

Overview of 5G Broadcast and Multicast Services

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ABSTRACT

The demand for access to high-quality live media on handheld devices is increasing at an unprecedented rate. Mobile broadband users are demanding live streaming video content anywhere, anytime and on all their devices. This puts immense pressure on mobile network operators to provide quality services to all their subscribers within the limited radio resources that are available to them.

Using a one-to-one dedicated connection to send the same content (for example, Live Sports action) to multiple users results in inefficient spectrum utilisation. Broadcasting/Multicasting allows network operators to offload content from dedicated services to shared services, thereby freeing-up network resources and improving spectral utilisation. This also enables network operators to use their existing infrastructure efficiently, thereby improving their ROI.

Though technologies like 3G and LTE also support Multimedia Broadcast Multicast service (MBMS), 5G NR based Broadcast/Multicast provides better performance as it has improved signal coverage even at cell edges and can also cater to high traffic demands in high mobility scenarios. The latency in 5G is also lower than 3G/LTE, thereby improving the overall end-user experience.

In this study, we have done a systematic literature review of 3GPP Broadcast/Multicast services. We present an overview of 5G Broadcast/Multicast technology and discuss some techniques that can be used to optimise resource utilisation and improve user experience. We then present a comparison between 5G and LTE Broadcast/Multicast performance and discuss how 5G Broadcast/Multicast can be used not just for entertainment but also for improving essential aspects of human life like Education, agriculture, and agriculture Public Safety.

Keywords: 5G, LTE, 3GPP, NR, MBMS

INTRODUCTION

Mobile users are demanding high-quality live video content anywhere, anytime and on all their devices. There is a sudden spike in live video viewership during important events like Olympics and UEFA European Football Championship. This puts immense pressure on mobile network operators (MNOs) to provide quality services to all their subscribers within the limited radio resources that are available to them.

Existing network resources are not enough to handle such high volumes of dedicated traffic. Hence, a model needs to deliver live and on-demand content to devices efficiently without compromising on user experience. Multicast/Broadcast Service (MBS) allows MNOs to offload popularly viewed content from dedicated service to shared broadcast service, freeing up network resources.

This paper presents an overview of 5G MBS and discusses the enhancements done in 5G to meet 5G NR MBS requirements. We also discuss some 5G MBS

schemes for efficient resource utilisation. We then present a comparison between 5G and LTE MBS performance and discuss a few use cases of 5G MBS.

LITERATURE REVIEW

MBMS was introduced in 3GPP Rel-6 specifications. It provided a basic transport mechanism for broadcast and multicast data (Hartung et al., 2009). In 3GPP Rel-9, one of the main goals was to improve the MBMS coverage area. Hence, LTE MBMS used extended CP (SCS 15KHz/ CP 16.7 μ s and SCS 7.5kHz/ CP 33 μ s CP) to improve delay tolerance, enabling broader cell coverage. A new concept called MBSFN was also introduced in which all eNBs in an MBSFN area transmit the same signal using the same time-frequency resource. UEs combine the received signals from multiple sources, resulting in better signal quality and coverage (Kottkamp et al., 2009).

In Rel-14, MBMS was enhanced to support 15km Inter-site Distance (ISD) by introducing a larger CP of 200 μ s (3GPP, 2017). It also added more flexibility in spectrum

allocation for broadcast and unicast services. Importantly, it allowed carriers to allocate 100% resources for broadcast services. It also allowed all types of devices to receive MBS. It even allowed free-to-air reception for devices without a SIM.

3GPP introduced a study item to evaluate whether existing Rel-14 LTE can meet 5G MBS requirements defined in (3GPP TR 38.913, 2020). For this study, performance evaluations were done in (Qualcomm Incorporated, 2019), (EBU, BBC, IRT, 2019), (Huawei, HiSilicon, 2019) and (Shanghai Jiao Tong University, 2019). The results are summarised in (3GPP TR 36.776, 2019). Based on these measurements, 3GPP adopted a few enhancements to improve the MBS experience in 5G, discussed in subsequent sections.

5G MBS trials are underway. BBC tested 5G Broadcast on a remote island to assess the capability of 5G MBS to reach rural areas (Moro, 2020). Nokia and TV Azteca carried out the first test of TV transmission over 5G in Latin America (Nokia, TV Azteca, 2021). Important events like the Tokyo Olympics can also be used as testbeds to evaluate the performance of 5G MBS (APB+ News, 2021). The results of these trials can be used to improve performance and come up with a wide range of valuable applications of 5G MBS.

OBJECTIVE OF THE PAPER

We have done a systematic study of 3GPP MBS from existing literature. The purpose of this paper is to give an overview of 5G MBS and discuss the enhancements done in 5G to meet 5G MBS requirements. We also present a comparison between 5G and LTE MBS performance with respect to coverage and mobility. We then present a few important use cases of 5G MBS.

The rest of this paper is structured in the following manner.

Section 4: This section gives an overview of 5G MBS and discusses the architectural and service level enhancements done in 5G to meet 5G MBS requirements.

Section 5: This section gives the radio level requirements of 5G MBS and the enhancements done in 5G to meet these requirements.

Section 6: This section gives a few examples of how 5G MBS can provide a high quality of service with efficient use of radio resources.

Section 7: This section compares 5G and LTE MBS performance with respect to coverage and mobility.

Section 8: This section presents a few important use cases of 5G MBS.

Section 9: This section gives a few challenges in the current implementation of 5G MBS.

Overview of 5G MBS

Broadcasting and multicasting allow network operators to offload popularly viewed content from dedicated service to shared service, freeing up network resources. Older technologies like 3G and LTE also supported Broadcast/Multicast services. However, 5G MBS aims to provide a better user experience and quality of service than 3G and LTE MBMS. In this section, we give a brief overview of 5G MBS. We also discuss the architectural and service level enhancements done to meet 5G MBS requirements.

5G MBS has the below service level and architectural requirements for supporting MBS.

- *Requirement I:* The architecture should be modular and flexible
- *Requirement II:* It should minimise impact to existing 5G architecture and external services
- *Requirement III:* Only NR NG-RAN connected to 5GC is considered as RAT
- *Requirement IV:* It should provide a mode of efficient transport for a variety of multicast and broadcast services
- *Requirement V:* It should provide a basic and enhanced level of service to transport application content.

In the below sub-sections, we discuss how these requirements are met.

ARCHITECTURE

Fig. 1 shows the reference architecture for MBS delivery (3GPP TR 23.757, 2021). Some essential functions of the newly introduced network functions are given in Table 2.

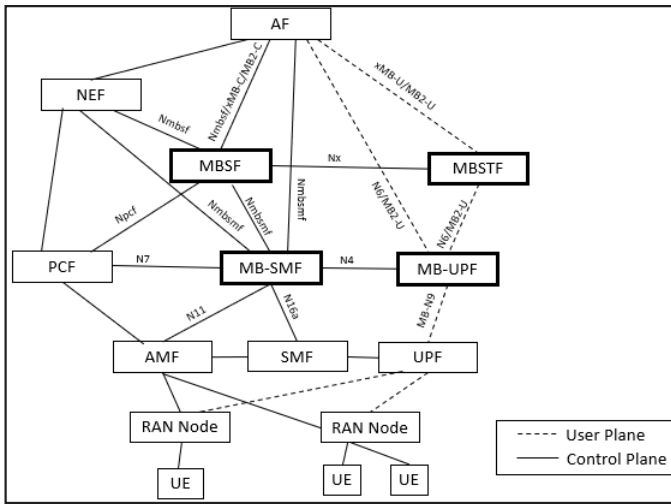


Fig. 1: 5G MBS Reference Architecture

This architecture leverages existing 5G unicast architecture and only adds a few modular functions and interfaces for MBS services. This avoids complicated enhancements in existing network nodes and user devices to support MBS. Flexibility in this architecture comes from the fact that the operator can choose to co-locate a few nodes or keep them separate. For example, MB-SMF, MB-UPF, MBSF and MBSTF are functional components that can be standalone or can be co-located with existing network functions like NEF and AF. This reference architecture meets Requirements I, II and III mentioned above.

Table 1: New Functional Entities (Source: (3GPP TR 23.757, 2021))

Network Function	Function
MBSF	<ul style="list-style-type: none"> • Service level functionality to support MBS, and interworking with LTE MBMS • Interacts with AF and MB-SMF for MBS session operations and transport • Selects MB-SMF for MBS Session • Interacts with MB-SMF to determine of MBS session transport parameters • Controls MBSTF • Determines sender IP multicast address for MBS session
MBSTF	<ul style="list-style-type: none"> • Acts as Media anchor for MBS data traffic if needed. • Generic packet transport functionalities available to any IP multicast enabled application such as framing, multiple flows, packet FEC (encoding) and ROHC. • Multicast/broadcast delivery of input files as objects or object flows • MBSTF is used only when MBSF is used
MB-SMF	<ul style="list-style-type: none"> • Used for MBS session management (including QoS control), • Controls MBS transport and configures MB-UPF and RAN (via AMF) for MBS flows based on policy rules
MB-UPF	<ul style="list-style-type: none"> • Packet filtering of incoming downlink packets for MBS flows. • Distribution of MBS data packets to RAN nodes (or UPF nodes). • QoS enforcement and counting/reporting based on existing means

Source: 3GPP TR 23.757, 2021.

Delivery Methods

To meet Requirement IV, (3GPP TR 23.757, 2021) defines different delivery methods for MBS packet flows, as shown in Fig. 2.

5GC to NG-RAN Packet Flow:

- 5GC Individual MBS traffic delivery: In this method, 5GC receives a single copy of MBS data and delivers the data to each UE via UE specific PDU sessions.

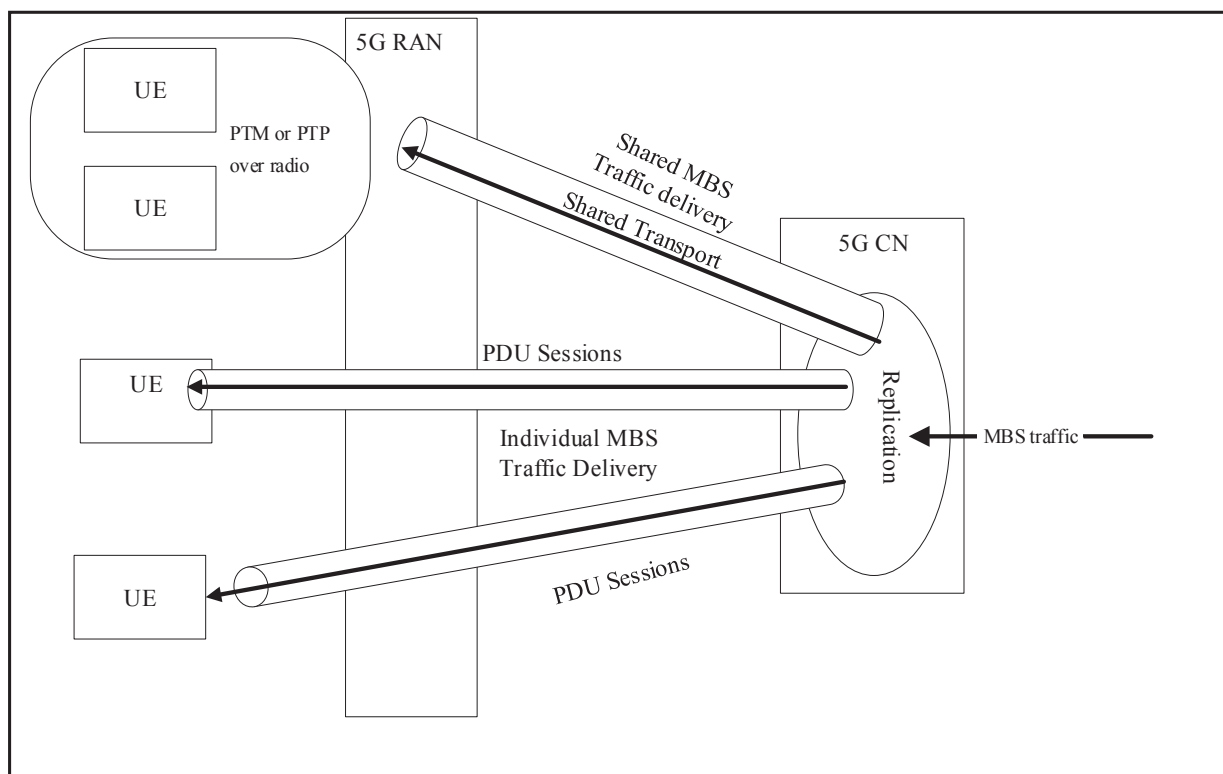
- 5GC Shared MBS traffic delivery: In this method, also 5GC receives a single copy of MBS data. 5GC then delivers the data to NG-RAN, which then delivers it to UEs through PTP or PTM mode.

5GC Individual MBS, traffic delivery method, is mainly used to support mobility when a UE moves from an NG-RAN that supports 5G MBS to a RAN node that does not support 5G MBS. In such cases, the network and UE switch from 5GC Shared MBS traffic delivery method to 5GC Individual MBS traffic delivery method.

NG-RAN to UEs Packet Flow:

- Point-to-Point (PTP) delivery: NG-RAN delivers separate copies of MBS data over the radio to individual UEs.
- Point-to-Multipoint (PTM) delivery: NG-RAN delivers a single copy of MBS data over the radio to a set of UEs.

NG-RAN independently takes decisions on switching between PTM and PTP for best service quality and resource efficiency.



Source: 3GPP TR 23.757, 2021.

Fig. 2: Delivery Modes

For multicast sessions, both 5GC shared delivery (with PTP or PTM) and 5GC Individual delivery may be used simultaneously. However, for broadcast service, only 5GC shared MBS traffic delivery with PTM is applicable.

Operation Modes

5G MBS supports both basic and enhanced service modes (Requirement V). In basic service mode, the 5G network

transparently transports application content. All decisions about transport (unicast, multicast or broadcast) are taken by the application server. In this mode, MBSF and MBSTF are not used.

In service mode, the 3GPP network is fully aware of the content and can take decisions on switching user service between broadcast or unicast. It also provides enhanced QoS support in this mode. MBSF plays an important role in service mode.

RADIO REQUIREMENTS FOR MBS SUPPORT IN 5G

In Rel-15, the primary focus of 5G NR was to provide unicast services. However, multicast and broadcast services have some additional set of radio requirements. In this section, we discuss the 5G NR radio requirements and the enhancements done in 5G MBS to meet these requirements.

5G NR radio requirements to support MBS are given in (3GPP TR 38.913, 2020) and are listed below:

- *Requirement 1:* It should support existing Multicast/Broadcast services and new services.
- *Requirement 2:* It should support dynamic adjustment of Multicast/Broadcast area.
- *Requirement 3:* It should support concurrent delivery of both unicast and Multicast/Broadcast services.
- *Requirement 4:* It should support efficient multiplexing with unicast transmissions.
- *Requirement 5:* It should support static and dynamic resource allocation between Multicast/Broadcast and unicast; It should also allocate up to 100% of downlink resources for Multicast/Broadcast.
- *Requirement 6:* It should support Multicast/Broadcast network sharing between multiple participating MNOs.
- *Requirement 7:* It should cover large geographical areas up to the size of an entire country in SFN mode with network synchronisation and allow cell radii of up to 100 km if required.
- *Requirement 8:* It should support mobility up to 250 km/hr.
- *Requirement 9:* It should leverage the usage of RAN equipment (hardware and software).
- *Requirement 10:* It should support Multicast/Broadcast services for all types of devices, including mMTC devices.

Apart from the requirements on larger coverage (Requirement 7) and high mobility (Requirement 8), all the other requirements are either fully or partially supported in 3GPP Rel-14 LTE specifications itself

(3GPP TR 36.776, 2019). However, to support extensive coverage and high mobility, a few radio enhancements have been done in 5G MBS as described below.

Coverage Enhancement: 5G MBS supports new numerology of 0.37kHz SCS and 300µs CP. Longer CP allows for larger delay spreads which in turn reduces inter-symbol interference and increases cell coverage.

Mobility Enhancement: 5G MBS also supports a new shorter 100µs CP with 2.5kHz SCS. This larger SCS helps in countering Doppler effects and thus allows 5G MBS reception for mobility up to 250 km/hr.

Table 2: MBS Numerologies

SCS (kHz)	CP (µs)	Active Symbol Period (µs)	Remarks
15	16.7	66.7	<ul style="list-style-type: none"> ● LTE Rel-9 to Rel-13 Numerology ● Supports 5Km ISD
1.25	200	800	<ul style="list-style-type: none"> ● Numerology introduced in LTE Rel-14 ● Supports up to 60Km ISD
0.37	300	2700	<ul style="list-style-type: none"> ● New numerology in 5G MBS ● Supports up to 90 Km ISD
2.5	100	400	<ul style="list-style-type: none"> ● New numerology in 5G MBS ● Supports 250kmph speed ● Supports 30 Km ISD

Source: Future Mobile Communication FORUM, 2020.

5G MBS FOR EFFICIENT RESOURCE UTILISATION

The main goal of all MNOs is to provide high-quality service with efficient use of network and radio resources. This section gives a few examples of how MNOs can achieve these goals with 5G MBS.

- In 5G, network slices with specific QoS can be allocated for different MBS services depending on the service’s QoS requirement, as shown in Fig. 3. This allows MNOs to allocate the right amount of resources for each service.

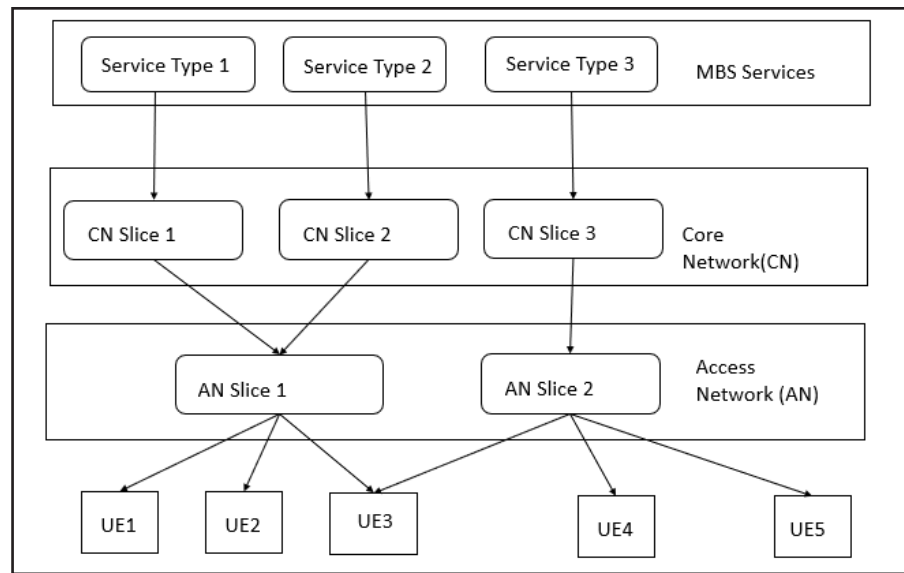
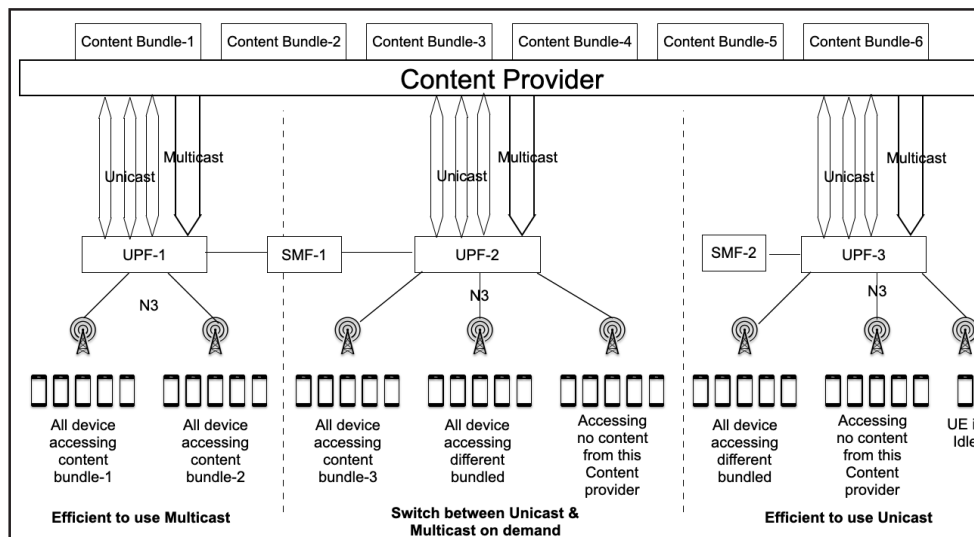


Fig. 3: Network Slicing for MBS Services

- Portions of available radio resources can be dynamically split between broadcast/multicast or unicast

radio channels depending on demand and load conditions, as shown in Fig. 4.



Source: 3GPP TR 23.757, 2021.

Fig. 4: Dynamic Switching between Multicast and Unicast

- Signalling mechanisms can be used to estimate audience density based on real-time user counting. This can help MNOs take informed decisions on whether to broadcast data or transmit it to individually UEs via unicast.

PERFORMANCE EVALUATION

In this section, we compare 5G and LTE MBS performance with respect to coverage and mobility. Coverage and Mobility Performance evaluation for different

numerologies was done by 3GPP and are detailed in (3GPP TR 36.776, 2019). In this evaluation, achievable SNR at

95% locations was measured for different numerologies for the scenarios given in Table 3.

Table 3: Evaluated Scenarios

Parameter	MPMT	HPHT-1	HPHT-2	LPLT
ISD	50km	125km	173.2km	15km
BS Power	60dBm	70dBm	70dBm	46 dBm
BS antenna height	100m	300m	300m	35m

Source: 3GPP TR 36.776, 2019.

COVERAGE

In (Qualcomm Incorporated, 2019) and (EBU, BBC, IRT, 2019), it is shown that the achievable SNR improved

significantly by using 300µs CP as compared to the LTE 200µs CP. For example, for rooftop receivers for MPMT and HPHT, 300ms CP gave an improvement of up to 8-10 dB SNR (Table 4 and Table 5).

Table 4: Achievable SINR for Rooftop Receiver

CP (µs)	Symbol Period (µs)	SCS (kHz)	LPLT	MPMT	HPHT1	HPHT2	Remark
200	800	1.250	20.2 dB	6.2 dB	-0.7 dB	-7.3 dB	Rel-14 LTE MBS
300	2700	0.370	20.3 dB	15.2 dB	8.6 dB	1.8 dB	5G MBS

Source: Qualcomm Incorporated, 2019.

Table 5: Achievable SINR for Rooftop Receiver

CP (µs)	Symbol Period (µs)	SCS (kHz)	LPLT	MPMT	HPHT1	HPHT2	Remark
200	800	1.250	26 dB	8-12 dB	Up to 4 dB	-	Rel-14 LTE MBS
300	2700	0.370	26 dB	14-20 dB	Up to 11 dB	-	5G MBS

Source: EBU, BBC, IRT, 2019.

Mobility

In (Qualcomm Incorporated, 2019), achievable throughput for car-mounted receivers in the LPLT scenario at 250km/hr with 16QAM was measured (Table 6). It is observed

that 100µs numerology achieved the same throughput with a lower SNR than the 200µs numerology. It was also observed that the 100µs numerology could reach beyond 15Mbps when SNR was increased. However, with 200µs numerology, the throughput could not cross 15 Mbps even with increased SNR.

Table 6: Achievable Throughput for Car-Mounted Receivers at 250 kmph

CP (µs)	Symbol Period (µs)	SCS (kHz)	SNR	Throughput	Remark
200	800	1.250	~16.5 dB	14.1 Mbps	Rel-14 LTE
			~19 dB	15.3 Mbps	
			> 20dB	Could not reach 16.4 Mbps	
100	400	2.5	~15 dB	14.1 Mbps	5G MBS
			~16 dB	15.3 Mbps	
			~17.2 dB	16.4 Mbps	

Source: Qualcomm Incorporated, 2019.

In (EBU, BBC, IRT, 2019) also it was shown that at speeds of 250km/hr, 100 μ s numerology achieves

better BLER as compared to 200 μ s numerology (Table 7).

Table 7: Achievable BLER

<i>CP (μs)</i>	<i>Symbol Period (μs)</i>	<i>SCS (kHz)</i>	<i>Speed</i>	<i>SNR</i>	<i>BLER</i>	<i>Remark</i>
200	800	1.250	120kmph	9.5 dB	10^{-1}	Rel-14 LTE
			250kmph	Up to 16 dB	Could not reach 10^{-1}	
100	400	2.5	120kmph	10db	10^{-1}	5G MBS
			250kmph	~ 10.7 dB	10^{-1}	

Source: EBU, BBC, IRT, 2019.

5G MBS USE CASES

Apart from entertainment, 5G MBS can be used in a wide range of important applications, as mentioned below.

Public Safety

Public safety is one of the most important applications of 5G MBS (Gap Wireless, 2021). With 5G MBS, emergency alerts and real-time warnings can be broadcast in specific areas. In situations like earthquakes, floods etc., rescue workers work in groups for coordinated rescue operations. 5G MBS can be used to send the same message to all users within the group. Since 5G supports high data rates and very low latencies, it can even deliver high-definition videos and instant location information to every rescue personnel in the group.

Remote Education

In emergencies and pandemics, teachers and students can't go to school. Hence it is essential to adopt new teaching methodologies. Due to the larger coverage of 5G MBS, even remote rural areas can be covered reliably. Hence it is possible to broadcast lectures and other visual modules to students in remote villages. This will result in fewer school drop-outs and continuity of education for most students. A case study has been done in a few schools in Finland using 5G Broadcast (Schools in Finland start Testing 5G in teaching, 2020).

eAgriculture

A lot of manual work in farming can be automated using 5G enabled robots and sensors for autonomous

seeding, planting, watering, weeding and monitoring (Brown, 2018). Since this entire autonomous agricultural ecosystem requires many IoT devices, 5G Multicast can send control messages and software/firmware updates to all these IoT devices simultaneously. Trials on this technology have been done by UK government funded testbed, 5G RuralFirst (Cisco, 2018).

CHALLENGES AND FUTURE WORK

Though 5G MBS supports switching between multicast and unicast, some packet loss is possible during this transition. Similarly, there can be some service interruption during transitions between NR/5GC and E-UTRAN/EPC. Work is going on in 3GPP to address these issues, and a solution is expected in Rel-17 specifications.

For time-sensitive MBS applications, MNOs are also considering using Mobile Edge Computing (MEC) to reduce network latency by shifting computing, data analytics and storage from external servers to the mobile edge. If MEC is integrated with 5G MBS, it will pave the way for many more fast and intelligent services in a wide range of areas.

CONCLUSION

5G MBS enables offloading of dedicated service to broadcast service, thereby freeing up network resources. It also provides a cost-effective and spectrally efficient model to converge Multicast/Broadcast services with other dedicated Services.

5G MBS provides better performance in terms of larger coverage and high mobility as compared to earlier technologies. Since 5G inherently supports eMBB, mMTC and uRLLC, 5G MBS can be used to develop a

variety of applications not just for entertainment, but also for some very basic needs like public safety, education and agriculture.

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GLOSSARY

Term	Expansion
3GPP	Third Generation Partnership Project
5GC	5G Core
BLER	Block Error Rate
BM-SC	Broadcast Multicast Service Center
CP	Cyclic Prefix
eMBB	Enhanced Mobile Broadband
eNB	Enhanced NodeB
HPHT	High Power HighTower
ISD	Inter-site Distance
LPLT	Low Power Low Tower
LTE	Long Term Evolution
MBMS	Multimedia Broadcast and Multicast Services
MBS	Multicast Broadcast Service
MBSF	Multicast Broadcast Service Function (Control Plane)
MBSFN	Multimedia Broadcast multicast service Single Frequency Network
MB-SMF	Multicast Broadcast Session Management Function
MBSTF	Multicast Broadcast Service Function (User Plane)
MB-UPF	Multicast Broadcast User Plan Function
MEC	Mobile Edge Computing
mMTC	Massive Machine Type Communication
MNO	Mobile Network Operator
MPMT	Medium Power Medium Tower
NG-RAN	Next Generation Radio Access Network
NR	New Radio
PDU	Protocol Data Unit
PTM	Point-to-Multipoint
PTP	Point-to-Point
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
ROM	Receive Only Mode
SCS	Subcarrier Spacing
SFN	Single Frequency Network
SIM	Subscriber Identity Module
SINR	Signal to Interference plus Noise Ratio
SNR	Signal to Noise Ratio
UE	User Equipment
URLLC	Ultra-Reliable Low Latency