WIVE Deliverable 2.6: Report on dynamic use of eMBMS and unicast

Juha Kalliovaara

Turku University of Applied Sciences, Turku, Finland

1 Introduction

This deliverable extends WIVE Deliverable 2.4 by focusing on the dynamic aspects in the use of eMBMS and unicast in LTE. It has to be pointed out that the Internet is based on unicast protocols, while the LTE eMBMS multicast/broadcast mechanisms are operated at the edge of the network as a delivery optimization mechanism, used typically for customer's within one operator's domain.

MBMS Operation On Demand (MooD) was standardized in 3GPP Release 12 to allow the operators to dynamically and seamlessly turn the eMBMS transmissions on or off based on the UE service service consumption reporting. Single-Cell Point-To-Multipoint (SC-PTM) was introduced in 3GPP Release 13 to allow higher granularity, based on cell level user distributions. SC-PTM allows very flexible and dynamic radio resource allocation for broadcast transmissions within one cell. 3GPP Release 14 included for example MBSFN and SC-PTM for vehicular to everything (V2X) and the enhanced TV service delivery for eMBMS, which allows to deploy dedicated eMBMS broadcast networks fulfilling public broadcast requirements. The PTM evolution in LTE is illustrated in Figure 1.

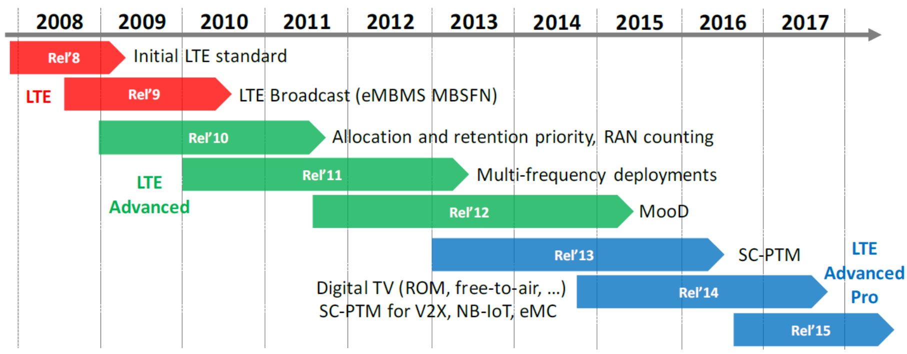

Fig. 1. Point-to-Multipoint Evolution in 4G LTE [1].

This Deliverable describes dynamic abilities and limitations of both MooD and SC-PTM and surveys the simulation studies conducted on their spectral efficiency.

2 MooD - MBMS Operation On Demand

MooD improves the dynamicity in eMBMS by allowing to i) set up an MBMS user service on the fly and seamlessly migrate an existing service to an MBMS user service, ii) judge if a unicast service would be better served by broadcast or unicast, and iii) enable an MBMS Broadcast Session for an ongoing MBMS User Service where previously there was none active [2].

Specifically, MooD specifies how to enable a Broadcast Multicast Service Center (BM-SC) to convert a non-MBMS unicast service to an MBMS User Service (described in [3]) and distributing the User Service Description (USD) describing the aforementioned MBMS User Service to interested UEs. In addition, MooD includes methods that may be able to determine or assist in determining the consumption of a service, and look into elements that may be able to be decision-makers on determining if unicast or broadcast transmission should be used [2].

A high-level MooD architecture is illustrated in Figure 2. When the BM-SC determines a high attachment rate to a unicast service, it activates an eMBMS User Service to carry the content with high attachment rate over an MBMS bearer. The red, blue or orange lines in the figure illustrate the unicast service transport, which can be converted and delivered to the UE through an MBMS user service from the BM-SC. The MBMS bearer is illustrated with a green-colored line.

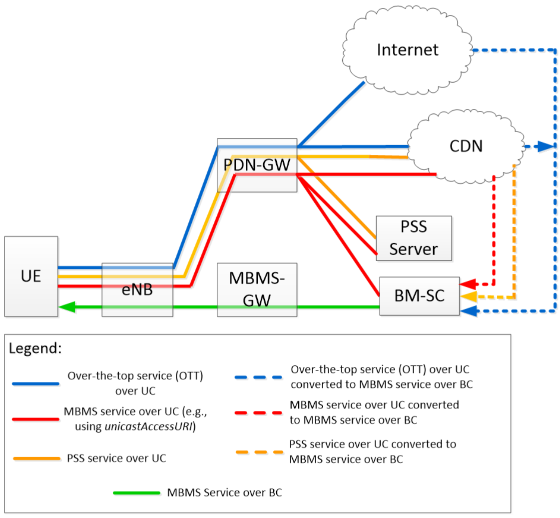

Fig. 2. High-level MooD architecture [2].

Telstra has trialed MooD and is planning to make their whole network Mood/eMBMS-capable during 2018 [4].

3 Single-Cell Point-To-Multipoint

SC-PTM was introduced in 3GPP Release 13 as complementary bearer type of eMBMS transmission [5]. SC-PTM reuses the logical entities and interfaces of eMBMS system architecture. As the name implies, SC-PTM does not include synchronized multicell transmissions. Thus, if the same content is requested over several cells, the involved eNBs independently use SC-PTM to transmit the content to the users covered by their site and thus may cause inter-cell interference to each other.

SC-PTM transmissions also enhance the coverage and transmission efficiency by enabling the Hybrid automatic repeat request (HARQ) retransmissions based on the uplink HARQ and channel state information (CSI) feedback (including channel quality indicator (CQI)) from connected UEs. Since the selection of the Modulation and Coding Scheme (MCS) and the re-transmissions are determined by the radio link conditions of the worst UE in the group, the gain from using uplink feedback in SC-PTM decreases gradually with increasing number of UEs [6]. SC-PTM can also use Transmission Time Interval (TTI) Bundling, which is designed to improve coverage at cell edge or in poor radio conditions [7].

4 Discussion and comparison of dynamicity in MooD and SC-PTM

This section discusses and compares the main features of MooD and SC-PTM with regard to their dynamic use in eMBMS transmissions. 5G-Xcast Deliverable 3.1 [1] section 3 gives a detailed overview on the general air interface, radio access technology and radio resource management limitations in 3GPP Release 14 MooD and SC-PTM.

– Even though MooD improves the dynamicity in the use of eMBMS, some problems stills persist. Firstly, MBSFN configurations are still static - MooD only turns MBMS transmissions on or off. The types of deployments for both MBSFNs and SC-PTM are also limited by the rigid OFDM numerology parameters.
– Large area MBSFN deployments require a large cyclic prefix length, which limits the high mobility in such deployments. The 200 μs cyclic prefix limits the mobility to around 100 km/h [1].
– The broadcast transmissions in MBSFNs also need the sites to be tightly synchronized, which increases the costs if the whole network needs to be synchronized for MBSFN transmissions. The network planning and deployment in SC-PTM is easier as the per cell basis transmissions do not need synchronization between the different sites.
– MBSFN benefits from spatial diversity, as several copies of the useful signal originating from different sites are received. The spatial diversity increases the useful signal strength and reduces inter-cell interference. To further reduce the inter-cell interference, a set of *reserved cells* can be deployed around the

MBSFN area. These cells do not have any transmissions during active MBSFN subframes. The use of reserved cells thus also decreases the efficiency in the use of radio spectrum.
- SC-PTM uses Physical Downlink Control Channel (PDCCH), which allows more flexible and efficient scheduling and radio resource allocation compared to MBSFNs. SC-PTM also allows lower latency than MBSFN [8]. MBSFN uses Multicast Traffic CHannel (MTCH) to transport the data on specific subframes. More detailed description on the radio access network (RAN) methods used in SC-PTM and eMBMS is available in [9].
- The MBSFN transmissions also lack a support for multiple antenna port transmissions. The MBSFN reference signals would need to be redesigned to enable multiple antenna use. As SC-PTM transmissions are based on Physical Downlink Shared Channel (PDSCH), they natively support multiple antenna port transmissions and thus diversity can be used to improve the efficiency and robustness of the SC-PTM transmissions. Multiplexing with unicast transmissions is also more flexible with PDSCH [10].
- In MBSFN, the area where the broadcast data has to be broadcasted is larger than what is actually required. Even though MooD enables the MBSFN transmissions to be dynamically turned on or off, the MBSFN areas still are statically configured and are not based on the user distribution. The SC-PTM transmissions are based on the user distribution and thus are more dynamic, but limited to a single cell. The simulation results in the next section study the spectral efficiency of MBSFN and SC-PTM.

5 Simulation results

5.1 5G-Xcast D3.1 SC-PTM/unicast spectral efficiency simulations

This subsection gives a main summary of the system-level simulations comparing unicast and SC-PTM in the IMT-2020 test environments for eMBB dense urban and rural environments (as detailed in ITU-R *Guidelines for evaluation of radio interface technologies for IMT-2020* [11]) from 5G-Xcast Deliverable 3.1 [1]. The test environments are assumed to be a point-to-point (PTP) solutions only, but the 5G-Xcast project has used them to evaluate PTM in the same environments.

The eNodeBs in the IMT-2020 test environments are placed in a regular grid and follow hexagonal layout. The simulation scenario includes 19 tri-sectored eNodeBs, and the topology is the same as in Figure 5 (but the MBSFN area is not defined in this simulation). The simulation details and parameters are available in Annex A.3 of 5G-Xcast Deliverable 3.1.

The average and 5-%ile user spectral efficiencies are used for unicast transmissions. Adaptive MCS scheme with support of HARQ is used for the unicast transmission mode, while the SC-PTM transmission mode uses fixed MCS settings that fulfil the criteria where 95% of the users have a packet loss lower than 10^{-3}.

The average and 5-%ile unicast user spectral efficiencies and the spectral efficiencies for the three used MCS settings for SC-PTM are illustrated in urban 100% indoor/outdoor environment in Figure 3 and in rural 100% indoor/outdoor environment in Figure 4. As the SC-PTM uses a fixed MCS setting for all users in the network, the presented average spectral densities also apply to the cell edge users.

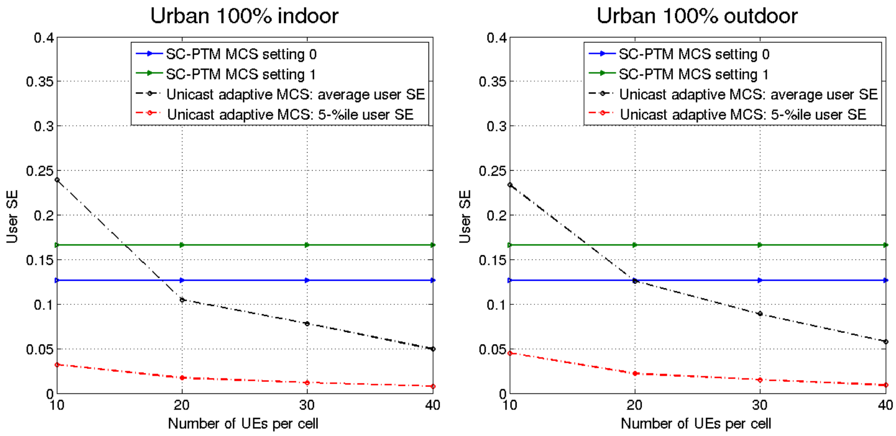

Fig. 3. Comparison of SC-PTM and Unicast for eMBB dense urban test environment [1].

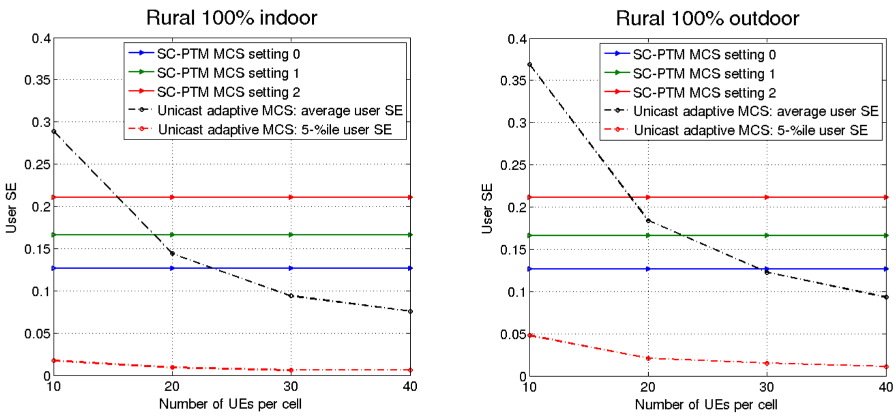

Fig. 4. Comparison of SC-PTM and Unicast for eMBB rural test environment [1].

The following conclusions can be drawn from the simulation results:

– With the SC-PTM, the spectral efficiency of cell-edge users is higher than unicast in all of the considered dense urban and rural IMT-2020 test environment use cases (the unicast cell-edge users are depicted by the unicast 5%-ile user SE.).
– Unicast has a better average spectral efficiency than SC-PTM when the user density is low, approximately 15 users per cell. In addition, the packet loss is negligible due to the link adaptation and HARQ schemes. With higher user densities, the SC-PTM average user spectral efficiency is higher and the packet loss rate is still affordable; 10^{-3}.
– The simulations presented in the deliverable also show that unicast transmission is more promising than SC-PTM in the indoor hotspot scenario defined in IMT-2020 test environment document [11]. This is because of the strong interference resulting from the dense deployment of SC-PTM indoor hotspots, which results in high packet loss rate beyond the affordable rate of 10^{-3}. To reduce the interference level and to fulfil the packet loss requirement, some of the access points should be switched off or MBSFN schemes used.

5.2 Simulation studies in 3GPP

The simulations in this section include studies where the uplink feedback schemes of SC-PTM are also studied. It has to be pointed out that uplink feedback schemes of SC-PTM are **not** available in 3GPP Releases, since the MBMS bearer used for media delivery in the core network is defined as a Radio Link Control-Unacknowledged Mode (RLC-UM). Retransmissions or channel state feedback are not possible in this mode. The simulation results show that uplink feedback modes would perform well especially when the number of UEs is very low.

5.2.1 Performance evaluation of UL feedback schemes for SC-PTM

The simulations presented at 3GPP TSG-RAN WG2 Meeting 89 in document *R2-151592: Performance evaluation of UL feedback schemes for SC-PTM* [6] study the spectral efficiency as a function of the number of UEs in the group for five different transmission schemes: unicast, MBSFN, and SC-PTM in three modes; i) without UL feedback, ii) with CQI and HARQ feedback, and iii) with CQI feedback and enhanced Outer Loop Link Adaptation (eOLLA). The simulation is conducted in a scenario which consists of 19 tri-sectored eNodeBs, as illustrated in Figure 5.

Figure 6 illustrates the spectral efficiency simulation results. In unicast transmissions, the spectral efficiency decreases when the number of UEs increases as the UEs share the available radio resources. The spectral efficiency of SC-PTM without UL feedback and MBSFN are constant regardless of the number of UEs. The spectral efficiency of SC-PTM schemes using UL feedback decreases when number of UEs increases. The higher the number of UEs is, the lower the used MCS and spectral efficiency will be.

SC-PTM without UL feedback has a higher spectral efficiency than unicast when the number of UEs is larger than 6. The difference in spectral efficiency

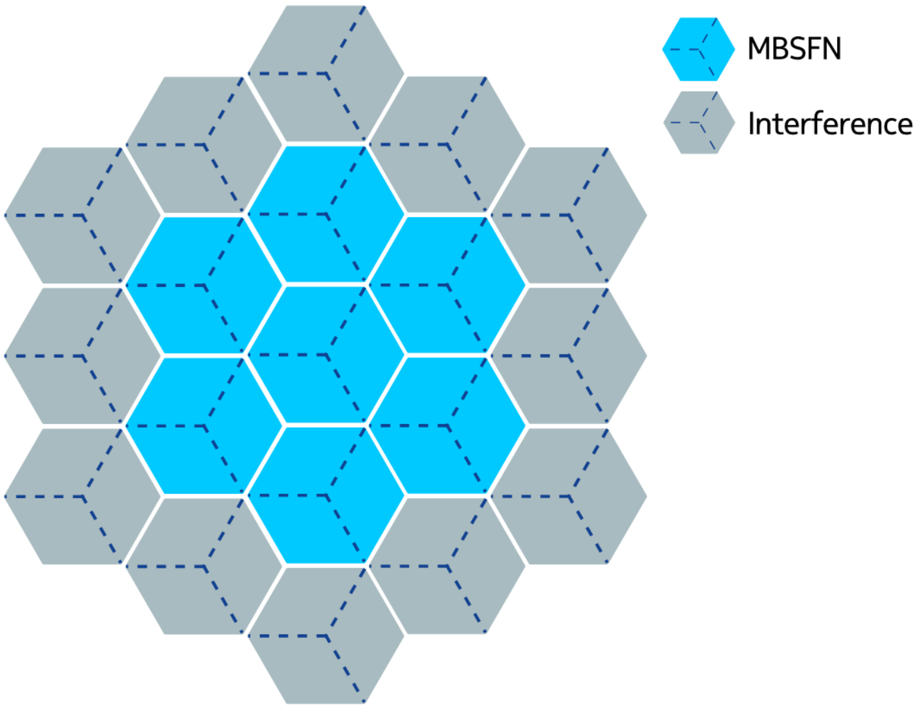

Fig. 5. Site (cell) layout and MBSFN configuration [6].

further increases when the number of UEs increases, as unicast spectral efficiency decreases and SC-PTM spectral efficiency is constant.

The spectral efficiency of SC-PTM is significantly higher when UL feedback is used. The two compared UL feedback schemes have a very similar performance, but SC-PTM with CQI feedback and eOLLA is less complex with regard to system design than SC-PTM with CQI and HARQ feedback. As the MCS and re-transmission are determined by the radio link conditions of the worst UE in the group, the gain from using UL feedback in SC-PTM decreases gradually as the number of UEs increases.

MBSFN transmission outperforms the other transmission schemes when the number of UEs is 4 or more. With 20 UEs, MBSFN spectral efficiency is approximately twice as high as with the SC-PTM schemes with UL feedback.

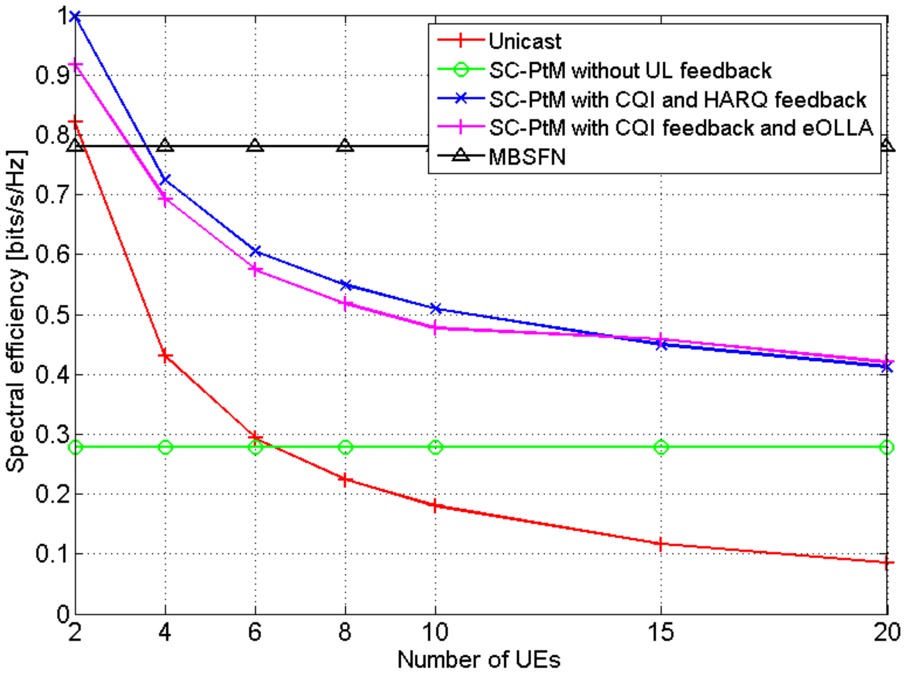

Fig. 6. Spectral efficiency expressed in bits/s/Hz as a function of the number of UEs in the group for the five investigated transmission schemes [6].

5.2.2 Comparison of SC-PTM and MBSFN use for Public Safety

The system-level simulations presented at 3GPP TSG-RAN WG2 Meeting 89 in document *R2-151516: Comparison of SC-PTM and MBSFN use for Public Safety* [10] study the spectrum efficiency of SC-PTM and MBSFN in different scenarios, with a focus on use for public safety. Figure 7 shows the comparison between SC-PTM and single cell MBSFN on spectrum efficiency with regard to different number of UEs per cell. The main observations are that that the SC-PTM is more efficient when UEs are only located in some cells of the MBSFN area and that the SC-PTM is always more efficient than a single cell MBSFN.

The use of reserved cells around the MBSFN area significantly decreases the spectral efficiency of MBSFN. This is because the interference avoidance gain from the reserved cells is not as large as the additional spectrum resource consumption by reserved cells. Because MBSFN only supports single antenna port transmission and extended cyclic prefix, the spectrum efficiency of single cell MBSFN is always lower than SC-PTM (with and without UL feedback).

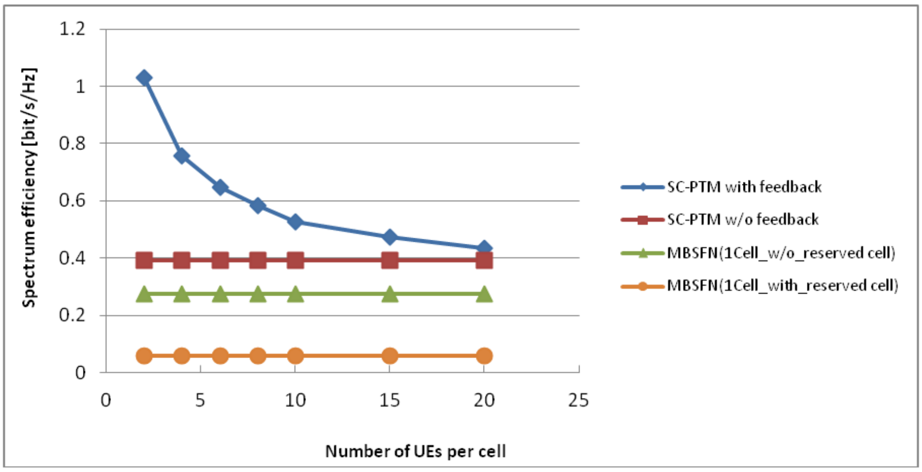

Fig. 7. SC-PTM vs. MBSFN (single-cell MBSFN area, 6 reserved cells if MBSFN area reserved cells are deployed) [10].

6 Flexible broadcast/multicast service in 5G

The MBMS services are not considered in 3GPP Release 15, but the following 3GPP Releases are expected to include novel architectures to resolve the issues regarding broadcast and multicast transmissions in the current eMBMS architecture. The development of more flexible broadcast/multicast service will be considered in 3GPP Release 16.

3GPP TS 22.261: Service requirements for the 5G system; Stage 1 (Release 16) [12] declares that *the proliferation of video services, ad-hoc broadcast/multicast streams, software delivery over wireless, group communications and broadcast/multicast IoT applications have created a need for a flexible and dynamic allocation of radio resources between unicast and multicast services within the network as well as support for a stand-alone deployment of broadcast/multicast network. Moreover, enabling such a service over a network for a wide range of inter-site distances between the radio base stations will enable a more efficient and effective delivery system for real-time and streaming broadcast/multicast content over wide geographic areas as well as in specific geographic areas spanning a limited number of base stations. A flexible broadcast/multicast service will allow the 5G system to efficiently deliver such services.*

The document lists the following set of specific requirements for the flexible broadcast/multicast service:

– The 5G system shall support operation of downlink only broadcast/multicast over a specific geographic area (e.g., a cell sector, a cell or a group of cells).
– The 5G system shall support operation of a downlink only broadcast/multicast system over a wide geographic area in a spectrally efficient manner for stationary and mobile UEs.
– The 5G system shall enable the operator to reserve 0% to 100% of radio resources of one or more radio carriers for the delivery of broadcast/multicast content.
– The 5G network shall allow the UE to receive content via a broadcast/multicast radio carrier while a concurrent data session is ongoing over another radio carrier.
– The 5G network shall allow the UE to receive content via a broadcast/multicast radio carrier while a concurrent data session is ongoing over another radio carrier.
– The 5G network shall allow the operator to configure and broadcast multiple quality levels (i.e., video resolutions) of broadcast/multicast content for the same user service in a stand-alone 3GPP based broadcast/multicast system.
– The 5G network shall support parallel transfer of multiple quality levels (i.e., video resolutions) of broadcast/multicast content for the same user service to the same UE taking into account e.g., UE capability, radio characteristics, application information.
– The 5G system shall support parallel transfer of multiple multicast/broadcast user services to a UE.
– The 5G system shall support a stand-alone multicast/broadcast network comprising of multiple cells with inter-site distances of up to 200 km.

7 Conclusions

This deliverable discusses the dynamic features and limitations of LTE eMBMS up to 3GPP Release 14. The 5G-PPP phase II project 5G-Xcast [13] is developing a new system architecture for efficient broadcast and multicast content delivery and contributing the project results actively in 3GPP during 2018 and 2019 to aid in the development of flexible broadcast/multicast/unicast architecture for 5G. The 5G-Xcast Deliverables will be made publicly available on the project website [13].

The simulation results presented in this deliverable compare the spectral efficiency of MBSFN, SC-PTM and unicast transmission schemes with regard to number of UEs in different scenarios. Different types of limitations in eMBMS/MBSFN and SC-PTM make their direct comparison difficult as the performance is different in each deployment type. Some conclusions can still be drawn from the simulation results: i) MBSFN is more efficient than other schemes when there is a very high number of users ii) SC-PTM always outperforms a single-cell eMBMS, and iii) UL feedback would increase SC-PTM performance, but it is currently not used with SC-PTM.

However, it is questionable whether all usage scenarios require a high level of dynamicity. If for example a dedicated multi-operator mobile network is built to constantly broadcast digital television content, the scenario could well be implemented with static MBSFN configurations which would be able to provide a certain quality of service and coverage. After the 3GPP Release 14 enhancements in TV content distribution, LTE broadcast can already be considered as a possible method to supplement or even to replace at least parts of the digital terrestrial television network.

References

1. 5G-Xcast, editors David Vargas (BBC) and De Mi (UNIS), *Deliverable D3.1: LTE-Advanced Pro Broadcast Radio Access Network Benchmark Version v1.1*, December 2017.
2. 3GPP, *3GPP TR 26.849 V12.1.0 (2015-06): Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service (MBMS) improvements; MBMS operation on demand (Release 12)*, June 2015.
3. ——, *3GPP TS 26.346 V15.0.0: 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs (Release 15)*, December 2017.
4. Telstra, *A change of MooD for live streaming*, December 2017. [Online]. Available: https://exchange.telstra.com.au/streaming-network-performance/
5. Alain Sultan, 3GPP TSG CT Meeting 69, *Release 13 analytical view version Sept. 9th 2015*, September 2015.
6. Nokia Networks, 3GPP TSG-RAN WG2 Meeting 89, *R2-151592, Performance evaluation of UL feedback schemes for SC-PTM*, April 2015.
7. R. Susitaival and M. Meyer, "Lte coverage improvement by tti bundling," in *VTC Spring 2009 - IEEE 69th Vehicular Technology Conference*, April 2009, pp. 1–5.

8. A. Daher, M. Coupechoux, P. Godlewski, P. Ngouat, and P. Minot, "Sc-ptm or mbsfn for mission critical communications?" in *2017 IEEE 85th Vehicular Technology Conference (VTC Spring)*, June 2017, pp. 1–6.
9. J. Kim, S. W. Choi, W. Y. Shin, Y. S. Song, and Y. K. Kim, "Group communication over lte: a radio access perspective," *IEEE Communications Magazine*, vol. 54, no. 4, pp. 16–23, April 2016.
10. Huawei et al., 3GPP TSG-RAN WG2 Meeting 89, *R2-151516, Comparison of SC-PTM and MBSFN use for Public Safety*, April 2015.
11. I.-R. W. P. 5D, *DRAFT NEW REPORT ITU-R M.[IMT-2020.EVAL]: Guidelines for evaluation of radio interface technologies for IMT-2020*, October 2017.
12. 3GPP, *3GPP TS 22.261 V16.2.0: Technical Specification Group Services and System Aspects; Service requirements for the 5G system; Stage 1 (Release 16)*, December 2017.
13. *5G-Xcast project.* [Online]. Available: http://5g-xcast.eu