ETSI TR 136 776 V16.0.0 (2020-11)

TECHNICAL REPORT

LTE;
Evolved Universal Terrestrial Radio Access (E-UTRA);
Study on LTE-based 5G terrestrial broadcast
(3GPP TR 36.776 version 16.0.0 Release 16)

Reference
DTR/TSGR-0136776vg00

Keywords
LTE

ETSI

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Sous-Préfecture de Grasse (06) N° 7803/88

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Contents

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1 Scope

The present document captures the findings of the study item, "Study on LTE-based 5G terrestrial broadcast " [2]. The purpose of this TR is to identify the gaps between the LTE-based eMBMS and the 5G requirements for dedicated broadcast networks defined in 3GPP TR 38.913 [3] and to study the solutions for closing these gaps.

This document is a 'living' document, i.e. it is permanently updated and presented to TSG-RAN meetings.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[2] 3GPP RP-181706: "New SID on LTE-based 5G Terrestrial Broadcast"

[3] 3GPP TR 38.913: "Study on scenarios and requirements for next generation access technologies"

[4] 3GPP TR 36.814: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects"

[5] 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz"

[6] ITU-R BT.2254-3: "Frequency and network planning aspects of DVB-T2"

[7] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2"

[8] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification"

[9] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures"

[10] R1-1902349: "Evaluation results and potential enhancements", Qualcomm Incorporated, Athens, Greece, Feb 25 – Mar 1, 2019

[11] R1-1901582, "Simulation results on enhancement techniques for LTE ENTV", Huawei, HiSilicon, Athens, Greece, Feb 25 – Mar 1, 2019

[12] R1-1902130: "Evaluation Results for LTE-Based 5G Terrestrial Broadcast", EBU, BBC, IRT, Athens, Greece, Feb 25 – Mar 1, 2019

[13] R1-1901780: "Simulation results for legacy LTE-based broadcast and effect of longer CP", Shanghai Jiao Tong University, Athens, Greece, Feb 25 – Mar 1, 2019

[14] R1-1812430, Evaluation Results for LTE-Based 5G Terrestrial Broadcast, EBU, BBC, IRT, 3GPP TSG RAN WG1 #95, Spokane USA 12th - 16th November 2018

[15] R1-1903419, Performance of Non-Uniform Constellations for LTE-Based 5G Terrestrial Broadcast, Shanghai Jiao Tong University, Athens, Greece, Feb 25 – Mar 1, 2019

[16] R1-1903512: "Link level analysis of CAS", Qualcomm Incorporated, Athens, Greece, Feb 25 – Mar 1, 2019

[17] 3GPP TS 23.246: "Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description"

[18] 3GPP TS 26.346: "MBMS: Protocols and Codecs"

[19] 3GPP TS 26.348: "Northbound Application Programming Interface (API) for Multimedia Broadcast/Multicast Service (MBMS) at the xMB reference point"

[20] 3GPP TS 23.468: "Group Communication System Enablers for LTE (GCSE_LTE), Stage 2"

[21] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception"

[22] 3GPP TR 36.888: "Study on provision of low-cost Machine-Type Communications (MTC) User Equipments (UEs) based on LTE"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol>	<Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

CAS	Cell acquisition subframe
EI	Equalisation interval
eMBMS	Evolved MBMS
MBMS	Multimedia Broadcast/Multicast System
MBSFN	Multicast/Broadcast Single Frequency Network
mMTC	massive Machine Type Communications
MNO	Mobile Network Operator
NR	New Radio
NUC	Non-uniform constellation
PMCH	Physical Multicast Channel
RAT	Radio Access Technology
SC-PTM	Single Cell Point To Multipoint
TV	Television
V2X	Vehicle to Everything

4 Introduction

3GPP TR 38.913 [3] defines the following requirements for support for MBMS in NR:

Req.1 The new RAT shall support existing Multicast/Broadcast services (e.g. download, streaming, group communication, TV, etc.) and new services (e.g. V2X, etc).

Req.2 The new RAT shall support dynamic adjustment of the Multicast/Broadcast area based on e.g. the user distribution or service requirements.

Req.3 The new RAT shall support concurrent delivery of both unicast and Multicast/Broadcast services to the users.

Req.4 The new RAT shall support efficient multiplexing with unicast transmissions in at least frequency domain and time domain.

Req.5 The new RAT shall support static and dynamic resource allocation between Multicast/Broadcast and unicast; the new RAT shall in particular allow support of up to 100% of DL resources for Multicast/Broadcast (100% meaning a dedicated MBMS carrier).

Req.6 The new RAT shall support Multicast/Broadcast network sharing between multiple participating MNOs, including the case of a dedicated MBMS network.

Req.7 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.

Req.8 The new RAT shall support Multicast/Broadcast services for fixed, portable and mobile UEs. Mobility up to 250 km/h shall be supported.

Req.9 The new RAT shall leverage usage of RAN equipment (hard- and software) including e.g. multi-antenna capabilities (e.g. MIMO) to improve Multicast/Broadcast capacity and reliability.

Req.10 The new RAT shall support Multicast/Broadcast services for mMTC devices.

The objective of this document is to study these requirements for LTE-based MBMS, to identify the gaps, and capture the potential solutions to close the gaps.

The above requirements could be divided into two groups:

1. Requirements whose analysis involves system-level and/or link-level simulations; and
2. Requirements whose analysis does not involve simulations.

Clause 5 provides the methodology for studying the requirements in general, and for each of the two groups defined above. Specifically, for the requirements requiring simulation work, the simulation assumptions and the setup are described.

Clause 6 provides the analysis of each of the above requirements, based on the methodology described in clause 5.

5 Methodology

5.1 General

The first step in the evaluation of a requirement should be to determine whether the requirement is already met by LTE or not. If the requirement is partially met, the remaining gaps should be identified.

It is identified that only Req.7 and Req.8 involve simulation work.

5.2 Methodology for requirements not involving simulations

Requirements not involving simulations (all requirements except Req.7 and Req.8) are to be verified based on analysis of current specifications.

5.3 Simulation assumptions

5.3.1 System-level simulation assumptions

For system-level evaluations, four scenarios are introduced as follows:

Table 1: Scenarios for system-level evaluations

Parameter	MPMT	HPHT-1	HPHT-2	LPLT
ISD	50km	125km	173.2km	15km
BS Power	60dBm	70dBm	70dBm	46 dBm
BS effective antenna height	100m	300m	300m	35m
CPs/Numerologies	CAS/SC-PTM: 4.7 us, 16.6us PMCH: 15kHz/7.5kHz/1.25kHz as baseline.			
Carrier frequency	700MHz			
Channel BW	10MHz as baseline			
BS antenna gain	10.5dBi	13dBi	13dBi	15dBi
BS antenna pattern	1Tx: rooftop and non-rooftop 2Tx: non-rooftop (FFS for rooftop)	1Tx: rooftop and non-rooftop 2Tx: non-rooftop (FFS for rooftop)	1Tx: rooftop and non-rooftop 2Tx: non-rooftop (FFS for rooftop)	3 sector antenna pattern Each sector has a horizontal and vertical pattern as defined in: [4], Table A.1.1: 3GPP Case 1 and Case 3 (Macro Cell) 2Tx for non-rooftop (FFS for rooftop)
Cellular Layout	Hexagonal grid, 61 cell sites, 1 sector per site	Hexagonal grid, 61 cell sites, 1 sector per site	Hexagonal grid, 61 cell sites, 1 sector per site	Hexagonal grid, 61 cell sites,3 sector per site
Tx EVM	[8%]			8%

For each of the four scenarios, four different types of receivers are considered:

Table 2: Channel characteristics for different scenarios

Parameter	Rooftop	Car-mounted	In-car	Indoor
Propagation model	ITU-R P.1546-5 50% / 1% (serving / interfering) as preferred assumption 50%/50% (serving / interfering)			
Fast fading channel type	Delay spread and path delay profile: adopt UMA/RMA model (according to [5, Subclause 7.5]). Fading distribution: Rayleigh except for the first path of rooftop (Rice). For rooftop, used fixed K=10dB. NOTE: this intends to describe the following procedure: - Run up to step 6 to obtain the delay coefficients per cluster - Normalized as described - Instead of generating the rays per cluster, take each of the delay coefficients for each cluster and generate a Gaussian random variable with the variance according to the power of the cluster.			
Receiver velocity	0	Up to 250km/h	Up to 250km/h	3km/h
Receiving antenna height	10m	1.5m	1.5m	1.5m
Height Loss: The difference between the signal level at 10m and the actual receiving antenna height	0dB	16.5dB for rural 23.5 dB for urban	16.5dB for rural 23.5 dB for urban	16.5dB for rural 23.5 dB for urban
Building or I2O loss penetration loss	0dB	0dB	μ = 9dB and σ = 5dB	20dB for urban 10dB for rural
Shadowing standard deviation	5.5dB	5.5dB	8dB for rural 6dB for urban	8dB for rural 6dB for urban
Shadowing correlation	1 for same site	1 for same site	1 for same site	1 for same site

Table 3: Receiver characteristics for different scenarios

Parameter	Rooftop	Car-mounted	In-car	Indoor
Receiver noise figure	6dB	6dB	9dB	9dB
Receiver noise bandwidth	9MHz	9MHz	9MHz	9MHz
Receiver antenna (gain & pattern)	13.15 dBi Discrimination pattern according to ITU-R BT.419-3 band IV, V	3.0 dBi Non-directional	-7.35dBi Non-directional	-7.35dBi Non-directional
Antenna Cable Loss	4dB	0dB	0dB	0dB
2-Rx Diversity	No (FFS for 2Tx)	Yes	Yes	Yes
Implementation Margin	1dB			
Body loss at receiver	0			
Rx EVM	4%			

For rooftop antenna alignment, one of the following two options (to be declared by company) is used:

- Opt1: Strongest transmitter (based on pathloss and shadowing).
- Opt2: Closest transmitter

X% pre-processing SINR (to be mapped to X% throughput by link level simulations) is used as a performance metric:

- Reporting points: 95% SINR. Other percentiles may also be reported.

The following options may be used for the distribution of UEs in the system level simulations:

- Uniform in all cells as a baseline
- "Worst case" (i.e., drop all UEs in the geographical point with the worst coverage) as an additional option

For SINR calculation, the formula in [6, Section 3.5] is used. Positioning of the EI is up to receiver implementation and should be declared in the evaluation, including the length of the EI.

Spectral efficiency is one of the performance metrics to be used for evaluation.

5.3.2 Link-level simulation assumptions

Table 4: Parameters for link-level simulations

Parameter	Values
System BW	10 MHz
Carrier frequency	700 MHz
CP/Numerology	CAS/SC-PTM: 4.7 us, 16.6us PMCH: 15kHz/7.5kHz/1.25kHz as baseline.
Doppler frequency	1Hz (rooftop antenna), Up to 120km/h and 250km/h for car-mounted/in-car, up to 3km/h for Indoor
Reference signal pattern	For existing numerologies, use existing reference signal patterns as baseline.
Channel estimation	Realistic based on RS design
Channel model	To be determined from system level evaluations for different ISDs. TDL-i for NLOS and TDL-v for LOS with the scaled delay spread derived from system level simulations.
Number of Rx antennas at the UE	Rooftop: 1 (baseline) /2 Mobile/car receiver: 2
MCS	Fixed MCS, selected by proponent

6 Analysis of requirements

6.1 General

This clause contains the analysis of the requirements for dedicated broadcast networks listed in clause 4, including potential enhancements.

6.2 Req.1: Support for existing and new services

Different use cases/services are supported by Rel-14 LTE specification:

- Broadcast TV services have been supported since Release 9, and were enhanced in Release 14.
- Download, streaming, and group communication based on SC-PTM have been supported since Release 13.
- Broadcast/multicast for V2X has been supported since Release 13 (based on SC-PTM or MBSFN transmission, see [7, Subclause 15.1.1]).
- Broadcast/multicast for IoT devices (eMTC and NB-IOT) have been supported from Release 14 (based on SC-PTM, see [7, Subclause 15.1]).

Conclusion:

Relevant for dedicated networks: Yes

Requirement met by Rel-14: Yes

6.3 Req.2: Dynamic adjustment of the multicast/broadcast area

eMBMS supports mechanisms to adjust the Multicast/Broadcast area from BMSC, specified in 3GPP TS 23.246 [18]. The BMSC can determine and adjust the MBMS Service Areas and provide a list of cell IDs in the MBMS Session Start and MBMS Session Update procedures. The MBMS Service Area and list of cell ID can be determined by the BMSC in one of the following ways:

- using procedures for "MBMS operation on demand (aka MOOD)" specified in 3GPP TS 23.246 [17]; or
- based on the reporting from the GCS AS using either:
  - procedures over the xMB interface, specified in 3GPP TS 26.346 [18] and 3GPP TS 26.348 [19]; or
  - procedures over the MB2 interface, specified in 3GPP TS 23.468 [20].

Conclusion:

Relevant for dedicated networks: Yes

Requirement met by Rel-14: Yes

6.4 Req.3: Simultaneous support for broadcast/multicast and unicast

Rel-14 LTE can provide simultaneous support for broadcast/multicast and unicast by the following means:

- On the same carrier, by time-multiplexing MBSFN and non-MBSFN subframes (TDM). The MBSFN subframes are signaled by fields *MBSFN-SubframeConfig*, *MBSFN-SubframeConfig-v1430*, in non-dedicated carriers. In dedicated carriers, *nonMBSFN-SubframeConfig-r14* includes the configuration for non-MBSFN subframes. See [8] for more details. In a given subframe, the PMCH uses the whole system bandwidth (see [9, Subclause 11.1]).
- On the same carrier, using SC-PTM for multicast/broadcast (can be TDM or FDM with unicast). SC-PTM uses PDSCH as the physical channel (see [7, Subclauses 6.1.3.2 and 5.3.1]) and thus allows for similar time-frequency granularity as unicast transmissions.
- On separate carriers, using a dedicated MBMS carrier for multicast/broadcast services.

Conclusion:

Relevant for dedicated networks: Yes

Requirement met by Rel-14: Yes

6.5 Req.4: Multiplexing of multicast/broadcast and unicast

This requirement is not relevant to dedicated MBMS networks.

Rel-14 LTE can support multiplexing of multicast/broadcast and unicast by the following means:

- SC-PTM supports multiplexing with unicast transmission in both the frequency domain and the time domain.
- MBSFN supports multiplexing with unicast transmission in the time domain.

6.6 Req.5: Dynamic resource allocation between multicast/broadcast and unicast and support for dedicated MBMS carrier

Regarding support for static and dynamic resource allocation between Multicast/Broadcast and unicast, it is not relevant to dedicated MBMS networks. Nevertheless, Rel-14 LTE can support dynamic resource allocation of broadcast and unicast. The following partitions between unicast and broadcast are supported depending on the type of carrier:

- Between 0%-60%: Pre Rel-14. The carrier can be used as a PCell.
- Between 60-80%: Rel-14 FeMBMS mixed carrier. The carrier supports unicast but cannot be used as a PCell.
- For SC-PTM transmission, partitions between 0 and 100% are supported

Regarding the requirement of support for a dedicated MBMS carrier, it is relevant and Rel-14 supports dedicated carrier with 100% allocation to MBMS by MBSFN and SC-PTM.

Conclusion:

Relevant for dedicated networks: Yes

Requirement met by Rel-14: Partially

6.7 Req.6: Support for network sharing

Rel.14 network architecture documented in Annex D in 3GPP TS 23.246 [17] supports shared eMBMS network over E-UTRAN, including dedicated eMBMS network.

Conclusion:

Relevant for dedicated networks: Yes

Requirement met by Rel-14: Yes

6.8 Req.7: Support for service over large geographic area

The large geographic area refers to an area of an entire country and/or cell size of 100 km.

6.8.1 General

In this context a large geographic area refers to the area covered by networks with the following inter-site distances (ISD):

- ~15 km, referred to as Low Power Low Tower (LPLT) network;
- ~50 km, referred to as Medium Power medium Tower (MPMT) network; and
- >100 km, referred to as High Power High Tower network, in particular:
    - ~125 km, referred to as HPHT-1 network; and
    - ~173 km, referred to as HPHT-2 network.

The measures of the ability to support the service over these networks are the SNR and spectral efficiency (SE) available to 95% of the users. The study in this TR comprised evaluating the 95% SNR and SE of the Rel.14 numerologies and the improvements that are possible by using new numerologies and enhanced receiver/transmitter schemes, such as MUST. The evaluations were performed for MBSFN transmission and SC-PTM (including CAS). The complete set of results related to the support of larger geographical areas can be found in annex A.

6.8.2 New numerologies for the support of larger ISDs for MBSFN

The MBSFN evaluations were performed by several sources and reported in [10], [11], [12], [13]. Based on these evaluations, the following observations can be summarized based on the 50/1 model (results for 50/50 can be found in the Annex):

For LPLT networks:

- Longer T_{cp} would provide limited improvement in SE in the LPLT network.
- Longer T_u would provide SE improvement in the LPLT network by reducing the CP overhead.

For MPMT networks:

- Longer $T_{cp} \geq 300\mu s$, combined with a longer $T_u >= 2,600\mu s$, provides significant improvement in SNR and SE for rooftop scenarios compared to the Rel.14 1.25kHz numerology:
    - the observed SNR gain is between 5dB and 10 dB;

  - the observed SE gain is ~100%.

- Longer T_u would further improve the SE in the MPMT network by reducing the CP overhead.

HPHT-1 networks:

- Longer $T_{cp} \geq 300\mu s$, ideally in the order of 400µs, combined with a longer $T_u >= 2{,}600\mu s$ would improve the in SNR in the HPHT-1 network of between 8dB and 15dB for rooftop scenarios compared to the Rel.14 1.25kHz numerology.

- Longer $T_{cp} \geq 300\mu s$, ideally in the order of 400µs, combined with a longer $T_u >= 2{,}600\mu s$ would improve the SE in the HPHT-1 network of 500% for rooftop scenarios compared to the Rel.14 1.25kHz numerology.

- Longer T_u would further improve the SE in the MPMT network by reducing the CP overhead.

HPHT-2 networks:

- Longer Tcp ≥300µs would provide limited improvement in SNR in the HPHT2 network of between 1dB and 2dB compared to the Rel.14 1.25kHz numerology.

- It would be challenging to provide service-level coverage even for the rooftop receiver in the HPHT2 network.

For all considered ISDs:

- It would be challenging to provide service-level coverage for 95% of users for indoor and in-car receivers..

For a given Tu, reducing RS density in the frequency domain (reducing EI) in the interference-limited scenarios incurs a 1-3 dB penalty in the SNR, however, the corresponding RS overhead reduction may simultaneously increase the SE.

6.8.3 CAS evaluation

CAS system level evaluations were performed by two sources and reported in [10] and [14]. The achievable SINR in these evaluations were highly dependent on the time variation assumptions, i.e. 50/1 or 50/50.

Synchronized CAS transmission (transmission of CAS in SFN manner with 15kHz numerology and 16.7us CP) provides SNR gain of up to 1.5 dB with respect to single-cell CAS. The results taking into account this consideration are summarised in Table 6.8.2-1.

Table 6.8.3-1 – SNR levels for CAS

		50/50 [10]	**50/1 [14]**
Car Mounted	LPLT	3.8 dB	-3.6 dB
	MPMT	1.9 dB	-6.1 dB
Fixed Rooftop	LPLT	12.8 dB	-0.4 dB
	MPMT	-0.2 dB	-1.8 dB
	HPHT1	0.5 dB	-6.9 dB

In the absence of link level simulations, RAN4 performance requirements [21] of the component channels of the CAS have been used to verify whether they would perform sufficiently well to meet the observed SNRs above. It is important to note that the RAN4 performance requirements in in TR 36.101 are for at least 2 Rx antennas and, in some cases, with 2 Tx antennas, hence, performance for the relevant fixed rooftop channel with 1 Tx and 1 Rx antennas can only be implied.

- **PDCCH**: the reference SNR is -1.7dB for 1 Tx and 2 Rx antennas (1T2R) [21, 8.4.1.1]. This figure is applicable for car mounted reception. The PDCCH would therefore be adequate for car mounted reception in the LPLT and MPMT networks with the 50/50 model but inadequate in both of these cases with the 50/1 model. The performance for 1T1R, applicable for fixed rooftop, is not provided, but it is estimated to be at least 3dB higher (1.3dB). With this reference SNR the PDCCH performance is inadequate for fixed rooftop reception in the MPMT and HPHT1 networks for both the 50/50 model and the 50/1 model. In [16] evaluation results are provided for PDCCH with the highest supported aggregation level, which would enable an operating SNR of -3.5dB SNR for rooftop reception assuming an AWGN channel. This provide adequate performance for the 50/50 channel model but not for the 50/1 channel model in some scenarios.

- **PBCH**: the reference SNR is -6.1dB for 1T2R [21, 8.6.1.1]. This figure is applicable for car mounted reception. The PBCH would therefore be adequate for car mounted reception from the LPLT and MPMT networks with either time model. The performance for 1T1R, applicable for fixed rooftop, is not provided, but it is estimated to be at least 3dB higher (-3.1dB). With this reference SNR the PBCH performance would be adequate for all fixed rooftop scenarios with the 50/50 model. However the PBCH would perform inadequately for fixed rooftop reception from the HPHT1 network for 50/1 model. Lower operating SNRs for PBCH may be achieved by attempting multiple decodes of PBCH.

- **PDSCH**: the reference SNR is -5.4dB for 1T2R [21, 8.2.1.1.1, test num 19]. This figure is applicable for car mounted reception. The PDSCH would therefore be adequate for car mounted reception from the LPLT and MPMT networks for the 50/50 model, adequate for LPLT with 50/1 model, but inadequate for MPMT with the 50/1 time model. The performance for 1T1R, applicable for fixed rooftop, is not provided, but it is estimated to be at least 3dB higher (-2.4dB). With respect to fixed rooftop, the PDSCH would only be inadequate for HPHT1 with the 50/1 time model.

- **PSS/SSS**: the operating SNR can be much lower than that observed for CAS SFN, as confirmed by previous 3GPP studies (e.g. [22, Table 5.2.1.2-2]). Lower operating SNRs for PSS/SSS can be achieved by performing non-coherent accumulation of these signals across multiple transmission periods.

The analysis above is summarised in table 6.8.3-2 below.

Table 6.8.3-2 Analysis of CAS

CAS Component Channel	Failures 50/50	Failures 50/1
PDCCH	According to results extrapolated from RAN4 performance requirements: MPMT Fixed Rooftop HPHT1 Fixed Rooftop According to results extrapolated from link level evaluations provided in [16]: None	LPLT Car Mounted MPMT Car Mounted MPMT Fixed Rooftop HPHT1 Fixed Rooftop
PBCH	None	HPHT1 Fixed Rooftop
PDSCH	None	MPMT Car Mounted HPHT1 Fixed Rooftop
PSS/SSS		
Notes: The performance for 1T1R, applicable for fixed rooftop, is not provided in TS 36.101, but it is estimated to be at least 3dB higher than the appropriate 1T2R reference SNR provided in the TS. The channel model in TS 36.101 is different from the one for the agreed evaluation assumptions which may lead to pessimistic results.		

6.8.4 MUST for support for larger ISDs

For the purpose of the evaluation, MUST was assumed to be the superposition of two layers, called the basic layer and the enhanced layer, where the basic layer is expected to provide large broadcasting coverage, and the enhanced layer is expected to offer higher spectral efficiency for parts of the broadcast users. The evaluations were performed and reported in [10] and [11], leading to the following observations:

- For MBSFN for rooftop receivers the reported gains from MUST are:
    - with 200us CP length, from 20% to 38%;
    - with 300us CP length, around 10%.
- For SC-PTM for rooftop receivers, the reported gains from MUST are in the range from 35% to 37%
- The average SE gains from MUST largely depend on the trade-off between the potential SE improvement in the target coverage area for the enhancement layer and the potential SE loss in the original coverage area for the basic layer.

6.8.5 Non-uniform constellation for support of larger ISDs

The SNR gains of Non-uniform constellations over QAM were evaluated and verified in AWGN channel and TDL channels, which were reported in [15]. Based on the evaluations, the observations can be summarized as follows:

- In general, SNR gains increase with the increasing order of the NUC.
  - In AWGN channel, 2D-16NUC provides about 0.1dB SNR gain over 16QAM while 2D-64NUC can provide 0.5dB SNR gain over 64QAM.
  - In TDL channel, 2D-16NUC provides limited gain over 16QAM, while 2D-64NUC maintains a visible SNR gain (about 0.3-0.4dB) over 64QAM.
- 2D-NUC provides more SNR gain than 1D-NUC over QAM.

6.8.6 Conclusion

Relevant for dedicated networks: Yes

Requirement met by Rel-14: No/can be improved.

The following conclusions are drawn with respect to Req.7:

- New numerologies with T_{cp} and T_u longer than the Rel.14 1.25 kHz numerology are found to be beneficial and would support the use case of fixed rooftop reception in the MPMT and HPHT1 networks with the following range of improvements:
  - MPMT: ~100% improvement in spectral efficiency, SNR improvement in the range of 5-10dB.
  - HPHT: up to ~500% improvement in spectral efficiency, SNR improvement in the range of 8dB-15dB.

  The T_{cp} and T_u should be at least 300 us (ideally in the order of 400µs) and at least 2.6ms respectively.
- New numerologies should target SE improvement, considering factors such as the RS pattern, in both the time and frequency domains, CP overheads and receiver complexity.
- For certain differentiation of coverage between the base layer and the enhanced layer, MUST can increase system spectral efficiency for both SC-PTM and MBSFN in the range between 10-37% depending on factors such as target coverage for the enhanced layer. As the target coverage of the enhancement layer decreases, the spectral efficiency gain is larger.
  - For the case where the baseline scenario is 100% power and time allocation to the base layer:
    - In most of the evaluated cases, there is a loss in spectral efficiency for the base layer (which may be marginal).
    - For the case where the SNR loss due to introduction of the base layer allows to keep the same MCS, MUST improves the system spectral efficiency without reducing performance of the base layer.
- With respect to the CAS, in lieu of LLS in the appropriate channel models and antenna configurations:
  - Under the 50/50 channel model, and based on extrapolation of the minimum performance requirements from [21], all channels in CAS perform adequately except for PDCCH in rooftop MPMT and HPHT. For PDCCH, and based on extrapolation from the link level results presented in [16], the PDCCH performance is adequate for rooftop MPMT and HPHT.
  - Under the 50/1 channel model, and based on extrapolation of the minimum performance requirements from [21], all channels in CAS may not perform adequately. Improvements in all the component channels of the CAS may be beneficial in order to support the use cases studied under the 50/1 time model.
  - A realistic scenario for CAS reception may lie in between the 50/50 time model and the 50/1 time model.
- 16/64 NUCs can provide additional SNR gains over 16/64 QAM, which can extend the coverage by 0.1-0.5dB. As the order of constellation increases, the gain is larger.

6.9 Req.8: Support for different mobility scenarios

The mobility scenarios that need to be supported include fixed, portable and mobile UEs and speeds up to 250 km/h.

6.9.1 General

The mobility scenarios that need to be supported include fixed, portable and mobile UEs and speeds up to 250 km/h. This requirement is to be considered along with Req.7, i.e. the high mobility needs to be supported for large ISDs. The complete set of results related to support of different mobility scenarios can be found in annex B.

6.9.2 New numerologies for support of different mobility scenarios

The MBSFN evaluations were performed by several sources and reported in [10], [11] and [12]. Based on these evaluations, the following observations can be summarized:

LPLT networks:

- For LPLT, the performance comparison between 100/400/0.33 numerology and the 1.25 kHz numerology at 250 kmph is as follows:
    - With channel estimation based on a very simple linear interpolator in time and frequency domains, the results show 1.25kHz numerology is not decodable at SE of 1bps/Hz.
    - With channel estimation based on 2D-MMSE, 100/400/0.33 outperforms 1.25kHz in the high SNR regime (corresponding SE larger than 1.3bps/Hz) from a link level perspective (which does not include the fact that 1.25kHz achieves higher SNR from a system level perspective). For the SNR point corresponding to 95% coverage in LPLT, 100/400/0.33 has a similar performance compared with 1.25kHz.
- The Rel-14 numerology with 7.5 kHz subcarrier spacing (33.3 µs CP) is not able to operate with sufficient SE in the considered LPLT networks due to the large Delay Spread of the network and the channel estimation based on a very simple linear interpolator in time and frequency domains.
- A CP of 100 µs would be a good compromise between Doppler performance and coverage for the LPLT car mounted reception use case.

MPMT networks:

- The spectral efficiency for MPMT scenario with Rel-14 numerology (200/800) provides the following spectral efficiencies at 120km/h:
    - Nominal transmitter height (100m): 0.88bps/Hz
    - 150m transmitter height: >1.14bps/Hz
- The spectral efficiency for MPMT scenario with Rel-14 numerology (200/800) provides the following spectral efficiencies at 250km/h:
    - Nominal transmitter height (100m): 0.68bps/Hz

6.9.3 MUST for mobility scenarios

The evaluations were performed and reported in [11], leading to the following observations:

- For MBSFN, the reported SE gains from MUST, relative to TDM, for the same differentiated coverage, are in the range from 25% to 50%;
- For SC-PTM, the corresponding reported gains from MUST are in the range from 31% to 79%;
- The average SE gains from MUST largely depend on the trade-off between the potential SE improvement in the target coverage area for the added enhancement layer and the potential SE loss in the original coverage area for the basic layer.

6.9.4 Conclusion

Relevant for dedicated networks: Yes

Requirement met by Rel-14: No/can be improved.

The following conclusions are drawn with respect to Req.8:

- New numerology with 100µs T_{cp} and 400 µs T_u shorter than the Rel.14 1.25 kHz numerology is found to be beneficial in some cases and would support the use case of car-mounted reception in the LPLT networks with the following:
  - For high SNR regime (corresponding SE larger than 1.3 bps/Hz), 100/400/0.33 may outperform Rel.14 1.25 kHz numerology from a link level perspective for the same SNR level, but 1.25kHz achieves higher SNR from a system level perspective
  - For the SNR point corresponding to 95% coverage in LPLT, 100/400/0.33 has similar performance as Rel.14 1.25 kHz numerology.
- For certain differentiation of coverage between the base layer and the enhanced layer, MUST can increase system spectral efficiency for both SC-PTM and MBSFN in the range between 25-79% depending on factors such as target coverage for the enhanced layer. As the target coverage of the enhancement layer decreases, the spectral efficiency gain is larger.
  - For the case where the baseline scenario is 100% power and time allocation to the base layer:
    - In most of the evaluated cases, there is a loss in spectral efficiency for the base layer (which may be marginal).
    - For the case where the SNR loss due to introduction of the base layer allows to keep the same MCS, MUST improves the system spectral efficiency without reducing performance of the base layer.

6.10 Req.9: Leverage RAN equipment to increase capacity and reliability

LTE Rel-14 can leverage the use of multiple transmit antennas at the eNB and receive antennas at the UE by the following means:

- For SC-PTM, multi-antenna eNB can use transmit diversity (SFBC) to increase reliability.
- For MBSFN, multi-antenna eNB can use implementation-based techniques such as cyclic delay diversity to increase reliability.
- Multiple antennas at the UE can be used to achieve diversity and array gain.

LTE Rel-14 does not support multi-layer MIMO transmission for either SC-PTM or MBSFN. Multi-layer transmission can increase the capacity of the broadcast networks, at least in some scenarios.

Conclusion:

Relevant for dedicated networks: Yes

Requirement met by Rel-14: Partially

6.11 Req.10: Support for mMTC UE

Rel-14 LTE supports delivery of broadcast services to NB-IoT and eMTC devices by using SC-PTM [6, Subclause 15.1.1].

Conclusion:

Relevant for dedicated networks: Yes

Requirement met by Rel-14: Yes

7 Conclusions

Table 7-1 summarizes the conclusions made in this TR with respect to the different requirements.

Requirement	Required simulations	Relevant to dedicated networks	Met by Rel-14	Notes
1	No	Yes	Yes	
2	No	Yes	Yes	
3	No	Yes	Yes	
4	No	No	-	
5	No	Yes	Partially	
6	No	Yes	Yes	
7	Yes	Yes	No/can be improved	Enhancements needed to meet the requirement proposed in sc. 6.8.6
8	Yes	Yes	No/can be improved	Enhancements needed to meet the requirement proposed in sc. 6.9.4
9	No	Yes	Partially	
10	No	Yes	Yes	

Annex A: Simulation results for Req.7

A.1. New numerologies for support of larger ISDs

A.1.1 Evaluated numerologies

Table A.1.1-1 summarizes the numerologies evaluated by the source companies in [10], [11], [13], [12]. Note that the Rel.14 1.25 kHz numerology is also included.

Table A.1.1-1 Evaluated numerologies

Source	Numerology ID	T_{cp} [us]	Tu [us]	Subcarrier spacing	FFT size (T_s = 1/15.35 MHz)	RS density
Source 1	1	200	800	1.250	12288	1/3
	2	300	2700	0.370	41472	1/5
	3	300	2700	0.370	41472	1/3
	4	386	2400	0.417	36864	1/5
	5	386	2400	0.417	36864	1/3
Source 2	1	200	800	1.250	12288	1/3
Source 3	1	200	800	1.25	12288	
	2	200	1800	0.556		
	3	200	2800	0.357		
	4	200	3800	0.263		
	5	200	4800	0.208		
	6	300	1700	0.588		
	7	300	2700	0.370		
	8	300	3700	0.270		
	9	300	4700	0.213		
	10	400	1600	0.635	24576	
	11	400	2600	0.385		
	12	400	3600	0.278		
	13	400	4600	0.217		
Source 4	1	16.7	66.7	15	1024	
	2	33.3	133.3	7.5	2048	
	3	100	400	2.5	6144	
	4	200	800	1.25	12288	
	5	400	1600	0.6125	24576	

A.1.2 Simulation assumptions

Table A.1.2-1 summarizes the simulation assumptions used by the source companies in [10], [11], [13], [12] in addition to the assumptions in subclause 5.3.1.

Table A.1.2-1 Simulation assumptions

Assumption options	Qualcomm	Huawei	EBU	SJTU
Rooftop antenna alignment: Opt1: strongest transmitter (including shadowing) Opt2: closest transmitter	Opt1	Opt1	Opt2	Opt2
UE distribution: Opt1: Uniform Opt2: Worst case	Opt1	Opt1	Opt2	Opt1
Pathloss model: Opt1: 50/1 Opt2: 50/50	Both (evaluated separately)	Opt1 for MBSFN Opt2 for SC-PTM	Opt1	Opt1
Equalization interval positioning	Maximum energy window	Maximum energy window	First signal above noise	?
Other			No EVM applied	

A.1.3 95% SNR levels and spectral efficiency

A.1.3.1 MBSFN

The tables in this section summarize the 95% SNR levels for MBSFN subframes obtained from system-level simulations by the source companies in [10], [11], [12], [13] for rooftop and indoor receivers. If the spectral efficiency corresponding to the 95% SNR levels was computed, it is also reproduced in the respective table. The results for the car-mounted receivers are shown in subclause B.1.3.

Table A.1.3.1-1 95% SNR levels and SE for 50/1 model from Source 1 in [10].

		Rooftop(1)		Indoor(1)		In-car(1)	
Source	**Num**	**95% SNR (dB)**	**SE (b/s/Hz)**	**95% SNR (dB)**	**SE (b/s/Hz)**	**95% SNR (dB)**	**SE (b/s/Hz)**
Source 1	LPLT						
	1	20.2	-	1.0	-	-8.8	-
	2	20.3	-	1.5	-	-8.2	-
	3	20.3	-	1.8	-	-7.9	-
	4	20.3	-	1.3	-	-8.7	-
	5	20.3	-	2.0	-	-8.3	-
	MPMT						
	1	6.2	0.52	-2.8	-		
	2	12.2	-	-2.0	-		
	3	15.2	1.37	-1.6	-		
	4	12.9	-	-2.5	-		
	5	15.2	-	-1.5	-		
	HPHT1						
	1	-0.7	0.10				
	2	5.9	-				
	3	8.6	0.86				
	4	6.5	-				
	5	9.6	-				
	HPHT2						
	1	-7.3	-				
	2	-1.4	-				
	3	1.8	-				
	4	-0.5	-				
	5	1.8	-				
Note 1: All the values were obtained under the assumption of 50/1 pathloss model							

Table A.1.3.1-2 95% SNR levels and SE for 50/50 model from Source 1 in [10].

		Rooftop(1)		Indoor(1)		In-car(1)	
Source	**Num**	**95% SNR (dB)**	**SE (b/s/Hz)**	**95% SNR (dB)**	**SE (b/s/Hz)**	**95% SNR (dB)**	**SE (b/s/Hz)**
Source 1	LPLT						
	1	20.2	-	1.2	-	-8.0	-
	2	20.3	-	1.8	-	-7.8	-
	3	20.3	-	2.0	-	-7.3	-
	4	20.4	-	1.4	-	-8.0	-
	5	20.4	-	1.5	-	-7.8	-
	MPMT						
	1	14.6	1.44	-2.4	-		
	2	16.5	-	-2.4	-		
	3	16.5	1.44	-2.3	-		
	4	16.5	-	-2.1	-		
	5	16.5	-	-2.1	-		
	HPHT1						
	1	11.3	0.88				
	2	14.8	-				
	3	14.9	1.44				
	4	14.7	-				
	5	15.4	-				
	HPHT2						
	1	2.8	-				
	2	5.3	-				
	3	5.7	-				
	4	4.8	-				
	5	6.3	-				
Note 1: All the values were obtained under the assumption of 50/50 pathloss model							

Table A.1.3.1-3 95% SNR levels and SE from Source 2 in [11].

		Rooftop	
Source	**Num**	**95% SNR (dB)**	**SE**
Source 2	MPMT		
	1	15.4	1.94
	HPHT-1		
	1	10.0	1.26
	HPHT-2		
	1	6.9	0.85

Table A.1.3.1-4 95% SNR levels and SE from Source 3 in [12].

		Rooftop	
Source	**Num**	**95% SNR (dB) (1)**	**SE improvement (%) (1,2,3)**
Source 3	LPLT		
	1	26	25-35%
	2		
	3		
	4		
	5		
	6		5-35%
	7		
	8		
	9		
	10		0-30%
	11		
	12		
	13		
	MPMT		
	1	8-12	Up to 50%
	2	8-16	25 – 120%
	3	13-17	95% -140%
	4	16-17	105 – 150%
	5	18	120-170%
	6	14.5-19	90 – 140%
	7	14-20	100-170%
	8	17.5-20.5	125-175%
	9	20.5	130-190%
	10	14.5-21	75-145%
	11	15-22	100-125%
	12	18-22	76%-130%
	13	22	80-140%
	HPHT1		
	1	up to 4	Up to 80%
	2	up to 7	20%-180%
	3	up to 9	30-230%
	4	8.5-10	220-260%
	5	9-11	25-300%
	6	up to 9	200-220%
	7	up to 11	260-300%
	8	9.5-12	260-320%
	9	10-13	300-360%
	10	11-13	290-310%
	11	11-15.5	310-420%
	12	11-16	310-420%
	13	11-16.5	320-490%

Note 1: Exact value depends on the RS density
Note 2: Values computed analytically
Note 3: % improvement based on the Rel.14 1.25kHz numerology

Table A.1.3.1-5 95% SNR levels from Source 4 in [13].

		Rooftop	Indoor	In-car
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**	**95% SNR (dB)**
Source 4	LPLT			
	1	5.99	-10.46	-9.73
	2	8.96	-9.45	-8.66
	3	13.26	-8.46	-7.71
	4	15.07	-8.31	-7.51
	5	15.15	-8.29	-7.48
	MPMT			
	1	6.36	-16.16	-14.94
	2	B2	-15.38	-14.23
	3	7.83	-13.26	-12.15
	4	14.59	-12.15	-10.91
	5	19.88	-11.75	-10.62
	HPHT1			
	1	5.71	-1B6	-16.70
	2	7.03	-16.65	-16.24
	3	9.66	-13.41	-12.55
	4	10.66	-11.55	-10.55
	5	18.44	-10.65	-9.43
	HPHT2			
	1	2.73	-28.78	-28.18
	2	3.62	-28.45	-28.01
	3	6.45	-24.48	-24.08
	4	8.52	-21.51	-21.03
	5	9.57	-20.31	-19.51

A.1.3.2 CAS/SC-PTM

The tables in this section summarize the 95% SNR levels for CAS/SC-PTM obtained from system-level simulations by the source companies in [10], [11]. If the spectral efficiency corresponding to the 95% SNR levels was computed, it is also reproduced in the respective table.

Table A.1.3.2-1 95% SNR levels for CAS for 50/1 model from Source 1 in [10].

		Rooftop	Indoor
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**
Source 1	LPLT		
	4.6us	7.5	-6.5
	16.6us	7.4	-6.3
	MPMT		
	4.6us	-6.7	-8.1
	16.6us	-6.4	-7.9
	HPHT1		
	4.6us	-10.1	-10.2
	16.6us	-10.0	-9.9

Table A.1.3.2-2 95% SNR levels for CAS for 50/50 model from Source 1 in [10].

		Rooftop(1)	Indoor(1)
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**
Source 1	LPLT		
	4.6us	11.2	-4.3
	16.6us	11.7	-4.2
	MPMT		
	4.6us	-1.0	-6.4
	16.6us	-0.8	-5.7
	HPHT1		
	4.6us	0	-6.4
	16.6us	0.3	-6.3
Note 1: All the values were obtained under the assumption of 50/50 pathloss model			

Table A.1.3.2-3 95% SNR levels and SE values for SC-PTM for 50/50 model from Source 2 in [11].

		Rooftop(1)	
Source	**Num**	**95% SNR (dB)**	**SE**
Source 2	MPMT		
	4.6us	12.0	2.26
	HPHT1		
	4.6us	13.6	2.51
	HPHT2		
	4.6us	11.3	1.96
Note 1: All the values were obtained under the assumption of 50/50 pathloss model			

A.1.3.3 CAS SFN

The tables in this section summarize the 95% SNR levels for CAS SFN obtained from system-level simulations by a source company in [10].

Table A.1.3.3-1 95% SNR levels for CAS SFN for 50/1 model from Source 1 in [10].

		Rooftop	Indoor
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**
Source 1	LPLT		
	4.6us	8.1	-4.9
	16.6us	8.4	-3.8
	MPMT		
	4.6us	-6.1	-7.2
	16.6us	-5.8	-6.8
	HPHT1		
	4.6us	-9.9	-
	16.6us	-9.3	-

Table A.1.3.3-2 95% SNR levels for CAS SFN for 50/50 model from Source 1 in [10].

		Rooftop(1)	Indoor(1)
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**
Source 1	LPLT		
	4.6us	12.1	-2.9
	16.6us	12.8	-2.2
	MPMT		
	4.6us	-0.4	-5.1
	16.6us	-0.2	-4.2
	HPHT1		
	4.6us	0.1	-
	16.6us	0.5	-
Note 1: All the values were obtained under the assumption of 50/50 pathloss model			

Table A.1.3.3-3 95% SNR levels for CAS SFN for 50/1 model from Source 3 in [14].

		Rooftop	**Indoor**
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**
Source 3	**LPLT**		
	4.6us	-	-
	16.6us	-0.4	-
	MPMT		
	4.6us	-	-
	16.6us	-1.8	-
	HPHT1		
	4.6us	-	-
	16.6us	-6.9	-

A.2 Evaluation of MUST

One source in [11] proposed MUST as an enhancement technique which could be used for SC-PTM and MBSFN based broadcast and provided simulation results for Rel-14 LTE baseline techniques (SC-PTM and MBSFN with 200us CP length) and for MUST.

For the purpose of the evaluation, MUST was assumed to be the superposition of two PDSCH channels for SC-PTM based broadcast, or two PMCH channels for MBSFN based broadcast. The two superposition layers are assumed to be the basic layer and the enhanced layer, where the basic layer is expected to provide large broadcasting coverage, and the enhanced layer is expected to offer higher spectral efficiency for parts of the broadcast users.

The pre-processing SINRs are provided by system-level simulation, which are summarized in Table A.2-1 including 95%-tile SINR without MUST for the baseline techniques and 95%-tile as well as 50%-tile SINR with MUST. Table A.2-2 shows the corresponding spectral efficiency.

Table A.2-1: SINR of SC-PTM and MBSFN for Rooftop

Techniques / **SINR (dB)**	**SC-PTM(1)**			**MBSFN(2,3)**		
	HPHT-2	**HPHT-1**	**MPMT**	**HPHT-2**	**HPHT-1**	**MPMT**
95%-tile SINR w/o MUST	11.3	13.6	12.0	6.9	10.0	15.4
95%-tile SINR w/ MUST	9.9	12.1	11.1	6.1	8.4	13.7
50%-tile SINR w/ MUST	9.9	12.2	4.3	5.3	10.0	9.4
Note 1: The signal time probability of serving and interfering transmitters for SC-PTM evaluation is 50%/50%. Note 2: The signal time probability of serving and interfering transmitters for MBSFN evaluation is 50%/1% Note 3: The numerology is 200us CP length.						

Table A.2-1: Spectral efficiency of SC-PTM and MBSFN for Rooftop

Techniques / Spectral efficiency (bps/Hz)	SC-PTM[1]			MBSFN[2,3]		
	HPHT-2	HPHT-1	MPMT	HPHT-2	HPHT-1	MPMT
w/o MUST	1.96	2.51	2.26	0.85	1.26	1.94
w/ MUST	2.70	3.39	2.57	1.11	1.74	2.33
w/ MUST gain	37.8%	35.1%	13.7%	30.6%	38.1%	20.1%
Note 1: The signal time probability of serving and interfering transmitters for SC-PTM evaluation is 50%/50%. Note 2: The signal time probability of serving and interfering transmitters for MBSFN evaluation is 50%/1% Note 3: The numerology is 200us CP length.						

Another source in [10] evaluated a MUST receiver model in which the transmit power is split between the base layer (BL) and the enhanced layer (EL), such that the fraction α of the transmit power is assigned to the EL. The BL observes the EL layer signal as noise, whereas the EL can completely cancel out the BL signal. The BL needs to maintain 95% of coverage whereas the coverage % of the EL can vary. The total throughput with MUST is computed as the aggregate of the throughputs of the BL and the EL, and it depends on α and the coverage % of the EL. The total throughput gain with MUST (G_{MUST}) is computed w.r.t. the total throughput of a TDM scheme in which the required coverage % is set based on the EL target during x % of time and based on the BL target (95%) during $(1 - x)$ % of time.

Figure A.2-2 shows that the MUST throughput gain with respect to the TDM transmission (no MUST) obtained in [10].

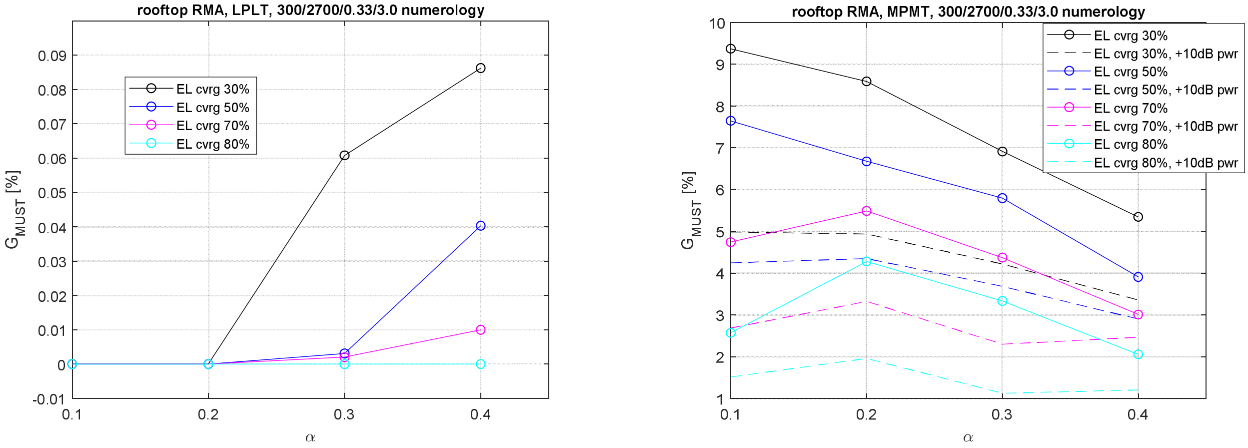

Figure A.2-2 – Throughput gain [%] of MUST vs. TDM

The gain obtained from MUST is less than 1% for rooftop receiver in LPLT scenario. For MPMT scenario, the gain is in single digits % and goes down quickly as the EL coverage % grows. Furthermore, any increase in the transmit signal power further reduces the gain.

A.3 Evaluation of Non-uniform constellation

One source in [15] evaluated the SNR gain of Non-uniform constellations over uniform QAM. Figure A.3-1 compares performance in AWGN for Uniform QAM and NUCs (including 1D-NUCs and 2D-NUCs) in constellation order 16 and 64. Figure A.3-2 compares the performance of 64QAM and 64NUCs in TDL-A channel.

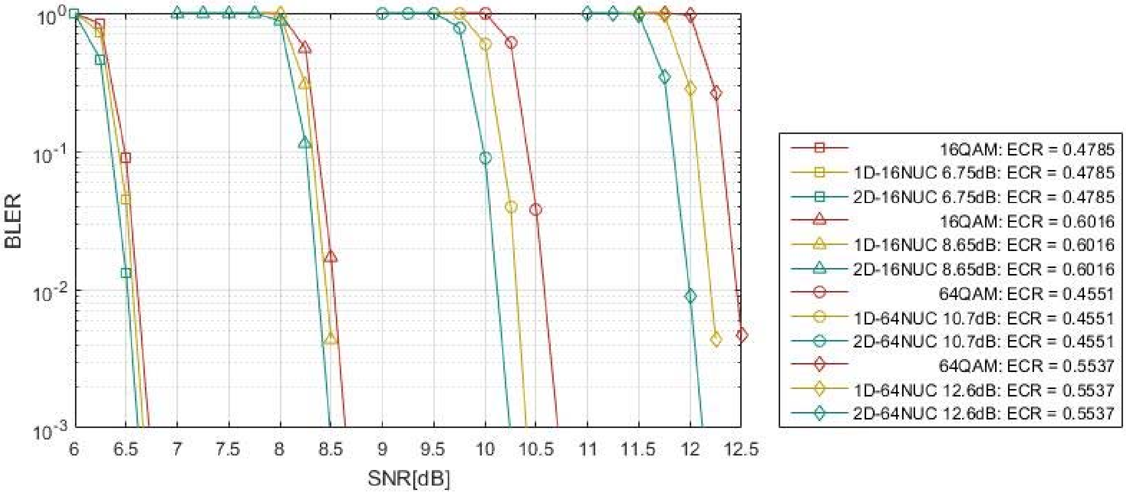

Figure A.3-1: Performance of NUCs in AWGN channel

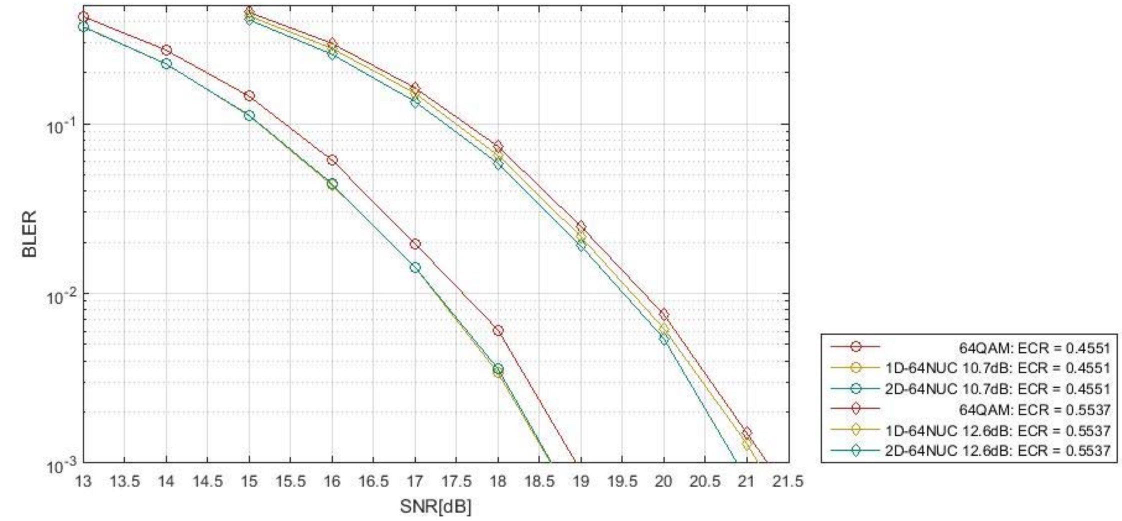

Figure A.3-2: Performance of NUCs in TDL-A channel

Annex B: Simulation results for Req.8

B.1 New numerologies for support of different mobility scenarios

B.1.1 Evaluated numerologies

Table B.1.1-1 summarizes the numerologies evaluated by the source companies in [10], [11], [13]. Note that the Rel.14 1.25 kHz numerology is also included.

Table B.1.1-1 Evaluated numerologies

Source	Numerology ID	T_{cp} [us]	Tu [us]	Subcarrier spacing	FFT size (T_s = 1/15.35 MHz)	RS density
Source 1	1	100	400	2.5	6144	1/3
	2	200	800	1.250	12288	1/3
Source 2	1	200	800	1.250	12288	1/3
Source 3	1	16.7	66.7	15	1024	1/3
	2	33.3	133.3	7.5	2048	1/3
	3	100	400	2.5	6144	1/3
	4	100	400	2.5	6144	
	5	200	800	1.25	12288	1/3
	6	200	800	1.25	12288	

B.1.2 95% SNR levels and spectral efficiency

B.1.2.1 MBSFN

The tables in this section summarize the 95% SNR levels for MBSFN subframes obtained from system-level simulations by the source companies in [10], [11], [13]. and the spectral efficiency corresponding to the 95% SNR levels for the car-mounted scenarios.

Table B.1.2.1-1 95% SNR levels and SE for car-mounted scenario from Source 1 in [10].

Car-mounted					
		50/1 model		**50/50 model**	
Source	**Numerology**	**95% SNR (dB)**	**SE (b/s/Hz)**	**95% SNR (dB)**	**SE (b/s/Hz)**
Source 1	LPLT				
	1	12.8	0.99(1)	13.7	1.14(1)
	2	13.9	0.99(1)	14.3	1.14(1)
	MPMT				
	2	9.7	0.88(2)/ 1.14(2,3)	11.1	

Note 1: SE values for car-mounted LPLT scenario are for 250 kmph
Note 2: This value was obtained with the speed of 120 kmph
Note 3: This value is obtained with a transmitter height of 150m, which provides a higher SNR value

Table B.1.2.1-2 95% SNR levels and SE for car-mounted scenario from Source 3 in [11].

		Car-mounted	
Source	**Num**	**95% SNR (dB)**	**SE**
Source 2	MPMT		
	1	5.4	0.68
	HPHT-1		
	1	0.9	0.28

Table B.1.2.1-3 95% SNR levels and SE for car-mounted scenario from Source 3 in [12].

Car-mounted			
Source	**Numerology**	**95% SNR (dB)**	**SE (b/s/Hz)**
Source 3	LPLT		
	1	2.32	1(1)
	2	5.87	
	3	14.27	
	4	11.56	
	5	15.57	
	6	15.52	
Note 1: SE of 1 bps/Hz was set as the target			

B.1.2.2 CAS/SC-PTM

The tables in this section summarize the 95% SNR levels for CAS/SC-PTM for car-mounted scenarios obtained from system-level simulations by the source companies in [10], [11]. If the spectral efficiency corresponding to the 95% SNR levels was computed, it is also reproduced in the respective table.

Table B.1.2.2-1 95% SNR levels for CAS for car-mounted scenarios from Source 1 in [10].

Car-mounted			
		50/1 model	**50/50 model**
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**
Source 1	LPLT		
	4.6us	-3.9	-0.1
	16.6us	-3.4	0
	MPMT		
	4.6us	-3.6	0.9
	16.6us	-3.5	1.0
	HPHT1		
	4.6us	-7.0	1.8
	16.6us	-6.8	2.1

Table B.1.2.2-2 95% SNR levels and SE values for SC-PTM for 50/50 model from Source 2 in [11].

		Car-mounted(1)	
Source	**Num**	**95% SNR (dB)**	**SE**
Source 2	MPMT		
	1	1.0	0.44
	HPHT1		
	1	1.5	0.44
Note 1: All the values were obtained under the assumption of 50/50 pathloss model			

B.1.2.3 CAS SFN

The tables in this section summarize the 95% SNR levels for CAS SFN for car-mounted scenarios obtained from system-level simulations by a source company in [10].

Table B.1.2.3-1 95% SNR levels for CAS SFN from Source 1 in [10].

		Car-mounted	
		50/1 model	**50/50 model**
Source	**Num**	**95% SNR (dB)**	**95% SNR (dB)**
Source 1	LPLT		
	4.6us	-0.7	2.8
	16.6us	0.7	3.8
	MPMT		
	4.6us	-2.8	1.4
	16.6us	-2.4	1.9

	HPHT1		
	4.6us	-6.5	2.1
	16.6us	-6.4	2.7

Table B.1.2.3-2 95% SNR levels for CAS SFN from Source 3 in [14].

		Car-mounted	
		50/1 model	50/50 model
Source	Num	95% SNR (dB)	95% SNR (dB)
Source 3	LPLT		
	4.6us	-	-
	16.6us	-3.6	-
	MPMT		
	4.6us	-	-
	16.6us	-6.1	-
	HPHT1		
	4.6us	-	-
	16.6us	-	-

B.2 Evaluation of MUST

The pre-processing SINRs provided by one source in [11] by system-level simulation are summarized in Table B.2-1 including 95%-tile SINR without MUST for the baseline techniques and 95%-tile as well as 50%-tile SINR with MUST. Table B.2-2 shows the resulting spectral efficiency.

Table B.2-1: SINR of SC-PTM and MBSFN for Rooftop

Techniques SINR (dB)	SC-PTM[1,3]		MBSFN[2,3]	
	HPHT-1	MPMT	HPHT-1	MPMT
95%-tile SINR w/o MUST	1.5	1.0	0.9	5.4
95%-tile SINR w/ MUST	0.8	0.1	0.3	4.1
50%-tile SINR w/ MUST	4.2	1.0	0.5	2.9
Note 1: The signal time probability of serving and interfering transmitters for SC-PTM evaluation is 50%/50%. Note 2: The signal time probability of serving and interfering transmitters for MBSFN evaluation is 50%/1% Note 3: The numerology is 200us CP length.				

Table B.2-1: SINR of SC-PTM and MBSFN for Rooftop

Techniques Spectral efficiency (bps/Hz)	SC-PTM[1,3]		MBSFN[2,3]	
	HPHT-1	MPMT	HPHT-1	MPMT
w/o MUST	0.44	0.44	0.28	0.68
w/ MUST	0.79	0.58	0.42	0.85
w/ MUST gain	79.5%	31.8%	50.0%	25.0%
Note 1: The signal time probability of serving and interfering transmitters for SC-PTM evaluation is 50%/50%. Note 2: The signal time probability of serving and interfering transmitters for MBSFN evaluation is 50%/1% Note 3: The numerology is 200us CP length.				

Annex C: Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2018-10	RAN1#94bis	R1-1810931				Skeleton TR	0.0.1
2018-10	RAN1#94bis	R1-1811661				Updated skeleton TR with refined wording and updated abbreviation list	0.0.2
2018-11	RAN1#95	R1-1813054				Included outcome of email discussions [94b-LTE-04] and [94b-LTE-03], and agreements from RAN1#94.	0.0.3
2018-11	RAN1#95	R1-1813786				Included relevant agreements and TPs from RAN1#95.	0.0.4
2018-11	RAN1#95	R1-1813794				Version for information to plenary inc. MCC clean-up	1.0.0
2019-02	RAN1#96	R1-1903522				Included relevant TPs from RAN1#96	1.0.1
2019-02	RAN1#96	R1-1903660				Endorsed by RAN1	1.1.0
2019-03	RAN#83	RP-190133				Version for approval to plenary inc. MCC clean-up	2.0.0
2019-03	RAN#83					Further RAN decision and approval, TR under change control (release 16)	16.0.0

History

Document history		
V16.0.0	November 2020	Publication