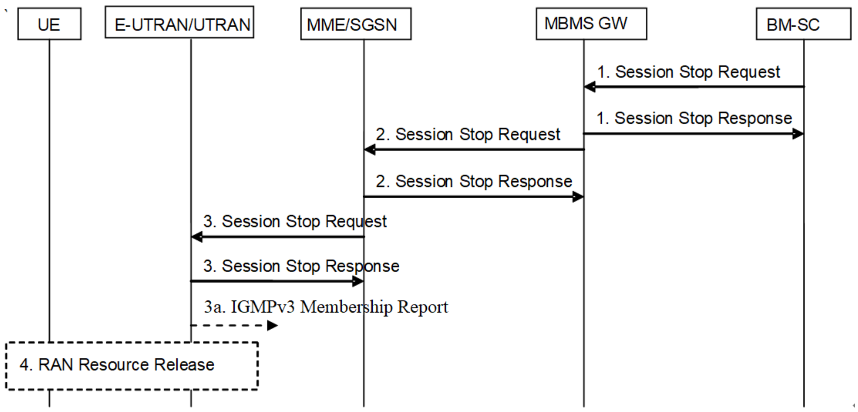


Figure 17 session complete

5.2.3 TMGI [15]

Temporary Mobile Group Identity (TMGI) is used within MBMS to uniquely identify Multicast and Broadcast bearer services.

TMGI is composed as shown in Figure 18.

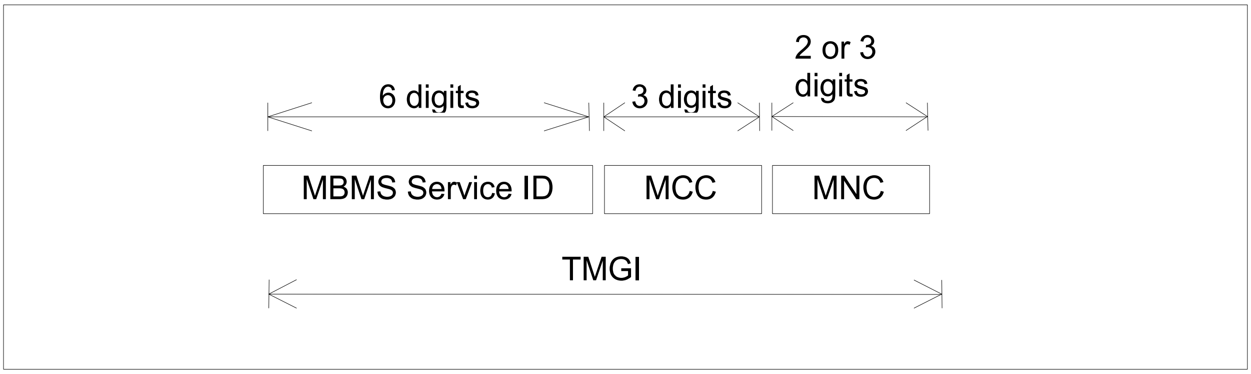


Figure 18 Structure of TMGI

The TMGI is composed of three parts:

1) MBMS Service ID consisting of three octets. MBMS Service ID consists of a 6-digit fixed-length hexadecimal number between 000000 and FFFFFF. MBMS Service ID uniquely identifies an MBMS bearer service within a PLMN. The structure of MBMS Service ID for services for Receive only mode is defined in 3GPP TS 24.116 [11].

2) Mobile Country Code (MCC) consisting of three digits. The MCC identifies uniquely the country of domicile of the BM-SC, except for the MCC value of 901, which does not identify any country and is assigned globally by ITU;

3) Mobile Network Code (MNC) consisting of two or three digits (depending on the assignment to the PLMN by its national numbering plan administrator). The MNC identifies the PLMN which the BM-SC belongs to, except for the MNC value of 56 when the MCC value is 901, which does not identify any PLMN. For more information on the use of the TMGI, see 3GPP TS 23.246 [2].

Any TMGI with MCC=901 and MNC=56 is used only for services for Receive Only Mode (see TS 23.246 [2] and 3GPP TS 24.116[11]). Broadcaster is allowed to use other values for UE with ROM if UE can get a configured TMGI value. How to get the configured TMGI is not defined in 3GPP while it can be pre-stored in the device, or configured by a server.

5.2.4 TV service configuration Management Object

If the Service Announcement is further supported by an application to MBMS client communication, then the receiver configuration for 5G Broadcast linear TV Receiver can be configured by the application providing relevant information from TV service configuration Management Object to the MBMS Client.

The TV service configuration Management Object is defined in TS 24.117 [12]. For the TV service configuration Management Object when used for 5G Broadcast, the following restrictions apply:

- The MO identifier is: urn:oma:mo:ext-3gpp-tv-config:1.0.

The management object provides information about the TMGIs associated with the services, as well as the frequency carrier for each service. The UE could also discover the broadcast TV services provided by the serving PLMN by scanning the reserved range of TMGIs for broadcast TV service.

5.2.5 Discovering 5G Broadcast Services

For 5G Broadcast Services as defined in this specification, the TMGI for broadcast bearer services can be obtained via the Service Announcement as defined in clause 5.5.2 and User service interface in clause 5.1.4. Furthermore, information about a TMGI for a 5G Broadcast Service may be received through the Service announcement file through the MBMS-API (see clause 5.1.2) or the TV Management Object (see clause 5.2.5).

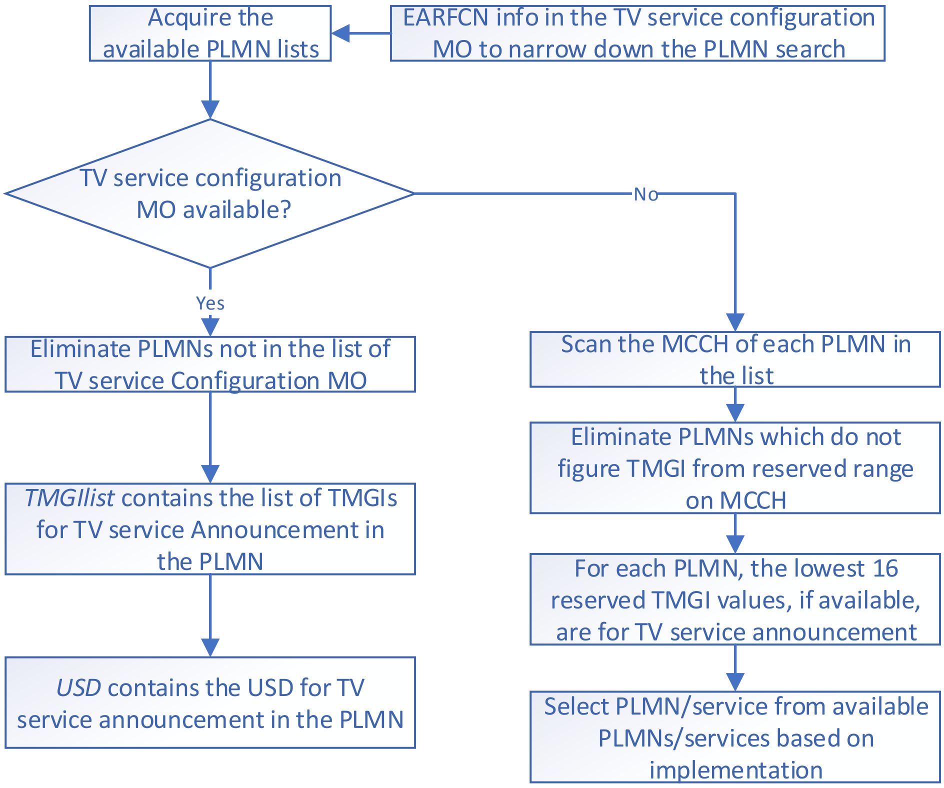


Figure 19 the service flow of ROM UE access the broadcast network

5.3 transmission configuration

3GPP provides a very brief but good feature summary of 5G broadcast in TR36.976[19], and hereby we just try to summarize the key sub-features for broadcast.

5.3.1 Frame structure and numerologies

To enable single site covering large area, 3GPP introduced 3 different numerologies on top of ECP in R9, which are 370Hz, 1.25KHz, and 2.5KHz.

Only frame structure type 1 is supported. All numerologies specified in TS 36.211 [8] are supported. For subframes using Δf other than 0.370 kHz, the frame structure is according to Figure 20. For transmissions using $\Delta f = 0.370$ kHz, the frame structure is shown in Figure 21.

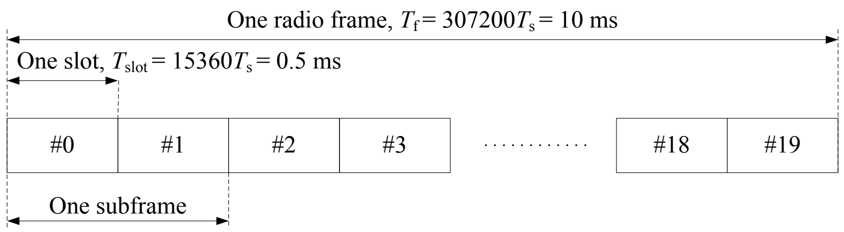


Figure 20 Frame structure type 1 for subframes not using *Δf* = 0.370 kHz For *Δf* = 1.25 kHz, one subframe contains a single slot with a duration of 1ms.

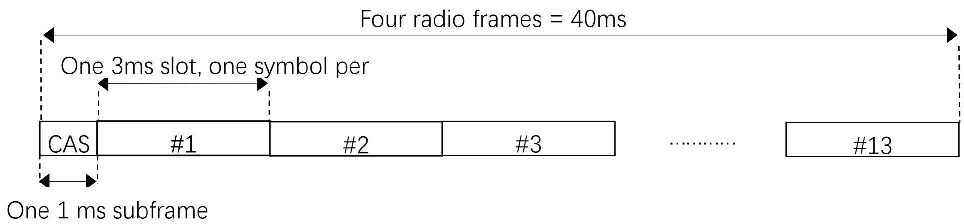


Figure 21: Frame structure type 1 for transmissions using *Δf* = 0.370 kHz. The CAS is a non-MBSFN subframe, and is configured with 15 kHz subcarrier spacing

5.3.2 MBMS Transmission

MBMS transmission is performed according to 3GPP TS 36.300 [8]clause 15.3.3.

MCCH configuration and scheduling is performed according to 3GPP TS 36.300 [8]clause 15.3.5 and 3GPP TS 36.331 [9] clause 5.8.1. In case of a MBMS-dedicated cell, the MBMS counting configuration is not supported.

MCCH information acquisition is performed according to 3GPP TS 36.300 [8] clause 15.3.5 and 3GPP TS 36.331 [9] clause 5.8.2. In case of a MBMS-dedicated cell, only RRC_IDLE is supported.

5.3.3 MAC Layer

MAC layer supports only:

- BCH reception for BCCH;
- DL-SCH reception for BCCH; and
- MCH reception for MCCH/MTCH.

BCH reception and DL-SCH reception in the MAC layer use transparent MAC [16], i.e. single MAC PDU per TTI with no headers. HARQ entity uses the dedicated broadcast

HARQ process, defined in [16].

MCH reception in the MAC layer is specified in 3GPP TS 36.321 [16] clause 5.12 and in 3GPP TS 36.300 [8] clause 15.3.3.

5.3.4 RLC layer

BCCH uses the RLC-TM mode.

MTCH and MCCH use the RLC-UM mode. RLC operation for MTCH and MCCH is described in 3GPP TS 36.300 [8] clause 15.3.3.

5.3.5 RRC layer

RRC layer supports only:

- System information reception (see 3GPP TS 36.331[9] clause 5.2) in MBMS-dedicated cell; and
- MBMS reception (see 3GPP TS 36.331 [9] clause 5.8) in MBMS-dedicated cell and in FeMBMS/Unicast-mixed cell.

For system information reception, the following applies:

- only BCCH-BCH-Message-MBMS and BCCH-DL-SCH-Message-MBMS message class is supported;
- acquisition of system information messages is performed according to 3GPP TS 36.331 [9] clause 5.2.3b.

For MBMS reception, the following applies:

- MBMS counting procedure and MBMS interest indication procedure are not supported.

5.4 Reception configuration

5.4.1 Introduction

A receiver for a 5G Broadcast System for linear TV and radio services discussed in this whitepaper shall support ROM device functionalities with further restrictions defined in this clause.

As examples, ROM devices support MBMS transmission but do not support uplink transmission. ROM devices may not have USIM. As such, ROM devices do not support two-way signaling procedures with the network, including connection establishment procedures and security procedures. ROM devices only support the idle mode. Not all idle mode procedures need to be supported, as described in subclause 5.2.3. For more details on ROM devices see clause 6.2, TS 36.300 [8]subclause 15.11, TS 23.246 [2] Annex D and TS 24.116 [11] clause 4.

As a matter of implementation, a traditional UE, including a UE supporting FeMBMS/Unicast-mixed cells TS 36.300 [8], can be configured to operate as a ROM device. The means for such configuration are outside of the scope of specifications.

As a matter of implementation, a cellular device can host a ROM device and a traditional UE capable of unicast. Such device is further described in TS 23.246 [2] Annex E and called ROM device with independent unicast. The co-hosted UE is connected to a different cell from the MBMS-dedicated cell serving the co-hosted ROM device. If the co-hosted UE and ROM device share baseband resources, the co-hosted UE can use MBMSInterestIndication signalling procedure, specified in TS 36.331 [9], to inform the serving RAN about the baseband resources occupied by the co-hosted ROM device and therefore not available for unicast.

There may be awareness at the application layer of the ROM device with independent unicast.

5.4.2 Access Stratum

5.4.2.1 General

Since a ROM device does not support uplink transmission or two-way signalling procedures, and does not comprise USIM, it cannot and does not need to support all the physical layer procedures of the conventional UE. By the same token, only a subset of idle mode procedures and RRM requirements applicable to a conventional UE are required to be supported. The following subsections provide an overview of the physical layer and idle mode procedures and the RRM requirements applicable to a ROM device.

A receiver for a 5G Broadcast System for linear TV and radio services shall conform to a ROM device only.

5.4.2.2 Physical layer procedures

A ROM device only shall support the following physical layer procedures specified in TS 36.213[26]:

- Cell search;
- Timing synchronization;
- PDSCH procedures;
- PDCCH assignment procedure; and
- PMCH procedures.

5.4.2.3 Idle mode procedures

A ROM device only shall support the following idle mode procedures specified in TS 36.304 [13]:

- Cell selection; and
- Cell reselection.

PLMN prioritization for cell reselection as specified in TS 36.304 [13] subclause 5.2.4.1 shall be supported with the following exception:

NAS layer PLMN selection does not apply to ROM device.

PLMN selection for ROM device as specified in TS 24.116 [11] shall be supported.

Note: ROM devices do not support DRX.

5.4.2.4 RRM requirements

ROM device only shall support the following requirements specified in TS 36.133 [13]:

- Cell selection; and
- Cell reselection, except for the following case
    - IRAT reselection;
    - paging-related requirements
        - CSG cell-related requirements.

5.4.3 MBMS Client

An MBMS client for a 5G Broadcast Receiver as discussed in this whitepaper shall support UE behavior in Receive Only Mode as defined Annex E of TS 23.246 [2].

A receiver for a 5G Broadcast System for linear TV and radio services as defined in this specification shall support:

- MBMS User Service Interface with the restrictions from clause 6.1.4.
- The MBMS-APIs with the restrictions from clause 6.1.4.
- The discovery of 5G Broadcast services according to clause 6.2.6

6 The comparison of 5G broadcast and other terrestrial digital TV standards

The first-generation terrestrial digital TV standards recommended by ITU mainly include DVB-T/H, DVB-SH, ISDB-T/TB, ATSC, DTMB and T-DMB. The second-generation terrestrial digital TV standards mainly include ATSC 3.0, DVB- T2 and DTMB-A, China's CMMB has not entered the ITU standard, and are China's industry standards. DVB-H, CMMB, T-DMB, DVB-T2 lite can all support mobile multimedia broadcasting services. Countries around the world adopt different terrestrial digital TV standards according to their own needs, and there is no need for global roaming of smart phones, so the standards of terrestrial digital TV in different countries are not completely the same.

The 5G terrestrial broadcasting technology is based on the 3GPP standard, which supports fixed receiving mode and mobile portable receiving mode. It is possible for 5G smart phones and other receivers to adopt the same standard. Theoretically, terminals equipped with 5G terrestrial broadcast demodulation technology can support global applications, which is a great thing (The digital signal demodulation part of 5g broadcast is unified, which may require the cooperation of different app and Middleware). ITU-R BT.2049 [1] has paid attention to the MBMS scheme of 3GPP since 2016. The 3gpp 5G technical proposal submission including 5G terrestrial broadcasting technology has been officially recognized as 5G standard by ITU-R, and 5G broadcast has also officially become an integral part of 5g standard. It is expected that there will be a wave of attention to 5G broadcast in the traditional broadcasting industry in the near future.

In this chapter, the history of the development of traditional digital terrestrial broadcasting technology is revisited. The performance of 5G terrestrial broadcasting technology, DTMB （The China's terrestrial digital television standard) or CMMB (The China's mobile multimedia broadcasting standard), as well as the second-generation terrestrial digital television standards DVB-T2 and ATSC 3.0 are compared. Technical performance comparison mainly includes system structure, bandwidth, ideal bit rate, spectrum efficiency, signal-to-noise ratio, ISD (inter-site distance) and so on.

Through the comparison of several different terrestrial broadcasting technology standards, analyze the advantages and disadvantages of 5G terrestrial broadcasting technology, especially the future "convergence of video cloud and distribution network technology", and discuss the development direction of the next generation of terrestrial broadcasting technology.

6.1 Characteristics of traditional terrestrial digital broadcasting technology and 5g terrestrial broadcasting technology

Traditional linear broadcasting is a one-way transmission. Users can only passively receive media content and cannot interact and share. In some places, there may be "blind spots" due to building obstructions and other reasons. It has always been the operator's "dream" to realize the media content of "Anytime, Anywhere". Therefore, both traditional broadcast operators and mobile communication network operators have been constantly exploring and striving to realize emerging technologies and innovative business models.

In recent years, the linear and non-linear services provided by mobile communication networks have grown rapidly. The largest contribution of data traffic in the network comes from mobile video. Since the content of mobile communication networks is distributed in unicast mode, with the video service With the continuous development of diversification and personalized needs of users, CDN's traffic pressure is increasing.

However, there are few commercial successful cases of traditional broadcast network operators' mobile TV services based on mobile multimedia broadcasting technologies such as DVB-H, CMMB, T-DMB, DVB-T2 lite and so on.

Therefore, traditional broadcast operators and mobile communication network operators are actively exploring. Interestingly, Internet video operators are more and more interested in the wide area coverage of 5g PTM terrestrial broadcasting technology, and hope to further open up. Traditional broadcast operators also hope to distribute program content to hundreds of millions of mobile terminals.

Compared with point-to-point (PTP), point-to-multipoint (PTM) transmission may be a more efficient delivery mechanism, as long as the service or application needs to deliver the same content to multiple users or devices at the same time. That is why PTM is regarded as an important function of 5G applications in many vertical industries.

HPHT (high-power, high-tower) is based on 5G terrestrial broadcasting technology. PTM will promote the distribution of audio-visual media content and services, especially when reporting popular events or conducting famous commercial activities, attracting a large number of viewers to watch at the same time, such as "live webcast with goods". The network coverage of PTM can be limited to a specific location, or extended to a wide area, even the scale of the whole country.

The application scenarios of 5G terrestrial broadcasting terminal are mainly divided into two categories: fixed antenna reception (including xDSL/FTTH access) and mobile reception (portable personal terminal and car-mounted antenna mobile reception). The details are as follows:

With xDSL/FTTH access, users can not only receive wireless signals of 5G HPHT/LPLT (depending on the signal field strength and signal quality of 5G HPHT or LPLT) through fixed antennas (indoor antennas/outdoor antennas) by using mobile phones/pads or televisions, but also watch videos through xDSL/FTTH networks.

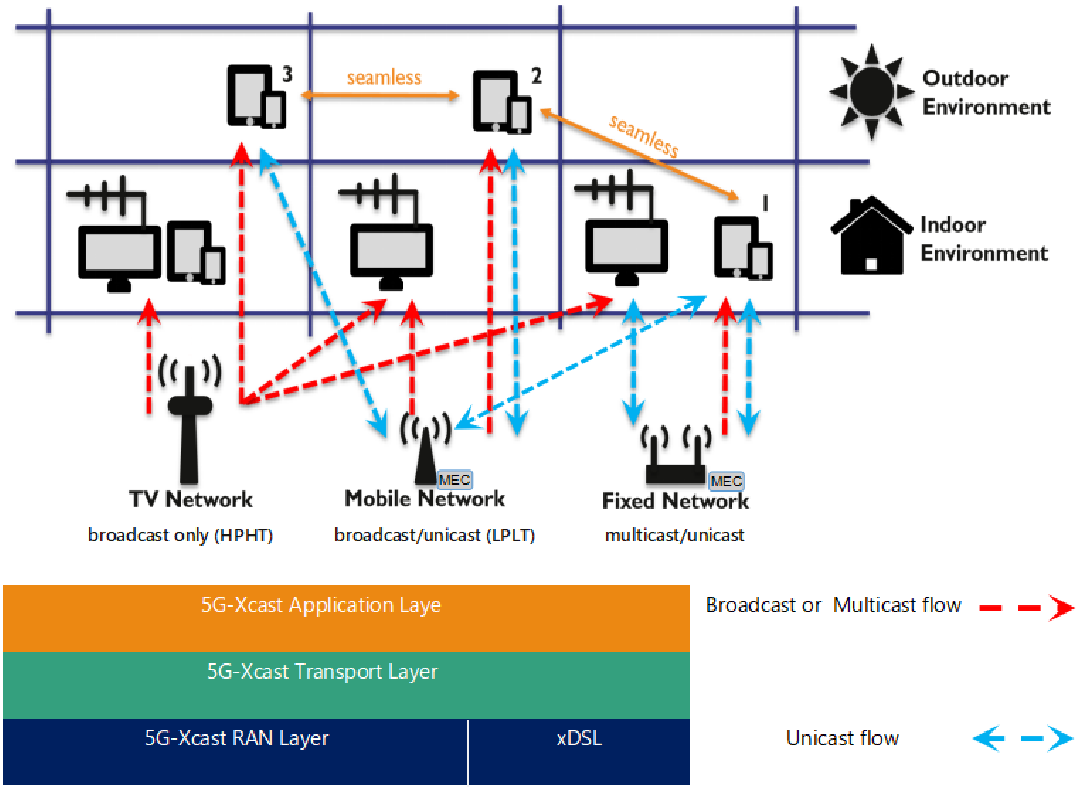


Figure 22 5G converged broadcast scenarios [28]

The user can watch the live video on the mobile device at home (1) through the fixed network connection. The user then leaves the outdoor location where the home connection is out of range (2), but wishes to continue watching the video without interruption using their mobile connection. Subsequently, the user moves to another area (3) covered by the television network. 1-3, users can receive both on-demand services and broadcast services, and users can move in or out of the coverage areas of different networks. During the whole process, the video should continue to play smoothly without interruption. Content and services can be delivered simultaneously through a combination of several networks and network types. When there are handovers between different access networks that may be operated by different operators, the continuity of user experience should be maintained. The combination of network and technology provides a seamless experience when users move between different places. Figure 22 and Figure 23Figure 1 and Figure 2 describes this application scenario[17].

In the process of watching videos using the "5G Converged Broadcasting" technology, users can also perform operations such as "time-shifting" and "sharing" the video to make up for the shortcomings of traditional linear broadcasting.

With the continuous development and application of MEC technology, large-scale video resources are distributed to corresponding nodes as efficiently as possible, which improves the user experience, meets different personalized needs, and brings new business scenarios of video CDN, including typical applications such as live broadcast of events, live broadcast of venues, AR of scenic spots and sinking of video CDN.

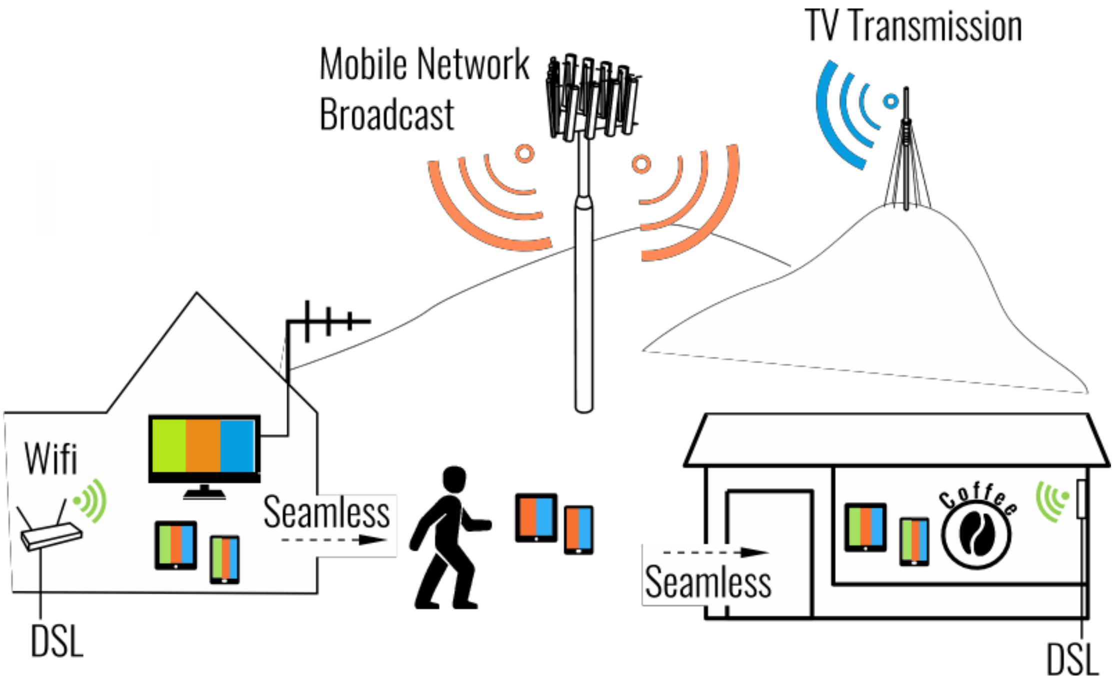


Figure 23 5G converged broadcast scenarios

The following chapter compares several different terrestrial broadcasting technical standards, analyzes the advantages and disadvantages of 5G terrestrial broadcasting technology, and discusses the development direction of 5G terrestrial broadcasting technology.

6.2 Development of 5G terrestrial broadcasting technology and comparison with other terrestrial digital TV standards

With the continuous development of 5G technology, it is believed that 5G broadcast may provide a second opportunity for the broadcasting industry to "transmit terrestrial broadcasting signals to mobile phones." A new study item in 3GPP Rel-16 evaluated Rel-14 against the original requirements of broadcast [18]. Under the umbrella of the EBU, the BBC and the IRT, together with companies such as Qualcomm and Huawei, have demonstrated that Rel-14 would benefit from enhancements in three key areas: a shorter 100 μs CP for mobility up to 250 km/h, a longer 300 μs CP for networks with ISD of 60 km, and a more robust cell acquisition subframe (CAS). These enhanced functions are designated as LTE-based 5G terrestrial broadcasting in Rel-16, or 5G terrestrial broadcasting for short [19].

Compared with the original broadcast requirements in TR 36.776 [20], Rel-14 found several shortcomings. In particular, Rel-14 required improvement to support SFN coverage with cell radii up to 100 km and mobile reception with speeds up to 250 km/h. Certain channels within the CAS were also found to be insufficiently robust. In order to solve the problem of SFN coverage in large distance and the problem of robustness of high-speed mobile reception, two additional numerologies were introduced in Rel-16 [21]. The first numerology has a 0.37 kHz subcarrier spacing and a CP duration of 300 μs (with overhead reduced to 10%). The longer 300 μs CP provides improved support for conventional broadcasting networks in SFN with large transmitter spacing. The second numerology has a 2.5 kHz subcarrier spacing and a CP duration of 100 μs. The wider subcarrier spacing of the 2.5 kHz numerology improves resiliency to Doppler, with benefits for high speed mobile reception. The numerologies and the physical resource blocks parameters defined in 5G Broadcast are shown in the follow 错误!未找到引用源。Table 1.

Table 1 5G OFDM numerology sets

	△f (kHz)	Subcarriers / RB	OFDM symbols per subframe	TCP (μs)	TU (μs)	ISD (km)	Overhead (%)
MBSFN Rel-9 to 12	15	12	12	16.7	66.7	5	20
MBSFN Rel-14	7.5	24	6	33.3	133.3	10	20

	1.25	144	1	200	800	60	20
MBSFN Rel-16	2.5	72	2	100	400	30	20
	0.37	486	1/3	300	2700	90	10
Note: Subcarriers / RB=Subcarriers per Resource Block, T_{CP}=CP duration, T_U=useful OFDM symbol duration, ISD=Intersite Distance.							

The frame structure of the new 5G broadcast digital is shown in the following Figure 3 and Figure 4. The MBSFN region in an MBSFN subframe is defined as the OFDM symbols not used for the non-MBSFN region. For subframes using$\Delta f = 7.5$ kHz, $\Delta f = 2.5$ kHz and $\Delta f = 1.25$ kHz， the MBSFN region is defined as one slot of 1 ms. For subframes using $\Delta f \approx 0.37$ kHz, the MBSFN region is defined as one slot of 3 ms.

In the research stage of Rel 16, it was found that the coverage was insufficient due to the digital mismatch between CAS and MBSFN, because CAS can only configure 16.7μs CP at 15 kHz numerology. Harmonizing the numerology of the CAS with the MBSFN subframes was too complex and therefore the CAS was made to be as robust as was practical. This was achieved by: Considering the possible reception failure of PCFICH, CFI can be configured in the MBMS-dedicated MIB; increasing the aggregation level for PDCCH to 16, which increases its decoding probability; and repeating PBCH within the CAS to make it more robust. With these enhancements it is possible to increase the robustness of the CAS in situations where different transmitters may interfere each other.

6.2.1 Comparison of frequency bandwidth and the bandwidth efficiency

Bandwidth is defined as the maximum aggregated system bandwidth. It may be composed of either a single or multiple carrier in RF (radio frequency). maximum aggregated system bandwidth in Hz (including frequency guard bands).

3GPP standardizes six spectrum bandwidth values: 1.4, 3, 5, 10, 15, and 20 MHz, with OFDMA (Orthogonal Frequency Division Multiple Access) multiplexing scheme in the downlink. Among them, 1.4MHz and 3MHz are mainly used to be compatible with 3G withdrawal frequency of operators in the early stage, and 5G broadcast does not recommend these two bandwidths.

Carrier aggregation is used to increase the bandwidth (and peak data rate) by the bonding of multiple carriers. Based on the LTE, each aggregated carrier is referred to as a component carrier and a maximum of 5 component carriers can be aggregated leading to a maximum carrier aggregation bandwidth of 100 MHz (i.e., 90 MHz maximum transmission bandwidth).

The following Table 2 list presents the comparison of spectrum bandwidth between 5G broadcast and the second generation terrestrial digital TV standard.

It can be seen from the table below that the spectrum bandwidth of 5G broadcast is incompatible with the second-generation digital terrestrial TV system. In the future, attention needs to be paid to frequency allocation and network planning. How to reasonably use the tight spectrum resources and improve transmission efficiency is a problem that needs to be considered.

Table 2 The comparison of spectrum bandwidth between 5G broadcast and DTT

Standard	1.7 MHz (OFDM)	5 MHz (OFDM)	6 MHz (OFDM)	7 MHz (OFDM)	8 MH (OFDM)	10 MHz (OFDM)	15 MHz (OFDM)	20 MHz (OFDM)
DVB-T2	●	●	●	●	●	●		
ATSC 3.0			●	●	●			
DTMB-A			●	●	●			
5G broadcsat		●				●	●	●

In 5G broadcast, the effective bandwidth limited to 90% of nominal channel bandwidth. A series of null carriers are used to reduce OOBE (Out of Band Emissions) resulting in the bandwidth efficiencies shown in the below Table 3. Thus, the maximum possible transmission bandwidth per carrier is 18 MHz.

Table 3 Bandwidth efficiency of 5G broadcast

Channel BW (MHz)	5 MHz (OFDM)	10 MHz (OFDM)	15 MHz (OFDM)	20 MHz (OFDM)

Transmission BW (MHz)	4.5	9	13.5	18
BW Efficiency (%)	90	90	90	90

In actual deployment and implementation, comprehensive considerations need to be made based on frequency allocation, network planning, and transmitter system performance. In HPHT transmission system, high power terrestrial digital TV transmitter with 5MHz or 10MHz is usually used.

The bandwidth efficiencies of the second generation terrestrial digital TV systems such as DVB-T2, DTMB-A and ATSC3.0 are shown in the following Table 4. Although CMMB (China Mobile Multimedia Broadcasting Standard) does not belong to the second generation terrestrial digital TV standard, the following table still makes data comparison for comparison reasons. This chapter mainly compares the spectrum bandwidth efficiency of common modes and does not consider those not commonly used.

Table 4 Bandwidth Efficiency of the Second Generation Terrestrial Digital Television System (including CMMB)

<table>
<tr><th>Waveform</th><th>CMMB (8MHz)</th><th>DTMB-A (8MHz)</th><th>DVB-T2 (8MHz)</th><th>ATSC 3.0 (6MHz)</th></tr>
<tr><td>Transmission BW (Normal mode)</td><td>7.512</td><td>7.56</td><td>7.61</td><td rowspan="2">5.832844-5.508844</td></tr>
<tr><td>Transmission BW (Extended mode)</td><td>NA</td><td>NA</td><td>7.77</td></tr>
<tr><td rowspan="2">BW Efficiency (%)</td><td rowspan="2">93.9</td><td rowspan="2">94.5</td><td>95.125</td><td rowspan="2">91.81-97.21</td></tr>
<tr><td>97.125</td></tr>
<tr><td colspan="5">Note:
1.As described in Section 4.2.2 of Doc. A/327 ATSC Recommended Practice: Guidelines for the Physical Layer Protocol, the carrier reduction coefficient ranges from 0 to 4 and the corresponding ranges of occupied bandwidths are from 5.832844 MHz to 5.508844 MHz for bsr_coefficient = 2 which is a typical value for 6 MHz system bandwidth.</td></tr>
</table>

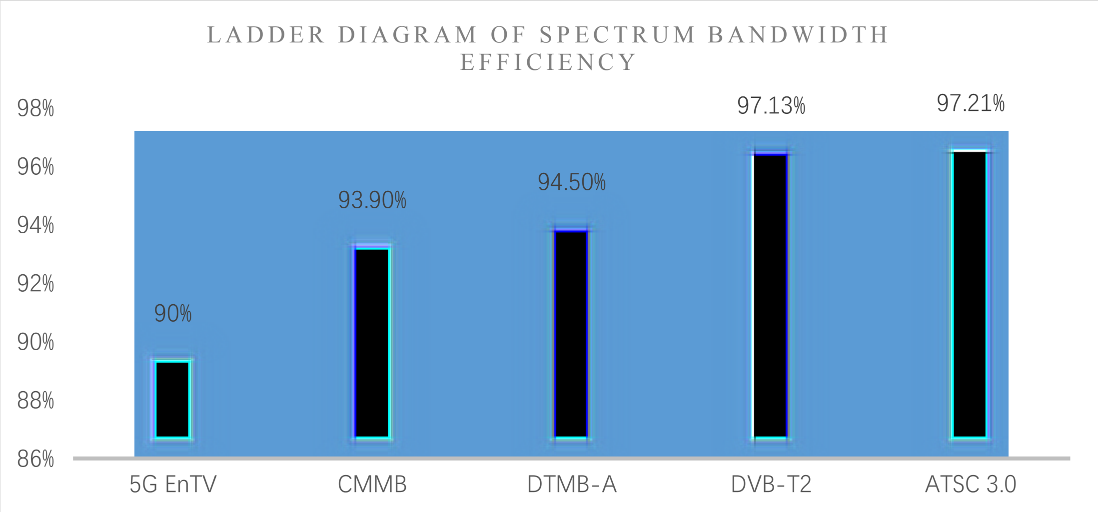


Figure 24 The comparison of bandwidth efficiency

According to recommendation ITU-R BT.1877-2 [22], the following ladder diagram compares the bandwidth efficiency of 5G broadcast, CMMB [23], DVB-T2 [24], DTMB-A and ATSC3.0 [25], as shown in Figure 24.

6.2.2 Comparison of peak data rate (bits/s) and the peak spectral efficiency (bits/s/Hz)

Peak data rate (bit/s): Peak data rate is defined as maximum transmission capacity of payload supported by system.

Peak spectral efficiency can be calculated as the peak data rate divided by the maximum bandwidth of the system BW in Hz (including the frequency bands).

$$SE_p = \frac{Rate_p}{BW}$$

Previous releases of LTE eMBMS defined MBSFN frames with up to 60% broadcast resource allocation (up to 6 out of 10 subframes in each frame could be allocated to broadcast as two were permanently designated for paging and two more for synchronization). The capacity not allocated to broadcast could be allocated to unicast traffic. The latest modifications in FeMBMS, the signalings required for synchronization, acquisition and system information are further compressed and packed into a newly design. The newly design enabled the configuration of up to 80% broadcast resource allocation and also a dedicated carrier with almost 100% broadcast allocation (97.5%), by minimizing the signaling required for synchronization, acquisition and system information and moving it into the newly defined Cell Acquisition Subframe (CAS) that is transmitted once every 40 subframes (i.e. 2.5% signaling overhead). Every CAS appears after/before the consecutive 39 MBSFN subframes.

For 5G broadcast, the peak data rate is the maximum Transport Block Size (TBS) delivered every TTI (Time Transmission Interval) excluding the CAS duration. The peak data rate KPI is calculated as:

$$Rate_{PFeMBMS} = \frac{39}{40} \times \frac{N_{TBS}}{T}$$

N_{TBS}can be obtained from Table 7.1.7.2.1-1, Table 7.1.7.1-1 and Table 7.1.7.1-1A in [26] and T is the subframe duration in seconds. $\frac{39}{40}$means that the number of 5G broadcast data subframes is 39 (one data frame contains 40 subframes). (Note that the transport block size changes with the number of antennas, and therefore MIMO configurations are also included in this calculation. Only the case where △f=1.25KHz will be described here.)

The air interface parameters of FeMBMS, including MBSFN and SC-PTM. Different MCS indexes are selected to provide the performance of the systems for different spectral efficiencies. For MBSFN and SC-PTM configurations, each MCS index employs a different modulation and TB size, which is directly related to a code-rate. According to the 3GPP specification, MCS0-MCS9 correspond to QPSK, MCS10-MCS16 correspond to 16QAM, MCS17-MCS27 correspond to 64QAM, and MCS28-MCS34 correspond to 256QAM.

The maximum $N_{TBS}$for 5MHz FeMBMS is 21384 bits when MCS34 is used, while the peak data rate reaches 20.85 Mbits/s. The calculation process is as follows:

MCS34: $I_{TBS} = 32$ N_{PRB}=21384

$$Rate_{PFeMBMS} = \frac{39}{40} \times \frac{N_{TBS}}{T} = \frac{39}{40} \times \frac{21384}{0.001} = 20.8494 \approx 20.85Mbps$$

$$SE_{p-FeMBMS} = \frac{Rate_p}{BW} = \frac{20.85}{5} = 4.17bps/Hz$$

The maximum $N_{TBS}$for 5MHz FeMBMS is 4008 bits when MCS9 is used, while the peak data rate reaches 3.91 Mbits/s. The calculation process is as follows:

MCS9 $I_{TBS} = 9$ N_{PRB}=4008

$$Rate_{PFeMBMS} = \frac{39}{40} \times \frac{N_{TBS}}{T} = \frac{39}{40} \times \frac{4008}{0.001} = 3.9078 \approx 3.91Mbps$$

$$SE_{p-FeMBMS} = \frac{Rate_p}{BW} = \frac{3.91}{5} = 0.78bps/Hz$$

For ATSC 3.0, the peak data rate with a Single-Input Single-Output (SISO) is calculated for the best combination possible, which is illustrated in follow table. (The carrier reduction coefficient ranges from 0 to 4 and the corresponding ranges of occupied bandwidths are from 5.832844 MHz to 5.508844 MHz for bsr_coefficient = 2 which is a typical value for 6 MHz system bandwidth. Here, maximum possible number using a coefficient 0 as specified in ATSC 3.0 standard).

Table 5 ATSC 3.0 parameters for the peak data rate

Parameter	**Value**	**Parameter**	**Value**
Frame duration	5 s	**Bandwidth**	6 MHz
FFT size	32k	**CP length**	192 samples
Bootstrap symbols	4	**Bootstrap symbol duration**	500 ms
L1-basic	163 cells	**L1-detail**	922 cells
Cred_coeff L1	4	**Modulation order**	4096NUC
Pilot Pattern	SP32_2	**LDPC code rate**	13/15
FEC block length	64800 bits	**BCH parity bits**	192

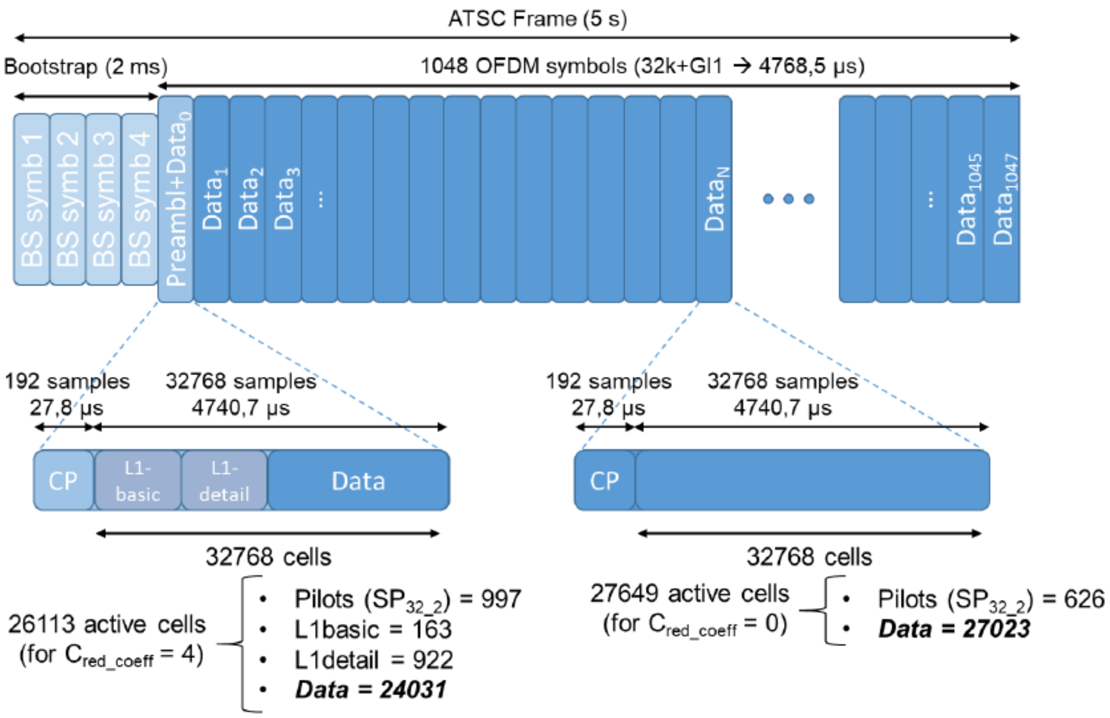


Figure 25 Maximum data cells that an ATSC 3.0 system can use

The above Figure 25 illustrates the process carried out for obtaining the maximum number of data cells in a frame$DataCell_{Frame}$ that an ATSC 3.0 system can transmit. So from this configuration, therefore, the calculation process of the $DataCell_{Frame}$ is as follows.

$$DataCell_{Frame}=24031+1047\times27023= 28317112 \text{ cells}$$

The first data symbol contains 997 pilots (pilot pattern SP32_2), 163 subcarriers for L1-basic and 922 for L1-detail. Therefore, there are 24031 data subcarriers. The 1047 remaining data symbols contain 626 pilots and 27023 data subcarriers. Once the number of data cells has been derived, the peak data rate is obtained taking into account the constellation order, FEC block size, FEC coding rate, and frame duration as:

Since the object of this section is the peak data rate calculation, subframe boundary symbols are not considered. The maximum number of constellation symbols (Mmax) with ATSC 3.0 is 4096 and the highest FEC block length is 64800 bits. Once the number of data cells has been derived, the peak data rate is obtained taking into account the constellation order, FEC block size, FEC coding rate, and frame duration as:

$$FEC_{Blocks} = \left\lceil \frac{28317112 \times \log_2^{4096}}{64800} \right\rceil = 5243$$

$$Rate_p = \frac{5243 \times (64800 \times \frac{13}{15} - 192)}{5} = 58.69Mbps$$

The peak spectral efficiency for ATSC 3.0 is calculated taking into account the peak data rate obtained in the section below ($Rate_p$=58.69 Mbps). This value is obtained for a SISO transmission in a 6 MHz channel bandwidth. Hence, ATSC 3.0 peak spectral efficiency is:

$$SE_{p-ATSC3.0} = \frac{Rate_p}{BW} = \frac{58.69}{6} = 9.78bps/Hz$$

The following line chart compares the peak spectral efficiency (bits/s/Hz) of FeMBMS, DVB-T2 and ATSC3.0 in AWGN channels, as shown in figure 7.

For more detailed comparison, see Annex 1. Table 6-5A and Table 6-5B list the comparison of peak data rate and peak spectral efficiency of various modulation waveforms.

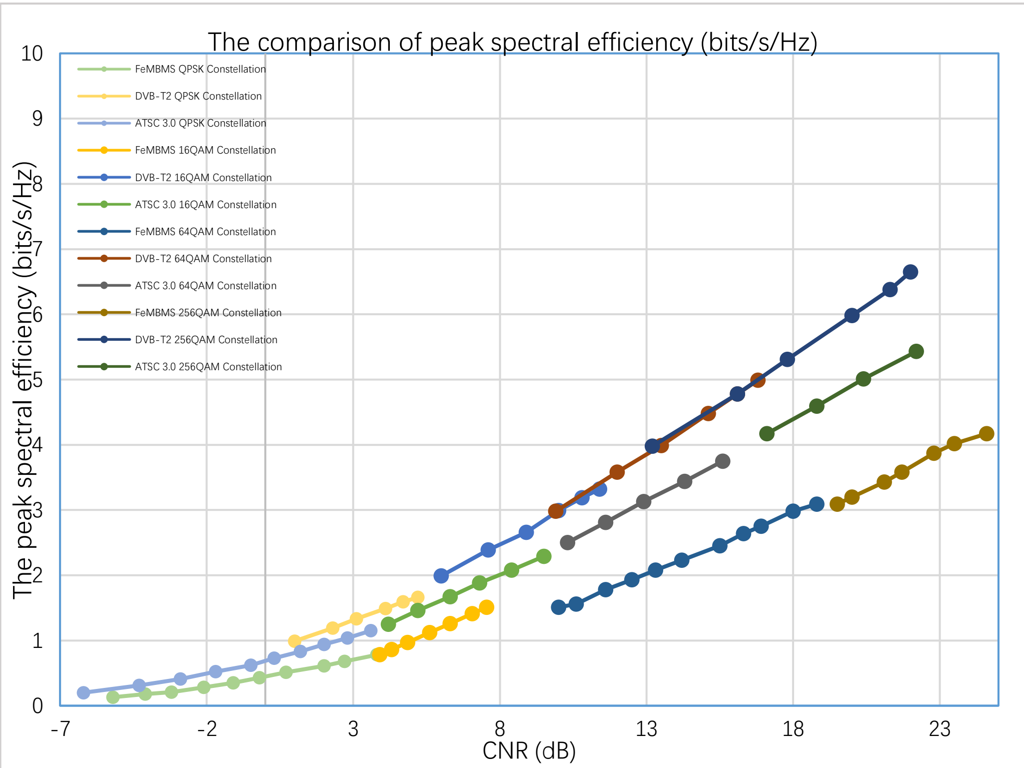


Figure 26 The comparison of peak spectral efficiency in AWGN channel (bits/s/Hz)

6.2.3 Comparison of Peak BICM spectral efficiency

The peak spectral Bit-Interleaved Coded Modulation (BICM) efficiency depends on the maximum modulation order and effective code rate. The peak spectral efficiency defined in bits per channel used (bpc) is the maximum spectral efficiency supported by the system just taking into account cells used for data, i.e., overheads due to synchronization or cyclic prefix and control channels are not considered.

$$SE_{BICM} = m \times CR$$

For FeMBMS,

$$CR = \frac{N_{TBS}}{N_b}$$

Each MCS index provides a different effective code-rate, since they are directly related to a particular TBS. The available bits for data are calculated as:

$$N_b = m \times N_{RB}(N_{symb}N_{SC}^{RB} - N_{ref})$$

Where m is the number of bits per subcarrier, N_{RB} is the number of RBs utilised, N_{symb} is the number of OFDM symbols per RB dedicated to the PTM service, N_{SC}^{RB} is the number of subcarriers per RB, and N_{ref} is the number of reference signals per RB. For 5MHz bandwidth FeMBMS with 1.25 kHz SCS numerology, the peak BICM spectral efficiency is obtained when MCS index is 34, while 256QAM is adopted and m = 8, N_{RB}= 25, N_{symb} = 1, N_{SC}^{RB}= 144, N_{ref}= 24, $I_{TBS} = 32$ and $N_{TBS} = 21384$. The detail physical resource blocks parameters is shown in the following Table 6.

$$N_{MBSFN(1.25KHz)}^{max}$$

$$CR_{PFeMBMS} = \frac{N_{TBS}}{N_b} = \frac{21384}{24000} = 0.891$$

$$SE_{BICMPFeMBMS} = 8 \times 0.891 = 7.128bpc$$

Table 6 Physical resource blocks parameters

Configuration		N_{sc}^{RB}	N_{symb}^{DL}
Normal cyclic prefix	$\Delta f = 15$ kHz	12	7

Extended cyclic prefix	$\Delta f = 15$ kHz		6
	$\Delta f = 7.5$ kHz	24	3
	$\Delta f = 2.5$ kHz	72	1
	$\Delta f = 1.25$ kHz	144	1
	$\Delta f \approx 0.37$ kHz	486	1

ATSC 3.0 provides a single 6 MHz bandwidth allocation, which can be extended to 12 MHz when two radio frequency carriers are used to achieve higher data rates through channel bonding. Here, we only analyze the peak BICM spectral efficiency for the bandwidth of 6MHz. ATSC 3.0 specifies the code rate range from 2/15 to 13/15 and the maximum constellation size of 4096 symbols. ATSC 3.0 uses BCH code as its outer code, which will be included in the calculation of effective code rate (although the system can be configured without BCH coding). In this case, the maximum effective code rate is 0.863. The comparison of Peak BICM spectral efficiency of ATSC 3.0, SC-PTM and MBSFN are shown in Table 7.

Table 7 Peak BICM spectral efficiency of ATSC 3.0, SC-PTM and MBSFN

	M_{max}	CR_{max}	SE_P
ATSC 3.0	12	0.863	10.356
MBSFN	8	0.891	7.128

6.2.4 Comparison of BICM spectral efficiency vs CNR in different scenarios

This section evaluates KPIs that are dependent on the network conditions. The required QoS is subject to a block error rate (BLER) lower than 0.1%. Different scenarios have been evaluated in order to assess the impact of the configurations adopted. These scenarios mainly include AWGN (Additive White Gaussian Noise), Rician, Rayleigh channel and so on. A bandwidth of 5 MHz has been used with both LTE configurations and a subcarrier spacing of Δf= 1.25 kHz is always used with MBSFN. This assumption is taken to study the potential advantages of different waveforms.

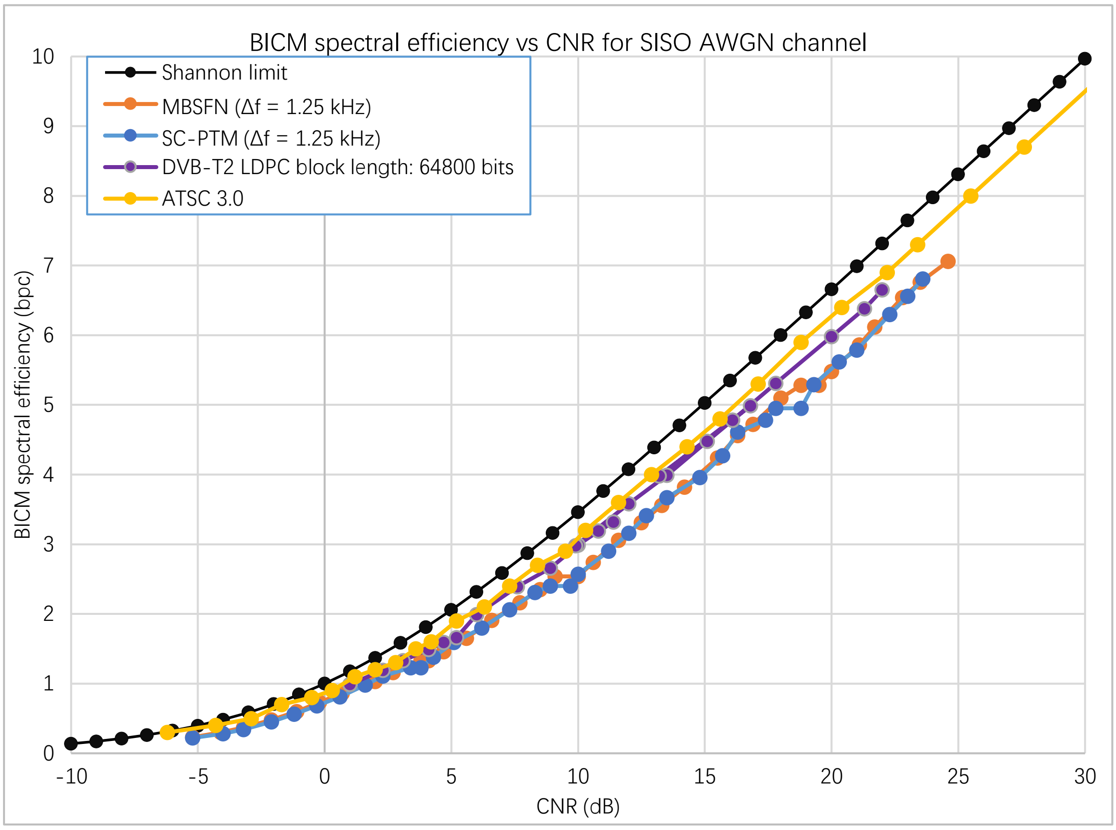


Figure 27 BICM spectral efficiency vs. CNR (dB) for SISO AWGN channel. DVB-T2, ATSC 3.0, MBSFN and SC-PTM, Δf= 1.25 kHz

1) Additive White Gaussian Noise (AWGN) Channel:

The Figure 27 below shows the BICM spectral efficiency in bits per channel use (bpc) as a function of the required CNR in an AWGN channel for SC-PTM, MBSFN, DVB-T2 and ATSC 3.0. The purpose of this study is to compare the performance of modulation and coding schemes of different technologies. Hence, in the comparisons only Single Input Single Output (SISO) antenna configurations is considered.

For the AWGN channel from the follow figure, the ATSC 3.0 and DVB-T2 provides important gains compared to SC-PTM and MBSFN, especially for high CNRs.

2) MIMO i.i.d. Rayleigh channel:

The following Figure 28 shows the BICM spectral efficiency versus required CNR for the independent and identically distributed (i.i.d.) Rayleigh MIMO channel with two transmit and receive antennas. ATSC 3.0 and SCPTM use two transmitter and receiver antennas, and MBSFN adopts 1×2 single input multiple output (SIMO) scheme (It should be noted that in this channel, in this channel SISO and SIMO provide the same performance since there is no cross-polar component that can be exploited with two receive antennas), which is a major disadvantage. There is no depolarization between the two transport streams using an ideal cross-polarity channel. It should be noted that DVB-T2 uses SISO scheme with one transmitter and antenna.

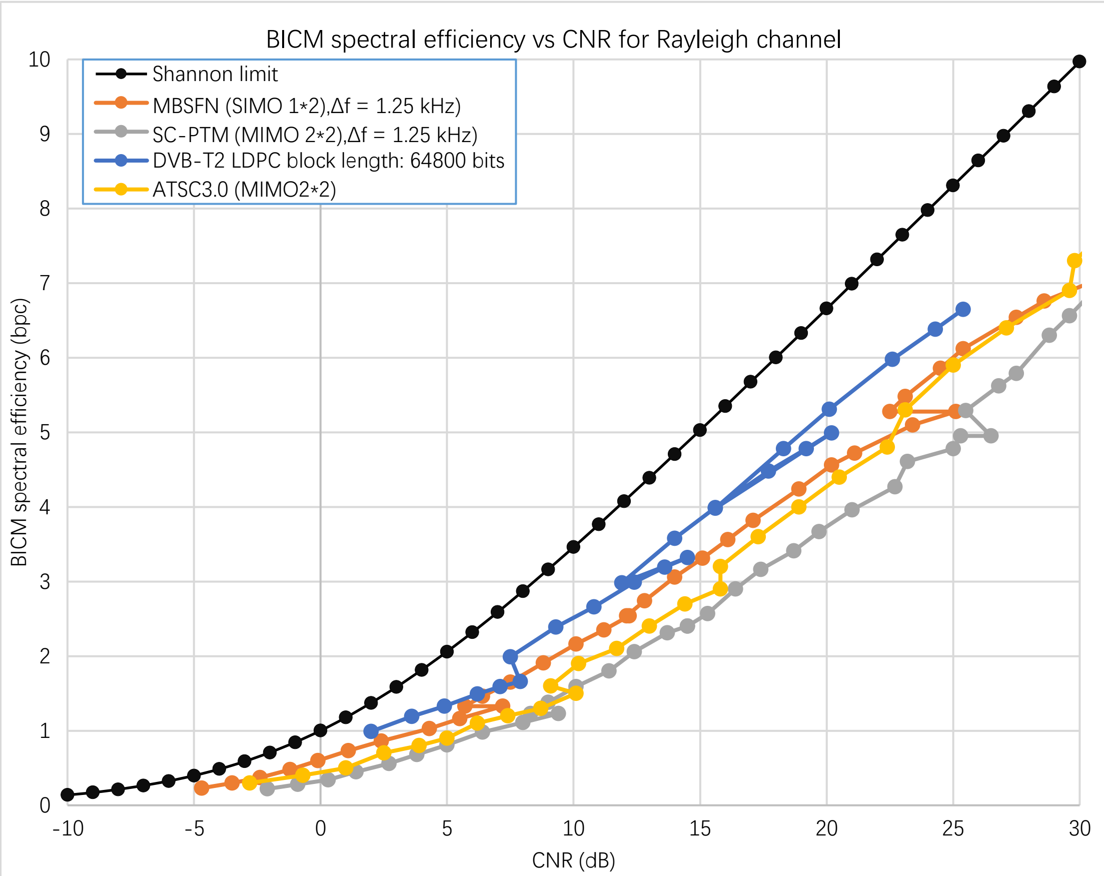


Figure 28 BICM spectral efficiency vs. CNR in dB of DVB-T2, ATSC 3.0, MBSFN and SC-PTM, Δf= 1.25 kHz

For the Rayleigh channel shown in the Figure 28 below, DVB-T2 shows excellent performance. The CNR gains of DVB-T2 over SC-PTM for low spectral efficiency are about 1dB, while those for high spectral efficiency are more than 4dB. MBSFN and SC-PTM are slightly inferior to ATSC 3.0 and DVB-T2 standards in overall performance, which should be paid attention to and comprehensively considered in future system design and network planning.

3) Rician channel:

The Figure 29 below describes the BICM spectrum efficiency of the dvb-F1 channel model and the required CNR, which is commonly used for modelling fixed-rooftop reception conditions.

Compared with the performance obtained by AWGN channel mentioned earlier, it can be observed that the performance of the three systems being evaluated is degraded. The same trend as the previous channel is obtained, that is, compared with SISO AWGN channel, the CNR threshold increases by about 0.1 to 0.4 dB for low spectral efficiency and 0.4 to 0.8 dB for high spectral efficiency.

In the Rician channel model, ATSC 3.0 and DVB-T2 have higher BICM performance. under the same CNR, the BICM performance of ATSC 3.0 and DVB-T2 both exceed SC-PTM and MBSFN. SC-PTM and MBSFN systems have similar trends. under the same CNR, there is no big difference in BICM spectral efficiency between them.

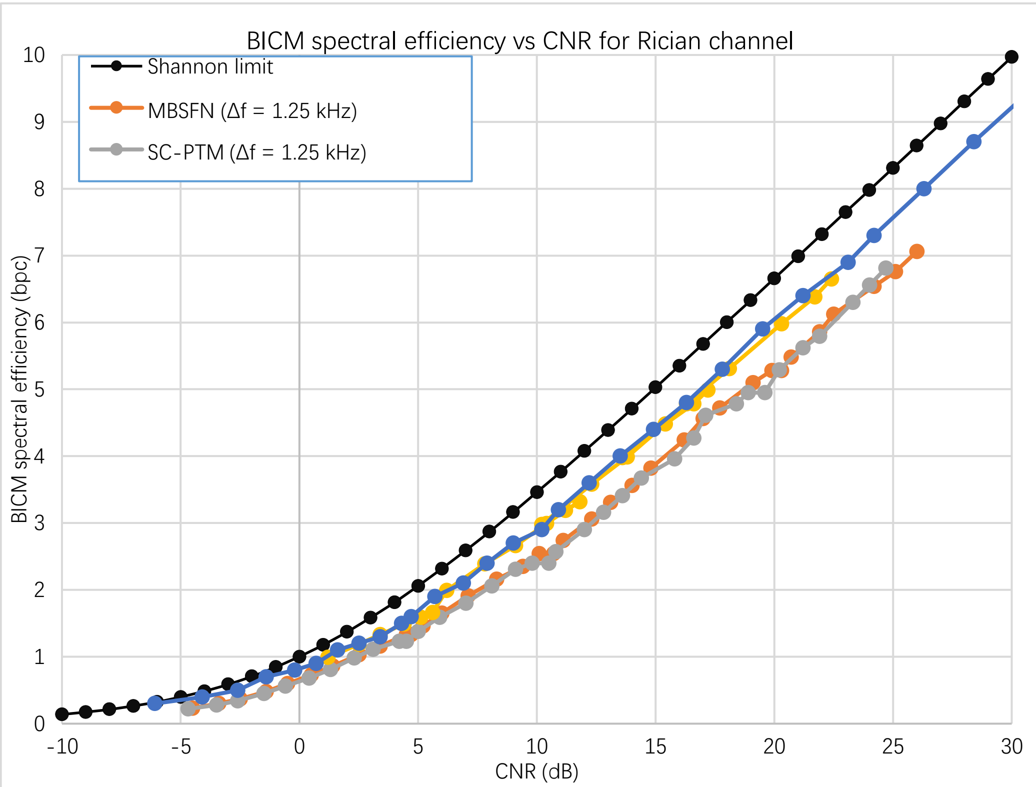


Figure 29 BICM spectral efficiency vs. CNR in dB of DVB-T2, ATSC 3.0, MBSFN and SC-PTM, Δf= 1.25 kHz

See annex 1 for more details, the comparison of peak data rate and peak spectral efficiency of various modulation waveforms.

6.2.5 Comparison of ISD (inter-site distance)

DVB-T2 and ATSC 3.0 both provide different guard interval fraction. A suitable combination of symbol length (i.e. FFT mode) and guard interval fraction allows for the minimization of the overhead implied by the guard interval. Particularly, ATSC 3.0 and DVB-T2 both support 32K FFT mode, which will lead to the extension of "useful" symbol time compared with 8k. In principle, because the inter-carrier distance in OFDM signal is short, long symbol time will lead to poor Doppler performance. Therefore, the 32k mode is mainly for fixed roof reception. Laboratory and field tests show that 32k mode is unlikely to be used to provide UHF mobile (vehicle) reception. Even in a portable (indoor or outdoor pedestrian) receiving environment with a low Doppler frequency, it is necessary to confirm that the 32k mode is suitable.

In addition, DVB-T2 also provides 1.7MHz bandwidth operation mode. This makes it possible to implement DAB frequency block structure conforming to GE06 plan. In this way, audio and mobile TV (with low bit rate) services can also be supported.

Compared with the original broadcast requirements in TR 36.776, Rel-14 found several shortcomings. In particular, Rel-14 required improvement to support SFN coverage with cell radii up to 100 km and mobile reception with speeds up to 250 km/h. Certain channels within the CAS were also found to be insufficiently robust. In order to solve the problem of SFN coverage in large distance and the problem of robustness of high-speed mobile reception, two additional numerologies were introduced in Rel-16. The first numerology has a 0.37 kHz subcarrier spacing and a CP duration of 300 μs (with overhead reduced to 10%). The longer 300 μs CP provides improved support for conventional broadcasting networks in SFN with large transmitter spacing. The second numerology has a 2.5 kHz subcarrier spacing and a CP duration of 100 μs. The wider subcarrier spacing of the 2.5 kHz numerology improves resiliency to Doppler, with benefits for high speed reception. Although the 300 μs CP theoretically supports ISD distance up to 90Km, it is still slightly insufficient in actual network planning and application, and it is expected that the later version will be further enhanced.

See annex 2 for more details, table 6-9 lists the detailed guard interval duration comparison of DVB-T2, ATSC 3.0 and FeMBMS.

6.3 summary

This chapter compares 5g terrestrial broadcasting with other terrestrial digital TV technical standards, and draws the following conclusions

- Spectrum bandwidth efficiency: the theoretical bandwidth efficiency of all systems is not less than 90%, in which DVB-T2 and ATSC 3.0 can reach 97%;
- Peak spectral efficiency: The peak spectral efficiency of 5G terrestrial broadcasting is slightly lower than the second-generation terrestrial digital TV standards ATSC 3.0 and DVB-T2;
- ISD (inter-site distance) comparison: the inter-site distance and flexibility of single frequency network (SFN) for 5G terrestrial broadcasting are slightly lower than the second-generation terrestrial digital television standards ATSC 3.0 and DVB-T2.

The overall performance of 5G terrestrial broadcasting is slightly lower than that of the second-generation terrestrial digital television standard, but it can basically meet the planning and deployment of the commonly used terrestrial digital television network.

7 Considerations on 5g broadcast deployment

7.1 Summary and prospect of 5G terrestrial digital broadcasting technology

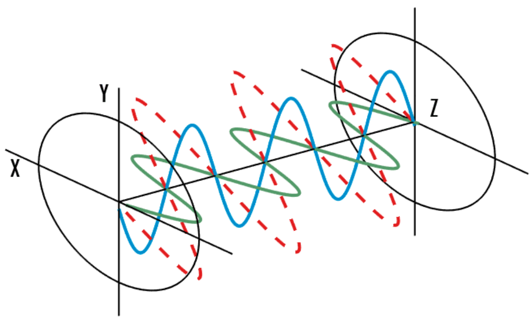
In the previous chapters, we discussed the 5G broadcast technology and other second-generation terrestrial digital TV technologies in detail. 5G terrestrial broadcasting technology is based on 3GPP standards, and supports fixed receiving mode and mobile portable receiving mode. Although the 5G broadcast technology is slightly inferior to the second-generation terrestrial digital TV technology in some performance, the 5G broadcast represents a pragmatic broadcasting method based on 3GPP technology, which can be rapidly popularized and promoted on smart phones, PADs and fixed TVs all over the world. Theoretically, terminals equipped with 5G terrestrial broadcast demodulation technology can support global applications, which is a great thing (The digital signal demodulation part of 5g broadcast is unified, which may require the cooperation of different app and Middleware). With additional key functions, the work done in Rel-16 represents a further improvement of the standard, which will provide greater flexibility and more reliable performance for deployment. Although its technical maturity has yet to be fully analyzed, especially in real-world tests, such as the 754MHz project in Beijing, China and the 5G-Today project in Germany.

The 5, 10, 15 and 20MHz RF bandwidths of 5G terrestrial broadcasting are not compatible with the existing DTT system. Countries around the world will face great difficulties in frequency allocation and network planning. In addition, system costs (such as adjusting cavity filters, etc.) will increase. It will be of great significance to promote compatibility of 6MHz, 7MHz and 8MHz in 3GPP in the future.

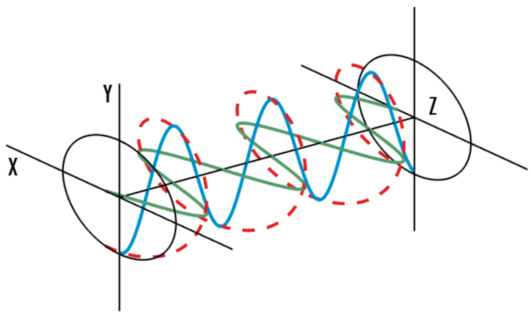
5G broadcast has reached a consensus in 3GPP, which should further support 5G broadcast, promote the "convergence" of HPHT and LPLT, and realize the use of 5G terrestrial broadcasting "Anytime and Anywhere".

7.2 Discussion on the application of UHF band circular polarized transmitting antenna in 5G broadcast

In traditional mobile multimedia broadcasting, the antenna gain of handheld portable devices is relatively low, usually the peak gain of telescopic antenna is about 2dBi. With the built-in antenna design of smart phones, the signal receiving ability is facing great challenges, and the antenna peak gain is generally -7.35dBi or even lower. Most of the traditional terrestrial digital TV transmitting antennas are linearly polarized (vertically polarized or horizontally polarized), which is not conducive to the signal reception of mobile devices. In view of this, it is suggested to consider using circularly polarized transmitting antenna in UHF band for signal transmission. The following Figure 30 shows linear polarization and horizontal polarization.



The electric field of linearly polarized light (left) consists of two perpendicular, equal in amplitude, linear components that have no phase difference. The resultant electric field wave propagates along the y = x plane.



The electric field of circularly polarized light (right) consists of two perpendicular, equal in amplitude, linear components that have a phase difference of π/2 or 90°. The resultant electric field wave propagates circularly.

Figure 30 Linear polarization and horizontal polarization.

The circularly polarized transmitting antenna has the following advantages:

Reflection or absorption ability of radio signals: Radio signals are reflected or absorbed depending on the material they come in contact with. Because linear polarized antennas are able to "attack" the problem in only one plane, if the reflecting surface does not reflect the signal precisely in the same plane, that signal strength will be lost. Since circular polarized antennas send and receive in all planes, the signal strength is not lost, but is transferred to a different plane and are still utilized. Different materials absorb the signal from different planes. As a result, circular polarized antennas give you a higher probability of a successful link because it is transmitting on all planes.

Phasing Issues: A radio transceiver system usually requires a clear line of sight between two points, so as to operate more effectively. Reflected linear signals return to the propagating antenna in the opposite phase, thereby weakening the propagating signal. Such systems have difficulty penetrating obstructions due to reflected signals, which weaken the propagating signal. Conversely, circularly-polarized systems also incur reflected signals, but the reflected signal is returned in the opposite orientation, largely avoiding conflict with the propagating signal. The result is that circularly-polarized signals are much better at penetrating and bending around obstructions.

Multi-path: Multi-path is caused when the primary signal and the reflected signal reach a receiver at nearly the same time. This creates an "out of phase" problem. The receiving radio must spend its resources to distinguish, sort out, and process the proper signal, thus degrading performance and speed. Linear Polarized antennas are more susceptible to multi-path due to increased possibility of reflection. Out of phase radios can cause dead-spots, decreased throughput, distance issues and reduce overall performance.

Rain and snow cause a microcosm of conditions explained above (i.e. reflectivity, absorption, phasing, multi-path). Circular polarization is more resistant to signal degradation due to inclement weather conditions for all the reason stated above.

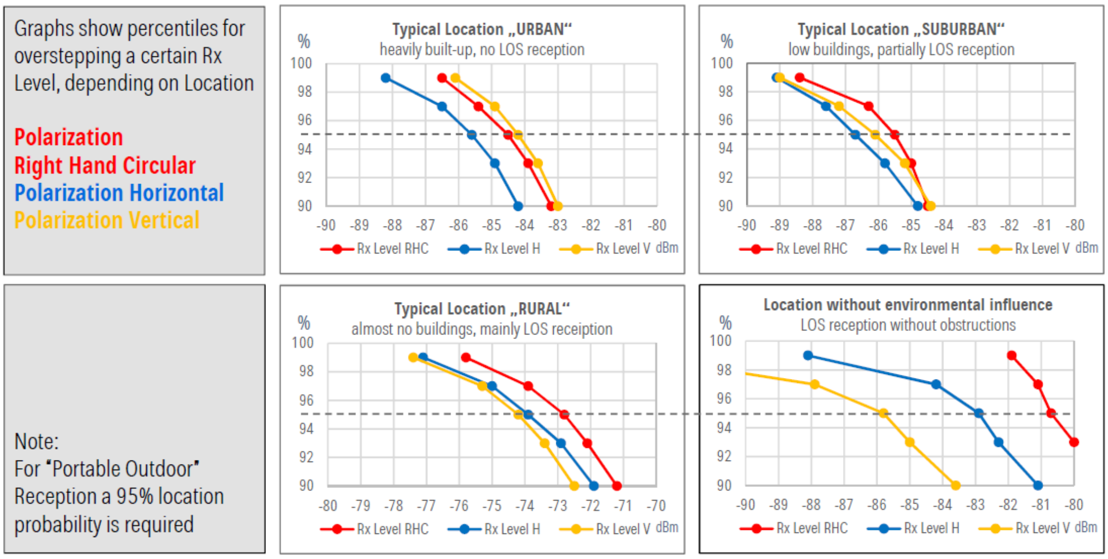


Figure 31 Evaluation of linear polarization and circular polarization in several scenarios

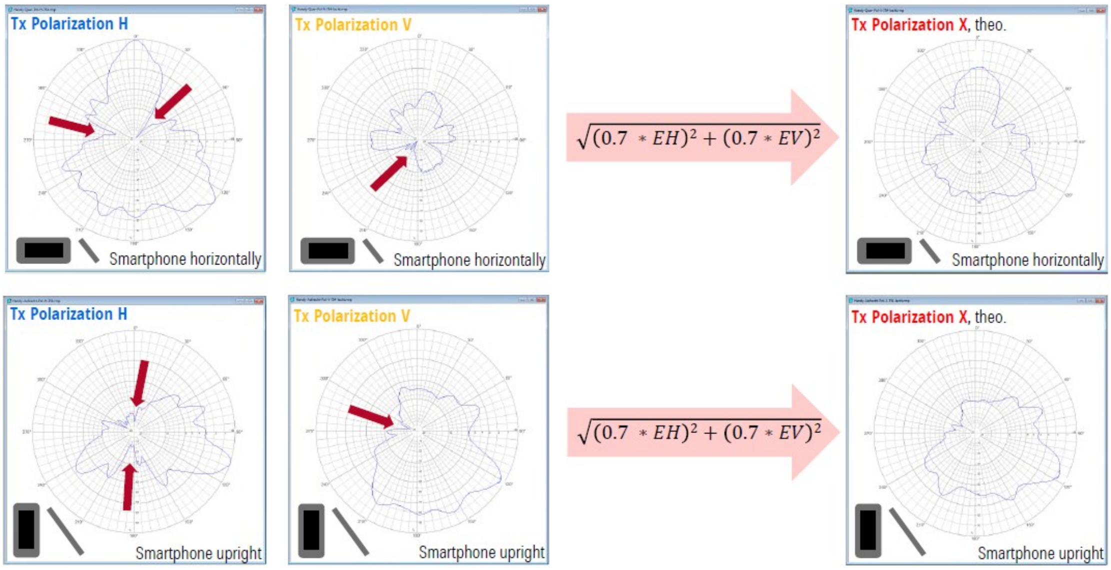


Figure 32 The "Filling" of smart phone receiving antenna pattern by circularly polarized RF signal

Field strength ⩾80 dBuV/m for 95% of locations will be necessary to cover mobiles "portable outdoor". Kathrein measured and evaluated the polarization effect of Tx antenna in the 5G Today project. The effects of linear polarization and circular polarization were evaluated in four scenes: urban, suburban, rural and location without environmental influence. By evaluating several specific scenarios, it is found that the percentage of circularly polarized RF signals exceeding a specific receiving level is higher. In addition, circularly polarized RF signals can "fill" the antenna patterns of smart phones at different angles, bringing positive effects. Figure 31 shows the evaluation results, and Figure 32 shows the "filling" of the receiving antenna pattern of the smart phone, which is from Katherin's document [29].

Based on the above discussion, it is suggested to consider adopting circularly polarized transmitting antenna to transmit 5G terrestrial broadcast RF signals in UHF band.

7.3 Test consideration

5G broadcast is developed based LTE FeMBMS with some additional features. For the test, the following parameters can be used as baseline for test.

RSSI

E-UTRAN carrier RSSI (Received Signal Strength Indicator)

Wide-band power of all subcarriers including thermal noise, co-carrier and adjacent carrier interference, and noise generated in the receiver. See more 3GPP 36.214 subclause 5.1.5.

RSRP

RS received power

Reference signal received power is the linear average of the power contributions of the resource elements that carry cell-specific reference signals within the considered measurement frequency.

CINR

Reference Signal CINR

Ratio between the reference signal received power (RSRP) and the interference and noise from the same reference signal set.

RSRQ

RS received quality

Reference signal received quality is the ratio N * RSRP / E-UTRA carrier RSSI, where N is the number of resource blocks of the E-UTRA carrier RSSI measurement bandwidth. The measurements in the numerator and denominator are made over the same set of resource blocks. See more 3GPP TS 36.214 subclause 5.1.3.

MER

Reference Symbol Modulation Error Ratio

Modulation Error Ratio of equalized constellation of Reference Symbol

Time Offset

Time difference between TSMW reference time and received LTE signal.

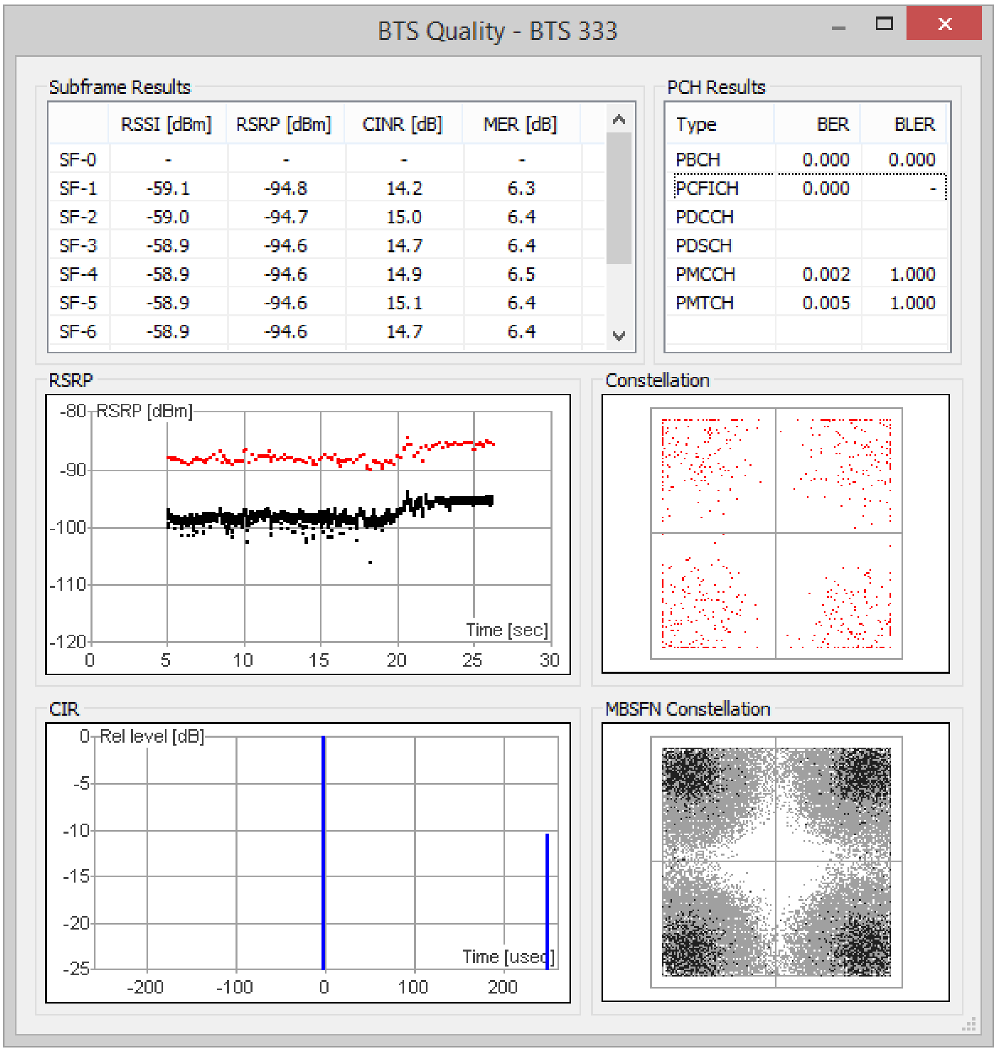


Figure 33 illustrative figure for test

For traditional video broadcasting, there are some consideration regarding the characteristics of video instead of just using BER to judge the performance of receiver because the importance of bits in a video stream would be different. For example, in some specs for broadcasting, different degradation criteria are used for receiver performance evaluation.

- Reference BER, defined BER **after different levels of channel coding**.
- Picture failure point (PFP), defined as the C/N when picture errors become visible. This is preferred when BER measurements are unstable or unavailable.

We also can treat them as objective test and subjective test respectively.

7.4 CMAF based Unified packaging protocol

CMAF (Common Media Application Format) is developed by MPEG organization and endorsed by ISO as ISO23000-19 standard. It targets to provide the unified container for HLS and DASH which can largely reduce the storage of CDN provider. Meanwhile, CMAF enables low latency packaging protocol to reduce the E2E latency.

CMAF-IF (CMAF Industry Forum) is founded by CTA WAVE project and takes lead of the promotion.

CMAF supports the feature of low-latency packets, which is the reason why it is selected as an IP technology in the evolution of major broadcast systems. Most of the major broadcast solutions adopted CMAF as packaging protocol, including DVB-I, ATSC, 3GPP and etc. DVB-I [30] supports DVB-DASH and DVB-DASH with low latency mode; ATSC3.0 [31] re-designs the FLUTE for CMAF; 3GPP also adopted CMAF as the packaging protocol in R16.

Here, we have obtained some real experimental data based on 5G network through the 5G Media Joint Creation Laboratory of Shanxi Institute of Media. The test results well support the following benefits, which are important features of the integration of 5G broadcast and unicast:

- Stable low-latency content delivery
- Support large bitrate and ultra-high-definition resolution, in line with 5G characteristics

The test topology of the laboratory is shown in the figure:

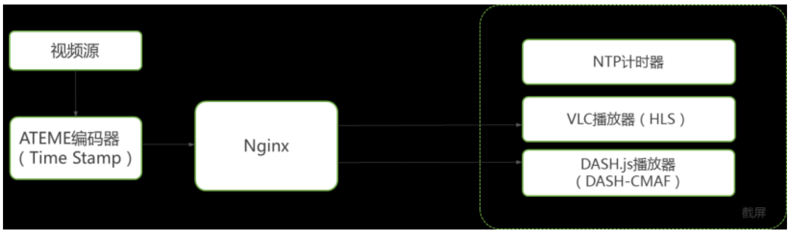


Table 8 latency test, H.264, 1 segment = 2s, 1080P@25fps

Data rate	Chunk size	End to end latency	CDN distribution latency	Player buffer size
10Mbps	100ms	4.279s	3.002s	2.718s
10Mbps	200ms	4.477s	3.105s	2.609s
10Mbps	300ms	4.251s	3.008s	2.773s
10Mbps	400ms	4.514s	2.999s	2.894s
10Mbps	500ms	4.296s	3.015s	2.907s
10Mbps	1000ms	3.933s	3.029s	2.092s
10Mbps	2000ms	3.828s	3.026s	1.317s

In the same test setup, we compare the latency of different segments of common HLS with the following results (1080P@25fps, bit rate = 10Mbps):

Table 9 latency test, H.264, 1080P@25fps

Segment size	End to end latency
2s	9.23s
4s	15.626s
6s	20.206s
10s	41.819s

We also get the following results for large data rate under 5G network.

Table 10 large data rate, H.264, 4K@25fps, 500ms chunk

Data rate	End to end latency	CDN distribution latency
20Mbps	4.626s	3s
30Mbps	4.922s	3.02s
50Mbps	4.64s	3.398s
80Mbps	4.828s	3.664s

From the results of Table 8 and Table 10, it can be observed that CMAF shows good stability in low-latency characteristics while the end to end latency remains almost the same despite of the data rate.

Furthermore, the reason why the impact of chunks on delay is not reflected is that the buffer size is much larger than the variable chunk sizes set in the experiment. This buffering effect makes the system robust with different and complex system parameters when 5G broadcast and unicast are integrated.

In Table 10, we see that the 5G network carrying large bit rate, ultra-high-definition, low-latency CMAF maintains good delay characteristics, which has certain reference significance for the deployment of ultra-high-definition services in 5G broadcast. In Table 9 we see that the content delivered based on the traditional segment method, as the segment size increases, the delay increases accordingly. When the segment size is 2s, the delay is 9.23s, but when the chunk size is 2000ms (2s), the delay is only 3.828s. The reason is that the buffering logic of the player is different. Based on the chunk mode, the player will continue to obtain the latest segment. The player can handle very low buffering and throughput fluctuations. Based on the segment method, the player uses the number of buffer segment as the metric for the playback control while the delay cannot be guaranteed.

In addition to the above analysis conclusions, CMAF has other features, such as the degree of standardization and protocol compatibility, general encryption methods, and delay mode compatibility.

Reference

[1] FuTURE Forum 5G broadcast and video WG, 5G broadcast Use Case whitepaper, Nov. 27th, 2020

[2] 3GPP, TS 38.913, Study on Scenarios and Requirements for Next Generation Access Technologies; v14.0, Oct. 2016

[3] 3GPP, TS 23.246, Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description, v16.1, Sep. 24th, 2019

[4] 3GPP, TS 26.346, Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs, v16.6.1, Oct., 2020

[5] 3GPP, TS 23.501, System architecture for the 5G System (5GS), v16.6, Sep.24th, 2020

[6] 3GPP, TR 26.891, 5G enhanced mobile broadband; Media distribution, v16.0, Dec. 21st, 2018

[7] 3GPP, TS 26.348, Northbound Application Programming Interface (API) for Multimedia Broadcast/Multicast Service (MBMS) at the xMB reference point, v16.3, March 2020

[8] 3GPP, TS 29.116, Representational state transfer over xMB reference point between content provider and BM-SC, v16.6, Sep. 2020

[9] 3GPP, TS 36.300, Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2, v16.3, Oct. 2020

[10] 3GPP, TS 36.331, Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification, v16.2.1, Oct. 2020

[11] 3GPP, TS 24.116, Stage 3 aspects of system architecture enhancements for TV services, v16.0, July 8th, 2020

[12] 3GPP, TS 24.117, TV service configuration Management Object (MO), v16.0, July 9th, 2020

[13] 3GPP, TS 36.304, Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode, v16.2, Oct. 2020

[14] 3GPP, TS 36.133, Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) and repeater ElectroMagnetic Compatibility (EMC), v16.2, Sep. 2019

[15] 3GPP, TS23.003, Numbering, addressing and identification, v16.4, Sep. 24th, 2020

[16] ITU-R BT.2049-7, “Broadcasting of multimedia and data applications for mobile reception”, February 2016.

[17] 5G-Xcast_D2.1 v1.1, “Definition of Use Cases, Requirements and KPIs”, June, 2018.

[18] 3GPP TR 38.913 v14.3.0, “Study on scenarios and requirements for next generation access technologies,” Aug. 2017.

[19] 3GPP TR 36.976 v16.0.0, “Overall description of LTE-based 5G broadcast (Release 16), Dec. 2019.

[20] 3GPP TR 36.776 v16.0.0, “Study on LTE-based 5G terrestrial broadcast (Release 16)”, March 2019.

[21] 3GPP TS 36.211 v16.2.0, “Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation”, June, 2020.

[22] RECOMMENDATION ITU-R BT.1877-2, “Error-correction, data framing, modulation and emission methods and selection guidance for second generation digital terrestrial television broadcasting systems”, December, 2019.

[23] GY/T 220.1-2006, Chinese Television and Radio Industry Standard“Mobile Multimedia Broadcasting Part 1: Framing Structure, Channel Coding and Modulation for Broadcasting Channel”, October, 2006.

[24] Report ITU-R BT.2254-3, “Frequency and network planning aspects of DVB-T2”, March, 2017.

[25] ATSC Recommended Practice: “Guidelines for the Physical Layer Protocol”, 30 January 2020.

[26] 3GPP TS 36.213 V16.2.0,”Evolved Universal Terrestrial Radio Access (E-UTRA);Physical layer procedures (Release 16)”, June, 2020.

[27] Zhiping Xia, Boyuan Xu, Xiangkun Meng, Yu Zhang, “Comparative Study on KPIs between FeMBMS and DTMB”.

[28] 5G-Xcast D3.1 v1.1, “Deliverable D3.1 LTE-Advanced Pro Broadcast Radio Access Network Benchmark”, June, 2018.

[29] Kathrein Broadcast GmbH，“Antenna Solutions for Next Generation TV”，Feb. 2020

[30] ETSI TS 103 285 V1.3.1 “Digital Video Broadcasting (DVB); MPEG-DASH Profile for Transport of ISO BMFF Based DVB Services over IP Based Networks”, Feb,2020

[31] ATSC A/331:2019 “Signaling, Delivery, Synchronization, and Error Protection”, June，2019

Annex 1

Table 11 MBSFN MCS table (Δf= 1.25 kHz)

Constellation	MCS index	BICM spectrum efficiency	Spectrum efficiency	Peak data rate (Mbits/s)	AWGN	i.i.d. Rayleigh	DVB-F1 Rician	Outdoor Portable device	indoor Portable device	TU6 mobility(120km/h)
QPSK	0	0.23	0.13	0.65	-5.2	-4.7	-4.5	-1.4	6.8	2.6
	1	0.3	0.18	0.9	-4.1	-3.5	-3.4	-	-	-
	2	0.37	0.21	1.05	-3.2	-2.4	-2.5	-	-	-
	3	0.48	0.28	1.4	-2.1	-1.2	-1.4	2	10.2	6.2
	4	0.6	0.35	1.75	-1.1	-0.1	-0.5	-	-	-
	5	0.73	0.43	2.15	-0.2	1.1	0.5	-	-	-
	6	0.86	0.51	2.55	0.7	2.4	1.4	5.1	13.9	9.9
	7	1.03	0.61	3.05	2	4.3	2.5	-	-	-
	8	1.16	0.68	3.4	2.7	5.5	3.4	-	-	-
	9	1.33	0.78	3.91	3.8	7.2	4.5	10.3	18.3	14.2
16QAM	10	1.33	0.78	3.9	4.1	5.7	4.7	-	-	-
	11	1.46	0.86	4.3	4.7	6.4	5.2	-	-	-
	12	1.65	0.97	4.85	5.6	7.5	6	9.8	18.9	14.6
	13	1.91	1.12	5.6	6.6	8.8	7.1	-	-	-
	14	2.16	1.26	6.3	7.7	10.1	8.3	-	-	-
	15	2.35	1.41	7.05	8.5	11.2	9.4	19.8	24.6	19.8
	16	2.54	1.51	7.55	9.1	12.2	10.1	-	-	-
64QAM	17	2.54	1.51	7.55	10	12.1	10.7	-	-	-
	18	2.74	1.56	7.8	10.6	12.8	11.1	19.7	25.4	20.8
	19	3.06	1.78	8.9	11.6	14	12.3	-	-	-

	20	3.31	1.93	9.65	12.5	15.1	13.1	-	-	-
	21	3.56	2.08	10.4	13.3	16.1	14	23.8	29	24.6
	22	3.82	2.23	11.15	14.2	17.1	14.8	-	-	-
	23	4.24	2.45	12.25	15.5	18.9	16.2	-	-	-
	24	4.56	2.64	13.2	16.3	20.2	17	31.1	35	29.9
	25	4.72	2.75	13.75	16.9	21.1	17.7	-	-	-
	26	5.1	2.98	14.9	18	23.4	19.1	-	-	-
	27	5.28	3.09	15.45	18.8	25.1	19.9	37.9	40.9	35.2

Table 12 SC-PTM MCS (Δf= 1.25 kHz)

Constellation	**MCS index**	**BICM spectrum efficiency**	**Spectrum efficiency**	**Peak data rate (Mbits/s)**	**AWGN**	**i.i.d. Rayleigh**	**DVB-F1 Rician**	**Outdoor Portable device**	**indoor Portable device**	**TU6 mobility(120km/h)**
QPSK	**0**	0.22	0.13	0.65	-5.2	-2.1	-4.7	0.1	4.8	2.6
	1	0.28	0.18	0.9	-4	-0.9	-3.5	-	-	-
	2	0.34	0.21	1.05	-3.2	0.3	-2.6	-	-	-
	3	0.45	0.28	1.4	-2.1	1.4	-1.5	3.4	8.8	5.9
	4	0.56	0.35	1.75	-1.2	2.7	-0.6	-	-	-
	5	0.68	0.43	2.15	-0.3	3.8	0.4	-	-	-
	6	0.81	0.51	2.55	0.6	5	1.3	7.2	11.9	9.4
	7	0.98	0.61	3.05	1.6	6.4	2.3	-	-	-
	8	1.11	0.68	3.4	2.3	8	3.1	-	-	-
	9	1.23	0.78	3.91	3.4	9.4	4.2	11.8	16.5	13.7
16QAM	**10**	1.23	0.78	3.9	3.8	8.3	4.5	-	-	-
	11	1.38	0.86	4.3	4.3	9	5	-	-	-
	12	1.59	0.97	4.85	5.1	10.1	5.9	11.7	17	14.4

	13	1.8	1.12	5.6	6.2	11.4	7	-	-	-
	14	2.06	1.26	6.3	7.3	12.4	8.1	-	-	-
	15	2.31	1.41	7.05	8.3	13.7	9.1	16.1	20.9	18.6
	16	2.4	1.51	7.55	8.9	14.5	9.8	-	-	-
	17	2.4	1.51	7.55	9.7	14.5	10.5	-	-	-
	18	2.57	1.56	7.8	10	15.3	10.8	17	22	19.7
	19	2.9	1.78	8.9	11.2	16.4	12	-	-	-
	20	3.16	1.93	9.65	12	17.4	12.8	-	-	-
	21	3.41	2.08	10.4	12.7	18.7	13.6	20.4	25.4	22.8
64QAM	**22**	3.67	2.23	11.15	13.5	19.7	14.4	-	-	-
	23	3.96	2.45	12.25	14.8	21	15.8	-	-	-
	24	4.27	2.64	13.2	15.7	22.7	16.6	24.7	29.2	26.8
	25	4.61	2.75	13.75	16.3	23.2	17.1	-	-	-
	26	4.78	2.98	14.9	17.4	25	18.4	-	-	-
	27	4.95	3.09	15.45	17.8	25.3	18.9	30.1	32.9	30.8
	28	4.95	3.09	15.45	18.8	26.5	19.6	-	-	-
	29	5.29	3.2	16	19.3	25.5	20.2	-	-	-
	30	5.62	3.43	17.15	20.3	26.8	21.2	29.4	33.2	31.1
256QAM	**31**	5.79	3.58	17.9	21	27.5	21.9	-	-	-
	32	6.3	3.87	19.35	22.3	28.8	23.3	-	-	-
	33	6.56	4.02	20.1	23	29.6	24	33.5	37.4	35.5
	34	6.81	4.17	20.85	23.6	30.3	24.7	-	-	-

Annex 2

Table 13 The comparison of guard interval duration between DVB-T2, ATSC 3.0 and FeMBMS

Standard	Parameters	1.7 MHz multi-carrier (OFDM)	5 MHz multi-carrier (OFDM)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)
DVB-T2	Guard interval duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration
	1k mode	34.69, 69.37, 138.75 μs	11.2, 22.4, 44.8 μs	9.3, 18.6, 37.3 μs	8, 16, 32 μs	7, 14, 28 μs	5.6, 11.2, 22.4 μs
	2k mode	34.69, 69.37, 138.75, 277.50 μs	11.2, 22.4, 44.8, 89.6 μs	9.3, 18.6, 37.3, 74.6 μs	8, 16, 32, 64 μs	7, 14, 28, 56 μs	5.6, 11.2, 22.4, 44.8 μs
	4k mode	69.37, 138.75, 277.50, 554.99 μs	22.4, 44.8, 89.6, 179.2 μs	18.6, 37.3, 74.6, 149.3 μs	16, 32, 64, 128 μs	14, 28, 56, 112 μs	11.2, 22.4, 44.8, 89.6 μs
	8k mode	34.69, 138.75, 277.50, 329.53, 554.99, 659.05, 1 109.98 μs	11.2, 44.8, 89.6, 106.4, 179.2, 212.8, 358.4 μs	9.3, 37.3, 74.6, 88.6, 149.3, 177.3, 298.6 μs	8, 32, 64, 75.9, 128, 152, 256 μs	7, 28, 56, 66.5, 112, 133, 224 μs	5.6, 22.4, 44.8, 53.2, 89.6, 106.4, 179.2 μs
	16k mode		22.4, 89.6, 179.2, 212.8, 358.4, 425.6, 716.8 μs	18.6, 74.6, 149.3, 177.3, 298.6, 354.6, 597.3 μs	16, 64, 128, 152, 256, 304, 512 μs	14, 56, 112, 133, 224, 266, 448 μs	11.2, 44.8, 89.6, 106.4, 179.2, 212.8, 358.4 μs
	32k mode		44.8, 179.2, 358.4, 425.6, 716.8, 851.2 μs	37.33, 149.33, 298.67, 354.67, 597.33, 709.33 μs	32, 128, 256, 304, 512, 608 μs	28, 112, 224, 266, 448, 532 μs	22.4, 89.6, 179.2, 212.8, 358.4, 425.6 μs
ATSC 3.0	Guard interval duration	NA	NA	192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration	192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration	192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration	NA
	8k mode			27.778, 55.556, 74.074, 111.111, 148.148, 222.222, 296.296 μs	23.810, 47.619, 63.492, 95.238, 126.984, 190.476, 253.968 μs	20.833, 41.667, 55.556, 83.333, 111.111, 166.667, 222.222 μs	

				(192, 384, 512, 768, 1024, 1536, 2048 sample duration)	(192, 384, 512, 768, 1024, 1536, 2048 sample duration)	(192, 384, 512, 768, 1024, 1536, 2048 sample duration)	
	16k mode			27.778, 55.556, 74.074, 111.111, 148.148, 222.222, 296.296, 351.852, 444.444, 527.778, 592.593 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096 sample duration)	23.810, 47.619, 63.492, 95.238, 126.984, 190.476, 253.968, 301.587, 380.952, 452.381, 507.937 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096 sample duration)	20.833, 41.667, 55.556, 83.333, 111.111, 166.667, 222.222, 263.889, 333.333, 395.833, 444.444 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096 sample duration)	
	32k mode			27.778, 55.556, 74.074, 111.111, 148.148, 222.222, 296.296, 351.852, 444.444, 527.778, 592.593, 703.704 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration)	23.810, 47.619, 63.492, 95.238, 126.984, 190.476, 253.968, 301.587, 380.952, 452.381, 507.937, 603.175 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration)	20.833, 41.667, 55.556, 83.333, 111.111, 166.667, 222.222, 263.889, 333.333, 395.833, 444.444, 527.778 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration)	
EeMBMS	Guard interval duration	NA	16.7,33.3,100,200, 300µs	NA	NA	NA	16.7,33.3,100,200, 300µs

Acknowledge

During the report drafting, we receive valuable input and tremendous support from experts, and we want to express our great appreciation for the following experts.

ABS - 广播电视科学研究院	张宇 (Yu Zhang) 周向 (Xiang Zhou)
Ateme	陈朋奕 (Ben Chen) Mickael Raulet
Baicells – 佰才邦	云翔 (Xiang Yun) 李娜 (Na Li) 周明宇 (Mingyu Zhou)
CBC – 中广传播	蒲珂 (Ke Pu)
Communication University of China – 中国传媒大学	史萍 (Ping Shi) 石东新 (Dongxin Shi) 李朝晖 (Chaohui Li) 潘达 (Da Pan)
Communication University of Shanxi – 山西传媒学院	任石青 (Shiqing Ren)
Hisense – 海信	宋一迪 (Yidi Song)
Keysight – 视德科技	封翔 (Xiang Feng)
Kwai – 快手	马英武 (Yingwu Ma)
MiGu – 咪咕	李琳 (Lin Li) 徐嵩 (Song Xu) 聂国梁 (Guoliang Nie)
Qualcomm – 高通	曹一卿 (Yiqing Cao) Thomas Stockhammer 李俨 (Yan Li)

	杜志敏 (Zhimin Du)
Quectel – 移远	姚立 (Li Yao) 滕霞 (Tanya Teng) 吴冰 (Daniel Wu)
Rohde & Schwarz – 罗德施瓦茨	王俊生 (Junsheng Wang)
Samsung - 三星	吴越 (Yue Wu)
Shanxi Cloud Media Development Co,, Ltd – 山西云媒体发展集团有限公司	王斌 (Bin Wang) 邵文卫 (Wenwei Shao) 王俊莉 (Junli Wang)
Shanxi Radio and TV Media Group Co.Ltd – 山西广播电视传媒（集团）有限公司	任晓瑛 (Xiaoying Ren)
Shanghai Jiaotong University – 上海交通大学	何大治 (Dazhi He) 徐胤 (Ying Xu)
vivo – 维沃	张元 (Yuan Zhang)
Xinjiang Broadcaster - 新疆广电网络	陈常伟 (Changwei Chen)
ZTE – 中兴	王瑞明 (Ruiming Wang) 张磊 (Lei Zhang) 陆薇 (Wei Lu)

Thanks for the CMAF test results provided by 5G Media Joint Creation Laboratory, which was cofounded by China Mobile Shanxi Branch, Communication University of Shanxi, Shanxi Cloud Media Development Co., Ltd and ZTE. Same thanks to ATEME which had put the latest CMAF setup into the laboratory.

未来移动通信论坛
FuTURE MOBILE COMMUNICATION FORUM