Analysis on eMBMS capability for TV broadcasting

1 Broadcast and multicast in LTE and 5G

The delivery of a common content to a large number of receivers is a very important use case in LTE and future 5G systems. The common content can be accessible by all receivers in the network (broadcast) or by a subset of receivers (multicast). Unlike the one-to-one transmission (unicast), broadcast/multicast represents a very efficient way of delivering content in a spectrally efficient way. Examples of broadcast applications include TV broadcasting, software updates, public safety and emergency warning systems. New applications like Ultra High Definition Television (UHDTV) and virtual reality require very high data rates.

Different challenges need to be addressed to design an efficient broadcast system. Before establishing a broadcast or a multicast session, the base stations need to know if the upcoming program is of interest to sufficient users in the cell. This information leads to an important decision on the resource usage: the required content can be delivered by using broadcast or by using unicast. If the number of users interested in the content is small, the base station can use resources more efficiently transmitting the content to each user separately using a tailored (usually high) modulation and coding scheme (MCS).

Since the broadcast and multicast content is aimed to be delivered to a large number of receivers, the selection of MCS plays a major role. A very high MCS is advantageous in terms of throughput and delivery time. However, some users may not be able to decode the content because of lower channel quality. A very low modulation and coding scheme guarantees that all users can decode the content, but the throughput is very low. To take a decision on the optimal MCS, the base station needs to have access to channel qualities of each user via channel quality indicators (CQIs).

This deliverable considers the use of the Long Term Evolution (LTE) Evolved Multimedia Broadcast Multicast Services (eMBMS) to broadcast TV content.

2. Introduction to LTE eMBMS

Multimedia Broadcast Multicast Service (MBMS) was first defined for the Universal Mobile Telecommunications System (UMTS)) in the 3rd Generation Partnership Project (3GPP) Release 6 to provide more efficient delivery of multicast and broadcast services.

In 3GPP Release 9, which was the second release of LTE, eMBMS was introduced. It aims to achieve improved multicast and broadcast capabilities through multicell Single Frequency Network (SFN) operation. The term Multimedia Broadcast Single Frequency Network (MBSFN) is used in eMBMS for a SFN where multicast or broadcast data is transmitted as a multicell transmission over a synchronized SFN.

MBSFN operation can provide several benefits, such as increased received signal strength as the terminals can combine the signal energy received from multiple cells. The signals received from multiple cells are seen as a single input from the User Equipment (UE) point of view. However, the signals have different delays. The signals received within the Guard Interval (GI) contribute positively to the received signal strength, while the signals received outside the GI cause interference. Receiving the signals from multiple cells can result in reduced interference level at the border between cells involved in the MBSFN and in additional diversity against fading on the radio channel. In overall, MBSFN can achieve significant improvements in multicast/broadcast reception quality and data rates and more power-efficient reception than by using unicast transmissions.

3GPP TS 36.300 **[36.300]** introduces the following definitions for eMBMS:

MBSFN Area: an MBSFN Area consists of a group of cells within an MBSFN Synchronization Area of a network, which are co-ordinated to achieve an MBSFN Transmission. Except for the MBSFN Area Reserved Cells, all cells within an MBSFN Area contribute to the MBSFN Transmission and advertise its availability. The UE may only need to consider a subset of the MBSFN areas that are configured, i.e. when it knows which MBSFN area applies for the service(s) it is interested to receive. One eNodeB can belong up to 8 MBSFN Areas.

MBMS Service Area is the geographic area where a given service is broadcast. The geographic area can be divided into several MBSFN Areas, as shown in Figure 1.

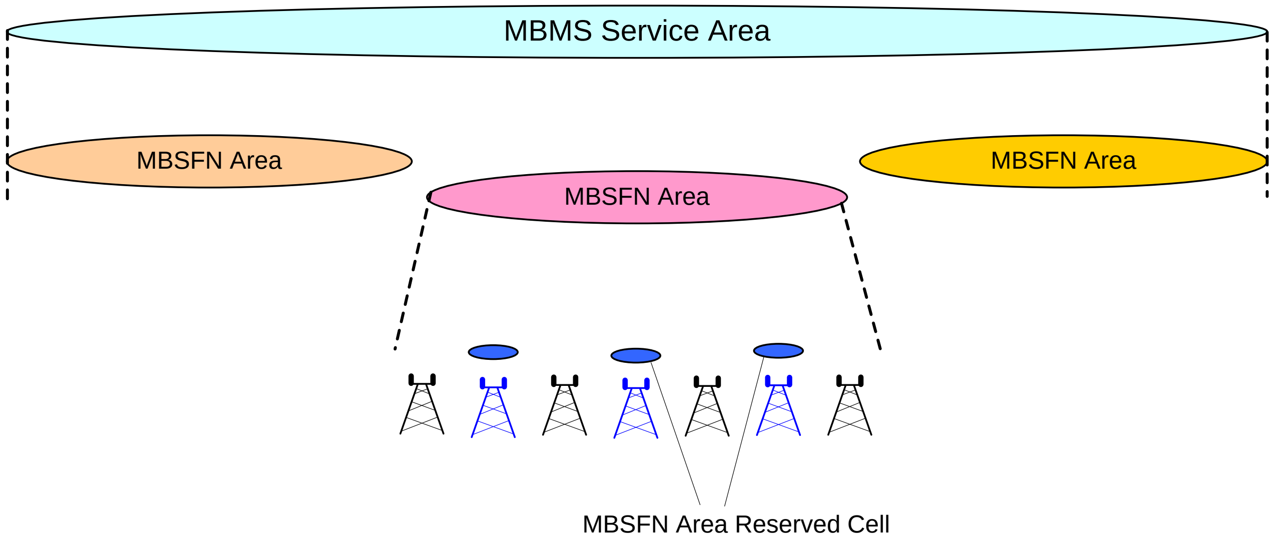

*Figure 1. MBMS Area definitions **[36.300]**.*

2.1 eMBMS architecture

The high-level LTE eMBMS architecture is shown in Figure 2.

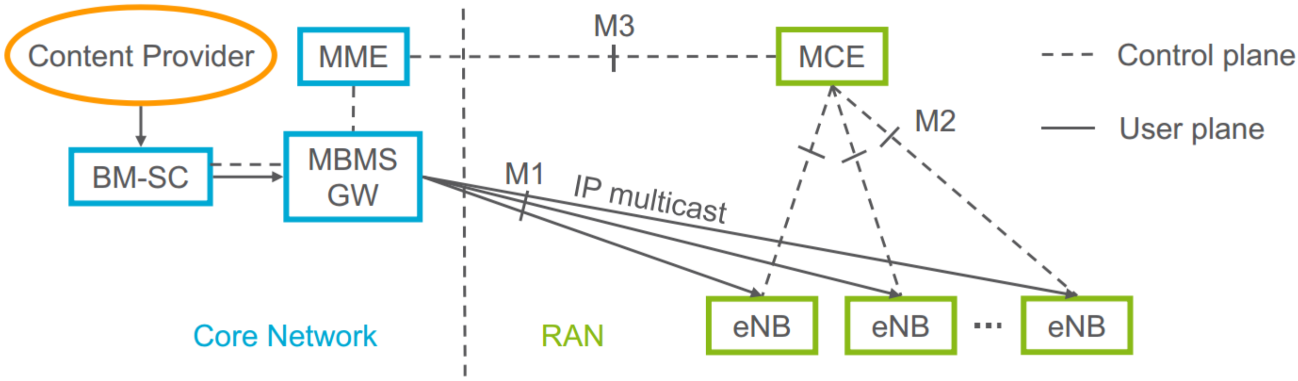

*Figure 2. LTE eMBMS architecture **[DPS14]**.*

The Broadcast-Multicast Service Center (BM-SC) is the entry point for eMBMS services. It is responsible for the authorization, announcement and initiation of eMBMS services. It handles membership and security functions and provides Forward Error Correction functionality on the eMBMS application layer (AL-FEC). It further initiates the SYNC protocol for the synchronization of all eNBs in an MBSFN area.

The MBMS Gateway (MBMS-GW) has two main tasks. While forwarding eMBMS user plane (UP) data packets to all eNBs of an MBSFN area by means of IP multicast, it manages and forwards the control signaling together with the **Mobility Management Entity (MME).**

The Multicast Coordination Entity (MCE) ensures equal resource scheduling and physical layer configuration of eMBMS in all eNBs of an MBSFN area. The MCE can be a centralized entity where one MCE serves several eNBs, or a distributed entity where each eNB have their own MCE.

2.1 MBSFN physical layer frame structure

eMBMS uses the LTE network to provide broadcast services and combines the multicast/broadcast data to the same frames with unicast data. MBSFN data transmission takes place via the **Multicast Channel (MCH)** transport channel, which is mapped to the **Physical Multicast Channel (PMCH)**.

MCH is a transport channel type supporting MBSFN transmission. As summarized in **[DPS14]**, two types of logical channels can be multiplexed and mapped to the MCH:

- **Multicast Traffic Channel (MTCH):** the logical channel type used to carry MBMS data corresponding to a certain MBMS service. If the number of services to be provided in an MBSFN area is large, multiple MTCHs can be configured.
- **Multicast Control Channel (MCCH):** the logical channel type used to carry control information necessary for reception of a certain MBMS service, including the subframe allocation and modulation-and coding scheme for each MCH. There is one MCCH per MBSFN area.

LTE Cyclic prefix (CP) -OFDM systems with subcarrier spacing of 15 kHz and a reduced subcarrier spacing of 7.5 kHz are adopted for MBSFN transmission **[36.211, 36.300]**. The introduction of the reduced subcarrier spacing is specifically targeted for MBSFN-based multicast/ broadcast transmissions. Extended CPs of ~17 µs and ~33 µs are adopted for MBSFN transmissions and amount to an overhead of 25% for the corresponding subcarrier spacings of 15 kHz and 7.5 kHz, respectively. The longer CP helps to ensure that the received signals remain within the GI at the UEs and thus reduces the likelihood of intersymbol interference (ISI). There is a trade-off between support for wide-area coverage and support for high mobile velocities when choosing whether to use the 15 kHz or 7.5 kHz subcarrier spacing.

MBSFN reference signals shall be transmitted in the MBSFN region of MBSFN subframes only when the PMCH is transmitted. MBSFN reference signals are transmitted on antenna port 4. LTE antenna ports are logical ports for which the LTE standard defines separate reference signals (pilot signals) that can be used in the UE channel estimation. The detailed generation and mapping of MBSFN reference signals are introduced in **[36.211]**.

As the channel in MBSFN operation is in fact a composite channel from multiple cells, the UE needs to perform a separate channel estimation for MBSFN transmissions. To avoid the need to mix normal reference symbols and reference symbols for MBSFN in the same subframe, frequency-division multiplexing of the PMCH and **Physical Downlink Shared Channel (PDSCH)** is not permitted within a given subframe. Instead, certain subframes may be specifically designated for MBSFN, and it is in these subframes that the PMCH would be transmitted.

LTE transmissions are organized into frames of length 10 ms in the time domain. Each frame is divided into ten equally sized subframes of 1 ms. Each subframe consists of two equally sized slots of 0.5 ms, and each slot consists of a number of OFDM symbols (including the CP).

MBSFN subframes mapped from the MCH to the PMCH are shown in Figure 3. An MBSFN subframe consists of two parts: a control region, used for transmission of regular unicast L1/L2 control signaling; and an MBSFN region, used for transmission of the MCH. Unicast control signaling may be needed in an MBSFN subframe. It can be used for example to schedule uplink transmissions in a later subframe, but can also be used for MBMS-related signaling.

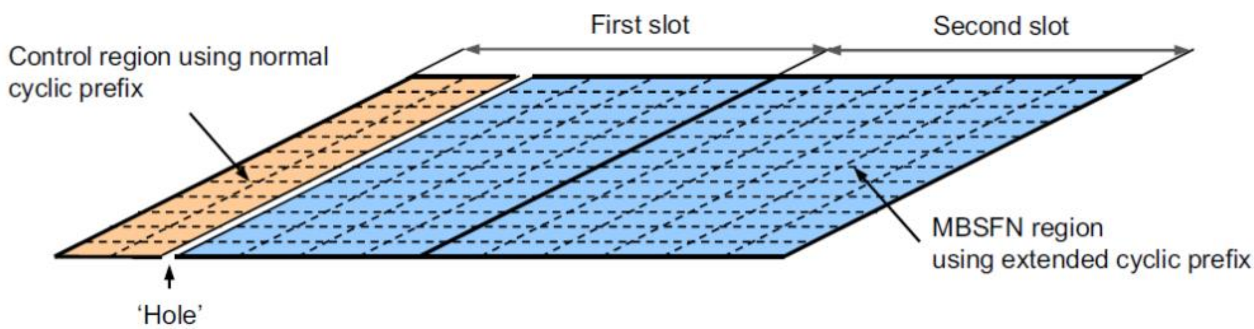

Figure 3. Resource-block structure for MBSFN subframes, assuming normal cyclic prefix for the control region [DPS14].

2.2 Main features added to LTE eMBMS since Release 9

Release 10

- Radio access network (RAN) -based counting of UEs which are interested in an eMBMS service. The counting allows the network to decide if it is more efficient to change the mode from broadcast back to unicast.

Release 11

- Methods to support eMBMS service acquisition and continuity in multifrequency deployments, in which the eMBMS service is present only on one frequency.
- Several additions for file based delivery.

Release 12

- **MBMS operation on Demand (MooD),** which automatically activates/deactivates the eMBMS service based on the counted number of interested UEs. This allows for example to create an eMBMS user service to deliver content which was initially delivered as unicast.
- **MBMS PHY measurements**: UEs can be ordered to perform measurements of signal power, error rates and such, which can then be used in network optimization, particularly in the MBSFN mode.
- **MBMS support as part of the Group Communication Service Enabler (GCSE)**; to be used in national security and public safety (NSPS) for example.
- **Enhanced eMBMS Operation (EMO);** targeted ad insertion and service continuity between Dynamic Adaptive Streaming over HTTP (DASH) broadcast over MBMS and unicast.

Release 13

- **Definition of Single Cell Point-to-Multipoint (SC-PTM) delivery mode**. The main motivation for SC-PTM was to fulfil the latency and coverage requirements for Mission Critical Services, but SC-PTM is not limited to them and is also available for commercial services. eMBMS originally uses MBSFN as the delivery mode. SC-PTM reuses the eMBMS architecture and its logical entities and interfaces. In SC-PTM, the UEs receive the broadcast data through a common radio resource in PDSCH. This allows to multiplex normal unicast and broadcast data within the same PDSCH subframe. SC-PTM is an efficient broadcast delivery mode for scenarios where the UEs are located within a small geographical area at the coverage granularity of a cell. MBSFN transmissions are not efficient in such cases, as their data is broadcast to all cells which belong to an MBSFN Area. MooD is not able to switch between SC-PTM and MBSFN, even if one mode is more optimal for media delivery over the other in a certain scenario.

Release 14

- **Longer cyclic prefix** (200 µs), which can cover up to 60 km Inter-Site-Distance (ISD).
- **Dedicated or mixed MBMS carrier**: Mixed unicast/broadcast from same carrier, up to 100% MBMS allocation.
- **Enhanced support for roof-top reception, handheld devices and car-mounted antenna**, as well as multiple subcarrier spacings (15 kHz, 7.5 kHz and 1.25 kHz) designed for different deployment/mobility scenarios.
- **Shared MBMS Broadcast**, where operators can aggregate their MBMS networks into a shared MBMS content distribution platform.
- **Standardized xMB interface towards the (TV) content provider** allows the reception reports to be delivered from the BM-SC to the application. Prior to release 14, the reports could only be delivered to one destination (either BM-SC or the application).

Future enhancements with regard to TV service distribution in Release 15

- The 3GPP document on *MBMS/PSS Enhancements to Support Television Services (Release 15)* ***[26.917]*** collects use cases, recommended requirements, architectural considerations, gaps, and optimization potentials for Packet Switched Streaming (PSS) and MBMS User Services in order to enable Television Services on top of PSS/MBMS User Services and MBMS bearer services. The supported TV service includes linear TV, Live, Video on Demand, smart TV, and Over The Top (OTT) content. The reference list in the document contains the relevant 3GPP documentation on the subject.

2.3 Main limitations of eMBMS in 3GPP Release 13

The main limitations of LTE eMBMS in 3GPP Release 13 include ***[zhang]***:

- There is no standalone eMBMS service delivery mode.
- The time allocation to eMBMS services is limited to a maximum of 60%.
- Support for only one spatial layer transmission, i.e., no support for Multiple-Input Multiple-Output (MIMO) technologies for increased transmission capacity.
- Designed mainly for mobile receivers, even with the specially designed 7.5 kHz OFDM subchannel bandwidth, the maximum CP of the 3GPP Release 13 eMBMS system is limited to 33.3 µs. When deployed in the SFN mode, this allows a maximum distance of only 10 km between adjacent transmitters, which is much shorter than the coverage radius of 90 km in the typical digital terrestrial television (DTT) broadcasting systems. It is potentially expensive to deploy DTT broadcasting services using the Release 13 LTE infrastructure, given the limitations on the physical layer design.

2.4 Main limitations of eMBMS in 3GPP Release 14

- MBSFN Service Areas and MBSFN Areas need to be statically preconfigured to set up a broadcast service.
- It is not possible to switch between SC-PTM and eMBMS within an MBMS session. This is due to the different and non-compatible transport and physical channels. There is no mechanism to inform the UE that it needs to switch between the modes.
- Switching between SC-PTM and MBSFN mode based on user traffic requires to relaunch the MBMS bearer, which can cause a service interruption on the UE.
- Service Area Identifier (SAI) is an identifier that references a single or a group of cells. The value range (0 to 65,535) may not be able to meet the deployment of a national-wide MBSFN area.
- MooD is restricted to an MBSFN Service Area value. Depending on the static configuration of an MBSFN Service Area, MooD may start an MBSFN transmission over a wide range of cells even if the demand only comes from one cell. MooD broadcast over a single cell thus

requires a 1:1 mapping of SAI to cell inside the MBSN Service Area in the eNB configuration.

- The BM-SC cannot provide feedback to the application if the bearer is not started in one or more eNB. Thus, the application does not have knowledge where the service succeeds or fails and there is no ability to dynamically provide alternative channel or repeats. It may also result for example in inaccurate service reporting for statistics and analysis and unnecessary resource usage.
- UE reports on the reception quality are not real-time and are difficult to correlate to the cause of error.
- No feedback from RAN to the core network (eMBMS delivery mode, eMBMS scheduling parameters)
- No mechanism to trigger eMBMS reception in the UE.

3 LTE eMBMS trials

The early trials and early deployments of eMBMS are covered well in the November 2016 report from LTE broadcast alliance **[expway]**. The report details the lessons learned from early commercial deployments and trials and describes the way in which the players in the LTE eMBMS ecosystem have successfully worked together to finalise network implementations and prove commercial cases. This section covers few key points and findings from the report, which is a recommended read for those interested in further details.

LTE eMBMS has been the subject of many demonstrations and trials since Mobile World Congress in 2013. Operators that have announced public work with the technology include 3, AT&T, Bell Mobility, China Mobile, China Telecom (including Wuxi Telecom), EE, Etisalat, Globe Telecom, KPN, KT, Megafon, Meo, MTS, Orange, PCCW, Polkomtel Plus, Reliance Jio, Singtel, SK Telecom, Smart Communications, Smartfren, TIM, Telstra, T-Mobile, Turkcell, Verizon Wireless, Vivo and Vodafone.

The trials have led to an understanding that there is no “killer app” for LTE eMBMS, but that it is rather an enabling technology that supports a multitude of services. The report states that EE has proved that user smartphone / tablet battery life is better using eMBMS than using unicast when viewing a stream, giving an increase in battery life of around an hour during sporting event trials. The increase in battery life results from a decrease in the number of device-to-network communication events required during a broadcast stream compared with a unicast stream.

LTE eMBMS work in commercial services and trials has made clear that the cost of enabling devices to use the technology will be small. Many handset vendors have enabled eMBMS in their devices. The GSA's report from November 2015 listed around 100 devices that were known to be shipping with eMBMS-capable chipsets or middleware. It is important to test end-to-end with different combinations of devices, middleware and video encoders. In their trials, Telstra has observed different behaviours and issues when moving from one middleware to another, when using different video encoder equipment, or using different end devices. Telstra will continue extensive trials and launch commercial LTE eMBMS services during 2017 **[telstra1, telstra2]**.

4 LTE eMBMS development in 3GPP

The current eMBMS system is developed as a sub-system of the LTE system and shares many physical-layer components with the unicast transmission mode. While this results in simpler receivers to receive the eMBMS services with minimal additional hardware, it also puts limitations on the achievable performance, the application scenarios, and the commercial business cases for delivering broadcasting-type services. Current LTE eMBMS exhibits some limitations considering the provision of multicast/broadcast services through mobile broadband cellular networks. eMBMS has low Doppler spead tolerance, and hence poor support for user mobility.

In the development of Release 14, there were several industry proposals of new study items **[RP-151305, RP-151914]** and Work Item called **Enhancements for TV Service(EnTV)** regarding the improvement of eMBMS support in LTE. 3GPP Technical Report 22.816 **[22.816]** was created to describe use cases, propose assumptions and potential requirements, and to analyse the gaps in order to enhance 3GPP systems for TV service support.

According to 3GPP TS 22.101 **[22.101]** clause 32.1 for TV Enhancements, *"3GPP enhancement for TV service support is a feature whereby 3GPP networks can provide unicast and broadcast transport, referred to as "TV transport services", to support distribution of TV programs. TV* *transport services can support the three types of TV services – Free-to-air (FTA), Free-to-view (FTV), and Subscribed services. Each type of TV service has different requirements in order to meet regulatory obligations and public service and commercial broadcaster's requirements regarding content distribution, hence many requirements captured below are optional to implement depending on the type of TV transport services an MNO chooses to offer."*

One of the use cases beyond 3GPP Technical Report 22.816 **[22.816]** from March 2016 is described in 3GPP TR 26.917 **[26.917]** from September 2017, which considers eMBMS enhancements to support television services in Release 15 and is called TV Service Delivery over eMBMS. The use case is shown in Figure 5 and described in the 3GPP TR 26.917 document as follows:

"A broadcast TV service provider 'ZZZZ', i.e., TV broadcaster, wishes to enable reception of its DTT (Digital Terrestrial TV) services on eMBMS UEs. These UEs are assumed to contain both the eMBMS radio receiver/modem and the eMBMS client or middleware functions. Examples of such UEs are LTE Broadcast capable handsets or tablets which already contain the MBMS client, as well as fixed TV sets which contain both eMBMS radio receiver and eMBMS client functions. ZZZZ wishes for certain native DTT service layer syntax and semantics employed in DTT networks such as DVB-T or DVB-T2 to be employed in service delivery over the eMBMS network to UEs. These may include, for example:

- *DTT identifier formats of service bundles, individual services, and programs within a service;*
- *Country-based service availability control;*
- *End-user specific description of services and programs (i.e., EPG functionality);*
- *Identification of media components of a service or program;*
- *Time-shifting characteristics of Near Video-On-Demand (NVOD) service offerings;*
- *Parental rating information;*
- *Signaling of interactive applications associated with a DTT service.*

The TV broadcaster realizes that because the receiving device will utilize MBMS service layer functions for reception of the DTT services, some form of translation will be required from native DTT service layer functionality to that of the MBMS service layer, for the associated service delivery *over an eMBMS system. It also realizes that native DTT media encoding and encapsulation formats will need to be converted to 3GPP media encoding and encapsulation formats."*

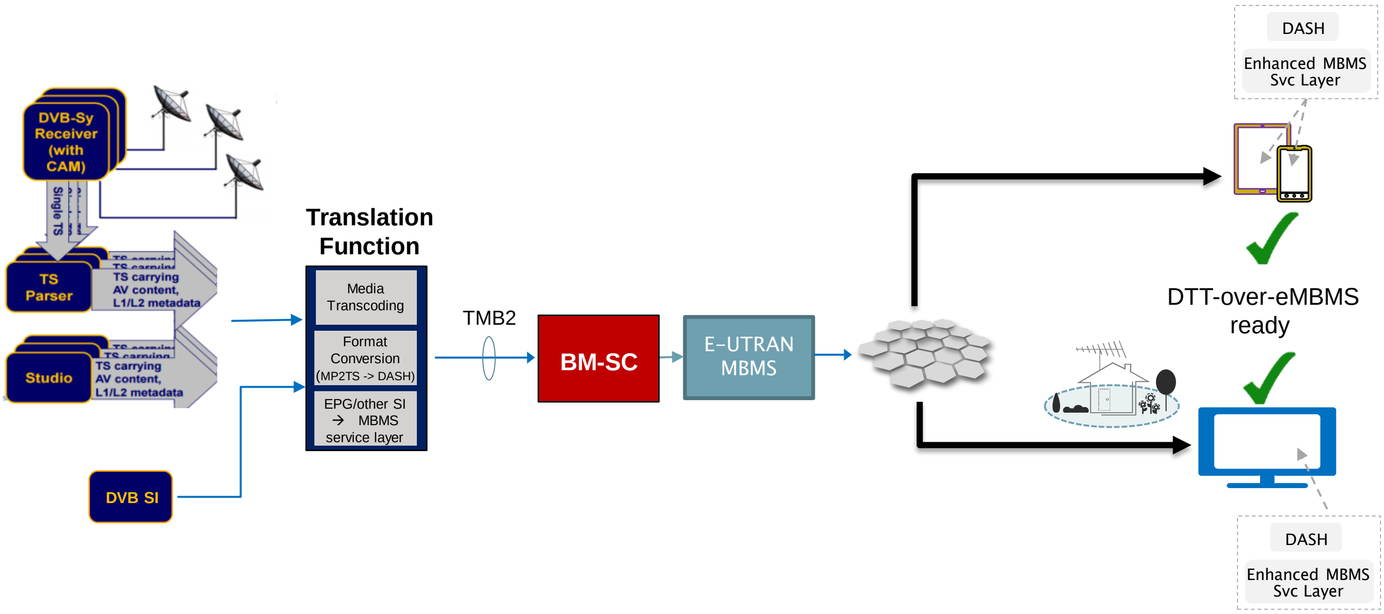

Figure 5. Example DTT-over-eMBMS Service Delivery Network Architecture [26.197].

5 Evolution of eMBMS in future 5G systems

Future broadcast services are envisioned to support diverse requirements, going from the extremely reliable and robust emergency alerts associated to public safety services to high reliability and low latency required by online gaming. Standardization bodies (cellular, terrestrial broadcast services and satellite services) are also devoting efforts to integrate cellular and terrestrial infrastructures to improve the provision of broadcast services **[d41]**.

In March 2017, Qualcomm proposed two different use cases and separate evolution paths for LTE eMBMS ***[qualcomm]***.

1) eMBMS as a radio-centric multicast mechanism; ie. a "mixed mode" multicast-unicast delivery optimization tool.

The "mixed mode" use case would provide internal multicast/broadcast delivery optimization tools, which are fully integrated within the unicast solution. The 5G New Radio (NR) "mixed mode" multicast/unicast should be based on NR numerology and frame formats, remove inefficiencies of eMBMS resource allocation and provide a unified framework for MBMS, SC-PTM/Public safety, Internet of Things (IoT) and vehicle-to-everything (V2X.) The main problem in MBMS is that it was started as a constant and static TV-like service. Even though more flexibility has been added, the backwards compatibility requirement prevents fully integrating multicast/broadcast into the overall unicast solution.

2) eMBMS as a "stand-alone" cellular-based dedicated broadcasting solution.

The 5G "stand-alone" MBMS should be based on 3GPP Release 14 Enhancements for TV service (EnTV). The starting point is a careful gap analysis to identify which enhancements are necessary. 5G Broadcast has not been included as one of the features of the first release of 5G, 3GPP Release 15. Some of the innovative use cases of 5G require point-to-multipoint (PTM) transmissions. PTM transmissions should be a delivery optimization tool (together with caching) rather than just a service as originally envisioned with MBMS. Broadcasters' interest in 3GPP technologies has increased recently and LTE eMBMS Rel'14 has incorporated many requirements. There is also a big potential in terms of convergence of fixed and mobile broadband networks and broadcast networks, subject to political decisions on spectrum.

In Europe, 5G-Xcast **[5GXCAST]** is a 5G-PPP Phase II project aiming to develop and demonstrate a large-scale media delivery technology solution for 5G over mobile, fixed and broadcast networks, with built-in unicast/multicast/broadcast and caching capabilities. It will also devise strategies to facilitate the migration of media content and services from legacy systems. In developing media delivery solutions, the project will take account of the wider use ranges of 5G including services to vehicles, public safety and health, and IoT to ensure they dovetail together.

6 conclusions

As the field trial report **[expway]** describes, there is a growing momentum behind LTE eMBMS. Important progress is being made in the development of LTE eMBMS, with proofs of concept completed and underway, commercial services launched and new services nearing commercialization. Trials of LTE eMBMS by broadcasters also show that it has potential as a replacement or a complement to other broadcasting distribution technologies for TV.

3GPP Release 14 introduces several significant improvements in eMBMS operation. It also introduced a standardized xMB interface between the content provider and the MNO and standardized APIs between the middleware and the application at the UE. SC-PTM, introduced in Release 13, offers significantly more flexibility in the coverage area as it can be defined at the granularity of cell level instead of MBMS Service Area.

More work is needed on LTE eMBMS service monitoring as there are no immediate indicators on reception quality or the performance of the broadcast within the coverage area. The penetration of eMBMS-capable UEs is an important factor for content partners as the content partners need to know that their content is reaching the largest possible audience at the highest possible quality **[expway]**.

Despite still having several limitations, some broadcasters may already consider the 3GPP Release 14 eMBMS features sufficient to broadcast TV content, but to realize the full potential of the technology further work is required on the part of network equipment vendors, network operators, chipset, middleware and device vendors, and standardization bodies.

References

[22.101] 3GPP TS 22.101 V15.1.0 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Service aspects; Service principles (Release 15), June 2017.

[22.816] 3GPP TR 22.816 V14.1.0 Technical Report 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; 3GPP enhancement for TV service (Release 14), Mar. 2016.

[26.917] *3GPP TR 26.917 V2.0.0, 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; MBMS/PSS Enhancements to Support Television Services (Release 15), Sep. 2017.*

[36.211] *3GPP TS 36.211 v14.1.0, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 14), Dec. 2016.*

[36.300] 3GPP TS 36.300 V14.3.0, Technical Specification 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 14)), June 2017.

[5GXCAST] *online: http://5g-xcast.eu/*

[d41] Flexible Air iNTerfAce for Scalable service delivery wiThin wIreless Communication networks of the 5th Generation (FANTASTIC-5G), Deliverable D4.1 Technical Results for Service Specific Multi Node/Multi-Antenna Solutions.

[DPS14] *E. Dahlman, S. Parkvall, and J. Sköld, '4G - LTE/LTE-Advanced for Mobile Broadband', Academic Press, 2014.*

[expway] LTE Broadcast – Lessons Learned from Trials and Early Deployments , LTE Broadcast Alliance, November 2016. http://www.expway.com/wp-content/uploads/2016/12/LTE-Broadcast-Paper-Final-30-November-2016.pdf

[qualcomm] *3GPP RAN #75 RP-170449 Agenda item: 9.1: Discussion on the evolution of MBMS, Qualcomm Incorporated, Dubrovnik, Croatia, March 6-9, 2017.*

[RP-151305] *Ericsson, Qualcomm, AT&T, 'Future eMBMS enhancements for LTE', 3GPP TSG-RAN #69, Phoenix, USA, Sept. 2015.*

[RP-151914] *Ericsson, Qualcomm Inc., Nokia Networks, EBU, "New WID: eMBMS enhancements for LTE", 3GPP TSG-RAN #70, Sitges, Spain, Dec. 2015.*

[telstra1] *Telstra and Expway Partner to Demonstrate Intelligent Switching of LTE Broadcast and Unicast On-Demand, Online,* Accessed 23.8.2017*:* http://www.expway.com/telstra-and-expway-partner-to-demonstrate-intelligent-switching-of-lte-broadcast-and-unicast-on-demand/

[telstra2] *Telstra bets big on LTE-Broadcast, Online,* Accessed 23.8.2017*:* https://www.computerworld.com.au/article/614927/telstra-bets-big-lte-broadcast/

[zhang] *L. Zhang; Y. Wu; G. K. Walker; W. Li; K. Salehian; A. Florea, "Improving LTE eMBMS With Extended OFDM Parameters and Layered-Division-Multiplexing," in IEEE Transactions on Broadcasting , vol.PP, no.99, pp.1-16*