5G BROADCAST RELEASE 16 IS APPROACHING

COMPLETING A NEW STEP TO DELIVER PUBLIC SERVICE MEDIA WITH 3GPP TECHNOLOGY

BY JORDI J. GIMENEZ (IRT), SIMON ELLIOTT (BBC) AND DAVID VARGAS (BBC)

Der auf LTE basierende 5G Terrestrial Broadcast Standard – bekannt auch als 5G Broadcast – wird bis Ende Juni 2020 als Teil des LTE Release 16 fertiggestellt sein. Auf Bestreben der öffentlich-rechtlichen Rundfunkanstalten und der Mobilfunkindustrie sollen mit der neuen Version einige Ineffizienzen behoben werden, die in Version 14 festgestellt wurden.

The LTE-based 5G Terrestrial Broadcast standard, popularly known as 5G Broadcast, will be completed by end of June 2020 as part of LTE Release 16. This new release comes after the effort done by public service broadcasters and the mobile industry to resolve a series of inefficiencies detected in Release 14.

Various attempts to integrate broadcast technologies in smartphones have had limited success so far. Popular mobile devices do not support broadcast technologies. Aftermarket devices such as dongles, which add functionality to receive broadcast services, have not been widely adopted either. Audiences are now consuming broadcaster's content on their mobile devices with dedicated applications such as the ARD Mediathek or BBC Sounds. However, the content for these apps is currently only delivered over-the-top and by unicast. 3GPP Release (Rel-) 14 enhanced the evolved Multimedia Broadcast Multicast Service (eMBMS) to fulfill the requirements for public service media (PSM) broadcasting [1] by giving service providers greater control over content delivery, the ability to configure carriers with effectively 100 % capacity for broadcast, and to enable large area Single Frequency Networks (SFN) with inter-site distances in the order of 15 km. Furthermore, neither uplink nor registration to the provisioning network is required to access the broadcast content. SIM-free, free-to-air reception is thus possible.

A new study item in 3GPP Rel-16 evaluated Rel-14 against the original requirements of broadcast [2]. Under the umbrella of EBU, BBC and IRT, together with companies such as Qualcomm and Huawei, has been demonstrated that Rel-14 would benefit from enhancements in three key areas: a shorter 100 µs CP (Cyclic Prefix) for mobility up to 250 km/h, a longer 300 µs CP for networks with inter-site distance (ISD) of 60 km or more, and a more robust cell acquisition subframe (CAS) [3]. These enhancements will be specified in Rel-16 as LTE-based 5G Terrestrial Broadcast, or, in short, 5G Terrestrial Broadcast [4].

3GPP Rel-14, the predecessor of LTE-based 5G Terrestrial Broadcast

Fulfilling the requirements of public service broadcasting (Fig. 1) opens the door to a single 3GPP based chipset in all smartphones that supports the reception of both broadcast and unicast content without the need to integrate additional technologies from other standards.

5G Terrestrial Broadcast has been built on LTE eMBMS which already included the following key features:

- **Receive-Only Mode (ROM)** for free-to-air reception with no need for uplink capabilities at the user device, a SIM card, or any network subscription.
- **Shared broadcast networks** enabling content distribution across multiple networks.
- **Transparent delivery mode** to transmit content without transcoding (e.g. an MPEG-TS may be transparently delivered across Rel-14 MBMS networks).
- **xMB interface** to the eMBMS system to configure and transport broadcast services.
- **Application Programming Interface (MBMS-API)** for web and client application development.

The eMBMS network architecture (Fig. 2) is composed of the BM-SC (Broadcast/Multicast Service Center), the MBMS-GW (Gateway) and the MCE (Multicell Coordination Entity) [5]. These entities can be detached from any other functionality of the LTE core to enable dedicated broadcast networks to be configured with features independent of the operator's network.

The xMB interface connects the BM-SC with the content provider [6]. In the smartphone, the MBMS-API provides the interface between the MBMS client and the content provider's application.

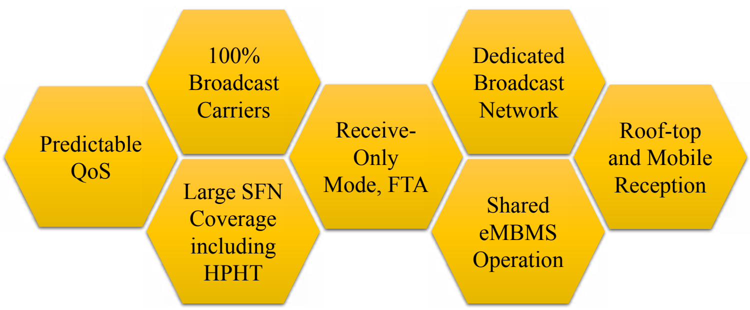


Figure 1: Public service media broadcasting requirement in 3GPP.

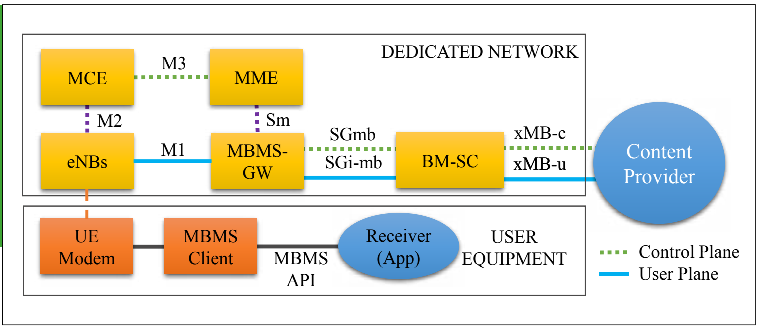


Figure 2: Architecture for TV services with LTE-based 5G Broadcast.

Table 1. OFDM Numerology Options for LTE-based 5G Broadcast

	Δ_f (kHz)	SC_{RB}	T_{CP} (µs)	T_U (µs)	ISD (km)	Overhead (%)
MBSFN Rel-9 to 13	15	12	16.7	66.7	5	20
MBSFN Rel-14/15	7.5	24	33.3	133.3	10	20
	1.25	144	200	800	60	20
MBSFN Rel-16	**2.5**	**72**	**100**	**400**	**30**	**20**
	0.370	**486**	**300**	**2700**	**90**	**10**

SC_{RB}=Subcarriers per Resource Block, T_{CP}= CP duration,
T_U= useful OFDM symbol duration, ISD=Intersite Distance.

To minimize signaling and control information, the Cell Acquisition Subframe (CAS) was introduced. It is a 1 ms subframe based on legacy LTE OFDM parameters that is transmitted once every 40 ms. It contains essential control channels and synchronization signals that permit demodulation of the desired broadcast data. The CAS comprises: PSS (Primary Synchronization Signal) and SSS (Secondary Synchronization Signal), for time and frequency synchronization; CS-RS (Cell-Specific Reference Signals), for channel estimation; PBCH (Physical Broadcast Channel), which contains MIB (Master Information Block), PCFICH (Physical Control Format Indicator Channel) which indicates the number of OFDM symbols used for control in the CAS, and PDCCH (Physical Downlink Control Channel) and PDSCH (Physical Downlink Shared Channel), which contains additional system information [7,8].

3GPP Rel-16, the LTE-based 5G Broadcast standard

Several deficiencies were identified in Rel-14 when compared with the original broadcast requirements in TR 36.776 [3]. 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 [9].

To resolve the first two issues, two additional numerologies were introduced. The first numerology has a 0.37 kHz subcarrier spacing and a CP duration of 300 µs (with overhead reduced to 10 %). The second numerology has a 2.5 kHz subcarrier spacing and a CP duration of 100 µs. The longer 300 µs CP provides improved support for conventional broadcasting networks in SFN with large transmitter spacing. The wider subcarrier spacing of the 2.5 kHz numerology improves resiliency to Doppler, with benefits for high speed reception. The numerologies defined in 5G Broadcast are shown in Table 1.

The frame structures of the new the 5G Broadcast numerologies are depicted in Fig 4.

Figure 5 illustrates the increased spectral efficiency (capacity) that could be achieved by extending the OFDM parameters in networks with larger inter-site distances. Longer CP durations, and correspondingly longer OFDM symbol durations, help the system cope with larger signal delays.

The Receive-only Mode (ROM) is enabled by configuring a specific Temporary Mobile Group Identity (TMGI) with a Mobile Country code (MCC) and Mobile Network Code (MNC) assigned by the ITU-T to MCC = 901 and MNC = 56. Services broadcast using this TMGI code can be received by devices without SIM card. If a SIM card is present, however, smartphones may still have access to any other unicast content (Fig. 3).

Additional changes were introduced in the radio access, in particular:

- **Dedicated broadcast carriers** with almost 100 % broadcast and minimized signaling.
- **New subframe type** with no unicast control region to reduce the signaling overhead.
- **New OFDM numerologies** to support large inter-site distances in SFN with a 200 µs OFDM cyclic prefix (CP), originally designed for 15 km transmitter separation.

Figure 3: Reception of ROM services and independent unicast connectivity.

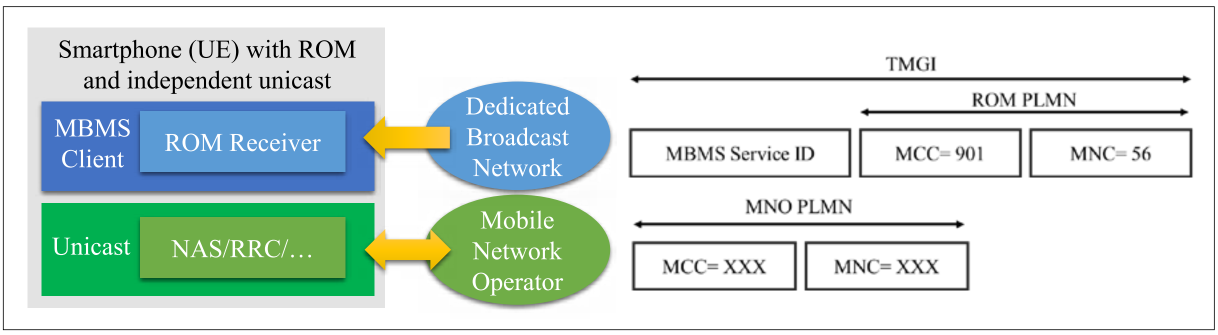
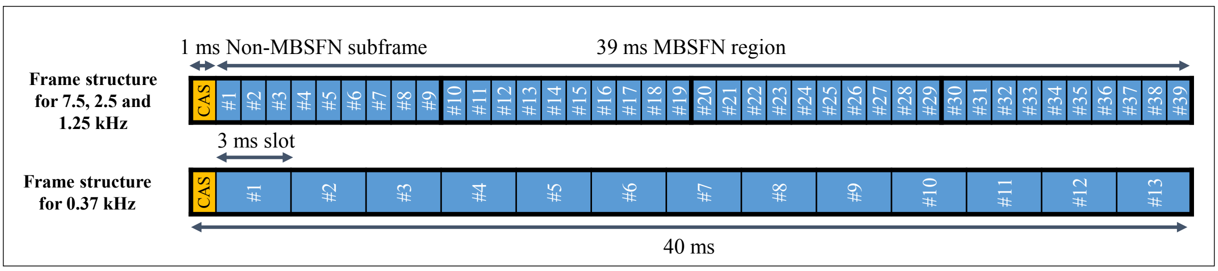


Figure 4: Frame structure for all transmission modes in LTE-based 5G Broadcast.



Furthermore the lower T_{CP}/T_U ratio of the 300 μs CP further reduces overhead with respect to Rel-14 [10]. However, hardware and implementation complexity in the chipset also play an important role in determining the final numerologies, as it is the case here.

The numerologies in Table 1 are accompanied by dedicated Reference Signals (RS) as shown in Fig. 6. The RS consists of known symbols with known values to assist channel estimation and equalization. To cope with SFN delay spreads, the RS are dense in the frequency domain, which introduces a large capacity overhead. Note that the frequency spacing between RS determines the length of delay up to which the channel may be correctly equalized [11]. 'Staggering' the RS pattern in time can reduce the overhead for comparatively static channels where time-frequency interpolation is possible. For fixed reception with the 300 us numerology, the RS pattern is less dense in time domain thus reducing overhead to around 8 % instead of 16 %. The RS for high mobility are denser than those in Rel-14, with 25 % overhead.

Overall, the new RS in Rel-16 provides better support for rapidly time-varying channels in mobile scenarios while supporting increased capacity for comparatively static channels found in fixed reception. The Rel-14 mode with 200 μs is a compromise between the two.

The study phase of Rel 16 detected coverage deficiencies caused by the numerology mismatched between the CAS and MBSFN for large area coverage as the CAS can only be configured with the 16.7 μs CP of the 15 kHz numerology. Harmonizing the numerology of the CAS with the MBSFN subframes was considered to be too complex and therefore the CAS was made to be as robust as was practical. This was achieved by: avoiding the decoding of PCFICH by CFI indication in the 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.

In addition to these enhancements, several studies conducted by EBU, BBC, IRT and Qualcomm showed the benefits of implementing frequency interleaving, phase tracking signals and physical layer time interleaving. The results presented in Fig. 7 show the big potential of time-interleaving as proposed in [12]. With this, the performance of 5G Broadcast will be boosted for mobility conditions with a gain of almost 4 dB that, otherwise, could only be achieved by increasing the robustness of the coding and therefore decreasing spectral efficiency.

However, none of these enhancements were incorporated into the standard as, despite demonstrating their benefits, and the fact that they are key features in all modern broadcast standards. No consensus on their adoption was reached between companies in 3GPP.

What is next?

5G Broadcast represents a pragmatic approach to broadcasting based on 3GPP technologies in order to reach portable and mobile devices with a single, 'native' technology. With additional key features, the work carried on in Rel-16 represents a further improvement to the standard which will provide greater flexibility for deployment and more reliable performance. The extent of which is, however, yet to be fully analyzed, particularly in real-world trials as those conducted by the 5G-Today project in Germany and the 5GRuralFirst in the UK.

It is unclear at the moment if there are further oppor-

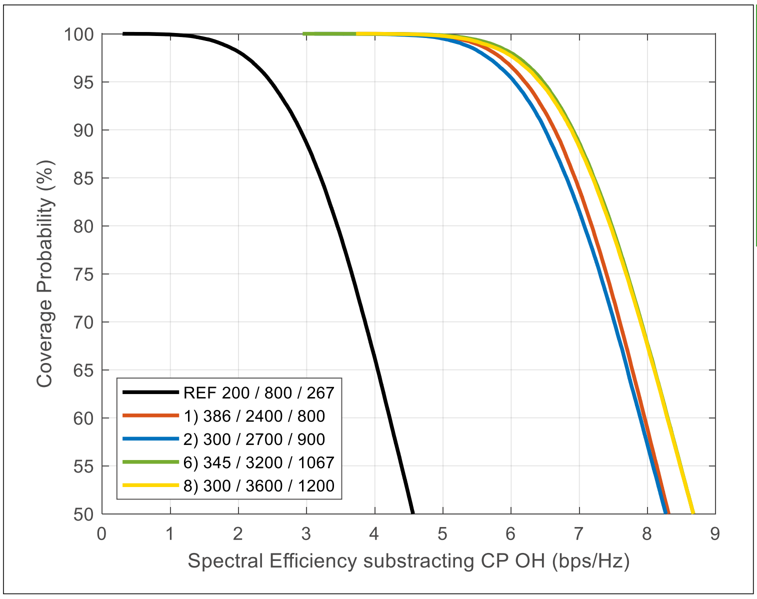
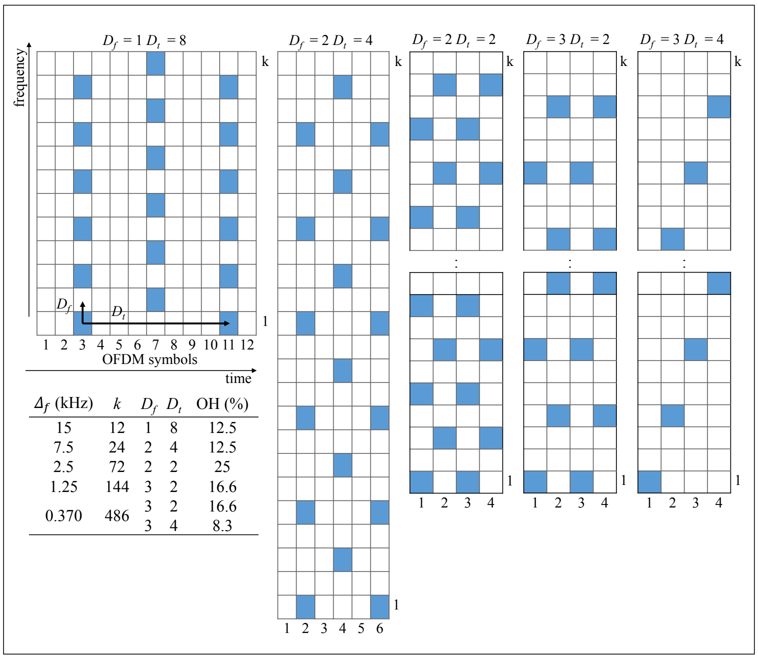


Figure 5: Coverage Probability vs Spectral Efficiency for potential transmission modes tested for fixed reception in an SFN scenario with transmitters separated 60 km



Δ_f (kHz)	k	D_f	D_t	OH (%)
15	12	1	8	12.5
7.5	24	2	4	12.5
2.5	72	2	2	25
1.25	144	3	2	16.6
0.370	486	3	2	16.6
		3	4	8.3

Figure 6: Reference signals for the different transmission modes of LTE-based 5G Terrestrial Broadcast.

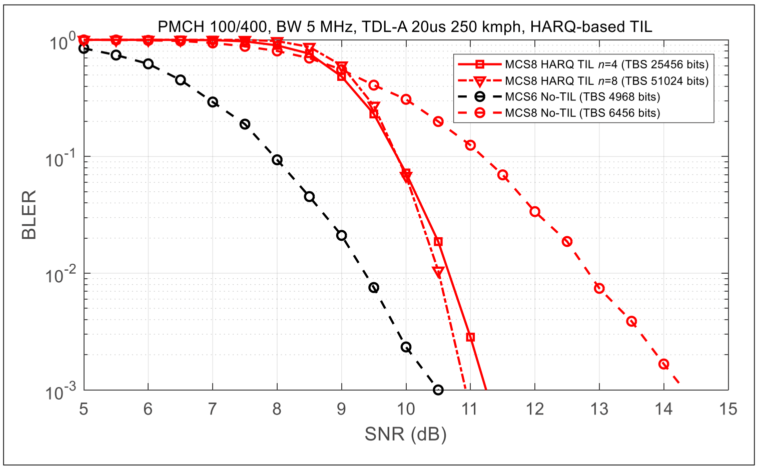


Figure 7: Gains derived from the potential introduction of time interleaving for LTE-based 5G Terrestrial Broadcast.


Source: IRT

DR. JORDI J. GIMENEZ

is Project Leader and Research Engineer at the Future Networks Division of the Institut für Rundfunktechnik GmbH

www.irt.de


Source: BBC

SIMON ELLIOTT

is Senior Distribution Manager at BBC Distribution and Business Development

www.bbc.co.uk


Source: BBC

DR. DAVID VARGAS

is Senior Research Engineer at BBC Research and Development

www.bbc.co.uk

tunities to improve 5G Broadcast. On the other hand, 3GPP is standardizing 5G New Radio (NR) and 5G Core (5GC) Rel-15 and Rel-16 specifications [13], and adding support for multicast and broadcast in Rel-17, with solutions which may not be compatible with LTE-based 5G Broadcast but are intended to serve new applications in different domains such as Vehicular Communications, Internet of Things (IoT), or Public Safety. Further support for similar features as those in LTE-based 5G Broadcast should not be precluded though as agreed within 3GPP.

References

[1] R. Beutler, "Production, Contribution, and Distribution of TV and Radio Services Over 3GPP Systems," SMPTE Motion Imaging Journal, vol. 128, no. 8, pp. 99-103, Sept. 2019.
[2] 3GPP TR 38.913 v14.3.0, "Study on scenarios and requirements for next generation access technologies," Aug. 2017.
[3] 3GPP TR 36.776 v16.0.0, "Study on LTE-based 5G terrestrial broadcast (Release 16)", March 2019.
[4] 3GPP TR 36.976 v16.0.0, "Overall description of LTE-based 5G broadcast (Release 16), Dec. 2019.
[5] T. Stockhammer, et al, "Enhanced TV Services over 3GPP MBMS," Proc. International Broadcasting Convention (IBC), Amsterdam, The Netherlands, 2017.
[6] W. Zia and V. Pauli, "xMB Interface for eMBMS Content Delivery in Release 14," Nomor White Paper, Jan. 2018.
[7] J. J. Gimenez, et al. "Enhanced TV Delivery with EMBMS: Coverage Evaluation for Roof-Top Reception," Proc. IEEE Broadband Multimedia Systems and Broadcasting (BMSB) 2018, Valencia, Spain.
[8] L. Richter and S. Ilsen, "Coverage Evaluation of LTE FeMBMS: a Case Study based on a DVB-T2 Network," Proc. IEEE Broadband Multimedia Systems and Broadcasting (BMSB) 2018, Valencia, Spain.
[9] D. Vargas and D. Mi (Editors), "LTE-Advanced Pro Broadcast Radio Access Network Benchmark," Deliverable D3.1 5G-Xcast 5G-PPP project, Nov. 2018.
[10] 3GPP R1-1907093 by EBU, BBC and IRT, "Spectral Efficiency of New Numerologies for Rooftop Reception", RAN1#97, Reno, United States, May 2019
[11] EBU, TR 3348, "Frequency and Network Planning Aspects of DVB-T2", v.4.1.1, Oct. 2014.
[12] 3GPP R1-1913259 by EBU, BBC and IRT, "On the performance evaluation of HARQ-based time-interleaving for LTE-based 5G terrestrial broadcast", RAN1#99, Reno, United States, Nov. 2019
[13] J. J. Gimenez, et al, "5G New Radio for Terrestrial Broadcast: A Forward-Looking Approach for NR-MBMS," IEEE Transactions on Broadcasting, vol. 65, no. 2, pp. 356-368, June 2019.