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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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where:

x the first digit:

1 presented to TSG for information;

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

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In the present document, modal verbs have the following meanings:

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

can indicates that something is possible

cannot indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

will indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

will not indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

might indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

might not indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

is (or any other verb in the indicative mood) indicates a statement of fact

is not (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

Introduction

In RAN #86 meeting, a new Rel-17 study item on NR coverage enhancements was approved [2]. The objective of this study item is to study potential coverage enhancement solutions for specific scenarios for both FR1 and FR2. The detailed objectives are as follows.

- The target scenarios and services include
  - Urban (outdoor gNB serving indoor UEs) scenario, and rural scenario (including extreme long distance rural scenario) for FR1
  - Indoor scenario (indoor gNB serving indoor UEs), and urban/suburban scenario (including outdoor gNB serving outdoor UEs and outdoor gNB serving indoor UEs) for FR2.
  - TDD and FDD for FR1.
  - VoIP and eMBB service for FR1.
  - eMBB service as first priority and VoIP as second priority for FR2.
  - LPWA services and scenarios are not included.
- Identify baseline coverage performance for both DL and UL for the above scenarios and services based on link-level simulation
  - UL channels (including PUSCH and PUCCH) are prioritized for FR1.
  - Both DL and UL channels for FR2.
- Identify the performance target for coverage enhancement, and study the potential solutions for coverage enhancements for the above scenarios and services
  - The target channels include at least PUSCH/PUCCH
  - Study enhanced solutions, e.g., time domain/frequency domain/DM-RS enhancement (including DM-RS-less transmissions)
  - Study the additional enhanced solutions for FR2 if any
  - Evaluate the performance of the potential solutions based on link level simulation.

1 Scope

The present document captures the results and findings from the study item "New SID on NR coverage enhancement" [2]. The purpose of this TR is to document the baseline coverage performance for both FR1 and FR2 considering the scenarios and services identified in [2], and to document the evaluation and findings of the potential enhancements for the identified scenarios and services.

This activity involves the Radio Access work area of the 3GPP studies and has potential impacts both on the Mobile Equipment and Access Network of the 3GPP systems.

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-193240: "New SID on NR coverage enhancement".

[3] Report ITU-R M.2412: "Guidelines for evaluation of radio interface technologies for IMT-2020".

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in 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 TR 21.905 [1].

example: text used to clarify abstract rules by applying them literally.

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 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 TR 21.905 [1].

ACK Acknowledgement
BWP Bandwidth Part
BS Base Station
CSI Channel State Information
CCE Control Channel Element
DL Downlink

DMRS	Dedicated Demodulation Reference Signals
eMBB	enhanced Mobile BroadBand
FDD	Frequency Division Duplex
gNB	NR Node B
HARQ	Hybrid Automatic Repeat reQuest
iBLER	initial BLock Error Rate
LLS	Link Level Simulation
MCS	Modulation and Coding Scheme
NACK	Negative Acknowledgement
OS	OFDM symbol
PDCCH	Physical Downlink Control Channel
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
PDSCH	Physical Downlink Shared Channel
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
rBLER	residual BLock Error Rate
SCS	Subcarrier Spacing
SLS	System Level Simulation
SR	Scheduling Request
SSB	Synchronization Signal Block
TBS	Transport Block Size
TDD	Time Division Duplex
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink

4 Evaluation methodology

For this study item, the basic evaluation methodology is based on link-level simulation and articulated in 2 steps. Simulation assumptions for step 1 are provided in Annex A.1 for FR1 and A.2 for FR2, respectively. Link budget template for step 2 is provided in Annex A.3.

- Step 1: Obtain the required SINR for the physical channels under target scenarios and service/reliability requirements. Simulations have been conducted neglecting:
    - Constraints imposed by certain beamforming implementation, such as the possibility to simultaneously receive or transmit with maximum gain in more than one direction;
    - PTRS overhead and compensation algorithms.
- Step 2: Obtain the baseline performance based on required SINR and link budget template.

The evaluation methodology based on system-level simulation is optional and the simulation assumptions for system-level simulation are up to companies' reports.

4.1 Antenna gain modelling

4.1.1 gNB antenna gain modelling

For link level simulation, two options for TDL channel model are considered:

- TDL channel model option 1: 2 or 4 gNB RF chains in LLS
- TDL channel model option 2 (optional): number of gNB RF chains in LLS = number of TXRUs

For TDL channel model option 1, the complexity of link level simulation can be simplified, while the practical gNB architecture can be reflected in TDL channel model option 2.

Figure 4.1-1 and Figure 4.1-2 depict gNB antenna gain modelling for TDL channel model option 1, and TDL channel model option 2 and CDL channel model respectively. *M* is the number of antenna elements, *N* is the number of TXRUs, *k* is the number of RF chains considered in LLS. For TDL channel model option 1, gNB antenna gains include 4 components, i.e., antenna gain component 1/2/3/4. For TDL channel model option 2 and CDL channel model, gNB antenna gains include 3 components, i.e., antenna gain component 1/3/4. The antenna gain component 1 is included in LLS, while the antenna gain component 2/3/4 are included in link budget template.

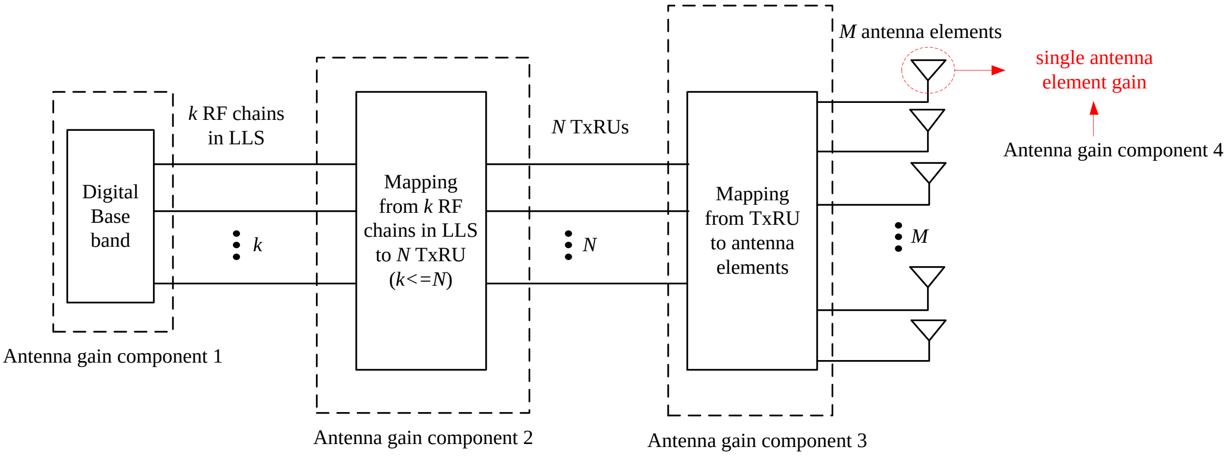

Figure 4.1-1: gNB antenna gain modelling for TDL channel model option 1

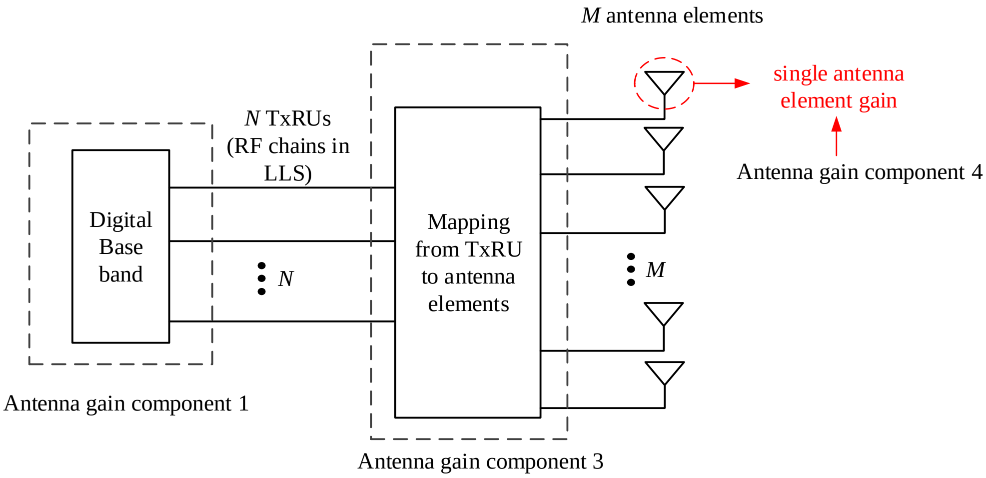

Figure 4.1-2: gNB antenna gain modelling for TDL channel model option 2 and CDL channel model

For TDL channel model option 1, the gain of antenna gain component 2 is expressed by:

Antenna gain component 2 = 10 * log 10(N/k)-Δ1,

where Δ1 is a correction factor to account for various non-idealities impacting the actual gain of antenna gain component 2, and reported by companies.

For TDL channel model option 2 and CDL channel model, antenna gain component 2 = 0.

For TDL channel model option 1, option 2 and CDL channel model, the gain of antenna gain components 3 and 4 is expressed by:

Antenna gain component 3 + Antenna gain component 4 = Antenna Element Gain + 10 * log 10(M/N) -Δ2.

where Δ2 is a correction factor to account for various non-idealities impacting the actual gain of antenna gain component 3, and reported by companies.

4.1.2 UE antenna gain modelling

UE antenna gain is expressed by:

UE antenna gain = Antenna Element Gain + 10 * log 10(M/k) -Δ3.

For FR1, antenna element gain = 0dBi; while for FR2, antenna element gain = 5dBi.

where k is the number of Tx/Rx chains, e.g., number of SRS/CSI-RS ports to be simulated in LLS and M is the number of antenna elements used for both transmission and reception, i.e., $M/2$ xpol antenna elements.

For FR1, $k = M$ is assumed for the simulations, and k=1 for Tx (optional $k = 2$), while $k \in \{2,4\}$ for Rx.

For FR2, there are two options for simulations:

- Option 1: $k \in \{1,2\}$for Tx and $k = 2$ for Rx,
- Option 2: $k = M$.

Δ3 is a correction factor to account for various non-idealities impacting the actual antenna array gain. For FR1, Δ3=0; while for FR2, Δ3 is channel/procedure dependent and reported by companies.

4.2 Performance metrics

For LLS based methodology, coverage bottleneck(s) identification is performed using at least MIL or MCL (assuming the set of simulation assumptions). Even when SLS is used to obtain some components of MIL or MCL, it is categorized as LLS based methodology. MCL values can also be used to identify the coverage bottleneck(s). MPL can be used as supplemental information for coverage bottleneck(s) identification.

The targets are in the form of the following:

1. Scenario dependent targets defined by MPL, which is calculated from target ISD;

- For each scenario, multiple target ISD values can be used to draw observations, and a single target ISD value can be used to identify bottlenecks. Target ISD values for each scenario are as follows
  - For FR1,
    - Urban 4GHz TDD – 400, 500m for observation and 400m for bottleneck identification
    - Urban 2.6GHz TDD – 400, 500m for observation and 400m for bottleneck identification
    - Rural 4GHz TDD NLOS O2I – 1732 and 3000 m for observation and 1732m with 33dBm/MHz BS transmit power for bottleneck identification
    - Rural 2.6 GHz TDD NLOS O2I – 1732 m for observation and bottleneck identification
    - Rural 2 GHz FDD NLOS O2I – 1732 m for observation and bottleneck identification
    - Rural 700MHz FDD NLOS O2I – 3000 m, 4000 m for observation and 4000m for bottleneck identification
    - Rural with long distance 4GHz TDD LOS O2O – 12 km for observation and bottleneck identification
  - For FR2,
    - Urban 28GHz TDD – 200m for observation and bottleneck identification
    - Indoor 28 GHz TDD – 20m for observation and bottleneck identification
- The following formula is used to convert an ISD value to a target MPL value:
  - For urban scenarios with $0.5GHz \le f_c \le 6GHz,$ (based on UMA_A NLOS model in [3]),

$$-\text{Target MPL (dB)} = 161.04 - 7.1 \cdot \log_{10}(W) + 7.5 \cdot \log_{10}(h) - (24.37 - 3.7 \cdot (h/h_{\mathrm{BS}})^2) \cdot \log_{10}(h_{\mathrm{BS}}) + \left(43.42 - 3.1 \cdot \log_{10}(h_{\mathrm{BS}})\right) \cdot (\log_{10}(d_{3\mathrm{D}}) - 3) + 20 \cdot \log_{10}(f_c) - \left(3.2 \cdot \left(\log_{10}(11.75 \cdot h_{\mathrm{UT}})\right)^2 -\right.$$

$4.97\Big) - 0.6 \cdot (h_{\mathrm{UT}} - 1.5)$, where $W = 20\mathrm{m}$ is the average street width, $h = 20\mathrm{m}$ is the average building height, $h_{\mathrm{BS}} = 25\mathrm{m}$ is the BS antenna height, $h_{\mathrm{UT}} = 1.5\mathrm{m}$ is the UT antenna height, f_{c} is the carrier frequency and $d_{3\mathrm{D}}$ is the target range calculated by ISD/sqrt(3).

- For rural scenarios (based on RMA_A NLOS model in [3]),

  - Target MPL (dB) $= 161.04 - 7.1 \cdot \log_{10}(W) + 7.5 \cdot \log_{10}(h) - (24.37 - 3.7 \cdot (h/h_{\mathrm{BS}})^2) \cdot \log_{10}(h_{\mathrm{BS}}) + \big(43.42 - 3.1 \cdot \log_{10}(h_{\mathrm{BS}})\big) \cdot (\log_{10}(d_{3\mathrm{D}}) - 3) + 20 \cdot \log_{10}(f_{\mathrm{c}}) - \Big(3.2 \cdot \big(\log_{10}(11.75 \cdot h_{\mathrm{UT}})\big)^2 - 4.97\Big)$,where $W = 20\mathrm{m}$, $h = 5\mathrm{m}$, $h_{\mathrm{BS}} = 35\mathrm{m}$, $h_{\mathrm{UT}} = 1.5\mathrm{m}$ and $d_{3\mathrm{D}}$ is the target range calculated by ISD/sqrt(3).

- For rural with long distance scenarios (based on RMa_A LOS model in [3]),

  - Target MPL (dB) $= 20 \cdot \log_{10}(40 \cdot \pi \cdot d_{\mathrm{BP}} \cdot f_{\mathrm{c}}/3) + \min(0.03 \cdot h^{1.72}, 10) \cdot \log_{10}(d_{\mathrm{BP}}) - \min(0.044 \cdot h^{1.72}, 14.77) + 0.002 \cdot \log_{10}(h) \cdot d_{\mathrm{BP}} + 40 \cdot \log_{10}(d_{3\mathrm{D}}/d_{\mathrm{BP}})$, where $h = 5\mathrm{m}$, $d_{\mathrm{BP}} = 2 \cdot \pi \cdot h_{\mathrm{BS}} \cdot h_{\mathrm{UT}} \cdot f_{\mathrm{c}}/c$, $h_{\mathrm{BS}} = 35\mathrm{m}$, $h_{\mathrm{UT}} = 1.5\mathrm{m}$, $c = 3 \cdot 10^8 \mathrm{m/s}$ and $d_{3\mathrm{D}}$ is the target range calculated by ISD/sqrt(3).

- For urban scenarios with $6GHz < f_c \leq 100GHz$, (based on UMA_A NLOS model in [3]),

  - Target MPL (dB) $= 13.54 + 39.08 \cdot \log_{10}(d_{3D}) + 20 \cdot \log_{10}(f_c) - 0.6 \cdot (h_{\mathrm{UT}} - 1.5)$, where $h_{\mathrm{UT}} = 1.5\mathrm{m}$ is the UT antenna height, f_{c} is the carrier frequency and $d_{3\mathrm{D}}$ is the target range calculated by ISD/sqrt(3).

- For indoor scenarios with $6GHz < f_c \leq 100GHz$, (based on InH_A NLOS model in [3]),

  - Target MPL (dB) $= 17.3 + 38.3 \cdot \log_{10}(d_{3D}) + 24.9 \cdot \log_{10}(f_c)$ where f_{c} is the carrier frequency and $d_{3\mathrm{D}}$ is the target range calculated by ISD/sqrt(3).

2. Service dependent targets defined by MCL=139.2 dB for VoIP;

- This metric is applicable to Rural 700MHz scenario, and used for drawing observation bottleneck identification.
- The derivation of the target value of 139.2 dB is found in Annex A.4.

3. Relative difference between channels in MIL

- MIL is used to derive relative differential values.
- Relative difference between channels is used to draw observation to identify bottlenecks.
- For FR1, for each channel, relative differential value is defined by the following formula:
  - (MIL of the channel) – (MIL of the worst channel among the channels that have more than 3 samples)
- For FR2, for each channel, relative differential value is defined by the following formula:
  - (MIL of the channel) – (MIL of PUCCH format 1)

<u>Definition of MCL:</u>

- MCL = Total transmit power – Receiver sensitivity + gNB antenna gain (component 2).
- More details can be found in the link budget template shown in Annex A.3

<u>Definition of MIL:</u>

- MIL = Total transmit power – Receiver sensitivity – Tx loss – Rx loss + gNB antenna gain (component 2 + 3 + 4) + UE antenna gain.
- More details can be found in the link budget template shown in Annex A.3

<u>Definition of MPL:</u>

- MPL = MIL – Shadow fading margin + BS selection/macro-diversity gain – Penetration margin + Other gains.

- More details can be found in the link budget template shown in Annex A.3

Definition of representative values:

For FR1 and FR2, representative values, which are applicable to MCL, MIL and MPL, are used for bottleneck identification. A representative value is computed for each scenario for each channel. A representative value is derived by taking the mean value (in dB domain) from companies' evaluation results. The highest and the lowest values, which are referred to as outlier, are excluded when the number of samples is more than 3.

The number of available samples for DL channels in FR1 4GHz scenario is given by the total number of available results for transmit power of both 33 dBm/MHz and 24 dBm/MHz, when applicable, derived one from the other by simple subtraction. Representative values are calculated for both 33 dBm/MHz and 24 dBm/MHz.

The number of available samples for UL channels in FR2 is given by the total number of available results for maximum transmit power of both 23 dBm and 12 dBm, when applicable, given that they can be derived one from the other by simple subtraction. Representative values are calculated only for 12 dBm, according to the assumption of commercial power class 3 UEs and a total maximum of 11 dBi antenna array gain.

No other aggregation/categorization based on simulation parameters is introduced for deriving representative values.

For FR1, if the number of samples used to compute a representative value is less than 4 for each scenario, this representative value is not used for bottleneck identification. In this case, observations may still be drawn.

For FR2, representative values are used for bottleneck identification regardless of the number of samples used to calculate them. Study of channels, scenarios and frame structures follow a prioritization depending on the number of available samples:

- 1st priority channels, scenarios and frame structures have more than 2 available samples.
- 2nd priority channels, scenarios and frame structures have less than 3 available samples.

In order to address the misalignment issue of the companies' evaluation results due to no categorization and/or different simulation assumptions, number of samples and standard deviation are displayed together with a representative value. In addition, descriptions on the potential fluctuation due to no categorization and/or different simulation assumptions are added to the observation.

For FR1, representative values are computed for the following channels, and they are used to draw observation and to identify bottlenecks if the number of samples for each scenario is more than 3.

- PUSCH for eMBB (FDD, & TDD with DDDSU and DDDSUDDSUU for 4GHz, DDDDDDDSUU for 2.6GHz)
- PUSCH for VoIP (FDD, & TDD with DDDSU and DDDSUDDSUU for 4GHz, DDDDDDDSUU for 2.6GHz)
- PUCCH Format 1 with 2bits
- PUCCH Format 3 with 11bits
- PUCCH Format 3 with 22bits
- SSB
- PRACH format 0
- PRACH format B4
- Broadcast PDCCH (PDCCH of Msg.2)
- PDSCH for Msg.2
- PUSCH of Msg.3
- PDSCH of Msg.4
- Unicast PDCCH
- PDSCH for eMBB (FDD, & TDD with DDDSU and DDDSUDDSUU for 4GHz, DDDDDDDSUU for 2.6GHz)
- PUCCH with HARQ-ACK for Msg.4
- PUSCH with SIP invite
- PUSCH for CSI 11bit

- PUSCH for CSI 22bit

For FR2, representative values are computed for the following channels:

- PUSCH for eMBB (DDDSU and DDSU)
- PUSCH for VoIP (DDDSU and DDSU)
- PUCCH Format 1 with 2bits
- PUCCH Format 3 with 11bits
- PUCCH Format 3 with 22bits
- SSB
- PRACH format B4
- PRACH format C2
- PDCCH of Msg.2
- PDSCH for Msg.2
- PUSCH of Msg.3
- PDSCH of Msg.4
- PDCCH
- PDSCH for eMBB (DDDSU and DDSU)
- PUCCH with HARQ-ACK for Msg.4
- PUSCH with SIP invite
- PUSCH for CSI 11bit
- PUSCH for CSI 22bit

Scenarios used for observation and bottleneck identification:

For FR1, the following scenarios are chosen for drawing observations and bottleneck identification, and the representative values are computed for each scenario.

- Urban 4GHz TDD
- Urban 2.6GHz TDD
- Rural 4GHz TDD NLOS O2I
- Rural 700MHz FDD NLOS O2I
- Rural 2GHz FDD NLOS O2I
- Rural 2.6GHz TDD NLOS O2I
- Rural 4GHz with long distance TDD LOS O2O

For FR2, the following scenarios are chosen for drawing observations and bottleneck identification:

- Urban 28GHz TDD NLOS O2I/O2O
- Indoor 28GHz TDD NLOS

For FR2, the following scenarios are chosen only for drawing observations:

- Suburban 28GHz TDD NLOS O2I/O2O

4.3 Link budget template

Single link budget template for both FR1 and FR2 with rows for MIL, MCL, MPL is adopted. The parameter assumptions of the link budget template for step 2 are provided in Annex A.3. RAN1 will not further discuss on specific values for the parameters related to MPL. IMT-2020 values are a starting point, but companies may use other values, and for the parameters that companies think IMT-2020 self-evaluation does not clearly define the values for some scenarios, it is up to companies to report.

5 Baseline coverage performance

5.1 Baseline coverage performance for FR1

5.1.1 Representative values and observation for each scenario

5.1.1.1 Urban 4GHz TDD scenario

The representative values for the metrics are summarized below. Table 5.1.1.1-1 to 5.1.1.1-6 show the results with BS Tx power of 33 dBm/MHz and 24 dBm/MHz.

Table 5.1.1.1-1: Representative values of MCL for Urban 4GHz TDD scenario with BS Tx power of 33 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB DDDSU	14	130.76	0.99
PUSCH for eMBB DDDSUDDSUU	11	132.37	0.86
PUSCH for VoIP DDDSU	11	142.78	2.40
PUSCH for VoIP DDDSUDDSUU	12	141.08	5.06
PUSCH with SIP invite DDDSU	1	144.80	0.00
PUSCH with SIP invite DDDSUDDSUU	0		
PUSCH for CSI 11bit DDDSU	2	146.00	2.00
PUSCH for CSI 22bit DDDSU	2	144.80	2.00
PUCCH Format 1	12	146.90	2.20
PUCCH Format 3 11bits	10	146.10	1.36
PUCCH Format 3 22bit	12	143.08	1.53
SSB	9	153.71	3.65
PRACH Format 0	2	144.85	0.02
PRACH Format B4	8	145.27	3.09
PRACH Format C2	0		
Broadcast PDCCH(PDCCH of Msg.2)	7	150.19	1.66
PDSCH for Msg.2	8	151.33	3.72
PUSCH of Msg.3	10	143.93	1.11
PDSCH of Msg.4	7	150.42	4.23
PUCCH w/ HARQ-ACK for Msg.4	3	148.59	2.23
Unicast PDCCH	13	156.83	3.91
PDSCH for eMBB DDDSU	12	153.24	4.59
PDSCH for eMBB DDDSUDDSUU	9	151.97	5.52

Table 5.1.1.1-2: Representative values of MIL for Urban 4GHz TDD scenario with BS Tx power of 33 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB DDDSU	14	139.01	0.97	0.00
PUSCH for eMBB DDDSUDDSUU	12	140.33	0.95	1.32
PUSCH for VoIP DDDSU	11	152.00	2.51	12.99
PUSCH for VoIP DDDSUDDSUU	15	151.23	2.48	12.22
PUSCH with SIP invite DDDSU	1	154.40	0.00	15.39
PUSCH with SIP invite DDDSUDDSUU	0			
PUSCH for CSI 11bit DDDSU	2	155.40	2.00	16.39
PUSCH for CSI 22bit DDDSU	2	154.25	2.05	15.24
PUCCH Format 1	13	156.20	3.57	17.19
PUCCH Format 3 11bits	11	155.55	1.52	16.54
PUCCH Format 3 22bit	13	151.85	2.99	12.84
SSB	9	160.89	2.99	21.88
PRACH Format 0	2	153.62	0.02	14.61
PRACH Format B4	8	153.50	4.82	14.49
PRACH Format C2	0			
Broadcast PDCCH(PDCCH of Msg.2)	7	158.54	2.12	19.53
PDSCH for Msg.2	8	159.45	3.47	20.44
PUSCH of Msg.3	12	152.10	2.00	13.09
PDSCH of Msg.4	7	158.27	2.29	19.26
PUCCH w/ HARQ-ACK for Msg.4	3	156.38	2.13	17.37
Unicast PDCCH	14	164.05	2.43	25.05
PDSCH for eMBB DDDSU	12	160.14	3.61	21.13
PDSCH for eMBB DDDSUDDSUU	10	159.84	3.56	20.83

Table 5.1.1.1-3: Representative values of MPL for Urban 4GHz TDD scenario with BS Tx power of 33 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 400m ISD=118.0dB	Gap from Deployment dependent target 500m ISD=121.8dB
PUSCH for eMBB DDDSU	16	109.84	2.52	-8.12	-11.91
PUSCH for eMBB DDDSUDDSUU	14	110.87	1.84	-7.09	-10.88
PUSCH for VoIP DDDSU	11	121.78	3.37	3.82	0.03
PUSCH for VoIP DDDSUDDSUU	15	120.90	2.82	2.93	-0.86
PUSCH with SIP invite DDDSU	1	129.30	0.00	11.33	7.55
PUSCH with SIP invite DDDSUDDSUU	0				
PUSCH for CSI 11bit DDDSU	2	130.25	1.95	12.28	8.50
PUSCH for CSI 22bit DDDSU	2	129.10	2.00	11.13	7.35
PUCCH Format 1	13	123.83	2.13	5.86	2.07
PUCCH Format 3 11bits	12	122.29	3.68	4.32	0.53
PUCCH Format 3 22bit	14	119.14	3.31	1.17	-2.62
SSB	9	127.90	2.96	9.93	6.15
PRACH Format 0	2	119.81	0.02	1.84	-1.94
PRACH Format B4	8	121.27	7.35	3.31	-0.48
PRACH Format C2	0				
Broadcast PDCCH(PDCCH of Msg.2)	7	124.80	2.43	6.83	3.05
PDSCH for Msg.2	8	129.65	4.29	11.68	7.89
PUSCH of Msg.3	12	123.01	2.34	5.04	1.26
PDSCH of Msg.4	7	127.44	2.39	9.47	5.68
PUCCH w/ HARQ-ACK for Msg.4	3	122.43	2.17	4.46	0.67
Unicast PDCCH	14	131.72	4.38	13.75	9.96
PDSCH for eMBB DDDSU	12	130.77	5.58	12.80	9.01
PDSCH for eMBB DDDSUDDSUU	10	129.67	3.93	11.70	7.91

Table 5.1.1.1-4: Representative values of MCL for Urban 4GHz TDD scenario with BS Tx power of 24 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB DDDSU	14	130.76	0.99
PUSCH for eMBB DDDSUDDSUU	11	132.37	0.86
PUSCH for VoIP DDDSU	11	142.78	2.40
PUSCH for VoIP DDDSUDDSUU	12	141.08	5.06
PUSCH with SIP invite DDDSU	1	144.80	0.00
PUSCH with SIP invite DDDSUDDSUU	0		
PUSCH for CSI 11bit DDDSU	2	146.00	2.00
PUSCH for CSI 22bit DDDSU	2	144.80	2.00
PUCCH Format 1	12	146.90	2.20
PUCCH Format 3 11bits	10	146.10	1.36
PUCCH Format 3 22bit	12	143.08	1.53
SSB	9	144.71	3.65
PRACH Format 0	2	144.85	0.02
PRACH Format B4	8	145.27	3.09
PRACH Format C2	0		
Broadcast PDCCH(PDCCH of Msg.2)	7	141.19	1.66
PDSCH for Msg.2	8	142.33	3.72
PUSCH of Msg.3	10	143.93	1.11
PDSCH of Msg.4	7	141.42	4.23
PUCCH w/ HARQ-ACK for Msg.4	3	148.59	
Unicast PDCCH	13	147.83	3.91
PDSCH for eMBB DDDSU	12	144.24	4.59
PDSCH for eMBB DDDSUDDSUU	9	142.97	5.52

Table 5.1.1.1-5: Representative values of MIL for Urban 4GHz TDD scenario with BS Tx power of 24 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB DDDSU	14	139.01	0.97	0.00
PUSCH for eMBB DDDSUDDSUU	12	140.33	0.95	1.32
PUSCH for VoIP DDDSU	11	152.00	2.51	12.99
PUSCH for VoIP DDDSUDDSUU	15	151.23	2.48	12.22
PUSCH with SIP invite DDDSU	1	154.40	0.00	15.39
PUSCH with SIP invite DDDSUDDSUU	0			
PUSCH for CSI 11bit DDDSU	2	155.40	2.00	16.39
PUSCH for CSI 22bit DDDSU	2	154.25	2.05	15.24
PUCCH Format 1	13	156.20	3.57	17.19
PUCCH Format 3 11bits	11	155.55	1.52	16.54
PUCCH Format 3 22bit	13	151.85	2.99	12.84
SSB	9	151.89	2.99	12.88
PRACH Format 0	2	153.62	0.02	14.61
PRACH Format B4	8	153.50	4.82	14.49
PRACH Format C2	0			
Broadcast PDCCH(PDCCH of Msg.2)	7	149.54	2.12	10.53
PDSCH for Msg.2	8	150.45	3.47	11.44
PUSCH of Msg.3	12	152.10	2.00	13.09
PDSCH of Msg.4	7	149.27	2.29	10.26
PUCCH w/ HARQ-ACK for Msg.4	3	156.38	2.13	17.37
Unicast PDCCH	14	155.05	2.43	16.05
PDSCH for eMBB DDDSU	12	151.14	3.61	12.13
PDSCH for eMBB DDDSUDDSUU	10	150.84	3.56	11.83

Table 5.1.1.1-6: Representative values of MPL for Urban 4GHz TDD scenario with BS Tx power of 24 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 400m ISD=118.0dB	Gap from Deployment dependent target 500m ISD=121.8dB
PUSCH for eMBB DDDSU	16	109.84	2.52	-8.12	-11.91
PUSCH for eMBB DDDSUDDSUU	14	110.87	1.84	-7.09	-10.88
PUSCH for VoIP DDDSU	11	121.78	3.37	3.82	0.03
PUSCH for VoIP DDDSUDDSUU	15	120.90	2.82	2.93	-0.86
PUSCH with SIP invite DDDSU	1	129.30	0.00	11.33	7.55
PUSCH with SIP invite DDDSUDDSUU	0				
PUSCH for CSI 11bit DDDSU	2	130.25	1.95	12.28	8.50
PUSCH for CSI 22bit DDDSU	2	129.10	2.00	11.13	7.35
PUCCH Format 1	13	123.83	2.13	5.86	2.07
PUCCH Format 3 11bits	12	122.29	3.68	4.32	0.53
PUCCH Format 3 22bit	14	119.14	3.31	1.17	-2.62
SSB	9	118.90	2.96	0.93	-2.85
PRACH Format 0	2	119.81	0.02	1.84	-1.94
PRACH Format B4	8	121.27	7.35	3.31	-0.48
PRACH Format C2	0				
Broadcast PDCCH(PDCCH of Msg.2)	7	115.80	2.43	-2.17	-5.95
PDSCH for Msg.2	8	120.65	4.29	2.68	-1.11
PUSCH of Msg.3	12	123.01	2.34	5.04	1.26
PDSCH of Msg.4	7	118.44	2.39	0.47	-3.32
PUCCH w/ HARQ-ACK for Msg.4	3	122.43	2.17	4.46	0.67
Unicast PDCCH	14	122.72	4.38	4.75	0.96
PDSCH for eMBB DDDSU	12	121.77	5.58	3.80	0.01
PDSCH for eMBB DDDSUDDSUU	10	120.67	3.93	2.70	-1.09

From the representative values for Urban 4GHz TDD scenario, the following observation is made:

- PUSCH for eMBB with frame structure DDDSU is the worst channel in terms of MIL, and can be the coverage bottleneck for the given scenario.
- In order to achieve the target MPL calculated from 400m ISD, the following channel(s) needs to be enhanced:
    - PUSCH for eMBB with frame structure DDDSU
    - PUSCH for eMBB with frame structure DDDSUDDSUU
- In order to achieve the target MPL calculated from 500m ISD, the following channel(s) needs to be enhanced:
    - PUSCH for eMBB with frame structure DDDSU
    - PUSCH for eMBB with frame structure DDDSUDDSUU
    - PUSCH for VoIP with frame structure DDDSU
        - However as shown by standard deviation in the table, this additional gain may be achieved by the existing technologies or parameter optimization, which means that new a functionality in Rel-17 is not always required.
    - PUSCH for VoIP with frame structure DDDSUDDSUU
        - However as shown by standard deviation in the table, this additional gain may be achieved by the existing technologies or parameter optimization, which means that a new functionality in Rel-17 is not always required.
    - PUCCH format 3 with 22 bit payload
    - PRACH Format B4

- However as shown by standard deviation in the table, this additional gain may be achieved by the existing technologies or parameter optimization, which means that a new functionality in Rel-17 is not always required.

- If low transmit power BS (i.e. 24dBm/MHz) is assumed, the following DL channel(s) needs to be enhanced, additionally.
  - For the target MPL calculated from 400m ISD
    - Broadcast PDCCH (PDCCH of Msg.2)
  - For the target MPL calculated from 500m ISD
    - SSB
    - Broadcast PDCCH (PDCCH of Msg.2)
    - PDSCH for eMBB with frame structure DDDSUDDSUU
      - However as shown by standard deviation in the table, this additional gain may be achieved by the existing technologies or parameter optimization, which means that a new functionality in Rel-17 is not always required.

5.1.1.2 Urban 2.6GHz TDD scenario

The representative values for the metrics are summarized in tables 5.1.1.2-1 to 5.1.1.2-3

Table 5.1.1.2-1: Representative values of MCL for Urban 2.6GHz TDD scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB DDDDDDDSUU	9	131.05	1.02
PUSCH for VoIP DDDDDDDSUU	7	142.23	1.95
PUSCH with SIP invite DDDDDDDSUU	0		
PUSCH for CSI 11bit DDDDDDDSUU	0		
PUSCH for CSI 22bit DDDDDDDSUU	0		
PUCCH Format 1	5	148.50	0.69
PUCCH Format 3 11bit	5	146.36	0.53
PUCCH Format 3 22bit	5	144.86	1.17
SSB	4	152.61	2.03
PRACH Format 0	4	147.51	2.66
PRACH Format B4	5	143.78	2.54
PRACH Format C2	2	146.76	1.50
Broadcast PDCCH(PDCCH of Msg.2)	4	151.62	0.12
PDSCH for Msg.2	2	148.03	2.99
PUSCH of Msg.3	6	144.29	0.75
PDSCH of Msg.4	2	149.34	1.00
PUCCH w/ HARQ-ACK for Msg.4	1	150.20	0.00
Unicast PDCCH	6	157.61	2.02
PDSCH for eMBB DDDDDDDSUU	6	157.01	0.74

Table 5.1.1.2-2: Representative values of MIL for Urban 2.6GHz TDD scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB DDDDDDDSUU	10	139.66	1.12	0.00
PUSCH for VoIP DDDDDDDSUU	10	149.65	3.61	10.00
PUSCH with SIP invite DDDDDDDSUU	0			
PUSCH for CSI 11bit DDDDDDDSUU	0			
PUSCH for CSI 22bit DDDDDDDSUU	0			
PUCCH Format 1	6	157.45	1.28	17.79
PUCCH Format 3 11bit	6	155.14	1.38	15.49
PUCCH Format 3 22bit	6	153.35	2.07	13.69
SSB	4	158.74	2.02	19.08
PRACH Format 0	4	156.28	2.66	16.62
PRACH Format B4	5	152.56	2.55	12.90
PRACH Format C2	2	155.53	1.50	15.87
Broadcast PDCCH(PDCCH of Msg.2)	4	159.07	1.44	19.41
PDSCH for Msg.2	2	155.48	1.66	15.82
PUSCH of Msg.3	8	153.51	1.75	13.85
PDSCH of Msg.4	2	156.64	0.48	16.98
PUCCH w/ HARQ-ACK for Msg.4	1	156.02	0.00	16.36
Unicast PDCCH	7	164.72	0.84	25.07
PDSCH for eMBB DDDDDDDSUU	7	164.29	1.18	24.64

Table 5.1.1.2-3: Representative values of MPL for Urban 2.6GHz TDD scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 400m ISD=114.2dB	Gap from Deployment dependent target 500m ISD=118.0dB
PUSCH for eMBB DDDDDDDSUU	10	109.10	1.00	-5.13	-8.92
PUSCH for VoIP DDDDDDDSUU	10	119.14	3.57	4.91	1.12
PUSCH with SIP invite DDDDDDDSUU	0				
PUSCH for CSI DDDDDDDSUU 11bit	0				
PUSCH for CSI DDDDDDDSUU 22bit	0				
PUCCH Format 1	6	123.65	1.26	9.43	5.64
PUCCH Format 3 11bit	6	121.56	1.17	7.34	3.55
PUCCH Format 3 22bit	6	119.94	1.55	5.72	1.93
SSB	4	126.47	0.48	12.24	8.45
PRACH Format 0	4	122.47	2.66	8.25	4.46
PRACH Format B4	5	118.75	2.55	4.52	0.73
PRACH Format C2	2	121.72	1.50	7.50	3.71
Broadcast PDCCH(PDCCH of Msg.2)	4	125.26	1.45	11.03	7.24
PDSCH for Msg.2	2	124.75	1.67	10.52	6.73
PUSCH of Msg.3	8	123.06	1.50	8.84	5.05
PDSCH of Msg.4	2	126.75	0.37	12.53	8.74
PUCCH w/ HARQ-ACK for Msg.4	1	123.90	0.00	9.68	5.89
Unicast PDCCH	7	131.25	1.29	17.03	13.24
PDSCH for eMBB DDDDDDDSUU	7	133.90	1.28	19.68	15.89

From the representative values for Urban 2.6GHz TDD scenario, the following observation is made:

- PUSCH for eMBB with frame structure DDDDDDDSUU is the worst channel in terms of MIL, and can be the coverage bottleneck for the given scenario.
- In order to achieve the target MPL calculated from 400m ISD, the following channel(s) needs to be enhanced:
  - PUSCH for eMBB with frame structure DDDDDDDSUU

- In order to achieve the target MPL calculated from 500m ISD, the following channel(s) needs to be enhanced:
  - PUSCH for eMBB with frame structure DDDDDDDSUU

5.1.1.3 Rural 4GHz TDD NLOS O2I scenario

The representative values for the metrics are summarized below. Tables 5.1.1.3-1 to 5.1.1.3-6 shows the results with BS Tx power of 33 dBm/MHz and 24 dBm/MHz, respectively.

Table 5.1.1.3-1: Representative values of MCL for Rural 4GHz TDD NLOS O2I scenario with BS Tx power of 33 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB DDDSU	10	137.58	2.85
PUSCH for eMBB DDDSUDDSUU	8	138.13	5.89
PUSCH for VoIP DDDSU	13	143.79	2.06
PUSCH for VoIP DDDSUDDSUU	9	139.46	7.26
PUSCH with SIP invite DDDSU	0		
PUSCH with SIP invite DDDSUDDSUU	0		
PUSCH for CSI 11bit DDDSU	0	0.00	0.00
PUSCH for CSI 22bit DDDSU	0	0.00	0.00
PUCCH Format 1	10	146.57	1.84
PUCCH Format 3 11bit	6	144.91	1.84
PUCCH Format 3 22bit	8	142.29	0.74
SSB	5	155.08	1.07
PRACH Format 0	2	146.85	1.98
PRACH Format B4	5	145.11	3.05
PRACH Format C2	0		
Broadcast PDCCH(PDCCH of Msg.2)	3	152.95	1.68
PDSCH for Msg.2	3	154.15	2.34
PUSCH of Msg.3	7	143.86	1.04
PDSCH of Msg.4	4	154.40	1.92
PUCCH w/ HARQ-ACK for Msg.4	2	149.99	0.05
Unicast PDCCH	10	156.11	3.12
PDSCH for eMBB DDDSU	8	152.81	3.49
PDSCH for eMBB DDDSUDDSUU	6	152.21	6.77

Table 5.1.1.3-2: Representative values of MIL for Rural 4GHz TDD NLOS O2I scenario with BS Tx power of 33 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB DDDSU	10	142.25	1.75	0.00
PUSCH for eMBB DDDSUDDSUU	9	144.22	1.03	1.97
PUSCH for VoIP DDDSU	13	148.04	1.76	5.79
PUSCH for VoIP DDDSUDDSUU	12	147.87	1.91	5.62
PUSCH with SIP invite DDDSU	0			
PUSCH with SIP invite DDDSUDDSUU	0			
PUSCH for CSI 11bit DDDSU	0			
PUSCH for CSI 22bit DDDSU	0			
PUCCH Format 1	11	152.06	1.46	9.81
PUCCH Format 3 11bit	7	150.63	1.35	8.38
PUCCH Format 3 22bit	9	147.71	1.50	5.46
SSB	5	157.19	0.86	14.94
PRACH Format 0	2	150.85	1.98	8.60
PRACH Format B4	5	146.48	3.88	4.23
PRACH Format C2	0			
Broadcast PDCCH(PDCCH of Msg.2)	3	156.66	0.71	14.41
PDSCH for Msg.2	3	156.20	3.37	13.95
PUSCH of Msg.3	9	148.11	1.58	5.86
PDSCH of Msg.4	4	156.67	0.65	14.42
PUCCH w/ HARQ-ACK for Msg.4	2	152.49	1.45	10.24
Unicast PDCCH	11	160.10	2.59	17.86
PDSCH for eMBB DDDSU	8	158.39	2.78	16.14
PDSCH for eMBB DDDSUDDSUU	7	158.53	4.36	16.28

Table 5.1.1.3-3: Representative values of MPL for Rural 4GHz TDD NLOS O2I scenario with BS Tx power of 33 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 1732m ISD=131.6dB	Gap from Deployment dependent target 3000m ISD=140.8dB
PUSCH for eMBB DDDSU	12	124.53	2.35	-7.05	-16.27
PUSCH for eMBB DDDSUDDSUU	11	126.18	1.88	-5.39	-14.61
PUSCH for VoIP DDDSU	13	129.69	1.84	-1.89	-11.11
PUSCH for VoIP DDDSUDDSUU	12	129.78	1.60	-1.80	-11.01
PUSCH with SIP invite DDDSU	0				
PUSCH with SIP invite DDDSUDDSUU	0				
PUSCH for CSI 11bit DDDSU	0				
PUSCH for CSI 22bit DDDSU	0				
PUCCH Format 1	11	130.34	2.15	-1.23	-10.45
PUCCH Format 3 11bit	7	129.04	1.62	-2.53	-11.75
PUCCH Format 3 22bit	9	126.09	1.67	-5.49	-14.71
SSB	5	135.28	1.38	3.71	-5.51
PRACH Format 0	2	129.33	3.44	-2.24	-11.46
PRACH Format B4	5	125.85	1.02	-5.72	-14.94
PRACH Format C2	0				
Broadcast PDCCH(PDCCH of Msg.2)	3	130.46	4.80	-1.11	-10.33
PDSCH for Msg.2	3	137.89	4.18	6.32	-2.90
PUSCH of Msg.3	9	129.68	1.98	-1.90	-11.12
PDSCH of Msg.4	4	137.60	0.79	6.03	-3.19
PUCCH w/ HARQ-ACK for Msg.4	2	130.10	2.89	-1.47	-10.69
Unicast PDCCH	11	138.11	2.05	6.54	-2.68
PDSCH for eMBB DDDSU	8	140.03	2.65	8.45	-0.76
PDSCH for eMBB DDDSUDDSUU	7	139.43	3.85	7.86	-1.36

Table 5.1.1.3-4: Representative values of MCL for Rural 4GHz TDD NLOS O2I scenario with BS Tx power of 24 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB DDDSU	10	137.58	2.85
PUSCH for eMBB DDDSUDDSUU	8	138.13	5.89
PUSCH for VoIP DDDSU	13	143.79	2.06
PUSCH for VoIP DDDSUDDSUU	9	139.46	7.26
PUSCH with SIP invite DDDSU	0		
PUSCH with SIP invite DDDSUDDSUU	0		
PUSCH for CSI 11bit DDDSU	0		
PUSCH for CSI 22bit DDDSU	0		
PUCCH Format 1	10	146.57	1.84
PUCCH Format 3 11bit	6	144.91	1.84
PUCCH Format 3 22bit	8	142.29	0.74
SSB	5	146.08	1.07
PRACH Format 0	2	146.85	1.98
PRACH Format B4	5	145.11	3.05
PRACH Format C2	0		
Broadcast PDCCH(PDCCH of Msg.2)	3	143.95	1.68
PDSCH for Msg.2	3	145.15	2.34
PUSCH of Msg.3	7	143.86	1.04
PDSCH of Msg.4	4	145.40	1.92
PUCCH w/ HARQ-ACK for Msg.4	2	149.99	0.05
Unicast PDCCH	10	147.11	3.12
PDSCH for eMBB DDDSU	8	143.81	3.49
PDSCH for eMBB DDDSUDDSUU	6	143.21	6.77

Table 5.1.1.3-5: Representative values of MIL for Rural 4GHz TDD NLOS O2I scenario with BS Tx power of 24 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB DDDSU	10	142.25	1.75	0.00
PUSCH for eMBB DDDSUDDSUU	9	144.22	1.03	1.97
PUSCH for VoIP DDDSU	13	148.04	1.76	5.79
PUSCH for VoIP DDDSUDDSUU	12	147.87	1.91	5.62
PUSCH with SIP invite DDDSU	0			
PUSCH with SIP invite DDDSUDDSUU	0			
PUSCH for CSI 11bit DDDSU	0			
PUSCH for CSI 22bit DDDSU	0			
PUCCH Format 1	11	152.06	1.46	9.81
PUCCH Format 3 11bit	7	150.63	1.35	8.38
PUCCH Format 3 22bit	9	147.71	1.50	5.46
SSB	5	148.19	0.86	5.94
PRACH Format 0	2	150.85	1.98	8.60
PRACH Format B4	5	146.48	3.88	4.23
PRACH Format C2	0			
Broadcast PDCCH(PDCCH of Msg.2)	3	147.66	0.71	5.41
PDSCH for Msg.2	3	147.20	3.37	4.95
PUSCH of Msg.3	9	148.11	1.58	5.86
PDSCH of Msg.4	4	147.67	0.65	5.42
PUCCH w/ HARQ-ACK for Msg.4	2	152.49	1.45	10.24
Unicast PDCCH	11	151.10	2.59	8.86
PDSCH for eMBB DDDSU	8	149.39	2.78	7.14
PDSCH for eMBB DDDSUDDSUU	7	149.53	4.36	7.28

Table 5.1.1.3-6: Representative values of MPL for Rural 4GHz TDD NLOS O2I scenario with BS Tx power of 24 dBm/MHz

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 1732m ISD=131.6dB	Gap from Deployment dependent target 3000m ISD=140.8dB
PUSCH for eMBB DDDSU	12	124.53	2.35	-7.05	-16.27
PUSCH for eMBB DDDSUDDSUU	11	126.18	1.88	-5.39	-14.61
PUSCH for VoIP DDDSU	13	129.69	1.84	-1.89	-11.11
PUSCH for VoIP DDDSUDDSUU	12	129.78	1.60	-1.80	-11.01
PUSCH with SIP invite DDDSU	0				
PUSCH with SIP invite DDDSUDDSUU	0				
PUSCH for CSI 11bit DDDSU	0				
PUSCH for CSI 22bit DDDSU	0				
PUCCH Format 1	11	130.34	2.15	-1.23	-10.45
PUCCH Format 3 11bit	7	129.04	1.62	-2.53	-11.75
PUCCH Format 3 22bit	9	126.09	1.67	-5.49	-14.71
SSB	5	126.28	1.38	-5.29	-14.51
PRACH Format 0	2	129.33	3.44	-2.24	-11.46
PRACH Format B4	5	125.85	1.02	-5.72	-14.94
PRACH Format C2	0				
Broadcast PDCCH(PDCCH of Msg.2)	3	121.46	4.80	-10.11	-19.33
PDSCH for Msg.2	3	128.89	4.18	-2.68	-11.90
PUSCH of Msg.3	9	129.68	1.98	-1.90	-11.12
PDSCH of Msg.4	4	128.60	0.79	-2.97	-12.19
PUCCH w/ HARQ-ACK for Msg.4	2	130.10	2.89	-1.47	-10.69
Unicast PDCCH	11	129.11	2.05	-2.46	-11.68
PDSCH for eMBB DDDSU	8	131.03	2.65	-0.55	-9.76
PDSCH for eMBB DDDSUDDSUU	7	130.43	3.85	-1.14	-10.36

From the representative values for Rural 4GHz TDD NLOS O2I scenario, the following observation is made:

- PUSCH for eMBB with frame structure DDDSU is the worst channel in terms of MIL, and can be the coverage bottleneck for the given scenario.
- In order to achieve the target MPL calculated from 1732m ISD, the following channel(s) needs to be enhanced for BS with 33dBm/MHz transmit power:
  - PUSCH for eMBB with frame structure DDDSU
  - PUSCH for eMBB with frame structure DDDSUDDSUU
  - PUSCH for VoIP with frame structure DDDSU
  - PUSCH for VoIP with frame structure DDDSUDDSUU
  - PUCCH Format 1
  - PUCCH Format 3 with 11bit payload
  - PUCCH Format 3 with 22bit payload
  - PRACH Format 0
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
  - PRACH Format B4
  - Broadcast PDCCH(PDCCH of Msg.2)

        - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.

    - PUSCH of Msg.3

    - PUCCH w/ HARQ-ACK for Msg.4

        - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.

- Achievement of the target MPL calculated from 3000m ISD is not easy because it requires enhancements for all the channels

    - Especially, PUSCH for eMBB with frame structure DDDSU requires huge amount of enhancement

5.1.1.4 Rural 2.6GHz TDD NLOS O2I scenario

The representative values for the metrics are summarized in Tables 5.1.1.4-1 to 5.1.1.4-3.

Table 5.1.1.4-1: Representative values of MCL for Rural 2.6GHz TDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB DDDDDDDSUU	7	137.71	3.63
PUSCH for VoIP DDDDDDDSUU	6	143.65	1.59
PUSCH with SIP invite DDDDDDDSUU	0		
PUSCH for CSI 11bit DDDDDDDSUU	0		
PUSCH for CSI 22bit DDDDDDDSUU	0		
PUCCH Format 1	5	147.94	0.59
PUCCH Format 3 11bit	4	146.40	0.66
PUCCH Format 3 22bit	3	144.94	1.25
SSB	4	155.94	0.93
PRACH Format 0	4	149.49	0.68
PRACH Format B4	6	148.61	1.39
PRACH Format C2	2	146.76	1.50
Broadcast PDCCH(PDCCH of Msg.2)	3	154.68	2.34
PDSCH for Msg.2	1	151.02	0.00
PUSCH of Msg.3	5	144.51	0.75
PDSCH of Msg.4	2	154.60	2.08
PUCCH w/ HARQ-ACK for Msg.4	1	150.20	0.00
Unicast PDCCH	5	156.44	2.43
PDSCH for eMBB DDDDDDDSUU	5	156.11	4.06

Table 5.1.1.4-2: Representative values of MIL for Rural 2.6GHz TDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB DDDDDDDSUU	7	142.46	1.05	0.00
PUSCH for VoIP DDDDDDDSUU	6	147.65	1.59	5.19
PUSCH with SIP invite DDDDDDDSUU	0			
PUSCH for CSI 11bit DDDDDDDSUU	0			
PUSCH for CSI 22bit DDDDDDDSUU	0			
PUCCH Format 1	5	151.50	0.04	9.04
PUCCH Format 3 11bit	4	149.30	0.45	6.84
PUCCH Format 3 22bit	3	147.94	2.07	5.48
SSB	4	157.11	0.75	14.65
PRACH Format 0	4	153.49	0.68	11.03
PRACH Format B4	6	152.61	1.39	10.15
PRACH Format C2	2	150.76	1.50	8.30
Broadcast PDCCH(PDCCH of Msg.2)	3	156.80	3.35	14.34
PDSCH for Msg.2	1	152.37	0.00	9.91
PUSCH of Msg.3	5	147.90	0.15	5.44
PDSCH of Msg.4	2	155.78	1.91	13.32
PUCCH w/ HARQ-ACK for Msg.4	1	151.20	0.00	8.74
Unicast PDCCH	5	161.62	1.47	19.16
PDSCH for eMBB DDDDDDDSUU	5	162.47	4.11	20.01

Table 5.1.1.4-3: Representative values of MPL for Rural 2.6GHz TDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 1732m ISD=127.8dB
PUSCH for eMBB DDDDDDDSUU	7	123.97	1.73	-3.86
PUSCH for VoIP DDDDDDDSUU	6	129.88	1.18	2.04
PUSCH with SIP invite DDDDDDDSUU	0			
PUSCH for CSI 11bit DDDDDDDSUU	0			
PUSCH for CSI 22bit DDDDDDDSUU	0			
PUCCH Format 1	5	130.17	1.25	2.33
PUCCH Format 3 11bit	4	127.33	1.46	-0.50
PUCCH Format 3 22bit	3	126.24	3.00	-1.60
SSB	4	134.81	0.16	6.97
PRACH Format 0	4	132.99	0.23	5.15
PRACH Format B4	6	131.88	1.24	4.05
PRACH Format C2	2	129.81	1.50	1.98
Broadcast PDCCH(PDCCH of Msg.2)	3	131.09	6.91	3.25
PDSCH for Msg.2	1	132.71	0.00	4.88
PUSCH of Msg.3	5	129.81	1.24	1.97
PDSCH of Msg.4	2	136.00	1.79	8.17
PUCCH w/ HARQ-ACK for Msg.4	1	127.99	0.00	0.16
Unicast PDCCH	5	139.24	1.08	11.40
PDSCH for eMBB DDDDDDDSUU	5	143.95	3.88	16.11

From the representative values for Rural 2.6GHz TDD NLOS O2I scenario, the following observation is made:

- PUSCH for eMBB with frame structure DDDDDDDSUU is the worst channel in terms of MIL, and can be the coverage bottleneck for the given scenario.
- In order to achieve the target MPL calculated from 1732m ISD, the following channel(s) needs to be enhanced:
  - PUSCH for eMBB with frame structure DDDDDDDSUU
  - PUCCH format 3 with 11bit payload

- PUCCH format 3 with 22bit payload
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.

5.1.1.5 Rural 2GHz FDD NLOS O2I scenario

The representative values for the metrics are summarized in Tables 5.1.1.5-1 to 5.1.1.6-3.

Table 5.1.1.5-1: Representative values of MCL for Rural 2GHz FDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB UUUUU	8	131.28	1.38
PUSCH for VoIP UUUUU	9	133.04	1.56
PUSCH with SIP invite UUUUU	1	130.86	0.00
PUSCH for CSI 11bit UUUUU	0		
PUSCH for CSI 22bit UUUUU	0		
PUCCH Format 1	8	135.77	0.44
PUCCH Format 3 11bit	6	133.33	0.25
PUCCH Format 3 22bit	5	131.45	1.00
SSB	3	149.20	2.14
PRACH Format 0	2	133.33	3.19
PRACH Format B4	4	132.26	2.13
PRACH Format C2	0		
Broadcast PDCCH(PDCCH of Msg.2)	2	147.84	0.42
PDSCH for Msg.2	1	147.17	0.00
PUSCH of Msg.3	5	133.13	0.60
PDSCH of Msg.4	2	147.73	0.18
PUCCH w/ HARQ-ACK for Msg.4	2	144.85	7.91
Unicast PDCCH	7	148.63	1.59
PDSCH for eMBB UUUUU	7	145.18	2.25

Table 5.1.1.5-2: Representative values of MIL for Rural 2GHz FDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB UUUUU	8	145.20	1.86	2.85
PUSCH for VoIP UUUUU	12	147.34	1.66	4.99
PUSCH with SIP invite UUUUU	1	142.92	0.00	0.57
PUSCH for CSI 11bit UUUUU	0			
PUSCH for CSI 22bit UUUUU	0			
PUCCH Format 1	9	151.38	1.63	9.03
PUCCH Format 3 11bit	7	148.72	1.62	6.38
PUCCH Format 3 22bit	6	146.96	1.18	4.61
SSB	3	157.42	4.00	15.08
PRACH Format 0	2	149.37	3.18	7.02
PRACH Format B4	4	142.35	2.02	0.00
PRACH Format C2	0			
Broadcast PDCCH(PDCCH of Msg.2)	2	153.66	0.01	11.32
PDSCH for Msg.2	1	152.56	0.00	10.22
PUSCH of Msg.3	7	147.14	3.66	4.79
PDSCH of Msg.4	2	153.55	0.25	11.21
PUCCH w/ HARQ-ACK for Msg.4	2	139.95	3.24	-2.40
Unicast PDCCH	8	161.79	1.12	19.44
PDSCH for eMBB UUUUU	8	158.80	1.84	16.46

Table 5.1.1.5-3: Representative values of MPL for Rural 2GHz FDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 1732m ISD=125.6dB
PUSCH for eMBB UUUUU	9	127.16	2.40	1.61
PUSCH for VoIP UUUUU	12	129.20	1.97	3.65
PUSCH with SIP invite UUUUU	1	123.46	0.00	-2.09
PUSCH for CSI 11bit UUUUU	0			
PUSCH for CSI 22bit UUUUU	0			
PUCCH Format 1	9	130.02	2.17	4.47
PUCCH Format 3 11bit	7	127.24	2.24	1.69
PUCCH Format 3 22bit	6	125.76	0.91	0.21
SSB	3	136.97	6.12	11.42
PRACH Format 0	2	128.42	3.18	2.87
PRACH Format B4	4	122.45	0.96	-3.10
PRACH Format C2	0	0.00	0.00	
Broadcast PDCCH(PDCCH of Msg.2)	2	131.80	0.91	6.24
PDSCH for Msg.2	1	134.93	0.00	9.38
PUSCH of Msg.3	7	128.86	3.92	3.31
PDSCH of Msg.4	2	135.01	0.66	9.45
PUCCH w/ HARQ-ACK for Msg.4	2	126.11	5.70	0.55
Unicast PDCCH	8	140.37	1.76	14.81
PDSCH for eMBB UUUUU	8	140.58	1.86	15.02

From the representative values for Rural 2GHz FDD NLOS O2I scenario, the following observation is made:

- PRACH format B4 is the worst channel in terms of MIL, and can be the coverage bottleneck for the given scenario.
    - Since the number of samples to derive the representative value is 4, further analysis is advisable for more accurate MIL estimation on this channel as necessity. It has not been pursued in this study item.
- In order to achieve the target MPL calculated from 1732m ISD, the following channel(s) needs to be enhanced:
    - PUSCH with SIP invite
        - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
    - PRACH format B4

5.1.1.6 Rural 700MHz FDD NLOS O2I scenario

The representative values for the metrics are summarized in Tables 5.1.1.6-1 to 5.1.1.6-3.

Table 5.1.1.6-1: Representative values of MCL for Rural 700MHz FDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Service dependent target MCL=139.2dB
PUSCH for eMBB UUUUU	11	132.45	2.19	N/A
PUSCH for VoIP UUUUU	10	134.19	1.55	-5.01
PUSCH with SIP invite UUUUU	1	135.00	0.00	-4.20
PUSCH for CSI 11bit UUUUU	2	137.75	3.05	-1.45
PUSCH for CSI 22bit UUUUU	2	136.25	3.05	-2.95
PUCCH Format 1	8	137.52	2.97	-1.68
PUCCH Format 3 11bit	5	135.85	1.63	-3.35
PUCCH Format 3 22bit	5	130.99	0.31	N/A
SSB	5	149.16	0.39	9.96
PRACH Format 0	9	139.30	3.96	0.10
PRACH Format B4	3	132.69	2.28	-6.51
PRACH Format C2	0			
Broadcast PDCCH(PDCCH of Msg.2)	4	146.15	1.54	6.95
PDSCH for Msg.2	6	143.86	2.42	4.66
PUSCH of Msg.3	7	134.71	1.38	-4.49
PDSCH of Msg.4	4	145.39	0.30	6.19
PUCCH w/ HARQ-ACK for Msg.4	1	136.93	0.00	-2.27
Unicast PDCCH	9	146.37	1.20	7.17
PDSCH for eMBB UUUUU	10	144.43	3.36	N/A

Table 5.1.1.6-2: Representative values of MIL for Rural 700MHz FDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB UUUUU	11	144.76	2.45	0.22
PUSCH for VoIP UUUUU	10	146.94	1.91	2.40
PUSCH with SIP invite UUUUU	1	148.30	0.00	3.76
PUSCH for CSI 11bit UUUUU	2	151.15	2.95	6.61
PUSCH for CSI 22bit UUUUU	2	149.60	2.90	5.06
PUCCH Format 1	8	150.54	2.20	6.00
PUCCH Format 3 11bit	5	148.87	1.00	4.33
PUCCH Format 3 22bit	5	144.54	1.92	0.00
SSB	5	160.31	1.71	15.77
PRACH Format 0	9	150.90	5.95	6.36
PRACH Format B4	3	142.19	5.32	-2.35
PRACH Format C2	0			
Broadcast PDCCH(PDCCH of Msg.2)	4	157.16	0.56	12.62
PDSCH for Msg.2	6	155.83	3.40	11.29
PUSCH of Msg.3	7	147.50	1.58	2.96
PDSCH of Msg.4	4	158.06	0.06	13.52
PUCCH w/ HARQ-ACK for Msg.4	1	142.41	0.00	-2.13
Unicast PDCCH	9	157.53	1.41	12.99
PDSCH for eMBB UUUUU	10	155.63	3.00	11.09

Table 5.1.1.6-3: Representative values of MPL for Rural 700MHz FDD NLOS O2I scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 3000m ISD=125.7dB	Gap from Deployment dependent target 4000m ISD=130.5dB
PUSCH for eMBB UUUUU	11	127.43	2.55	1.78	-3.05
PUSCH for VoIP UUUUU	10	129.26	1.94	3.60	-1.22
PUSCH with SIP invite UUUUU	1	133.10	0.00	7.45	2.62
PUSCH for CSI 11bit UUUUU	2	135.90	3.00	10.25	5.42
PUSCH for CSI 22bit UUUUU	2	134.40	2.90	8.75	3.92
PUCCH Format 1	8	129.47	2.33	3.82	-1.01
PUCCH Format 3 11bit	5	127.90	0.99	2.25	-2.58
PUCCH Format 3 22bit	5	123.37	0.76	-2.28	-7.11
SSB	5	140.66	1.32	15.01	10.18
PRACH Format 0	9	132.71	7.89	7.06	2.23
PRACH Format B4	3	121.17	5.43	-4.48	-9.31
PRACH Format C2	0				
Broadcast PDCCH(PDCCH of Msg.2)	4	138.38	1.62	12.73	7.90
PDSCH for Msg.2	6	139.04	3.84	13.39	8.56
PUSCH of Msg.3	7	129.88	1.58	4.23	-0.60
PDSCH of Msg.4	4	140.45	0.05	14.79	9.97
PUCCH w/ HARQ-ACK for Msg.4	1	121.22	0.00	-4.43	-9.26
Unicast PDCCH	9	137.31	2.15	11.65	6.83
PDSCH for eMBB UUUUU	10	138.06	3.59	12.40	7.58

From the representative values for Rural 700MHz FDD NLOS O2I scenario, the following observation is made:

- For the service based requirement for VoIP that is defined by 139.2dB MCL, the following channels can be bottlenecks for the given scenario.
  - PUSCH for VoIP
  - PUSCH with SIP invite
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
  - PUSCH for CSI with 11bit payload
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
  - PUSCH for CSI with 22bit payload
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
  - PUCCH Format 1
  - PUCCH Format 3 with 11bit payload
  - PRACH Format B4
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
  - PUSCH of Msg.3
- PUCCH format 3 with 22 bit payload is the worst channel in terms of MIL, and can be the coverage bottleneck for the given scenario.
  - As the table of representative values (in annex) shows, the gap between the worst and the 2nd worst channel (PUSCH for eMBB) is relatively small, i.e. in the range of standard deviation. Thus more analysis is

necessary for the accurate bottleneck channel identification. However, it has not been pursued in this study item.

- In order to achieve the target MPL calculated from 3000m ISD, the following channel(s) needs to be enhanced:
  - PUCCH Format 3 with 22 bit payload
  - PRACH format B4
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
  - PUCCH w/ HARQ-ACK for Msg.4
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
- In order to achieve the target MPL calculated from 4000m ISD, the following channel(s) needs to be enhanced:
  - PUSCH for eMBB
  - PUSCH for VoIP
  - PUCCH Format 1
  - PUCCH Format 3 with 11bit payload
  - PUCCH Format 3 with 22bit payload
  - PRACH Format B4
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.
  - PUSCH of Msg.3
    - However as shown by standard deviation in the table, this additional gain may be achieved by the existing technologies or parameter optimization, which means that a new functionality in Rel-17 is not always required.
  - PUCCH w/ HARQ-ACK for Msg.4
    - However, due to the lack of the number of samples, the statistical correctness of this estimation has not been pursued in this study item.

5.1.1.7 Rural 4GHz with long distance TDD LOS O2O scenario

The representative values for the metrics are summarized in Tables 5.1.1.7-1 to 5.1.1.7-3.

Table 5.1.1.7-1: Representative values of MCL for Rural 4GHz with long distance TDD LOS O2O scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH for eMBB DDDSU	6	132.14	1.85
PUSCH for eMBB DDDSUDDSUU	3	134.31	0.00
PUSCH for VoIP DDDSU	6	140.57	4.40
PUSCH for VoIP DDDSUDDSUU	3	145.71	7.18
PUSCH with SIP invite DDDSU	0		
PUSCH with SIP invite DDDSUDDSUU	0		
PUSCH for CSI 11bit DDDSU	0		
PUSCH for CSI 22 bit DDDSU	0		
PUCCH Format 1	0		
PUCCH Format 3 11bit	2	149.47	0.44
PUCCH Format 3 22bit	1	147.97	0.00
SSB	0		
PRACH Format 0	2	152.97	0.22
PRACH Format B4	2	150.15	0.98
PRACH Format C2	2	148.41	2.22
Broadcast PDCCH(PDCCH of Msg.2)	0		
PDSCH for Msg.2	1	162.63	0.00
PUSCH of Msg.3	1	152.55	0.00
PDSCH of Msg.4	2	146.18	0.32
PUCCH w/ HARQ-ACK for Msg.4	1	152.83	0.00
Unicast PDCCH	1	152.83	0.00
PDSCH for eMBB DDDSU	3	155.09	5.38
PDSCH for eMBB DDDSUDDSUU	1	146.98	0.00

Table 5.1.1.7-2: Representative values of MIL for Rural 4GHz with long distance TDD LOS O2O scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference between channels
PUSCH for eMBB DDDSU	6	140.28	2.65	0.00
PUSCH for eMBB DDDSUDDSUU	3	143.33	0.00	3.04
PUSCH for VoIP DDDSU	6	149.06	3.00	8.78
PUSCH for VoIP DDDSUDDSUU	3	154.73	1.71	14.45
PUSCH with SIP invite DDDSU	0			
PUSCH with SIP invite DDDSUDDSUU	0			
PUSCH for CSI 11bit DDDSU	0			
PUSCH for CSI 22bit DDDSU	0			
PUCCH Format 1	0			
PUCCH Format 3 11bit	2	153.47	0.44	13.18
PUCCH Format 3 22bit	1	151.97	0.00	11.69
SSB	0			
PRACH Format 0	2	156.97	0.22	16.68
PRACH Format B4	2	154.15	0.98	13.87
PRACH Format C2	2	152.41	2.22	16.68
Broadcast PDCCH(PDCCH of Msg.2)	0			
PDSCH for Msg.2	1	163.98	0.00	23.70
PUSCH of Msg.3	1	153.90	0.00	13.62
PDSCH of Msg.4	2	150.18	0.32	9.90
PUCCH w/ HARQ-ACK for Msg.4	1	154.18	0.00	13.90
Unicast PDCCH	1	154.18	0.00	13.90
PDSCH for eMBB DDDSU	3	163.23	6.93	22.94
PDSCH for eMBB DDDSUDDSUU	1	166.03	0.00	25.75

Table 5.1.1.7-3: Representative values of MPL for Rural 4GHz with long distance TDD LOS O2O scenario

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from Deployment dependent target 12km ISD=132.4dB
PUSCH for eMBB DDDSU	6	129.28	1.82	-3.15
PUSCH for eMBB DDDSUDDSUU	3	130.01	0.00	-2.42
PUSCH for VoIP DDDSU	6	137.59	1.64	5.16
PUSCH for VoIP DDDSUDDSUU	3	141.42	1.15	8.99
PUSCH with SIP invite DDDSU	0			
PUSCH with SIP invite DDDSUDDSUU	0			
PUSCH for CSI 11bit DDDSU	0			
PUSCH for CSI 22bit DDDSU	0			
PUCCH Format 1	0			
PUCCH Format 3 11bit	2	137.38	1.41	4.95
PUCCH Format 3 22bit	1	134.91	0.00	2.48
SSB	0			
PRACH Format 0	2	143.89	0.94	11.46
PRACH Format B4	2	138.07	1.96	5.63
PRACH Format C2	2	136.32	3.19	3.89
Broadcast PDCCH(PDCCH of Msg.2)	0			
PDSCH for Msg.2	1	146.92	0.00	14.49
PUSCH of Msg.3	1	140.11	0.00	7.68
PDSCH of Msg.4	2	137.11	0.39	4.67
PUCCH w/ HARQ-ACK for Msg.4	1	140.39	0.00	7.96
Unicast PDCCH	1	140.39	0.00	7.96
PDSCH for eMBB DDDSU	3	146.02	5.18	13.59
PDSCH for eMBB DDDSUDDSUU	1	148.40	0.00	15.97

For Rural 4GHz with long distance TDD LOS O2O scenario, the following observation is made:

- PUSCH for eMBB with frame structure DDDSU is the worst channel in terms of MIL. However, due to the lack of the number of samples for each channel, the statistical analysis by relative difference between channels could not be performed.
- In order to achieve the target MPL calculated from 12km ISD, at least the following channel(s) needs to be enhanced:
  - PUSCH for eMBB with frame structure DDDSU
  - PUSCH for eMBB with frame structure DDDSUDDSUU
  - This does not mean that other channels do not require any enhancements. RAN1 did not perform any analysis for this point because of the lack of the number of samples for each channel for this scenario.

5.1.2 Bottleneck identification by representative values

Bottleneck identification is performed by the following procedure:

- The potential bottleneck channels identified by absolute metrics, then
- The potential bottleneck channels identified by absolute metrics can be further filtered by using relative difference between channels in MIL

The result of the bottleneck channel identification by the procedure above is summarized in Table 5.1.2-1.

Table 5.1.2-1: Potential bottleneck channels for FR1

Scenario	Target metrics	Channels (and Frame format)	MIL			
			Number of samples	Representative value	Standard Deviation (w/o outlier)	Gap from the worst channel
Urban 4GHz TDD	Scenario dependent target ISD=400m	PUSCH for eMBB DDDSU	14	139.01	0.97	0.00
		PUSCH for eMBB DDDSUDDSUU	12	140.33	0.95	1.32
		Broadcast PDCCH(PDCCH of Msg.2) (24dBm/MHz DL Tx power)	7	149.54	2.12	10.53
Urban 2.6GHz TDD	Scenario dependent target ISD=400m	PUSCH for eMBB DDDDDDDSUU	10	139.66	1.12	0.00
Rural 4GHz TDD NLOS O2I	Scenario dependent target ISD=1732m with BS Tx power of 33dBm/MHz	PUSCH for eMBB DDDSU	10	142.25	1.75	0.00
		PUSCH for eMBB DDDSUDDSUU	9	144.22	1.03	1.97
		PRACH Format B4	5	146.48	3.88	4.23
		PUCCH Format 3 22bit	9	147.71	1.50	5.46
		PUSCH for VoIP DDDSUDDSUU	12	147.87	1.91	5.62
		PUSCH for VoIP DDDSU	13	148.04	1.76	5.79
		PUSCH of Msg.3	9	148.11	1.58	5.86
		PUCCH Format 3 11bit	7	150.63	1.35	8.38
		PUCCH Format 1	11	152.06	1.46	9.81
Rural 2.6GHz TDD NLOS O2I	Scenario dependent target ISD=1732m	PUSCH for eMBB DDDDDDDSUU	7	142.46	1.05	0.00
		PUCCH Format 3 11bit	4	149.30	0.45	6.84
Rural 2GHz FDD NLOS O2I	Scenario dependent target ISD=1732m	PRACH Format B4	4	142.35	2.02	0.00
Rural 700MHz FDD NLOS O2I	Service dependent target MCL=139.2dB	PUSCH for VoIP UUUUU	10	146.94	1.91	0.00
		PUSCH of Msg.3	7	147.50	1.58	0.56
		PUCCH Format 3 11bit	5	148.87	1.00	1.92
		PUCCH Format 1	8	150.54	2.20	3.60
	Scenario dependent target ISD=4000m	PUCCH Format 3 22bit	5	144.54	1.92	0.00
		PUSCH for eMBB UUUUU	11	144.76	2.45	0.22
		PUSCH for VoIP UUUUU	10	146.94	1.91	2.40
		PUSCH of Msg.3	7	147.50	1.58	2.96
		PUCCH Format 3 11bit	5	148.87	1.00	4.33
		PUCCH Format 1	8	150.54	2.20	6.00
Rural 4GHz with long distance TDD LOS O2O	Scenario dependent target ISD=12km	PUSCH for eMBB DDDSU	6	140.28	2.65	0.00
		PUSCH for VoIP DDDSU	6	149.06	3.00	8.78

The following channels are identified as the potential bottleneck channels derived from the absolute metrics (i.e. service dependent metric and scenario dependent metric) and the relative metric (i.e. relative difference between channels)

- 1st priority
  - PUSCH for eMBB (for FDD and TDD with DDDSU, DDDSUDDSUU and DDDDDDDSUU)
  - PUSCH for VoIP (for FDD and TDD with DDDSU, DDDSUDDSUU)
- 2nd priority
  - PRACH format B4

- PUSCH of Msg.3
- PUCCH format 1
- PUCCH format 3 with 11bit
- PUCCH format 3 with 22bit
- Broadcast PDCCH

5.1.3 Observation from the simulation result not using representative values

One source (R1-2007741) evaluated the target performance, i.e. the 5th percentile geometry SINR value, based on system-level simulation. Compared to the baseline performance, i.e., required SNR based on link level simulation, the following is observed for FR1. The details are shown in Table 1-15 of Annex B.

- In Urban 4 GHz O2I scenario with ISD 500m, PUSCH eMBB, PUSCH VoIP, Msg3, PRACH B4, PUCCH Format 1 with 2 bits, PUCCH Format 3 with 11 bits and PUCCH Format 3 with 22 bits require coverage compensation
- In Rural 4 GHz O2I scenario with ISD 1732m, PUSCH eMBB, Msg3, PRACH B4, PUCCH Format 1 with 2 bits, PUCCH Format 3 with 11 bits and PUCCH Format 3 with 22 bits require coverage compensation
- In Rural 2.6 GHz O2I scenario with ISD 1732m, PUSCH eMBB, Msg3, PRACH B4, PUCCH Format 1 with 2 bits, PUCCH Format 3 with 11 bits and PUCCH Format 3 with 22 bits, require coverage compensation
- In Rural 700MHz O2O scenario with ISD 1732m, no channel requires coverage compensation.
- In Rural with long distance 700MHz O2O scenario with ISD 12km, no channel requires coverage compensation.

5.2 Baseline coverage performance for FR2

5.2.1 Representative values and observation for each scenario

5.2.1.1 Urban 28GHz TDD NLOS O2I scenario

The representative values for the metrics are summarized below. Table 5.2.1.1-1 to 5.2.1.1-3 show the results for UE Tx power of 12 dBm.

Table 5.2.1.1-1: Representative values of MCL for Urban 28GHz TDD NLOS O2I scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH eMBB DDDSU	9	94.05	5.81
PUSCH eMBB DDSU	3	90.38	5.87
PUSCH VoIP DDDSU	6	107.66	4.68
PUSCH VoIP DDSU	4	103.13	0.97
PUSCH with SIP invite DDDSU	1	130.40	0.00
PUSCH for CSI 11bits DDDSU	2	133.10	3.10
PUSCH for CSI 22bits DDDSU	2	131.60	0.10
PUCCH Format 1	8	109.37	6.14
PUCCH Format 3 11bits	8	109.88	5.32
PUCCH Format 3 22bits	7	106.45	5.17
SSB	6	131.14	2.14
PRACH Format B4	6	116.28	2.93
PRACH Format C2	0		
PDCCH of Msg2	5	132.49	3.29
PDSCH of Msg2 DDDSU	2	136.38	11.02
PDSCH of Msg2 DDSU	1	125.36	0.00
PUSCH of Msg3	7	110.81	5.61
PDSCH of Msg4	4	129.91	3.20
PUCCH with HARQ-ACK Msg4	1	119.69	0.00
PDCCH	10	132.89	5.53
PDSCH eMBB DDDSU	9	124.51	3.25
PDSCH eMBB DDSU	3	121.94	1.69

Table 5.2.1.1-2: Representative values of MIL for Urban 28GHz TDD NLOS O2I scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference vs. PUCCH Format 1
PUSCH eMBB DDDSU	9	125.31	3.78	-17.83
PUSCH eMBB DDSU	3	123.94	1.74	-19.20
PUSCH VoIP DDDSU	6	140.46	1.94	-2.68
PUSCH VoIP DDSU	4	139.26	0.93	-3.88
PUSCH with SIP invite DDDSU	1	139.40	0.00	-3.74
PUSCH for CSI 11bits DDDSU	2	142.50	3.70	-0.64
PUSCH for CSI 22bits DDDSU	2	140.45	0.15	-2.69
PUCCH Format 1	8	143.14	4.53	0.00
PUCCH Format 3 11bits	8	142.27	3.16	-0.86
PUCCH Format 3 22bits	7	139.18	2.58	-3.96
SSB	6	155.47	3.37	12.34
PRACH Format B4	6	141.22	5.70	-1.92
PRACH Format C2	0			
PDCCH of Msg2	5	151.83	0.31	8.69
PDSCH of Msg2 DDDSU	2	153.95	3.56	10.81
PDSCH of Msg2 DDSU	1	150.39	0.00	7.25
PUSCH of Msg3	7	139.72	5.69	-3.41
PDSCH of Msg4	4	150.01	1.72	6.87
PUCCH with HARQ-ACK Msg4	1	141.35	0.00	-1.79
PDCCH	10	158.70	4.47	15.56
PDSCH eMBB DDDSU	9	154.36	4.54	11.23
PDSCH eMBB DDSU	3	154.14	5.21	11.00

Table 5.2.1.1-3: Representative values of MPL for Urban 28GHz TDD NLOS O2I scenario for UE Tx power of 12dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from 200m ISD requirement (123.1dB)
PUSCH eMBB DDDSU	10	91.38	1.62	-31.72
PUSCH eMBB DDSU	3	92.76	0.59	-30.34
PUSCH VoIP DDDSU	6	108.82	1.46	-14.28
PUSCH VoIP DDSU	4	109.16	0.25	-13.95
PUSCH with SIP invite DDDSU	1	106.10	0.00	-17.00
PUSCH for CSI 11bits DDDSU	2	109.20	3.70	-13.90
PUSCH for CSI 22bits DDDSU	2	107.20	0.10	-15.90
PUCCH Format 1	7	105.94	2.05	-17.16
PUCCH Format 3 11bits	7	105.62	2.11	-17.48
PUCCH Format 3 22bits	7	102.78	1.99	-20.32
SSB	7	120.44	4.36	-2.66
PRACH Format B4	5	102.80	6.93	-20.30
PRACH Format C2	1	95.22	0.00	-27.88
PDCCH of Msg2	4	118.58	0.23	-4.52
PDSCH of Msg2 DDDSU	2	122.63	1.58	-0.47
PDSCH of Msg2 DDSU	1	121.05	0.00	-2.05
PUSCH of Msg3	7	103.53	5.74	-19.57
PDSCH of Msg4	3	118.82	6.52	-4.28
PUCCH with HARQ-ACK Msg4	1	99.65	0.00	-23.45
PDCCH	10	125.75	5.07	2.65
PDSCH eMBB DDDSU	9	120.56	7.31	-2.54
PDSCH eMBB DDSU	3	122.96	6.03	-0.14

From the representative values for Urban 28GHz TDD NLOS O2I scenario, the following observations can be made:

For the 1st priority channels (with more than 2 available samples):

- With absolute MPL target corresponding to ISD target 200m, only PDCCH can meet the absolute MPL target. 1st priority channels which do not meet the absolute MPL target are:
  - PUSCH eMBB DDDSU
  - PUSCH eMBB DDSU
  - PUSCH VoIP DDDSU
  - PDSCH eMBB DDSU
  - PUCCH Format 1
  - PUCCH Format 3 11bits
  - PUCCH Format 3 22bits
  - SSB
  - PRACH Format B4: 20.30dB
  - PDCCH of Msg2
  - PUSCH of Msg3
  - PDSCH of Msg4
  - PDSCH eMBB DDDSU
  - PUSCH VoIP DDSU

- With relative differential MIL target using PUCCH Format 1 as reference, 1st priority channels which display lower coverage than the reference are:
  - PUSCH eMBB DDDSU
  - PUSCH eMBB DDSU
  - PUSCH VoIP DDDSU
  - PUSCH VoIP DDSU
  - PUCCH Format 3 11bits
  - PUCCH Format 3 22bits
  - PRACH Format B4
  - PUSCH of Msg3

For 2nd priority channels (with less than 3 available samples):

- With absolute MPL target of 200m ISD, no channel can meet the target. 2nd priority channels which do not meet the absolute MPL target are:
  - PUSCH with SIP invite DDDSU
  - PUSCH for CSI 11bits DDDSU
  - PUSCH for CSI 22bits DDDSU
  - PRACH Format C2
  - PDSCH of Msg2 DDDSU
  - PDSCH of Msg2 DDSU
  - PUCCH with HARQ-ACK Msg4
- With relative differential MIL target using PUCCH Format 1 as reference, 2nd priority channels which display lower coverage than the reference are:
  - PUSCH with SIP invite DDDSU
  - PUSCH for CSI 11bits DDDSU
  - PUSCH for CSI 22bits DDDSU
  - PUCCH with HARQ-ACK Msg4

5.2.1.2 Urban 28GHz TDD NLOS O2O scenario

The representative values for the metrics are summarized below. Table 5.2.1.2-1 to 5.2.1.2-3 show the results for UE Tx power of 12 dBm.

Table 5.2.1.2-1: Representative values of MCL for Urban 28GHz TDD NLOS O2O scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH eMBB DDDSU	9	92.49	3.22
PUSCH eMBB DDSU	3	90.63	5.59
PUSCH VoIP DDDSU	7	110.49	4.15
PUSCH VoIP DDSU	4	105.54	0.11
PUCCH Format 0	1	107.90	0.00
PUCCH Format 1	9	111.60	5.60
PUCCH Format 2	1	104.30	0.00
PUCCH Format 3 11bits	7	109.28	4.52
PUCCH Format 3 22bits	9	108.42	4.86
SSB	5	130.88	0.83
PRACH Format B4	5	111.12	3.29
PRACH Format C2	0		
PDCCH of Msg2	4	127.37	1.07
PDSCH of Msg2 DDDSU	2	127.51	2.60
PDSCH of Msg2 DDSU	1	124.91	0.00
PUSCH of Msg3	6	109.22	5.56
PDSCH of Msg4	4	124.84	0.96
PUCCH with HARQ-ACK for Msg4	1	120.80	0.00
PDCCH	9	129.17	1.90
PDSCH eMBB DDDSU	9	122.51	1.34
PDSCH eMBB DDSU	3	122.10	1.53

Table 5.2.1.2-2: Representative values of MIL for Urban 28GHz TDD NLOS O2O scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference vs. PUCCH Format 1
PUSCH eMBB DDDSU	9	123.60	1.73	-20.10
PUSCH eMBB DDSU	3	123.99	1.78	-19.71
PUSCH VoIP DDDSU	7	144.52	2.01	0.82
PUSCH VoIP DDSU	4	141.88	0.15	-1.83
PUCCH Format 0	1	132.90	0.00	-10.80
PUCCH Format 1	9	143.70	3.58	0.00
PUCCH Format 2	1	129.4	0.00	-14.30
PUCCH Format 3 11bits	7	143.54	3.08	-0.16
PUCCH Format 3 22bits	9	141.22	3.58	-2.48
SSB	5	156.88	3.89	13.18
PRACH Format B4	5	136.13	0.88	-7.57
PRACH Format C2	0			
PDCCH of Msg2	4	150.69	0.59	6.99
PDSCH of Msg2 DDDSU	2	150.70	0.77	7.00
PDSCH of Msg2 DDSU	1	149.93	0.00	6.23
PUSCH of Msg3	6	137.28	2.94	-6.42
PDSCH of Msg4	4	146.87	1.33	3.17
PUCCH with HARQ-ACK for Msg4	1	142.46	0.00	-1.24
PDCCH	9	159.40	4.01	15.70
PDSCH eMBB DDDSU	9	153.17	5.36	9.47
PDSCH eMBB DDSU	3	154.30	5.08	10.60

Table 5.2.1.2-3: Representative values of MPL for Urban 28GHz TDD NLOS O2O scenario for UE Tx power of 12dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from 200m ISD requirement (123.1dB)
PUSCH eMBB DDDSU	10	110.94	2.74	-12.16
PUSCH eMBB DDSU	3	110.62	2.03	-12.48
PUSCH VoIP DDDSU	7	130.97	1.79	7.87
PUSCH VoIP DDSU	4	128.01	0.13	4.91
PUCCH Format 0	1	118.7	0.00	-4.4
PUCCH Format 1	9	127.85	4.19	4.75
PUCCH Format 2	1	115.20	0.00	-7.9
PUCCH Format 3 11bits	7	127.34	3.78	4.24
PUCCH Format 3 22bits	9	124.99	4.25	1.89
SSB	6	140.74	3.13	17.64
PRACH Format B4	5	121.36	1.45	-1.74
PRACH Format C2	1	122.52	0.00	-0.58
PDCCH of Msg2	4	134.02	0.20	10.92
PDSCH of Msg2 DDDSU	2	136.85	0.77	13.75
PDSCH of Msg2 DDSU	1	136.08	0.00	12.98
PUSCH of Msg3	7	124.60	2.97	1.50
PDSCH of Msg4	3	133.41	2.53	10.31
PUCCH with HARQ-ACK for Msg4	1	125.90	0.00	2.80
PDCCH	9	143.09	4.24	19.99
PDSCH eMBB DDDSU	10	139.61	5.33	16.51
PDSCH eMBB DDSU	3	140.93	5.63	17.83

From the representative values for Urban 28GHz TDD NLOS O2O scenario, the following observations can be made:

For the 1st priority channels (with more than 2 available samples):

- With absolute MPL target corresponding to target ISD 200m, all channels except PUSCH and PRACH can meet the absolute MPL target. 1st priority channels which do not meet the absolute MPL target are:
    - PUSCH eMBB DDDSU
    - PUSCH eMBB DDSU
    - PRACH Format B4
- With relative differential MIL target using PUCCH Format 1 as reference, 1st priority channels which display lower coverage than the reference are:
    - PUSCH eMBB DDDSU
    - PUSCH eMBB DDSU
    - PUSCH VoIP DDSU
    - PUCCH Format 3 11bits
    - PUCCH Format 3 22bits
    - PRACH Format B4
    - PUSCH of Msg3

For 2nd priority channels (with less than 3 available samples):

- With absolute MPL target of 200m ISD, no channel can meet the target. 2nd priority channels which do not meet the absolute MPL target are:
    - PUCCH Format 0

  - PUCCH Format 2
  - PRACH Format C2
- With relative MIL target using PUCCH Format 1 as reference, no MIL result is available for PRACH Format C2. 2nd priority channels which display lower coverage than the reference are:
  - PUCCH Format 0
  - PUCCH Format 2
  - PUCCH with HARQ-ACK for Msg4

5.2.1.3 Indoor 28GHz TDD NLOS scenario

The representative values for the metrics are summarized below. Table 5.2.1.3-1 to 5.2.1.3-3 show the results for UE Tx power of 12 dBm.

Table 5.2.1.3-1: Representative values of MCL for Indoor 28GHz TDD NLOS scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH eMBB DDDSU	10	93.54	3.92
PUSCH eMBB DDSU	3	88.90	1.30
PUSCH VoIP DDDSU	7	109.93	3.21
PUSCH VoIP DDSU	3	106.55	1.85
PUCCH Format 0	1	108.30	0.00
PUCCH Format 1	10	114.47	3.23
PUCCH Format 2	1	104.30	0.00
PUCCH Format 3 11bits	8	111.19	1.65
PUCCH Format 3 22bits	9	108.76	1.68
SSB	5	115.83	1.05
PRACH Format B4	5	112.38	3.28
PRACH Format C2	0		
PDCCH of Msg2	5	112.32	1.49
PDSCH of Msg2 DDDSU	2	111.29	2.21
PDSCH of Msg2 DDSU	1	109.08	0.00
PUSCH of Msg3	6	109.18	3.05
PDSCH of Msg4	4	108.77	1.67
PUCCH with HARQ-ACK Msg4	1	116.52	0.00
PDCCH	10	113.13	2.24
PDSCH eMBB DDDSU	10	109.01	7.04
PDSCH eMBB DDSU	2	115.67	8.99

Table 5.2.1.3-2: Representative values of MIL for Indoor 28GHz TDD NLOS scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference vs. PUCCH Format 1
PUSCH eMBB DDDSU	10	122.95	3.94	-20.78
PUSCH eMBB DDSU	3	120.32	3.15	-23.42
PUSCH VoIP DDDSU	7	140.33	0.93	-3.41
PUSCH VoIP DDSU	3	137.97	1.84	-5.76
PUCCH Format 0	1	133.30	0.00	-10.43
PUCCH Format 1	10	143.73	2.60	0.00
PUCCH Format 2	1	129.40	0.00	-14.33
PUCCH Format 3 11bits	8	141.21	2.66	-2.53
PUCCH Format 3 22bits	9	138.78	2.83	-4.95
SSB	5	138.15	5.45	-5.59
PRACH Format B4	5	138.17	5.47	-5.57
PRACH Format C2	0			
PDCCH of Msg2	5	131.35	1.69	-12.38
PDSCH of Msg2 DDDSU	2	130.72	0.04	-13.01
PDSCH of Msg2 DDSU	1	130.68	0.00	-13.05
PUSCH of Msg3	6	137.47	4.37	-6.27
PDSCH of Msg4	4	127.08	2.72	-16.65
PUCCH with HARQ-ACK Msg4	1	137.41	0.00	-6.32
PDCCH	10	137.84	4.47	-5.89
PDSCH eMBB DDDSU	10	135.38	10.62	-8.35
PDSCH eMBB DDSU	2	145.51	12.23	1.78

Table 5.2.1.3-3: Representative values of MPL for Indoor 28GHz TDD NLOS scenario for UE Tx power of 12dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from 20m ISD requirement (94.03dB)
PUSCH eMBB DDDSU	10	118.21	4.00	24.18
PUSCH eMBB DDSU	3	116.29	4.80	22.26
PUSCH VoIP DDDSU	7	136.69	1.98	42.66
PUSCH VoIP DDSU	3	133.94	3.03	39.91
PUCCH Format 0	1	128.10	0.00	34.07
PUCCH Format 1	8	137.16	3.65	43.13
PUCCH Format 2	1	124.20	0.00	30.17
PUCCH Format 3 11bits	8	133.00	3.20	38.97
PUCCH Format 3 22bits	9	131.83	4.51	37.80
SSB	6	130.39	3.84	36.36
PRACH Format B4	4	127.92	1.08	33.89
PRACH Format C2	1	130.35	0.00	36.32
PDCCH of Msg2	4	123.88	0.12	29.85
PDSCH of Msg2 DDDSU	2	125.52	0.04	31.49
PDSCH of Msg2 DDSU	1	125.48	0.00	31.45
PUSCH of Msg3	6	132.82	4.01	38.79
PDSCH of Msg4	3	121.27	3.97	27.24
PUCCH with HARQ-ACK Msg4	1	129.85	0.00	35.82
PDCCH	9	132.26	4.70	38.23
PDSCH eMBB DDDSU	9	132.61	11.47	38.58
PDSCH eMBB DDSU	2	142.07	13.99	48.04

From the representative values for Indoor 28GHz TDD NLOS scenario, the following observations can be made:

For the 1st priority channels (with more than 2 available samples) and the 2nd priority channels (with less than 3 available samples):

- Absolute MPL target corresponding to ISD 20m is met by all channels.

- No potential bottleneck channel seems to exist for this scenario.

5.2.1.4 Suburban 28GHz TDD NLOS O2I scenario

The number of available results for suburban 28 GHz TDD NLOS O2I scenario was deemed insufficient to achieve statistical relevance. Therefore, it has been deprioritized and no coverage bottleneck identification has been carried out for this scenario. Only representative values for the considered metrics, with corresponding observations, are summarized in Tables 5.2.1.4-1 to 5.2.1.4-3, for UE Tx power of 12 dBm, for completeness.

Table 5.2.1.4-1: Representative values of MCL for Suburban 28GHz TDD NLOS O2I scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH eMBB DDDSU	3	99.68	9.32
PUSCH eMBB DDSU	2	93.28	0.60
PUSCH VoIP	3	105.88	5.45
PUCCH Format 1	2	110.14	6.27
PUCCH Format 3 11bits	2	106.71	3.02
PUCCH Format 3 22bits	2	105.50	4.20
SSB	1	132.55	0.00
PUSCH of Msg3	1	100.04	0.00
PDCCH	3	134.10	5.65
PDSCH eMBB DDDSU	3	127.26	5.91
PDSCH eMBB DDSU	1	130.39	0.00

Table 5.2.1.4-2: Representative values of MIL for Suburban 28GHz TDD NLOS O2I scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference vs. PUCCH Format 1
PUSCH eMBB DDDSU	3	134.44	6.01	-10.80
PUSCH eMBB DDSU	2	130.38	0.60	-14.86
PUSCH VoIP	3	140.64	2.20	-4.60
PUCCH Format 1	2	145.24	1.24	0.00
PUCCH Format 3 11bits	2	141.81	2.01	-3.43
PUCCH Format 3 22bits	2	140.59	0.83	-4.65
SSB	1	165.63	0.00	20.40
PUSCH of Msg3	1	137.14	0.00	-8.10
PDCCH	3	165.85	1.73	20.62
PDSCH eMBB DDDSU	3	162.35	7.31	17.11
PDSCH eMBB DDSU	1	166.48	0.00	21.25

Table 5.2.1.4-3: Representative values of MPL for Suburban 28GHz TDD NLOS O2I scenario for UE Tx power of 12dBm.

Channels (and Frame format)	Number of Samples	Representa tive value	Standard Deviation (w/o outlier)	Gap from 200m ISD requirement (123.1dB)	Gap from 400m ISD requirement (134.87dB)	Gap from 500m ISD requirement (138.66dB)
PUSCH eMBB DDDSU	3	101.77	4.52	-21.33	-33.10	-36.89
PUSCH eMBB DDSU	2	98.76	0.60	-24.34	-36.11	-39.90
PUSCH VoIP	3	107.97	0.91	-15.13	-26.90	-30.69
PUCCH Format 1	2	108.78	0.15	-14.32	-26.09	-29.88
PUCCH Format 3 11bits	2	105.35	3.40	-17.75	-29.52	-33.31
PUCCH Format 3 22bits	2	104.14	2.23	-18.97	-30.74	-34.53
SSB	1	134.01	0.00	10.91	-0.86	-4.65
PUSCH of Msg3	1	105.52	0.00	-17.58	-29.35	-33.14
PDCCH	3	129.86	2.87	6.76	-5.01	-8.80
PDSCH eMBB DDDSU	3	129.68	8.79	6.58	-5.19	-8.98
PDSCH eMBB DDSU	1	134.86	0.00	11.76	-0.01	-3.80

From the representative values for Suburban 28GHz TDD NLOS O2I scenario, the following observations can be made:

For the 1st priority channels (with more than 2 available samples):

- No channel can meet the absolute MPL target if the target ISD is set to 400m and 500m. Conversely, if ISD target is set to 200m then the only 1st priority channels which do not meet the absolute MPL target are PUSCH eMBB DDDSU and PUSCH VoIP DDDSU.
- With relative differential MIL target using PUCCH Format 1 as reference, 1st priority channels which display lower coverage than the reference are:
  - PUSCH eMBB DDDSU
  - PUSCH VoIP DDDSU
  - PUCCH Format 3 11bits
  - PUCCH Format 3 22bits
  - PUSCH of Msg3
  - PUSCH eMBB DDSU

For 2nd priority channels (with less than 3 available samples):

- Absolute MPL target corresponding to ISD 200m cannot be met by any UL channel. Considering ISD target larger than 200m is very challenging for 2nd priority channels as well. Larger ISD target are not met by any channel.
- With relative differential MIL target using PUCCH Format 1 as reference, 2nd priority channels which display lower coverage than the reference are:
  - PUSCH Format 3 11 bits
  - PUSCH Format 3 22 bits
  - PUSCH for Msg3
  - PUSCH eMBB DDSU

5.2.1.5 Suburban 28GHz TDD NLOS O2O scenario

The number of available results for suburban 28 GHz TDD NLOS O2O scenario was deemed insufficient to achieve statistical relevance. Therefore, it has been deprioritized and no coverage bottleneck identification has been carried out for this scenario. Only representative values for the considered metrics, with corresponding observations, are summarized in Tables 5.2.1.5-1 to 5.2.1.5-3, for UE Tx power of 12 dBm, for completeness.

Table 5.2.1.5-1: Representative values of MCL for Suburban 28GHz TDD NLOS O2O scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)
PUSCH eMBB DDDSU	4	102.99	10.22
PUSCH eMBB DDSU	2	92.96	0.27
PUSCH VoIP	4	109.85	3.85
PUCCH Format 1	3	112.26	5.86
PUCCH Format 3 11bits	3	109.80	2.90
PUCCH Format 3 22bits	3	107.81	2.85
SSB	1	131.63	0.00
PUSCH of Msg3	1	99.74	0.00
PDCCH	4	130.90	0.02
PDSCH eMBB DDDSU	4	124.77	5.43
PDSCH eMBB DDSU	1	130.19	0.00

Table 5.2.1.5-2: Representative values of MIL for Suburban 28GHz TDD NLOS O2O scenario for UE Tx power of 12 dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Relative difference vs. PUCCH Format 1
PUSCH eMBB DDDSU	4	136.57	6.70	-9.12
PUSCH eMBB DDSU	2	130.06	0.28	-15.63
PUSCH VoIP	4	143.43	0.33	-2.26
PUCCH Format 1	3	145.69	1.12	0.00
PUCCH Format 3 11bits	3	143.23	1.84	-2.46
PUCCH Format 3 22bits	3	141.23	1.88	-4.46
SSB	1	164.71	0.00	19.02
PUSCH of Msg3	1	136.84	0.00	-8.85
PDCCH	4	164.99	0.99	19.30
PDSCH eMBB DDDSU	4	159.35	6.93	13.66
PDSCH eMBB DDSU	1	166.28	0.00	20.59

Table 5.2.1.5-3: Representative values of MPL for Suburban 28GHz TDD NLOS O2O scenario for UE Tx power of 12dBm.

Channels (and Frame format)	Number of Samples	Representative value	Standard Deviation (w/o outlier)	Gap from 200m ISD requirement (123.1dB)	Gap from 400m ISD requirement (134.87dB)	Gap from 500m ISD requirement (138.66dB)
PUSCH eMBB DDDSU	4	123.47	5.96	0.36	-11.41	-15.20
PUSCH eMBB DDSU	2	117.70	0.28	-5.41	-17.18	-20.97
PUSCH VoIP	4	130.46	0.29	7.35	-4.42	-8.21
PUCCH Format 1	3	129.27	0.20	6.17	-5.60	-9.39
PUCCH Format 3 11bits	3	126.81	2.76	3.71	-8.06	-11.85
PUCCH Format 3 22bits	3	124.81	2.81	1.71	-10.06	-13.85
SSB	1	152.35	0.00	29.25	17.48	13.69
PUSCH of Msg3	1	124.48	0.00	1.38	-10.39	-14.18
PDCCH	4	148.90	1.97	25.80	14.03	10.24
PDSCH eMBB DDDSU	4	146.25	7.68	23.15	11.38	7.59
PDSCH eMBB DDSU	1	153.92	0.00	30.82	19.05	15.26

From the representative values for Suburban 28GHz TDD NLOS O2O scenario, the following observations can be made:

For 1st priority channels (with more than 2 available samples):

- Absolute MPL targets corresponding to ISD target 200m is met by all channels. No 1st priority UL channel can meet the absolute MPL target if the target ISD is set to 400m and 500m. Conversely, if ISD target is set to 200m then only PUSCH eMBB DDDSU and PUSCH VoIP DDDSU do not meet the absolute MPL target.

- With relative differential MIL target using PUCCH Format 1 as reference, 1st priority channels which display lower coverage than the reference are:

  - PUSCH eMBB DDDU

  - PUSCH VoIP DDDSU

  - PUCCH Format 3 11bits

  - PUCCH Format 3 22bits

For 2nd priority channels (with less than 3 available samples):

- Absolute MPL targets corresponding to target ISD 200m is met by all channels. Absolute MPL targets corresponding to target 400m or 500m cannot be met by any 2nd priority channel.

- With relative differential MIL target using PUCCH Format 1 as reference, 2nd priority channels which display lower coverage than the reference, and the corresponding gaps to the reference MIL are:

  - PUSCH for Msg3

  - PUSCH eMBB DDSU

5.2.2 Bottleneck identification by representative values

Bottleneck identification is performed by the following procedure:

- The potential bottleneck channels identified by absolute metrics, then

- The potential bottleneck channels identified by absolute metrics can be further filtered by using relative difference between channels in MIL

The result of the bottleneck channel identification by the procedure above is summarized in Table 5.2.2-1, where no aspect related to the deprioritized Suburban scenario is captured.

Table 5.2.2-1: Potential bottleneck channels for FR2

Scenario	Target metrics	Channels (and Frame format)	MIL			
			Number of samples	Representative value	Standard Deviation (w/o outlier)	Relative difference vs. PUCCH Format 1
Urban 28GHz TDD NLOS O2I	Scenario dependent target ISD=200m	PUSCH eMBB DDDSU	9	125.31	3.78	-17.83
		PUSCH eMBB DDSU	3	123.94	1.74	-19.20
		PUCCH Format 3 11bits	8	142.27	3.16	-0.86
		PUCCH Format 3 22bits	7	139.18	2.58	-3.96
		PRACH Format B4	6	141.22	5.70	-1.92
		PUSCH of Msg3	7	139.72	5.69	-3.41
Urban 28GHz TDD NLOS O2O	Scenario dependent target ISD=200m	PUSCH eMBB DDDSU	9	123.60	1.73	-20.10
		PUSCH eMBB DDSU	3	123.99	1.78	-19.71
		PRACH Format B4	5	136.13	0.88	-7.57

The following channels were identified as the potential bottleneck channels for Urban 28 GHz scenario:

- PUSCH eMBB (DDDSU and DDSU)

- PUSCH VoIP (DDDSU and DDSU)

- PUCCH F3 11bits

- PUCCH F3 22bits
- PRACH B4
- PUSCH of Msg3

Note: PRACH Format B4 is reference to assess how many additional dBs over the baseline PRACH enhancements may target. PUCCH Format 3 with either 11 bits or 22 bits or both is reference to assess how many additional dBs over the baseline PUCCH Format 3 enhancements may target.

No evident coverage bottleneck was identified for Indoor scenario for FR2.

5.2.3 Observation from the simulation result not using representative values

One source (R1-2007742) evaluated the target performance, i.e. the 5th percentile geometry SINR value, based on system-level simulation. Compared to the baseline performance, i.e., required SNR based on link level simulation, the following is observed.

- In Indoor 28 GHz scenario, only PUSCH eMBB requires coverage compensation.
- In Urban 28 GHz O2I scenario, PUSCH eMBB, Msg3, PRACH Format B4, PUCCH Format 3 11 bits, PUCCH Format 3 22 bits, PBCH, PDSCH eMBB and Msg4 require coverage compensation.
- In Urban 28 GHz O2O scenario, only PUSCH eMBB requires coverage compensation.

6 Potential techniques for coverage enhancements

6.1 PUSCH coverage enhancements

6.1.1 Time-domain based solutions

Time domain based solutions are studied, including enhancements on PUSCH repetition type A, enhancement on PUSCH repetition Type B, TB processing over multi-slot PUSCH, OCC spreading based repetition, symbol-level repetition, TB interleaving, RV repetition, and early termination of PUSCH repetitions.

Enhancements on PUSCH repetition type A were studied from several aspects, including increasing the maximum number of repetitions, the number of repetitions counted on the basis of available UL slots and flexible symbol resource allocation in different slots. Potential specification impacts of enhancements on increasing the maximum number of repetitions include: TDRA (Time-Domain Resource Allocation). Potential specification impacts of enhancements on the number of repetitions counted on the basis of available UL slots include: TDRA (Time-Domain Resource Allocation), mechanism to determine transmission occasion of actual repetition, and mechanism to determine whether special slot can be determined as an available UL slot. Potential specification impacts of enhancements on flexible symbol resource allocation in different slots include: TDRA (Time-Domain Resource Allocation) and mechanism to determine UL symbols for each slot.

Enhancements on PUSCH repetition type B were studied from several aspects, including actual PUSCH transmission across the slot boundary/invalid symbols, the length of actual repetition larger than 14 symbols, and RV enhancement. Potential specification impacts of enhancements on PUSCH repetition type B include: TBS determination, DM-RS pattern, TDRA (Time-Domain Resource Allocation), RV determination. Note that power consistency and phase continuity may or may not be required depending on factors such as cross-slot channel estimation, etc.

TB processing over multi-slot PUSCH was studied from several aspects, including TBS determined based on single slot and transmitted in parts over multiple slots, TBS determined based on multiple slots and transmitted over multiple slots. Potential specification impacts of TB processing over multi-slot PUSCH include: TDRA (Time-Domain Resource Allocation), TBS determination, RV determination. Note that power consistency, phase continuity and enhancements for DM-RS configurations may or may not be required depending on factors such as cross-slot channel estimation, etc.

Seven sources (R1-2008874, R1-2007743, R1-2007954, R1-2008557, R1-2007930, R1-2008479, R1-2007583) evaluate the performance of enhancements on PUSCH repetition type A.

- One source (R1-2008874) shows 3.2 dB (O2I) and 4 dB (O2O) SNR gain when the actual number of repetition is increased from 3 to 8 (counted on the basis of available UL slots) for VoIP at 2% rBLER for FR1 TDD, compared to Rel-16 PUSCH repetition type A with 8 nominal repetitions. HARQ is not used.

- One source (R1-2007743) shows 1.0~1.5 dB SNR gain for PUSCH transmission with 4 repetitions and maximum 1 re-transmissions (maximum 8 actual transmissions in total, redundancy version {0, 2, 3, 1}) for VoIP at 2% rBLER for FR1 TDD 4GHz with 'DDDSUDDSUU' configured by 16 repetitions, compared to PUSCH transmission with 2 repetitions and maximum 3 re-transmissions (maximum 8 actual transmissions in total, redundancy version {0, 2}).

- One source (R1-2008557) shows 6.8 dB SNR gain, when the actual number of repetition is increased for VoIP at 2% rBLER for FR1 TDD, compared to Rel-16 PUSCH repetition type A. HARQ is not used.

- One source (R1-2007954) shows 2.0 dB SNR gain, when the actual number of repetition is doubled for eMBB with the TBS fixed at 136 bits at 10% iBLER for FR1 FDD, compared to Rel-16 PUSCH repetition type A with 8 repetitions. HARQ is not used.

- One source (R1-2008479) shows 0.8 dB SNR gain with the repetition and the frequency hopping is enabled for eMBB at 10% iBLER for FR1 FDD. The TBS is changed to keep the target data rate 100kpbs for with or without repetition.

- One source (R1-2007583) shows about 2.0 dB SNR gain when the actual number of repetition is doubled, e.g. from 2 to 4, from 4 to 8, for eMBB at 10% iBLER for FR1 TDD. HARQ is not used. Note: the observed gain was for different data rates where the data rate was sometimes less than the required 100kbps for the eMBB use case.

- One source (R1-2007583) shows about 8.1dB SNR gain for PUSCH transmission with 3 retransmissions combined with 4 actual repetitions for VoIP at 2% rBLER for FR1 TDD, compared to PUSCH transmission with no repetition and no retransmission.

- One source (R1-2007930) shows when the TBS is adjusted to maintain the target data rate of 100kbps, +0.4, +0.2, -1.6 dB SNR gain was observed when the number of repetitions was increased to 4, 8, 16 respectively for eMBB at 10% iBLER for FR1 FDD using Rel-16 PUSCH repetition type A.

Table 6.1.1-1 Performance evaluation for enhancements on PUSCH repetition type A

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2008874)	FR1		3.2 dB	DDDSUDDSUU, O2I, repetitions counted on the basis of available UL slots
			4.0 dB	DDDSUDDSUU, VoIP, O2O, repetitions counted on the basis of available UL slots
Source 2 (R1-2007743)	FR1		1~1.5 dB	Rural, O2O, 2 DMRS symbols. Baseline scheme: 2 repetitions with maximum 3 re-transmissions (Max 8 transmissions) Enhanced scheme: 4 repetitions with maximum 1 re-transmission (Max 8 transmissions).
Source 3 (R1-2007954)	FR1	~2.0dB		~2dB performance gain can be observed when doubling the repetition level. Rural 3km/h, 700MHz, FDD, TBS = 136 bits, MCS 0, 2 DMRS symbols, 12 data symbols
Source 4 (R1-2008557)	FR1	6.4 dB	6.8 dB	Comparing w and w/o repetition (number of repetition is 4) To support repetition for e.g. DDDSU, new mechanism is necessary
Source 5 (R1-2007930)	FR1	0.4 dB		Keeping the target data rate= 100kbps Simulation assumptions: Rural 3km/h, 700MHz, FDD Baseline: no repeats, TBS=112,100kbps Enhancement: Repetitions = 4, TBS = 456, 100kbps
		0.2 dB		Keeping the target data rate= 100kbps Simulation assumptions: Rural 3km/h, 700MHz, FDD Baseline: no repeats, TBS=112,100kbps Enhancement: Repetitions = 8, TBS = 888, 100kbps
		-1.6 dB		Keeping the target data rate = 100kbps Simulation assumptions: Rural 3km/h, 700MHz, FDD Baseline: no repeats, TBS=112,100kbps Enhancement: Repetitions = 16, TBS = 1800, 100kbps
Source 6 (R1-2008479)	FR1	~2.2dB		About 2.2dB gain is observation if the repetition number is doubled. FDD 700MHz MCS=120/1024 4PRB, No frequency hopping, 1DMRS symbol, 3km/h
		0.8dB		Keeping the target data rate, with frequency hopping. MCS=120/0124 without repetition; MCS=251/1024with one more repetition. Details are in R1-2008479
Source 7 (R1-2007583)	FR1		8.1dB	Compared with no repetition, no retransmission, 8.1dB gain is obtained in TDD (DDDSUDDSUU) with 3 retransmissions combined with 4 actual repetitions.
		~2dB		By double the actual repetition for eMBB, ~2dB gain can be obtained.

Five sources (R1-2008874, R1-2007743, R1-2007680, R1-2009583, R1-2009647) evaluate the performance of enhancements on PUSCH repetition type B.

- Three sources (R1-2008874, R1-2009583, R1-2009647) show 0.2~2.0 dB SNR gain when the actual PUSCH transmission can cross the slot boundary, cross-slot channel estimation is used, and the length of actual repetition can be larger than 14 symbols for VoIP at 2% rBLER for FR1 TDD, compared to Rel-16 PUSCH repetition type B without joint channel estimation. HARQ is not used.

- One source (R1-2007743) show 0.8 dB required SNR gain when the actual PUSCH transmission can across the slot boundary or the length of actual repetition can be larger than 14 symbols and cross-slot channel estimation is used for VoIP at 2% rBLER for FR1 TDD, compared to Rel-16 PUSCH repetition type B without joint channel estimation. HARQ is not used. Same TB size is used for both baseline and enhancement.

- One source (R1-2009647) shows around 1.4 dB SNR gain when the actual PUSCH transmission can cross the slot boundary, cross-slot channel estimation is used, and the length of actual repetition can be larger than 14 symbols for VoIP at 2% rBLER for FR2 TDD, compared to Rel-16 PUSCH repetition type B without joint channel estimation.

- One source (R1-2009583) shows 0.33~1.3 dB SNR gain when the actual PUSCH transmission can cross the slot boundary, cross-slot channel estimation is used, and the length of actual repetition can be larger than 14 symbols for eMBB at 10% iBLER for FR1 TDD, compared to Rel-16 PUSCH repetition type B with 14-symbol actual repetition. HARQ is not used.

- One source (R1-2009583) shows the number of RBs can be reduced from 38 to 33, when the actual PUSCH transmission can cross the slot boundary, cross-slot channel estimation is used, and the length of actual repetition can be larger than 14 symbols for VoIP at 2% rBLER for FR1 TDD, compared to Rel-16 PUSCH repetition type B with 14-symbol actual repetition. HARQ is not used.

- One source (R1-2009583) shows the number of RBs can be reduced from 30 to 26, when the actual PUSCH transmission can cross the slot boundary, cross-slot channel estimation is used, and the length of actual repetition can be larger than 14 symbols for eMBB at 10% iBLER for FR2 TDD, compared to Rel-16 PUSCH repetition type B with 14-symbol actual repetition. HARQ is not used.

- One source (R1-2007680) shows around 2.0 dB SNR gain for RV enhancement for eMBB at 10% iBLER for FR 1 TDD, compared to Rel-16 PUSCH repetition type B without joint channel estimation.

Table 6.1.1-2 Performance evaluation for enhancement on PUSCH repetition Type B

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2008874)	FR1		0.8 dB	DDDSUDDSUU, O2I/O2O, across slot boundary, length > 14 OS
Source 2 (R1-2007743)	FR1		0.8 dB	4GHz, 'DDDSU' (S: 10D:2G:2U) Baseline scheme: 14-symbol PUSCH, MCS#5 Enhanced scheme: 16-symbol PUSCH, MSC#4
	FR1		0.8 dB	4GHz, 'DDDSU' (S: 10D:2G:2U) Baseline scheme: PUSCH of 2 repetitions, and the length of each nominal repetition is L=8. Enhanced scheme: Actual repetition can cross slot boundary. The duration of each actual repetition is L=8.
Source 3 (R1-2007680)	FR1	2dB		For some RV and TDD configuration, especially for RV0 or RV3 with higher transmission code rate due to limited symbols for actual repetition.
Source 4 (R1-2009583)	FR1		2dB	4GHz, DDDSU, rural, 3km/hr, 3PRBs, 2 DMRS, Baseline scheme: 14-symbol PUSCH, MCS#7 Enhancement: 16-symbol extended PUSCH, MCS#5
		0.38dB		4GHz, DDDSU, rural, 120km/hr, 3PRBs, MCS#5 Baseline scheme: 14-symbol PUSCH, 4 DMRS Enhancement: 16-symbol extended PUSCH, 5 DMRS
			0.36dB	4GHz, DDDSU, rural 120km/hr, 2PRBs MCS#9 Baseline scheme: 14-symbol PUSCH, 4 DMRS Enhancement: 16-symbol extended PUSCH, 5 DMRS
			0.2dB	4GHz, DDDSU, rural 120km/hr, 2PRBs, MCS#8 Baseline scheme: 14-symbol PUSCH, 2 DMRS Enhancement: 16-symbol extended PUSCH, 3 DMRS
		0.33dB		4GHz, DDDSU, rural 120km/hr, 5 PRBs, MCS#2 Baseline scheme: 14-symbol PUSCH, 3 DMRS Enhancement: 16-symbol extended PUSCH, 4 DMRS
	FR2	30PRB→26PRB		PUSCH, 28GHz, DDDSU, eMBB, 2DMRS, indoor, (Gain in terms of the number of RBs reduced), MCS#5 Baseline scheme: 14-symbol PUSCH Enhancement: 16-symbol extended PUSCH
	FR1		38PRB→33PRB	PUSCH, 4GHz, DDDSU, VoIP, rural, 2DMRS,pi/2 BPSK (Gain in terms of the number of RBs reduced) , MCS#0

				Baseline scheme: 14-symbol PUSCH Enhancement: 16-symbol extended PUSCH
	FR1	1.3dB		PUSCH, 4GHz, DDDSU, eMBB, rural, QPSK, 4 PRB, 120km/hr Baseline scheme: 14-symbol PUSCH, 2DMRS, MCS#3 Enhancement: 16-symbol extended PUSCH, 3DMRS, MCS#2
Source 5 (R1-2009647)	FR1		1.75 dB	4GHz O2I, DDDSUDDDSU, max # of HARQ tx: 4, Latency: 50 ms, TBS: 368, For VoIP, 2% rBLER Baseline scheme: PUSCH symbol length: {2, 14, 2, 14} Enhancement: PUSCH symbol length: 16
	FR2		1.4 dB	28GHz O2I, DDDSUDDDSU, max # of HARQ tx: 16, Latency: 50 ms, TBS: 368, For VoIP, 2% rBLER Baseline scheme: PUSCH symbol length: {2, 14, 2, 14} Enhancement: PUSCH symbol length: 16

Seven sources (R1-2008874, R1-2007905, R1-2007954, R1-2008626, R1-2009583, R1-2009792, R1-2007930) evaluate the performance of TB processing over multi-slot PUSCH.

- Two sources (R1-2008874, R1-2008626) show 0.6~2 dB SNR gain when TBS determined based on multiple slots and transmitted over multiple slots for VoIP at 2% rBLER for FR1, compared to TB is determined based on single slot with repetition in Rel-16. HARQ is not used. If HARQ is enabled, legacy transmissions incur increased frequency domain resource use and a fair comparison cannot be made. Different redundancy version {0, 2, 3, 1} is used for repetitions in R1-2008874. The same redundancy version is used for repetitions in R1-2008626. Gains due to reduction in upper-layer (MAC/RLC/PDCP) headers is not reflected in R1-2008626.

- Two sources (R1-2008874, R1-2008626) show 1.0~2.7 dB SNR gain when TBS determined based on multiple slots and transmitted over multiple slots for eMBB at 10% iBLER for FR1, compared to TB is determined based on single slot with repetition in Rel-16. HARQ is not used. If HARQ is enabled, legacy transmissions incur increased frequency domain resource use and a fair comparison cannot be made. Different redundancy version {0, 2, 3, 1} is used for repetitions in R1-2008874. The same redundancy version is used for repetitions in R1-2008626. Gains due to reduction in upper-layer (MAC/RLC/PDCP) headers is not reflected in R1-2008626.

- One source (R1-2007905) shows 0.8 dB SNR gain when TBS determined based on multiple slots and transmitted over multiple slots for eMBB at 10% iBLER for FR1, compared to TB is determined based on single slot with repetition in Rel-16. HARQ is not used. The same redundancy version is used for repetitions.

- One source (R1-2009792) show 1.0 dB SNR gain when TBS determined based on multiple slots and transmitted over multiple slots for eMBB at 10% iBLER for FR1 and cross-slot channel estimation is used, compared to TB is determined based on single slot with repetition in Rel-16 without cross-slot channel estimation. HARQ is not used. The same redundancy version is used for repetitions.

- One source (R1-2009583) shows 0.4 and 2.0 dB SNR gain and with different number of aggregated slots and modulation schemes when TBS determined based on multiple slots and transmitted over multiple slots for VoIP at 2% rBLER for FR1 FDD and cross-slot channel estimation is used, compared to TB is determined based on single slot without repetition in Rel-16. HARQ is not used. Up to 10dB power boosting gain can be obtained depending on different number of aggregated slots when TBS determined based on multiple slots and transmitted over multiple slots for FR1 FDD VoIP.

- One source (R1-2009583) shows 0~1.75 dB SNR gain when TBS determined based on multiple slots and transmitted over multiple slots for eMBB at 10% iBLER for FR1 and cross-slot channel estimation is used, compared to TB is determined based on single slot without repetition in Rel-16. HARQ is not used. Up to 6.98 dB power boosting gain can be obtained depending on the number of aggregated slots when TBS determined based on multiple slots and transmitted over multiple slots for FR1 eMBB.

- One source (R1-2007954) shows 0.2 dB SNR gain and 6.2 dB link budget gain when TBS determined based on multiple slots and transmitted over multiple slots for VoIP at 2% rBLER for FR1 TDD, compared to TB is determined based on single slot without repetition in Rel-16. HARQ is not used.

- One source (R1-2007930) shows 2 (w/ frequency hopping) and 2.5 dB (w/o frequency hopping) SNR gain when TBS determined based on multiple slots and transmitted over multiple slots with gaps for eMBB at 10% iBLER, compared to Rel-16 where repeats are scheduled over contiguous slots. HARQ is not used. Perfect channel estimation is assumed.

Table 6.1.1-3 Performance evaluation for TB processing over multi-slot PUSCH

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2008874)	FR1		1.0 dB	DDDSUDDSUU, O2I, TBS based on 4 slots
			0.6 dB	DDDSUDDSUU, O2O, TBS based on 4 slots
		2.7 dB		DDDSUDDSUU, rural, O2O, TBS based on 4 slots
Source 2 (R1-2007905)	FR1	0.8 dB		2 slots aggregation, TBS based on 2 slots, DDDSU, rural TDL-D, 30ns
Source 3 (R1-2007954)	FR1		~0.2dB	Baseline scheme 1: 4 PRBs in a slot, 14 symbols. TB spanning multiple slots: 1 PRB spanning 4 slots Link level simulation results for these two schemes are similar, but link budget gain of ~6dB for TB spanning 4 slots over baseline scheme can be observed. Simulation assumption: 3km/h, 4 GHz, TDD with DDDSU
Source 4 (R1-2008626)	FR1	1-2 dB	1-2 dB	Baseline: 1 PRB/slot. TB sized per slot. Proposal: Aggregate PRBs across multiple slots. Size TB for total aggregated resources. Observation: 2 slot aggregation results in ~1 dB gain, while 4 slot aggregation results in 2 dB gain. Additional gain due to overhead reduction is not included here.
Source 5 (R1-2009583)	FR1	0~1.0dB		TBS determined based on multiple slots and transmitted over multiple slots, 700MHz FDD, TB over 2 or 3 slots, QPSK, 3km/hr, Compared to the baseline, up to 3dB and 4.7dB power boosting gain is possible for 2 and 3 slot transmission scheme, respectively.
		1.0dB		TBS determined based on multiple slots and transmitted over multiple slots, 700MHz FDD, TB over 3 slots, pi/2 BPSK, 3km/hr, Compared to the baseline, up to 4.7dB power boosting gain is possible
		0.43dB~1.75dB		TBS determined based on multiple slots and transmitted over multiple slots, 4GHz, TDD, rural, TB over 2 or 5 slots, QPSK, 3km/hr, Compared to the baseline, up to 3dB and 6.98 dB power boosting gain is possible for 2 and 5-slot transmission scheme, respectively
			2.0dB	TBS determined based on multiple slots and transmitted over multiple slots, 700MHz, FDD, TB over 6 slots, QPSK, 3km/hr, Compared to the baseline, up to additional 7.7 dB power boosting gain is possible
			0.4dB	TBS determined based on multiple slots and transmitted over multiple slots, 700MHz, FDD, TB over 10 slots, pi/2 BPSK, 3km/hr, Compared to the baseline, up to 10dB power boosting gain is possible
Source 6 (R1-2009792)	FR1	1 dB		Rural 700MHz, FDD, 15kHz SCS, 2 DMRS symbols per slot, UE speed: 3km/h; Target throughput: 100kbps

				Baseline scheme: 4 PRBs, TBS = 432 bits, MCS11 (table 3), 4 repetitions (type A). Enhanced scheme: 4 PRBs, TBS = 432 bits, MCS5 (table 3), transmitted over time resource of 4 slots, no repetition.
Source 7 (R1-2007930)	FR1	2.5		Simulation Assumptions: No FH, Rural, 30km/h, 8 Repetitions, 100kbps Baseline: Repetitions sent contiguously (i.e. no gaps) Enhancement: Gaps between Repeats= 7 slots
		2.0		Simulation Assumption: With FH, Rural, 30km/h, 8 Repetitions, 100kbps Baseline: Repetitions sent contiguously (i.e. no gaps) Enhancement: Gaps between Repeats= 7 slots

One source (R1-2008378) evaluates the performance of symbol level repetition and shows around 0.4 dB SNR gain for UE speed 3km/h and around 0.3dB SNR loss for UE speed 120km/h, respectively, for eMBB at 10% iBLER for FR1, compared to Rel-16 PUSCH repetition type A.

Table 6.1.1-4 Performance evaluation for symbol level repetition

Source	Solutions	Performance gain	Key Assumptions
R1-2008378	Symbol-level repetition	0.4 dB (3km/h) -0.3 dB (120km/h)	Rural, 4 GHz, DDDSUDDSUU, 3 km/h/120km/h 4PRBs, 2 repetitions, w/o HARQ Baseline: PUSCH repetition Type A w/o cross-slot channel estimation 3 km/h: Type 1, 2 DMRS symbol, no multiplexing with data 120 km/h: Type 1, 3 DMRS symbol, no multiplexing with data

6.1.2 Frequency-domain based solutions

Frequency domain based solutions are studied, including enhancements on inter-slot/intra-slot frequency hopping, enhancements on frequency hopping for PUSCH repetition type B, sub-PRB transmission for VoIP.

Enhancements on inter-slot frequency hopping were studied from several aspects, including more frequency offsets, e.g. 4 for BWP less than 50 PRBs, 8 for BWP greater than 50 PRBs, and more frequency hopping positions, e.g. 4. Potential specification impacts of enhancements on inter-slot frequency hopping include: frequency domain hopping offsets/positions.

Enhancements on intra-slot frequency hopping were studied from several aspects, including more frequency offsets, e.g. 4 for BWP less than 50 PRBs, 8 for BWP greater than 50 PRBs, more frequency hopping positions, e.g. 3, more time-domain hop positions within a slot, e.g. 3, and DM-RS sharing among multiple PUSCH transmissions with the same frequency position between two consecutive slots [related to clause 6.1.3]. Potential specification impacts of enhancements on intra-slot frequency hopping include: Frequency domain hopping offsets, DM-RS pattern, TBS determination, power consistency and phase continuity for DM-RS sharing among multiple PUSCH transmissions.

Sub-PRB transmission for VoIP was studied from several aspects, including number of tones, sub-PRB transmission with single slot and sub-PRB transmission with multi-slot aggregation. Potential specification impacts of sub-PRB transmission with single slot include: frequency domain resource allocation, TBS determination, DM-RS pattern, hopping pattern within/between the PRBs, PUSCH signal generation for DFT-s-OFDM waveform, RF requirement. Potential specification impacts of sub-PRB transmission with multi-slot aggregation include: frequency domain resource allocation, time domain resource allocation, TBS determination, DM-RS pattern, RV determination, hopping pattern within/between the PRBs, PUSCH signal generation for DFT-s-OFDM waveform, RF requirement.

Six sources (R1-2007743, R1-2007954, R1-2009729, R1-2007680, R1-2008419, R1-2007583) evaluate the performance of inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions.

- Five sources (R1-2007743, R1-2007954, R1-2007680, R1-2008419, R1-2007583) show 0.3~1.7 dB SNR gain for inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions for eMBB at

10% iBLER for FR1, compared to Rel-16 inter frequency hopping. Cross-slot channel estimation is not used, 2 RX is assumed for gains higher than 0.3dB, 300ns is assumed for gains higher than 0.3dB.

- One source (R1-2009729) shows no gain for inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions for eMBB at 10% iBLER for FR1, compared to Rel-16 inter frequency hopping.
- One source (R1-2008419) shows no gain for inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions and joint channel estimation over multiple slots is implemented for eMBB at 10% iBLER for FR1, compared to Rel-16 inter frequency hopping with joint channel estimation over multiple slots.

Table 6.1.2-1 Performance evaluation for enhancements on inter-slot frequency hopping

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2007743)	FR1	0.5 dB		4GHz, Rural, MCS#2, one DMRS per hop Baseline scheme: 2 FH positions Enhanced scheme: 4 FH positions
Source 2 (R1-2007954)	FR1	0.3dB		Rural 3km/h, 700MHz, FDD, TBS=136 bits, MCS 0, 8 repetitions, 2 DMRS symbols, 12 data symbols For 4 Rx antennas, ~0.3dB performance gain can be achieved for 4 frequency hops compared to 2 frequency hops.
		1.5dB		Same simulation assumptions as above. For 2 Rx antennas, ~1.5dB performance gain can be achieved for 4 frequency hops compared to 2 frequency hops.
Source 3 (R1-2009729)	FR1	0 dB		Scenario: Urban 4GHz with 64 TXRUs. Baseline: 4 repetitions with 2 inter-slot frequency hops. Comparison: 4 repetitions with 4 inter-slot frequency hops.
Source 4 (R1-2007680)	FR1	1dB		More frequency hopping locations, no offsets, from 2 hops to 4.
Source 5 (R1-2008419)	FR1	1.3 dB (LLS)		4 hops vs. 2 hops, no cross-slot est. 1% BLER For 300ns delay spread, 3kmph, 2 Rx, 2 DMRS 4 PRBs, MCS0, 700 MHz 8 repetitions (no retransmissions) Details in R1-2008419
		0.3 dB (LLS)		4 hops vs. 2 hops, no cross-slot est. 1% BLER For 30ns delay spread, 3kmph, 2 Rx, 2 DMRS 4 PRBs, MCS0, 700 MHz 8 repetitions (no retransmissions) Details in R1-2008419
		0 dB (LLS)		4 hops vs. 2 hops, with cross-slot est. 1% BLER For 30ns delay spread, 3kmph, 2 Rx, 2 DMRS 4 PRBs, MCS0, 700 MHz 8 repetitions (no retransmissions) Details in R1-2008419
Source 6 (R1-2007930)	FR1	1 dB		Simulation assumptions: Rural 3km/h, 700MHz, FDD, TBS = 456, Repeats = 4,100kbps, 2 DMRS/slot, 2 Rx Antennas Baseline: no FH Enhancement: 2 FH positions

Source 7 (R1-2007583)	FR1	1.7dB		Baseline scheme: no FH positions Enhanced scheme: 2 FH positions 30RB, MCS3, 300ns, 4GHz, 1T4R
		0.8dB		Baseline scheme: 2 FH positions Enhanced scheme: 4 FH positions 30RB, MCS3, 300ns, 4GHz, 1T4R
			0.75	Compared with 3 retransmissions combined with 4 actual repetitions for VoIP, 0.75 dB gain is obtained with inter slot frequency hopping at Urban scenario @4GHz DDDSUDDSUU.

Four sources (R1-2008874, R1-2009647, R1-2007680, R1-2007930) evaluate the performance of sub-PRB transmission with multi-slot aggregation.

- One source (R1-2008874) shows around 0.8 dB link budget gain for sub-PRB transmission with multi-slot aggregation (6 tones) for VoIP at 2% rBLER for FR1, compared to Rel-16 PRB-based transmission with repetition. HARQ is not used. Different redundancy version {0, 2, 3, 1} is used for Rel-16 PRB-based transmission with repetition.
- One source (R1-2009647) shows around 5.6 dB link budget gain for sub-PRB transmission with multi-slot aggregation (6 tones) for VoIP at 2% rBLER for FR1, compared to Rel-16 PRB-based transmission with 4 PRBs without repetition. HARQ is not used.
- One source (R1-2009647) shows around 1.6 and 8.5 dB link budget gain for sub-PRB transmission with multi-slot aggregation (6 tones) for eMBB at 10% iBELR for FR1, respectively, depending on the number of aggregation slots, compared to Rel-16 PRB-based transmission with 1 PRB and 4 PRBs, respectively without repetition. HARQ is not used.
- One source (R1-2007930) evaluated the performance of sub-PRB transmission with 2 tones which showed 7 dB PAPR reduction. This PAPR reduction allows for MPR relaxation for VoIP use case at 2% rBLER for FR1, compared to Rel-16 PRB-based transmission with DFT-s-OFDM.
- One source (R1-2007680) shows no gain for sub-PRB transmission with multi-slot aggregation (6 tones) for VoIP at 2% rBLER for FR1, compared to Rel-16 PRB-based transmission with repetition. HARQ is not used.

Table 6.1.2-2 Performance evaluation for sub-PRB transmission

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2008874)	FR1		0.8 dB	DDDSUDDSUU, O2O, half PRB and 8 slots
Source 2 (R1-2009647)	FR1		5.6 dB	DDDSUDDSUU, TBS=80 per 5ms, 2.7 times smaller T-F resource for subPRB (4PRB*1slot vs 0.5PRB*3slots), TDL-A, Delay spread: 30ns, SCS=30KHz, 4Ghz Note: Required SNR: rel-16 is better with 3.4dB; Occupied BW (thus noise power): sub-PRB is better as 9dB;
		8.5dB		TBS=50 (per transmission), TDL-C, Delay spread: 300ns, Same T-F resource (4PRB*1slot vs 0.5PRB*8slots), SCS=30KHz, 4Ghz Note: Required SNR: rel-16 is better with 0.5dB; Occupied BW (thus noise power): sub-PRB is better as 9dB;
		1.6dB		TBS=50 (per transmission), TDL-A, Delay spread: 30ns, Same T-F resource (1PRB*1slot vs 0.5PRB*2slots), SCS=30KHz, 4Ghz Note: Required SNR: rel-16 is better with 1.4dB;

				Occupied BW (thus noise power): sub-PRB is better as 3dB;
Source 3 (R1-2007680)	FR1		0dB	Sub-PRB with the whole TB transmitted over 2 slots compared to repetition type A with 2 repetitions
Source 4 (R1-2007930)	FR1		0~5 dB	No MCL gain. Gain comes from reduction in MPR and A-MPR due to reduction in PAPR/CM. 2 tone Pi/2 BPSK (i.e. LTE-M sub-PRB solution with near zero PAPR)

One source (R1-2008874) evaluates the performance of enhanced intra-slot frequency hopping with more frequency offsets/ more frequency hopping positions and shows around 1.8 dB SNR gain for VoIP at 2% rBLER and 0.4 dB SNR gain for eMBB at 2% rBLER for FR1, compared to Rel-16 intra-slot frequency hopping.

Table 6.1.2-3 Performance evaluation for enhanced intra-slot frequency hopping

Source	Solutions	Performance gain		Key Assumptions
		eMBB	voice	
R1-2008874	Enhanced intra-slot frequency hopping		1.8 dB	DDDSUDDSUU, O2O
		0.4 dB		DDDSUDDSUU, rural O2I

6.1.3 DM-RS enhancements

DM-RS enhancements are studied, including joint channel estimation or DM-RS bundling, enhancements on DM-RS density, adaptive configuration, and DM-RS balancing among frequency hops.

Joint channel estimation or DM-RS bundling with/without optimization of DMRS location/granularity was studied from several aspects, including cross-slot channel estimation over consecutive slots, cross-slot channel estimation over non-consecutive slots, cross-repetition channel estimation within one slot, and inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation. Potential specification impacts of joint channel estimation or DM-RS bundling include: power consistency and phase continuity, DM-RS placement in special slot and DM-RS configuration, Time domain hopping interval for inter-slot frequency hopping with inter-slot bundling.

Enhancements on DM-RS density were studied from several aspects, including lower DM-RS density in time domain, DM-RS sharing among multiple PUSCH transmissions in the time domain, lower DMRS density in frequency domain, 1-comb DM-RS, e.g., DM-RS with single port spans to occupy the whole DM-RS symbol, and additional DM-RS symbol position in a slot. Potential specification impacts of lower DM-RS density in time domain, and DM-RS sharing among multiple PUSCH transmissions include: DM-RS pattern and configuration, power consistency, phase continuity, and TBS determination. Potential specification impacts of lower DMRS density in the frequency domain include: DM-RS design, DM-RS pattern and configuration. Potential specification impacts of 1-comb DM-RS include: DM-RS design, and TBS determination. Potential specification impacts of additional DM-RS symbol position in a slot include: DM-RS position.

Adaptive DM-RS configuration was studied. Potential specification impacts include: related signaling design.

DM-RS balancing among frequency hops was studied. Potential specification impacts include: related signaling design, DMRS configuration and pattern.

Fifteen sources (R1-2008874, R1-2007743, R1-2007954, R1-2008626, R1-2008399, R1-2008378, R1-2008559, R1-2009647, R1-2008026, R1-2007680, R1-2008419, R1-2009792, R1-2008479, R1-2009583, R1-2007583) evaluate the performance of joint channel estimation.

- Eleven sources (R1-2008874, R1-2007743, R1-2008626, R1-2008399, R1-2008378, R1-2008026, R1-2007680, R1-2008419, R1-2009792, R1-2008479, R1-2007583) show 0.2~2.1 dB SNR gain for joint channel estimation over multiple slots for eMBB at 10% iBLER depending on the number of slots for FR1, compared to Rel-16 PUSCH transmission without joint channel estimation.

- One source (R1-2007954) shows 2 dB SNR gain for joint channel estimation over multiple non-consecutive slots with inter-slot frequency hopping for eMBB at 10% iBLER, compared to Rel-16 inter-slot frequency hopping without joint channel estimation.
- Three sources (R1-2009647, R1-2008559) show 0.9~1.3 dB SNR gain for joint channel estimation over multiple slots for VoIP at 2% rBLER depending on the number of slots for FR1, compared to Rel-16 PUSCH transmission without joint channel estimation.
- One source (R1-2009583) shows 0.3 dB SNR gain for joint channel estimation over multiple slots with DMRS in a special slot for VoIP at 2% rBLER, compared to Rel-16 PUSCH transmission without joint channel estimation.
- One source shows (R1-2009647) 0.85~1.1 dB SNR gain for joint channel estimation over multiple slots for VoIP at 2% rBLER depending on the number of slots for FR2, compared to Rel-16 PUSCH transmission without joint channel estimation.
- One source (R1-2007680) shows 0.8 dB SNR gain for joint channel estimation over multiple repetition within a slot, compared to Rel-16 PUSCH transmission without joint channel estimation.
- Two sources (R1-2008026, R1-2007680) show 1.0~1.22 dB required SNR gain for lower DM-RS density in time domain with joint channel estimation and using multi-slot PUSCH with 4 symbols in the special slot over multiple slots for eMBB at 10% iBLER for FR1, compared to Rel-16 DM-RS density without joint channel estimation.
- One source (R1-2007680) shows 1.0 dB required SNR gain for lower DM-RS density in time domain with joint channel estimation over multiple repetition within a slot for eMBB at 10% iBLER for FR1, compared to Rel-16 PUSCH transmission without joint channel estimation.

Table 6.1.3-1 Performance evaluation for joint channel estimation

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2008874)	FR1	0.4 dB		DDDSUDDSUU, rural O2I, 2 slots
		0.8 dB		FDD, rural O2I, 2 slots
Source 2 (R1-2007743)	FR1	1.8 dB		4GHz, MCS#5, one DMRS per repetition, 8 repetitions, No FH. Baseline scheme: No cross-slot channel estimation Enhanced scheme: Cross-slot channel estimation
Source 3 (R1-2007954)	FR1	~2.0dB		Rural 3km/h, 700MHz, FDD, TBS=136 bits, MCS 0, 8 repetitions, 2 DMRS symbols, 12 data symbols. Cross-slot channel estimation is employed with a fixed window size of 4 slots For Rel-15 inter-slot FH, cross-slot channel estimation can provide ~2dB performance gain compared to the case without cross-slot channel estimation.
Source 4 (R1-2008626)	FR1	1-2 dB		Baseline: PUSCH 1RB allocation, 4 reps. Enhancement: PUSCH 1 RB allocation, 0/2/4 reps, with cross-slot channel estimation.
Source 5 (R1-2008399)	FR1	1.5 dB		Baseline: PUCCH, 1 RB allocation, repetition with 4 slots in FDD Enhancement: PUCCH, 1 RB allocation, repetition with 4 slots in FDD, cross-slot channel estimation with 4 slots
Source 6 (R1-2008378)	FR1	1.0 dB		Rural, 4 GHz, DDDSUDDSUU, 3 km/h 4PRBs, 2 repetitions, w/o HARQ Baseline: w/o cross-slot channel estimation Enhancement: w/ cross-slot channel estimation
Source 7 (R1-2008559)	FR1		1 dB	Number of repetition is 2 for consecutive 2 UL slots assuming DDDSUDDSUU for FR1

Source 8 (R1-2009647)	FR1		1.3 dB	DDDSUDDSUU, 4GHz with O2I, 4PRB, Delay spread: 300 ns, Max # of HARQ tx: 4, Latency: 50 ms, 1 DMRS
	FR1		0.9 dB	DDDSUDDSUU, 4GHz with O2I, 4PRB, Delay spread: 300 ns, Max # of HARQ tx: 4, Latency: 50 ms, 2 DMRS
	FR2		1.1 dB	DDDSUDDDSU, 28GHz with O2I, 4PRB, Delay spread: 100 ns, Max # of HARQ tx: 16, Latency: 50 ms, 1 DMRS
	FR2		0.85 dB	DDDSUDDDSU, 28GHz with O2I, 4PRB, Delay spread: 100 ns, Max # of HARQ tx: 16, Latency: 50 ms, 2 DMRS
Source 9 (R1-2008026)	FR1	0.4dB		Urban O2I 2.6GHz 7D1S2U (6D:4S:4U for the Special slot) Baseline：2 uplink slot without cross slot channel estimation, no FH Enhancement：2 uplink slot with cross slot channel estimation, no FH
	FR1	1.22 dB		Urban O2I 2.6GHz 7D1S2U (6D:4S:4U for Special slot) Baseline : MCS #4 2 uplink slot without cross slot channel estimation, 2 DMRS symbol per slot Enhancement : MCS #3, 4 symbol in special slot+ 2 uplink slot, with single DMRS symbol per slot(including the special slot), with cross slot channel estimation
Source 10 (R1-2007680)	FR1	0.8dB		4 repetitions transmission in one slot
		0.3dB		4 repetitions transmission among 4 slots
		1dB		DMRS-less in time domain with joint channel estimation for 4 repetitions within one slot.
		1dB		DMRS-less in time domain with joint channel estimation for 4 repetitions across 4 slots.
Source 11 (R1-2008419)	FR1	1.1 dB (LLS)		With vs. without cross-slot est., no FH 4 DMRS 1% BLER For 300ns delay spread, 3kmph, 2 Rx 4 PRBs, MCS0, 700 MHz 8 repetitions (no retransmissions) Details in R1-2008419
Source 12 (R1-2009792)	FR1	0.4 dB		Urban 4GHz NLOS, 2DMRS symbols per slot, UE speed: 3km/h Baseline scheme: no cross-slot channel estimation. Enhanced scheme: cross-slot channel estimation with 2-slot bundling.
Source 13 (R1-2008479)	FR1	0.2dB		FDD 700MHz MCS=120/1024 4PRB, No frequency hopping, **1DMRS** symbol, 3km/h 2 repetitions with or without cross slot channel estimation
		0.4dB		FDD 700MHz MCS=120/1024 4PRB, No frequency hopping, **1DMRS** symbol, 3km/h 4 repetitions with or without cross slot channel estimation
		0.6dB		FDD 700MHz MCS=120/1024 4PRB, No frequency hopping, **1DMRS** symbol, 3km/h 8 repetitions with or without cross slot channel estimation
		0.6dB		FDD 700MHz MCS=120/1024 4PRB, No frequency hopping, **2 DMRS** symbol, 3km/h 4 repetitions with or without cross slot channel estimation

		1dB		FDD 700MHz MCS=120/1024 4PRB, No frequency hopping, **2 DMRS** symbol, 3km/h 8 repetitions with or without cross slot channel estimation
Source 14 (R1-2009583)	FR1		0.3dB	4GHz TDD Rural, 4 PRBs, DDDSU, 120km/hr, VoIP Baseline : QPSK, 2 DMRS in uplink slot Enhancement : 2 DMRS in uplink slot, 1 DMRS in special slot, cross-slot channel estimation assisted by DMRS in special slot
Source 15 (R1-2007583)	FR1	1.4dB 2.1dB		Compared with single slot channel estimation, 1.4dB and 2.1 dB SNR gain can be obtained by 2 and 3 consecutive slots joint channel estimation at 10% BLER. Other parameter settings: 1T 64R, TDL-C, 3 km/h, 300ns, Type I, max-length=1, 1 DMRS symbol per slot

Five sources (R1-2008874, R1-2007743, R1-2007954, R1-2009647, R1-2008419) evaluate the performance of inter-slot frequency hopping with inter-slot bundling and joint channel estimation.

- Two sources (R1-2008874, R1-2009647) show 0.5~2.5 dB SNR gain for inter-slot frequency hopping with inter-slot bundling for VoIP at 2% rBLER depending on bundle size, DM-RS configurations for FR1, compared to Rel-16 inter-slot frequency hopping.
- One source (R1-2009647) shows 1.0~1.55 dB SNR gain for inter-slot frequency hopping with inter-slot bundling for VoIP at 2% rBLER depending on bundle size, DM-RS configurations for FR2, compared to Rel-16 inter-slot frequency hopping.
- Three sources (R1-2007743, R1-2007954, R1-2008419) show 0.5~3 dB SNR gain for inter-slot frequency hopping with inter-slot bundling for eMBB at 10% iBLER depending on bundle size for FR1, compared to Rel-16 inter-slot frequency hopping.
- One source (R1-2007954) shows 1 dB SNR gain for inter-slot frequency hopping with inter-slot bundling and joint channel estimation over multiple slot for eMBB at 10% iBLER for FR1, compared to Rel-16 inter-slot frequency hopping with joint channel estimation over multiple non-consecutive slots.

Table 6.1.3-2 Performance evaluation for inter-slot frequency hopping with inter-slot bundling

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2008874)	FR1		0.5 dB	FDD, O2I, 2 slots bundling
Source 2 (R1-2007743)	FR1	0.5 dB		4GHz, Urban, MCS#3, one DMRS per hop. Baseline scheme: Inter-slot FH Enhanced scheme: FH per two repetitions and cross-slot channel estimation among two repetitions per hop.
Source 3 (R1-2007954)	FR1	~1.0dB		Rural 3km/h, 700MHz, FDD, TBS=136 bits, MCS 0, 8 repetitions, 2 DMRS symbols, 12 data symbols Enhanced inter-slot FH pattern: same frequency resource in 4 consecutive slots. Cross-slot channel estimation is employed with a fixed window size of 4 slots for both Rel-15 inter-slot FH and enhanced inter-slot FH. When employing cross-slot channel estimation, ~1.0dB performance gain can be achieved by enhanced inter-slot FH pattern, compared to Rel-15 inter-slot FH.
		~3.0dB		Same simulation assumptions as above. Enhanced inter-slot FH pattern: same frequency resource in 4 consecutive slots.

				Compared to Rel-15 inter-slot FH without cross-slot channel estimation, ~3dB can be achieved by enhanced inter-slot frequency hopping with cross-slot channel estimation
Source 4 (R1-2009647)	FR1		2.5 dB	Residual BLER DDDSUDDSUU, 4GHz with O2I, 4PRB, Delay spread: 300 ns, Max # of HARQ tx: 4, Latency: 50 ms, Frequency hopping offset: 40RBs, 1 DMRS
	FR1		2.1 dB	Residual BLER DDDSUDDSUU, 4GHz with O2I, 4PRB, Delay spread: 300 ns, Max # of HARQ tx: 4, Latency: 50 ms, Frequency hopping offset: 40RBs, 2 DMRS
	FR2		1.55 dB	Residual BLER DDDSUDDDSU, 28GHz with O2I, 4PRB, Delay spread: 100 ns, Max # of HARQ tx: 16, Latency: 50 ms, Frequency hopping offset: 40RBs, 1 DMRS
	FR2		1 dB	Residual BLER DDDSUDDDSU, 28GHz with O2I, 4PRB, Delay spread: 100 ns, Max # of HARQ tx: 16, Latency: 50 ms, Frequency hopping offset: 40RBs, 2 DMRS
Source 5 (R1-2008419)	FR1	1.3 dB (LLS)		With vs. without cross-slot est. With frequency hopping (2 hops) 1% BLER For 30ns delay spread, 3kmph, 2 Rx, 2 DMRS 4 PRBs, MCS0, 700 MHz 8 repetitions (no retransmissions) Details in R1-2008419

Two sources (R1-2007743, R1-2007954) evaluate the performance of lower DM-RS density.

- One source (R1-2007743) shows around 1.0 dB SNR gain for lower DM-RS density in frequency domain for eMBB at 10% iBLER for FR1, compared to Rel-16 DM-RS density. The results is based on the assumption with only 1 RX antenna, single front-loaded DMRS symbol and without frequency hopping.

- One source (R1-2007954) shows around 0.2 dB SNR loss for lower DM-RS density in time domain for eMBB at 10% iBLER for FR1, compared to Rel-16 DM-RS density.

Table 6.1.3-3 Performance evaluation for lower DMRS density

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2007743)	FR1	1 dB		2GHz, 14-symbol PUSCH, one DMRS, DMRS type 1, one port transmission. Baseline scheme: DMRS type 1, one port transmission, 3 dB power boosting on DMRS RE compared to data RE. Enhanced scheme: Only mapping DMRS type 1 on even PRBs, 6 dB power boosting on DMRS RE compared to data RE.
Source 2 (R1-2007954)	FR1	-0.2dB		Baseline scheme: 2 DMRS symbols in each slot Lower DMRS density scheme: 2 DMRS symbols in even slots and no DMRS in odd slots Rural 3km/h, 700MHz, FDD, TBS=136 bits, MCS 0, 8 repetitions, 2 DMRS symbols, 12 data symbols

Three sources (R1-2008874, R1-2007954, R1-2008559) evaluate the performance of higher DM-RS density.

- One source (R1-2008874) shows 0.5~1.5 dB SNR gain for 1-comb DM-RS for eMBB at 10% iBLER for FR1, compared to Rel-16 DM-RS density without power boosting.

- One source (R1-2008559) shows around 1.0 dB SNR gain for additional DM-RS symbol position for VoIP at 2% rBLER for FR1, compared to Rel-16 DM-RS density with only single DMRS symbol.
- One source (R1-2007954) shows around 0.05 dB SNR loss for higher DM-RS density in time domain for eMBB 10% iBLER for FR1, compared to Rel-16 DM-RS density.

Table 6.1.3-4 Performance evaluation for higher DMRS density

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
Source 1 (R1-2008874)	FR1	0.5 dB		DDDSUDDSUU, urban O2I, 1-comb DM-RS
		1.5 dB		DDDSUDDSUU, rural O2O, 1-comb DM-RS
Source 2 (R1-2007954)	FR1	-0.05dB		Baseline scheme: 4 DMRS symbols in each slot Higher DMRS density: 5 or 6 DMRS symbols in each slot Rural 3km/h, 700MHz, FDD, TBS=136 bits, MCS 0, 8 transmissions, 2 DMRS symbols, 12 data symbols. Inter-slot FH
Source 3 (R1-2008559)	FR1		1 dB	Symbol duration 1 or 2 Additional DMRS symbol position : pos3

One source (R1-2008626) evaluates the performance of adaptive DM-RS configuration and shows 1.7 dB SNR gain for eMBB at 10% iBLER for FR1, compared to Rel-16 semi-static DM-RS configuration. For low SNR such as -10 to -12 dB, it shows that adaptive DM-RS configuration can bring 10-100% increase in throughput compared to an ill-suited DMRS configuration depending on factors such as UE speed, DMRS bundling, and PUSCH repetition.

Table 6.1.3-5 Performance evaluation for adaptive DMRS configuration

Source	Frequency Range	Performance gain		Key Assumptions
		eMBB	voice	
R1-2008626	FR1	1.7 dB		PUSCH with 14 symbol allocation. 1 Tx, 4 Rx. Channel: TDL-C 300ns, 3 kmph. Performance gap between optimal DMRS and suboptimal DMRS choice is reported as gain.

6.1.4 Power-domain based solutions

Power domain based solutions are studied, including waveform design to optimize MPR/A-MPR, FDD high power UE, and power boosting for pi/2 BPSK.

UE transmit waveform design to reduce MPR was studied from several aspects, including tone reservation, FDSS (Frequency Domain Spectral Shaping) without spectral extension for pi/2 BPSK, and FDSS with and without spectral extension for QPSK. Potential specification impacts include: related signalling, design for spectral extension, RF requirements. Note: For tone reservation, a fraction of tones allocated to a UE are reserved for the UE to shape its waveform; no data is transmitted on these tones.

Power boosting for pi/2 BPSK was studied, including beyond 26 dBm as a function of the UL duty cycle. Potential specification impacts include: UE behavior for power boosting based on the UL time domain resource allocation, explicit or implicit signaling, RF requirement.

One source (R1-2008626) evaluates the performance of UE transmit waveform design to reduce MPR and shows 1 ~1.5 dB gain, compared to Rel-16 DFT-S-OFDM and CP-OFDM.

One source (R1-2007905) evaluates the performance of power boosting for pi/2 BPSK and shows around 3 dB gain for UL duty cycle less than 50% and around 6 dB gain for UL duty cycle less than 25%.

Table 6.1.4 Performance evaluation for power domain based solutions

Source	Solutions	Performance gain	Key Assumptions
R1-2007905	Power boosting for pi/2 BPSK	3 dB for <50% UL duty cycle	
		6 dB for <25 % UL duty cycle	
R1-2008626	Techniques to reduce MPR in uplink transmissions	1-1.5 dB (due to increase in tx power)	Aimed at increasing uplink transmit power for DFT-S-OFDM and CP-OFDM waveforms.

6.1.5 Spatial-domain based solutions

Spatial domain based solutions were studies from several aspects, including multiple layer PUSCH transmission with DFT-S-OFDM and Open-loop Tx diversity. Potential specification impacts include: mechanism to indicate the support of multiple layer PUSCH transmission with DFT-S-OFDM and to determine the precoder, e.g. reuse a subset of the R15 codebooks, and signalling related to support of Tx diversity for PUSCH with DFT-s-OFDM, and different PUSCH spatial filter parameters and different antenna ports for different PUSCH transmissions

One source (R1-2008743) evaluates the performance of Alamouti-based transmit diversity and shows 2-2.7dB SNR gain for FR1, and 2-3dB SNR gain with QPSK and up to 8.5dB SNR gain with 16QAM for FR2.

One source (R1-2008419) evaluates the performance of multiple layer PUSCH transmission with DFT-S-OFDM and shows around 3 dB cubic metric gain, compared to multiple layer PUSCH transmission with CP-OFDM.

Table 6.1.5 Performance evaluation for spatial domain based solutions

Source	Solutions	Performance gain	Key Assumptions
R1-2008743	Alamouti-based transmit diversity	2-2.7dB in FR1 2-3dB with QPSK, up to 8.5dB with 16QAM in FR2	PAPR preserving SFBC and /or single symbol STBC
R1-2008419	Multi-Layer DFT-S-OFDM	~3 dB cubic metric gain vs. CP-OFDM	Rank 2 QPSK transmission

6.1.6 Others

SIP signal compression was studied for enhancement large payload PUSCH including SigComp used for application information compression and the compression efficiency. Potential specification impacts include: using compression algorithm to compress the large SIP signaling message in higher layer.

Dynamic PUSCH waveform adaptation was studied. Potential specification impacts include: related signaling design.

One source (R1-2008626) evaluates the performance of dynamic switching between DFT-S-OFDM and CP-OFDM and shows 2~3 dB gain, compared to semi-static switching between DFT-S-OFDM and CP-OFDM when using QPSK modulation.

Table 6.1.6 Performance evaluation for switching between DFT-S-OFDM and CP-OFDM

Company	Solutions	Performance gain	Key Assumptions
R1-2008626	Implicit switching between DFT-S-OFDM and CP-OFDM	2-3dB (due to change in tx power)	Aimed at avoiding a RRC reconfig to change waveform from CP-OFDM to DFT-S-OFDM.

6.2 PUCCH coverage enhancements

PUCCH enhancements are studied and the study on the following schemes is prioritized:

- DMRS-less PUCCH
  - FFS: design detail for DMRS-less PUCCH, e.g., sequence based PUCCH transmission, v.s. reuse Rel-15 scheme to transmit UCI without DMRS
- Rel-16 PUSCH-repetition-Type-B like PUCCH repetition at least for UCI <=11 bits.
- (Explicit or implicit) Dynamic PUCCH repetition factor indication
- DMRS bundling cross PUCCH repetitions
  - Including study of transmitting a subset of PUCCH repetitions without DMRS, at least for UCI<=11 bits

6.2.1 DMRS-less PUCCH

DMRS-less PUCCH has been studied. The performance (SNR) gain observed for DMRS-less PUCCH over Rel-15/16 baseline is captured in Table 6.2.1-1. The performance (PAPR/CM) gain observed for DMRS-less PUCCH over Rel-15/16 baseline is captured in Table 6.2.1-2. The key simulation assumptions for DMRS-less PUCCH study are captured in Table 6.2.1-3.

For DMRS-less PUCCH, the potential spec impact includes the following. A new PUCCH format would need to be specified, including the power control of the new PUCCH format. The new PUCCH format would be an addition to existing PUCCH formats. Two approaches to generate sequence for DMRS-less PUCCH (i.e., reuse Rel-15/16 CGS/ZC/Gold/m-sequence or design new sequences) were studied. If reusing Rel-15/16 CGS/ZC/Gold/m-sequence of the same length being supported by the current Rel-15/16 specification, no new sequences need to be specified. If new sequences (including new sequence type or same type as in Rel-15/16 but with different length) or sequences based on modification of NR Rel-15/16 UCI encoding scheme are adopted, the new sequences or the modification of NR Rel-15/16 UCI encoding scheme need to be specified. UCI to sequence mapping and sequence to RE mapping need to be specified. New RAN4 MPR requirement may need to be defined, if new sequences other than Rel-15/16 CGS/ZC/Gold/m-sequences are adopted. UCI multiplexing for this new PUCCH format need to be specified.

For DMRS-less PUCCH, receiver needs to implement a non-coherent sequence detector/correlator for reception of the new PUCCH format. For reception of the new PUCCH format, channel and noise covariance matrix estimation using DMRS is not required. Receiver implementation for the new PUCCH format is an extension of the PUCCH format 0 receiver with similarity that both are noncoherent sequence detectors, while the new receiver needs to perform correlation over a larger sequence pool. The size of the sequence pool over which the receiver for the new PUCCH format needs to perform correlation increases exponentially with the number of UCI bits. Computation efficient implementations of the receiver for the new PUCCH format have been studied. Their complexity can be lower or higher than the decoder for existing NR PUCCH coherent receiver depending on the adopted sequence, on the UCI payload size and on the implementation of the considered coherent receiver. gNB receivers may use PUCCH DM-RS for channel parameter estimation, channel tracking, and/or interference estimation. Absence of DMRS in the new PUCCH format requires such gNB receivers to rely on other reference signals or pursue data-aided estimation and tracking. In the non-coherent sequence detector at receiver, changes to existing implementation for DTX detection, including noise and interference power estimation, may be necessary if the existing implementation relies on the presence of DMRS.

For DMRS-less PUCCH, UE needs to implement a UCI to sequence mapping and sequence to RE mapping for the new PUCCH format. Four potential approaches to implement the sequences for DMRS-less PUCCH were studied. Approach 1: Reuse Rel-15/16 CGS/ZC/Gold/m-sequences generation with the same sequence length being supported in Rel-15/16. Approach 2: Reuse Rel-15/16 CGS/ZC/Gold/m-sequences generation with a different sequence length being supported in Rel-15/16. Approach 3: Modification of NR Rel-15/16 UCI encoding scheme to generate the sequences. Approach 4: implement a new sequence generation which is not covered by above, if the new sequence is adopted in spec.

For long PUCCH format, the number of UCI bits that the DMRS-less PUCCH support is up to 11 bits. RAN1 has not concluded on which of 2 or 3 bits is the minimum number of UCI bits that DMRS-less PUCCH can support.

Table 6.2.1-1: Performance (SNR) gain observed for DMRS-less PUCCH over Rel-15/16 baseline

Simulated scenario	Performance metric	Observed SNR gains	Source
Scenario 1: 2 bits UCI Baseline: PF1 Enhancement: DMRS-less PUCCH	1% FA, 1% ACK miss detection, 0.1% NACK->ACK error	3dB	Source 3 (receiver assumption 1) (R1-2009802)
		3dB	Source 10 (R1-2008272)
		3~4dB	Source 9 (receiver assumption A) (R1-2009747)
Scenario 2: 3/4/6 bits UCI Baseline: PF3 Enhancement: DMRS-less PUCCH Note: Source 2 (R1-2009602)/ Source 7 (R1-2008420) simulated 3-7 bits UCI	1% BLER	3dB	Source 3 (receiver assumption 2) (R1-2009802)
		3dB	Source 4 (R1-2008400)
		1.5 ~ 2.1dB	Source 8 (R1-2009451)
		0 ~ 0.2dB	Source 7 (R1-2008420)
	1% FA, 1% BLER	0dB	Source 2 (R1-2009602)
		0.3~0.5dB	Source 6 (R1-2009648)
	1% FA, 1% ACK miss detection, and 0.1% NACK to ACK	1~2dB	Source 6 (R1-2009648)
		2.8dB	Source 3 (receiver assumption 2) (R1-2009802)
		1dB	Source 3 (receiver assumption 1) (R1-2009802)
		0dB	Source 7 (R1-2009737)
Scenario 3: 11 bits UCI Baseline: PF3 Enhancement: DMRS-less PUCCH Note: Source 2 (R1-2009602)/Source 7 (R1-2008420) simulated 8-11 bits UCI	1% BLER	3~4dB	Source 3 (receiver assumption 2) (R1-2009802)
		0.8~1.5dB	Source 3 (receiver assumption 1) (R1-2009802)
		3dB	Source 9 (receiver assumption B) (R1-2009747)
		2.4dB	Source 9 (receiver assumption A) （R1-2009747）
		2~3dB	Source 1 (R1-2009696)
		1.5~2.1dB	Source 8 (R1-2009451)
		0 ~ 0.2dB	Source 7 (R1-2008420)
		1 ~ 2.7dB	Source 5 (R1-2008027)
	1% FA, 1% BLER	0.3dB	Source 2 (R1-2009602)
		2.1dB	Source 3 (receiver assumption 2) (R1-2009802)
	1% FA, 1% ACK miss detection, and 0.1% NACK to ACK error	4dB	Source 6 (R1-2009648)
		3.8dB	Source 1 (R1-2009696)
		4dB	Source 3 (receiver assumption 2) (R1-2009802)
		0.9~4.8dB	Source 3 (receiver assumption 1) (R1-2009802)
		4.1dB	Source 9 (receiver assumption B) (R1-2009747)
		2.8dB	Source 9 (receiver assumption A) (R1-2009747)
		0dB	Source 7 (R1-2009737)
	1% FA, 1% BLER, and 5% undetectable error rate	4dB	Source 3 (receiver assumption 2) (R1-2009802)
		1.5~2.8dB	Source 3 (receiver assumption 1) (R1-2009802)
		3dB	Source 9 (receiver assumption B) (R1-2009747)
		2dB	Source 9 (receiver assumption A) (R1-2009747)
		0dB	Source 7 (R1-2009737)
Scenario 3: 22/24 bits UCI Baseline: PF3 Enhancement: DMRS-less PUCCH	1% BLER	-2dB	Source 8 (R1-2009451)
		1dB	Source 3 (receiver assumption 2) (R1-2009802)

Note 1: false alarm rate is the probability that DTX is detected as a correct payload.

Note 2: undetectable error rate = # instances that a UCI payload is declared as correct when the UCI payload is in error / Total # instances that UCI payloads are in error, where a UCI payload is declared as correct if it passes the error detection check.

Table 6.2.1-2: Performance (PAPR/CM) gain observed for DMRS-less PUCCH over Rel-15/16 baseline

Modulation order	Observed PAPR/CM gain	Source
QPSK	3.5dB PARR gain 1dB CM gain	Source 3 (R1-2009802)
	6.3dB PAPR gain	Source 8 (R1-2009451)
	4.5dB PAPR gain 1.7dB CM gain	Source 9 (R1-2009747)
Pi/2 BPSK	0.5dB PAPR gain 0.6dB CM gain	Source 3 (R1-2009802)
	4.8 dB PAPR gain	Source 8 (R1-2009451)
	2.4dB PAPR gain	Source 9 (R1-2009747)

Table 6.2.1-3: Key simulation assumptions for DMRS-less PUCCH study

Company	Key simulation assumptions
Source 1 (R1-2009696)	Channel model of TDL-C 300 ns, UE speed of 3km/h Receiver for Rel-15/16 PUCCH: ML coherent receiver Receiver for sequence based PUCCH: ML noncoherent sequence detector
Source 2 (R1-2009602)	Channel model of TDL-C 300 ns, UE speed of 3km/h Receiver for Rel-15/16 PUCCH: ML coherent receiver (MMSE channel estimator and equalizer) and non-coherent receiver Receiver for sequence based PUCCH: ML noncoherent sequence detector/correlator
Source 3 (R1-2009802)	Channel model of TDL-C and TDL-A with up to 800 ns channel delay spread (including effects of timing error), up to 1111 Hz doppler (including effect of frequency error) Receiver assumption 1: - Receiver for Rel-15/16 PUCCH: noncoherent ML detection performed on union of PUCCH DMRS and UCI symbols. Error detection based on noncoherent duo metric. - Receiver for sequence based PUCCH: ML noncoherent receiver (correlator with 2D-FFT or fast Hadamard transform) Receiver assumption 2: - Receiver for Rel-15/16 PUCCH: ML coherent receiver - Receiver for sequence based PUCCH: ML noncoherent receiver (correlator with 2D-FFT or fast Hadamard transform)
Source 4 (R1-2008400)	Receiver for Rel-15/16 PUCCH: MMSE channel estimation (with genie Doppler and delay spread) + ML coherent detection Receiver for sequence based PUCCH: ML noncoherent sequence detector/correlator
Source 5 (R1-2008027)	Channel model of TDL-C 300 ns Receiver for Rel-15/16 PUCCH: ML coherent receiver Receiver for sequence based PUCCH: ML noncoherent sequence detector/correlator
Source 6 (R1-2009648)	Channel model of TDL-C 100 ns, UE speed of 3km/h Receiver for Rel-15/16 PUCCH: ML coherent receiver Receiver for sequence based PUCCH: ML noncoherent sequence detector/correlator Ideal noise power estimation is used for both receiver for both legacy PUCCH and new sequence based PUCCH, and the noise power is used only in DTX detection.
Source 7 (R1-2008420,	Channel model of TDL-C 300 ns, UE speed of 3km/h Receiver for Rel-15/16 PUCCH: conventional and ML noncoherent

R1-2009737)	receiver Receiver for sequence based PUCCH: ML noncoherent receiver
Source 8 (R1-2009451)	Receiver for Rel-15/16 PUCCH: advanced receivers for <=11 bits (non-coherent ML), conventional receiver for 22 bits (LS channel estimation + MMSE/MRC) Receiver for sequence based PUCCH: ML noncoherent sequence detector/correlator for 4/11 bit case; non-coherent LLR unit adapted to 3GPP polar code for 22-bit case. Also simulated low-complexity receiver for 11-bit UCI case.
Source 9 (R1-2009747)	Channel model of TDL-C 300 ns, UE speed of 3km/h or 120km/h Receiver assumption A: - Receiver (higher complexity) for Rel-15/16 PUCCH: ML non-coherent receiver - Receiver (higher complexity) for sequence based PUCCH: ML non-coherent receiver Receiver assumption B: - Receiver (lower complexity) for Rel-15/16 PUCCH: 2D-Wiener filter based channel estimation + MMSE equalization+ ML coherent detection - Receiver (lower complexity) for sequence based PUCCH: Rx signal combination +CHIRRUP algorithm based sequence detection
Source 10 (R1-2008272)	Channel model of TDL-C 300 ns, UE speed of 3km/h Receiver for Rel-15/16 PUCCH: LMMSE-IRC receiver. Receiver for sequence based PUCCH: ML correlation.

6.2.2 PUSCH-repetition-Type-B like PUCCH repetition

PUSCH-repetition-Type-B like PUCCH repetition has been studied. The performance gain observed for PUSCH-repetition-Type-B like PUCCH repetition over Rel-15/16 baseline is captured in Table 6.2.2-1.

For PUSCH-repetition-Type-B like PUCCH repetition, the potential spec impact includes the following. Nominal repetition, actual repetition, segmentation for type B PUCCH repetition, and flexible time domain resource allocation in each slot need to be specified. Procedure to handle postpone/cancel PUCCH repetitions (including interaction with dynamic SFI) needs to be specified. Power control for actual repetitions needs to be specified. The issue of whether supporting type B PUCCH repetitions with different PUCCH formats was studied and three options were identified to resolve this issue. The three options are the following. Option 1: Restrict type B PUCCH repetition applicable to actual repetitions with the same PUCCH format. Option 2: Allow type B PUCCH repetition with different PUCCH formats. The procedure to handle format switch between repetitions needs to be specified. Option 3: Introduce and specify PUCCH format 3/4 of length 1/2/3 OFDM symbols to support type B PUCCH repetition.

For PUSCH-repetition-type-B like PUCCH repetition, the impact to receiver includes the following. gNB needs to process more than one PUCCH repetitions in a slot. gNB needs to combine multiple repetitions with different code rates/time length.

PUSCH-repetition-type-B like PUCCH repetition is only applicable to UCI <=11 bits.

Table 6.2.2-1: Performance gain observed for PUSCH repetition Type-B like PUCCH repetition

Company	Observed performance gain	Key simulation assumptions
Source 6 (R1-2009648)	0.5dB (w/o DMRS bundling) 1~1.5dB (w DMRS bundling) Note: the 1~1.5 gain observed is a combination of DMRS bundling gain and type-B PUSCH repetition.	11 bits UCI, w/ DTX detection, 1% BLER Receiver for Rel-15/16 PUCCH: coherent detection, DTX is performed based on union of DMRS and UCI symbols. Receiver for PUCCH enhancement scheme: with and without joint channel estimation for the consecutive PUCCH repetitions, in addition to receiver for Rel-15 and Rel-16 UEs. Note: Ideal noise power estimation is used for above receivers, and the noise power is used only in DTX detection.

6.2.3 Dynamic PUCCH repetition factor indication

Dynamic PUCCH repetition factor indication has been studied. The performance gain observed for dynamic PUCCH repetition factor indication over Rel-15/16 baseline is captured in Table 6.2.3-1.

For dynamic PUCCH repetition factor indication, the potential spec impact includes the following. A new PUCCH repetition signalling mechanism needs to be specified

For dynamic PUCCH repetition factor indication, there is no impact identified to receiver.

For dynamic PUCCH repetition factor indication, the impact to UE implementation is that UE needs to implement transmissions of the PUCCH repetitions based on the dynamic indicator.

Table 6.2.3-1: Performance gain observed for Dynamic PUCCH repetition factor indication

Company	Observed performance gain	Key simulation assumptions
Source 7 (R1-2008420)	5 dB (with repetition factor 8)	11 bits CSI, w/o DTX detection, 10% BLER Receiver for Rel-15/16 PUCCH: conventional DMRS based receiver Receiver for PUCCH enhancement scheme: conventional DMRS based receiver (without cross slot channel estimation).
Source 1 (R1-2009696)	Reducing the number of PUCCH repetitions for more than 70% cases.	11 bits UCI, w/o DTX detection, 1% BLER

6.2.4 DMRS bundling across PUCCH repetitions

DMRS bundling across PUCCH repetitions has been studied. The performance gain observed for DMRS bundling across PUCCH repetitions over Rel-15/16 baseline is captured in Table 6.2.4-1.

For DMRS bundling across PUCCH repetitions, the potential spec impact includes the following. Restrictions to guarantee phase coherency across repetitions need to be specified. UE behaviour needs to be defined if the phase coherency of PUCCH repetition is impacted by other procedures. DMRS bundling with inter-slot frequency hopping pattern enhancement need to be specified, if the frequency hopping enhancement is agreed.

For DMRS bundling across PUCCH repetitions, new channel estimator needs to be implemented at receiver to process DMRS across multiple repetitions.

For DMRS bundling across PUCCH repetitions, same phase and transmission power need to be maintained at UE across PUCCH repetitions.

For DMRS bundling across PUCCH repetitions, the impact to system includes the following. gNB needs to maintain phase coherence across slots. gNB cannot switch beamformers or make any RF adjustments across multiple slots. UE needs to maintain phase coherence across multiple slots. UE-side adjustments for timing and frequency will have to be postponed to a later slot. UE may not have the best timing and frequency settings for multiple uplink slots.

For DMRS bundling across PUCCH repetitions, restrictions of the scheme include the following. Phase coherency across PUCCH repetitions is required. The same frequency resource allocation across PUCCH repetitions is required. The same power across PUCCH repetitions is required.

Table 6.2.4-1: Performance gain observed for DMRS bundling across PUCCH repetitions over Rel-15/16 baseline

Company	Observed performance gain	Key simulation assumptions
Source 1 (R1-2009696)	1 dB	22 bits UCI, w/o DTX detection, 1% BLER, 4 PUCCH repetitions Receiver for Rel-15/16 PUCCH: ML coherent receiver, w/o cross-slot channel estimation Receiver for PUCCH enhancement scheme: ML coherent receiver, w/ cross-slot channel estimation
Source 2 (R1-2009602)	~1.2 dB	22 bits UCI, w/o DTX detection, 1% BLER, 8 PUCCH repetitions

		Receiver for Rel-15/16 PUCCH: coherent receiver, w/o cross-slot channel estimation Receiver for PUCCH enhancement scheme: coherent receiver, w/ cross-slot channel estimation
Source 6 (R1-2009648)	0.85 ~ 1.3 dB	11 bits UCI, w/ DTX detection, 1% BLER, 2 PUCCH repetitions Receiver for Rel-15/16 PUCCH: Coherent detection, DTX is performed based on union of DMRS and UCI symbols. Channel estimation is performed individually for each repetition. Receiver for PUCCH enhancement scheme: Joint channel estimation is used for PUCCH repetitions in consecutive slots, in addition to receiver for Rel-15 and Rel-16 UEs. Note: Ideal noise power estimation is used for both receivers, and the noise power is used only in DTX detection.

6.3 Coverage enhancements for channels other than PUSCH and PUCCH

6.3.1 Enhancements for Msg3 PUSCH

Msg3 PUSCH enhancement is studied including at least Msg3 PUSCH repetition. Enhancement to PUSCH scheduled by RAR UL grant does not consider the optimization specific for CFRA case.

Enhancements on Msg3 PUSCH repetition were studied from several aspects, including the indication of the number of repetitions for Msg3 initial transmission and re-transmission, the repetition type, the feasibility and applicability of enhancements studied for PUSCH in RRC_CONNECTED state for Msg3 PUSCH initial and re-transmission, inter-slot frequency hopping and differentiation between enhanced UE and legacy UE.

- Potential specification impacts of indication of the number of repetitions for Msg3 initial transmission include:
  - Explicit indication mechanism, e.g., indicated by RAR UL grant, DCI format 1_0 with CRC scrambled by RA-RNTI or SIB1.
  - Implicit indication mechanism, e.g., determined by PRACH configuration or information carried by RAR.
- Potential specification impacts of indication of the number of repetitions for Msg3 re-transmission include:
  - Explicit indication mechanism, e.g., indicated by DCI format 0_0 with CRC scrambled by TC-RNTI.
  - Implicit indication mechanism, e.g., determined by Msg3 initial transmission.
- Potential specification impacts of the repetition type include:
  - Introducing PUSCH repetition Type A.
- Potential specification impacts of the feasibility and applicability of enhancements studied for PUSCH in RRC_CONNECTED state for Msg3 PUSCH initial and re-transmission include:
  - The potential specification impacts for the solutions studied in Clause 6.1.
- Potential specification impacts of inter-slot frequency hopping include:
  - Inter-slot frequency hopping configuration and frequency hopping pattern.
- Potential specification impacts of differentiation between enhanced UE and legacy UE include:
  - Mechanism to differentiate enhanced UE and legacy UE, e.g., separate PRACH configurations (e.g, separate PRACH occasions or preambles) and separate Msg3 configurations (e.g., separate DMRS ports).

Power domain-based solutions were studied for Msg3 PUSCH, including pi/2 BPSK waveform using DFT-s-OFDM and power control enhancements.

- Potential specification impacts of pi/2 BPSK waveform using DFT-s-OFDM include defining the usage of pi/2 BPSK modulation for Msg3 and either explicit or implicit power boosting based on the Msg3 time domain resource allocation.
- Potential specification impacts of power control enhancements include configuration of multiple sets of power control parameters.

Spatial domain based solutions were studied from several aspects for Msg3 PUSCH, including spatial filter setting between PRACH transmission and corresponding Msg3 PUSCH transmission and open-loop transmission diversity.

- Potential specification impacts of spatial filter setting between PRACH transmission and corresponding Msg3 PUSCH transmission include specifying the same spatial filter between PRACH transmission and corresponding Msg3 PUSCH transmission, mechanism to differentiate enhanced UE and legacy UE.
- Potential specification impacts of open-loop transmission diversity include, mechanism to indicate support of transmission diversity for Msg3 PUSCH with DFT-s-OFDM, mechanism to differentiate enhanced UE and legacy UE, mechanism to determine the precoder cycling pattern during random access procedure, e.g. on different Msg3 PUSCH repetitions.

Nine sources (R1-2007745, R1-2007956, R1-2009719, R1-2008028, R1-2009719, R1-2008421, R1-2009793, R1-2007585, R1-2008480) evaluated the performance of enhancements on Msg3 repetition.

- Eight sources (R1-2007745, R1-2007956, R1-2009719, R1-2008028, R1-2009719, R1-2008421, R1-2009793, R1-2007585) show about 2 dB gain when the number of repetitions is doubled in FR1.
- One source (R1-2009793) shows 4.27 dB gain when the number of repetitions is increased to 8 in FR2.
- One source (R1-2008028) shows 1.1~1.75 dB gain when performing cross-slot channel estimation among 2 repetitions.
- One source (R1-2007745) shows 0.5~1.07 dB gain when performing cross-slot channel estimation among 4 repetitions.
- One source (R1-2008480) shows 3.8 dB gain with 2 repetitions and inter-slot hopping comparing with no repetition and no intra-slot hopping.
- One source (R1-2008480) shows 3.2 dB gain with 2 repetitions and inter-slot hopping comparing with no repetition and intra-slot hopping.

Table 6.3.1-1 Performance evaluation for Msg3 PUSCH repetition

Source	Frequency Range	Performance gain	Key Assumptions
Source 1 (R1-2007745)	FR1	2.6dB	Rural, 700MHz, O2O, No FH Baseline scheme: Msg3 PUSCH with one repetition. Enhanced scheme: Msg3 PUSCH with two repetitions.
		2.4 dB	Urban, 4GHz, O2I, No FH Baseline scheme: Msg3 PUSCH with one repetition. Enhanced scheme: Msg3 PUSCH with two repetitions.
		5.2 dB	Rural, 700MHz, O2O, No FH Baseline scheme: Msg3 PUSCH with one repetition. Enhanced scheme: Msg3 PUSCH with four repetitions.
		4.7 dB	Urban, 4GHz, O2I, No FH Baseline scheme: Msg3 PUSCH with one repetition. Enhanced scheme: Msg3 PUSCH with four repetitions.
		0.5dB~ 1.07dB	Urban, 4GHz, O2I Baseline scheme: Msg3 PUSCH with 4 repetitions. Enhanced scheme: Msg3 PUSCH with 4 repetitions and cross-slot channel estimation.
Source 2 (R1-2007956)	FR1	~2dB	TBS = 56, MCS = 0, 3 DMRS symbols that are allocated in each slot and UE moving speed of 3km/h ~2dB performance gain can be observed with doubling the repetition levels for Msg3 PUSCH
	FR1	3.46 dB	Channel: Urban

Source 3 (R1- 2009719)			Center frequency: 2.6 GHz, (2 repetition) RV: 0,0
		6.27 dB	Channel: Urban Center frequency: 2.6 GHz, (4 repetition) RV: 0,0,0,0
Source 4 (R1- 2008028)	FR1	2.25dB	Urban O2I 2.6GHz Baseline : Msg 3 PUSCH with no repetition Enhancements: Msg 3 PUSCH with 2 repetitions (2 slots with no cross slot channel estimation)
		4dB	Urban O2I 2.6GHz Baseline : Msg 3 PUSCH with no repetition Enhancements: Msg 3 PUSCH with 2 repetitions (2 slots with cross slot channel estimation)
		3.35~3.75 dB	Urban O2I 2.6GHz Baseline : Msg 3 PUSCH with no repetition Enhancements: Msg 3 PUSCH with 2 repetitions (2 slots with cross slot channel estimation) with reduced DMRS
Source 5 (R1- 2009719)	FR1	2-3dB	PUSCH repetition Type A and single slot channel estimation is evaluated as shown in R1-2005395. Repetition number is set as 2. Additional gain is achieved via cross slot PUSCH channel estimation.
Source 6 (R1- 2008421)	FR1	5.8 dB	No vs. 8 repetitions, no frequency hopping 1% BLER For 30ns delay spread, 3kmph, 2 Rx, 3 DMRS 2 PRBs, MCS0, 700 MHz no retransmissions Details in R1-2008421
Source 7 (R1- 2009793)	FR1	6.83 dB	Urban 4GHz, NLOS O2I Baseline scheme: no repetition Enhanced scheme: 8 repetitions
	FR2	4.27 dB	Urban 28GHz, NLOS O2I Baseline scheme: no repetition Enhanced scheme: 8 repetitions
Source 8 (R1- 2007585)	FR1	0.1-0.3dB	Compared with no frequency hopping, intra-slot hopping can obtain 0.1-0.3dB SNR gain.
		6 dB	Rural 4GHz, NLOS O2I, no frequency hopping Baseline scheme: no repetition Enhanced scheme: 8 repetitions
Source 9 (R1- 2008480)	FR1	3.2dB	2.6GHz TDD, TBS=56bits, 2PRB, MCS=157/1024, 3km/h 2 repetition with inter-slot hopping comparing with no repetition with intra-slot hopping
		3.8dB	2.6GHz TDD, TBS=56bits, 2PRB, MCS=157/1024, 3km/h 2 repetition with inter-slot hopping comparing with no repetition and no intra-slot hopping

One source (R1-2009719) evaluated the performance of power boosting using pi/2 BPSK waveform for Msg3 and shows 3 dB gain for UL duty cycle lower than 50% and 6 dB gain for UL duty cycle lower than 25%.

Table 6.3.1-2 Performance evaluation for pi/2 BPSK waveform for Msg3 PUSCH

Source	Solution	Performance gain	Key Assumptions
Source 1 (R1-2009719)	Power boosting using pi/2 BPSK waveform	3 dB	<50% UL duty cycle
		6 dB	<25% UL duty cycle

6.3.2 Enhancements for PRACH

PRACH enhancements were studied from several aspects, including multiple PRACH transmissions with the same beam, multiple PRACH transmissions with different beams, and PRACH enhancements with finer beam.

Potential specification impacts of multiple PRACH transmissions include:

- For multiple PRACH transmissions with the same transmission beam and multiple PRACH transmissions with different transmission beams, mechanism on triggering/initiating multiple PRACH transmissions, determination of number of transmissions and transmission pattern, differentiation between enhanced UE and legacy UE and possible collision handling between PRACH transmission with and without multiple PRACH transmissions.
- Only for multiple PRACH transmissions with different transmission beams, transmission beam to be used for each initial transmission and beam determination for the following steps in RACH procedure.

Potential specification impacts of PRACH enhancements with finer beam include finer beam for PRACH based on CSI-RS resources configured during initial access.

Two sources (R1-2007745, R1-2009793) evaluated the performance of PRACH enhancements.

- One source (R1-2007745) shows 3.7 dB and 5.2 dB gain when performing 2 and 4 PRACH transmissions with the same transmission beam respectively at 4 GHz in urban scenario.
- One source (R1-2007745) shows 1.7 dB and 3.7 dB gain when performing 2 and 4 PRACH transmissions with the same transmission beam respectively at 28 GHz in urban scenario.
- One source (R1-2009793) shows 2 dB gain when performing 2 PRACH transmissions with different transmission beams at 2 GHz in rural scenario.
- One source (R1-2009793) shows 2 dB and 4.7 dB gain when performing 2 and 4 PRACH transmissions with different transmission beams respectively at 28 GHz in urban scenario.

Table 6.3.2-1 Performance evaluation for PRACH enhancements

Source	Solution	Performance gain	Key Assumptions
Source 1 (R1-2007745)	Multiple PRACH transmissions with the same beam	3.7 dB	Urban, 4GHz, O2I Baseline scheme: one PRACH transmission Enhanced scheme: PRACH with 2 repetitions
		5.2 dB	Urban, 4GHz, O2I Baseline scheme: one PRACH transmission Enhanced scheme: PRACH with 4 repetitions
		1.7 dB	Urban, 28GHz, O2I Baseline scheme: one PRACH transmission Enhanced scheme: PRACH with 2 repetitions
		3.7 dB	Urban, 28GHz, O2I Baseline scheme: one PRACH transmission Enhanced scheme: PRACH with 4 repetitions
	Multiple PRACH transmissions with different beams	2.5 dB	Rural, 2GHz Baseline scheme: 1 PRACH transmission Enhanced scheme: 2 PRACH transmission with different beam
Source 2 (R1-2009793)	Multiple PRACH transmissions with different beams	2 dB	Urban, 28GHz, O2I Baseline scheme: one PRACH transmission Enhanced scheme: bundle of 2 msg1 transmissions, each transmitted using a different narrow TX beam. Reported gain is the one corresponding to the highest measured RSRP at gNB.
		4.7 dB	Urban, 28GHz, O2I Baseline scheme: one PRACH transmission Enhanced scheme: bundle of 4 msg1 transmissions, each transmitted using a different narrow TX beam. Reported gain is the one corresponding to the highest measured RSRP at gNB.

6.3.3 Enhancements for broadcast PDCCH

Broadcast PDCCH repetition was studied. Potential specification impacts include PDCCH repetition configuration.

Compact DCI and PDCCH-less for broadcast PDCCH were studied for broadcast PDCCH. Potential specification impacts of compact DCI include mechanism for DCI bit field design for fallback DCI. Potential specification impacts of PDCCH-less include the mechanism to indicate the scheduling information for broadcast PDSCH carrying SIB messages.

Three sources (R1-2007745, R1-2009719, R1-2009309) evaluated the performance of enhancements on PDCCH repetition.

- Two sources (R1-2009719, R1-2009309) show 2 dB gain and one source (R1-2007745) shows 2.8~3.1 dB gain when the number of repetitions is increased to 2.
- One source (R1-2007745) shows 4~5.8 dB gain and one source (R1-2009309) shows 4 dB gain when the number of repetitions is increased to 4.
- One source (R1-2009309) shows about 3dB and 6dB gain if DMRS bundling is considered for 2 and 4 repetitions respectively.

One source (R1-2009719) evaluated the performance of compact DCI and shows 1.5 dB gain if the number of DCI payload size is reduced from 40 bits to 20 bits.

Table 6.3.3-1 Performance evaluation for PDCCH enhancements

Source	Solution	Performance gain	Key Assumptions
Source 1 (R1-2007745)	PDCCH repetition	2.8~3.1 dB	Rural, 2GHz, 2Tx-2Rx, AL=16 Baseline scheme: one PDCCH transmission Enhanced scheme: PDCCH with 2 repetitions with separate decoding or joint decoding among 2 repetitions.
		4~5.8 dB	Urban, 4GHz, 4Tx-4Rx, AL=16 Baseline scheme: one PDCCH transmission Enhanced scheme: PDCCH with 4 repetitions with separate decoding or joint decoding among 2 repetitions.
Source 2 (R1-2009719)	Aggregation for time domain	2 dB	Number of PDCCH symbol = 2 and 4
	Compact DCI	1.5 dB	Payload size = 40 bits and 20 bits
Source 3 (R1-2009309)	PDCCH repetitions; PDCCH-DMRS bundling	2-6 dB	Setup: Urban 64 Tx, 4 Rx, TDL-C 300ns, AL 16 Baseline: NR R15/16 PDCCH (no repetitions, no bundling) Enhancement: 2 or 4 repetitions; with or without DMRS bundling.

6.3.4 Enhancements for Msg4

Msg4 PDSCH enhancements were studied from several aspects, including introducing early CSI on Msg3 PUSCH for early link adaptation, scaling factor for TBS determination and PDSCH repetition. Potential specification impacts of early CSI on Msg3 PUSCH for early link adaptation include: CSI-RS resources configured during initial access. Potential specification impacts of scaling factor for TBS determination include: TBS determination. Potential specification impacts of PDSCH repetition include: PDSCH repetition configuration, DMRS design among PDSCH repetitions.

6.3.5 Enhancements for PUCCH with Msg4 HARQ-ACK

PUCCH repetition carrying HARQ-ACK for Msg4 was studied. Potential specification impacts include related signaling design, differentiation between enhanced UE and legacy UE.

One source (R1-2007745) evaluated the performance of PUCCH repetition with HARQ-ACK for Msg4 and shows 3 dB and 6 dB gain when the number repetitions is increased to 2 and 4 respectively at 2 GHz in rural scenario.

Table 6.3.5-1 Performance evaluation for PUCCH carrying HARQ-ACK for Msg4

Source	Solution	Performance gain	Key Assumptions
Source 1 (R1-2007745)	PUCCH repetition	3 dB	Rural, 2GHz, 2Rx, PUCCH format 1, 1 bit Baseline scheme: one PUCCH transmission Enhanced scheme: PUCCH with 2 repetitions
		6 dB	Rural, 2GHz, 2Rx, PUCCH format 1, 1 bit Baseline scheme: one PUCCH transmission Enhanced scheme: PUCCH with 4 repetitions

6.3.6 Enhancements for SSB

Increasing the number of SSB beams was studied, and potential specification impacts include mechanism for indication of SSB beam index, mechanism to ensure backward compatibility with legacy UE.

UE awareness of paired orthogonally polarized SSBs has been studied. Potential specification impacts of dual polarized SSBs with the same spatial filter setting include mechanisms to ensure UE awareness of polarization properties of SSBs, e.g., communication of paired SSB indices associated with the same spatial filtering and different polarizations, to the UE.

One source (R1-2007745) evaluated the performance of increasing the number of SSBs and shows 1.84 dB gain when the number of SSBs is increased from 4 to 8 at 700MHz in rural scenario.

Table 6.3.6-1 Performance evaluation for SSB enhancements

Source	Solution	Performance gain	Key Assumptions
Source 1 (R1-2007745)	Increasing the number of SSBs	1.84 dB	Rural, 700MHz Baseline scheme: 4 SSBs Enhanced scheme: 8 SSBs

6.3.7 Beam reporting during initial/random access procedure

Beam reporting during initial/random access procedure is intended to enhance Msg3 re-transmission, Msg4 initial transmission, Msg4 re-transmission and PDSCH out of RACH procedure while without dedicated RRC configuration.

Beam reporting during initial/random access procedure was studied from several aspects, including the best SSB, alternative SSB beam and early CSI report in Msg3 PUSCH. Potential specification impacts include signaling design in Msg3 PUSCH, CSI-RS resources configured during initial access, beam indication for the following steps for RACH procedure.

6.3.8 Others

A-CSI repetition on PUSCH was studied. Potential specification impacts include mechanism to determine A-CSI repetitions on PUSCH, e.g. A-CSI request and/or repetition factor in UL DCI, one A-CSI in each PUSCH repetition, and PUSCH repetition type A.

A-CSI on PUCCH to allow A-CSI repetition was studied. Potential specification impacts include mechanism to determine the repetition of A-CSI PUCCH, e.g. CSI request and/or repetition factor in the downlink DCI, configuration of repetition levels per PUCCH resource, and related timeline, mechanism for the PUCCH resource determination, e.g. based on existing PUCCH resource configuration framework in DL DCI (i.e., DCI format 1_0, 1_1, 1_2), existing PUCCH formats that can carry CSI, and RS resource for CSI measurement (e.g. aperiodic CSI-RS, DMRS).

One source (R1-2008421) evaluated the performance of A-CSI repetition on PUSCH and shows 4 dB gain for 8 repetitions with 11 bits CSI at 10% BLER target at 4GHz.

Table 6.3.8-1 Performance evaluation for A-CSI on PUSCH

Source	Solution	Performance gain	Key Assumptions
Source 1 (R1-2008421)	A-CSI repetition on PUSCH	4.0 dB	8 aperiodic repetitions vs. no repetition 11 bits CSI; 10% BLER For 300ns delay spread, 3kmph, 4 Rx Format 3, 4 GHz No frequency hopping, 4 DMRS

7 Conclusions

The following channels are identified as the potential bottleneck channels for FR1:

- 1st priority
  - PUSCH for eMBB (for FDD and TDD with DDDSU, DDDSUDDSUU and DDDDDDDSUU)
  - PUSCH for VoIP (for FDD and TDD with DDDSU, DDDSUDDSUU)
- 2nd priority
  - PRACH format B4
  - PUSCH of Msg.3
  - PUCCH format 1
  - PUCCH format 3 with 11bit
  - PUCCH format 3 with 22bit
  - Broadcast PDCCH

The following channels are identified as the potential bottleneck channels for Urban 28 GHz scenario:

- PUSCH eMBB (DDDSU and DDSU)
- PUSCH VoIP (DDDSU and DDSU)
- PUCCH F3 11bits
- PUCCH F3 22bits
- PRACH B4
- PUSCH of Msg3

Enhancements on PUSCH repetition type A is beneficial for PUSCH coverage enhancements for TDD. It is recommended to support enhancements on PUSCH repetition type A in Rel-17, including the following two options (potential down-selection during the WI phase):

- Option 1: Increasing the maximum number of repetitions, e.g., up to 32.
- Option 2: The number of repetitions counted on the basis of available UL slots.

TB processing over multi-slot PUSCH is beneficial for PUSCH coverage enhancements. It is recommended to support TB processing over multi-slot PUSCH in Rel-17, including:

- TBS determined based on multiple slots and transmitted over multiple integer slots.

Joint channel estimation is beneficial for PUSCH coverage enhancements. It is recommended to support joint channel estimation or DM-RS bundling for PUSCH in Rel-17, including:

- Joint channel estimation over consecutive PUSCH transmissions

- Inter-slot frequency hopping with inter-slot bundling

Annex <A>: Simulation assumptions

A.1 Simulation assumptions for FR1

This clause describes the link-level simulation assumptions for FR1. Table A.1-1 shows the general parameters for all channels. Table A.1-2~Table A.1-8 shows the channel-specific parameters for each channel respectively.

Table A.1-1: General parameters for FR1

<table>
<tr><th>Parameter</th><th>Value</th></tr>
<tr><td>Scenario and frequency</td><td>Urban: 4GHz (TDD), 2.6GHz (TDD)
Rural: 4GHz (TDD), 2.6GHz (TDD), 2GHz (FDD), 700MHz (FDD)
Rural with long distance: 700MHz (FDD), 4GHz (TDD)</td></tr>
<tr><td>Frame structure for TDD</td><td>DDDSU (S: 10D:2G:2U) only for 4GHz
DDDSUDDSUU (S: 10D:2G:2U) only for 4GHz
DDDDDDDSUU (S: 6D:4G:4U) only for 2.6GHz
Other frame structures can be reported by companies.</td></tr>
<tr><td>Target data rates for eMBB</td><td>Urban: DL 10Mbps, UL 1Mbps
Rural: DL 1Mbps, UL 100kbps
Rural with long distance: DL 1Mbps, UL 100kbps, 30kbps (optional)</td></tr>
<tr><td>Packet size for VoIP</td><td>A packet size of 320 bits with 20ms data arriving interval is adopted.
<table>
<tr><th></th><th>Size (bits)</th></tr>
<tr><td>Payload</td><td>256</td></tr>
<tr><td>CRC</td><td>16 (TBS size lower than 3824 bits)</td></tr>
<tr><td>MAC</td><td>16 (with 12 bits SN size)</td></tr>
<tr><td>RLC</td><td>8 (with 6 bits SN size)</td></tr>
<tr><td>PDCP</td><td>16</td></tr>
<tr><td>RTP/UDP/IP</td><td>24 (w RoHC)</td></tr>
</table>
If applicable, companies report TB size assumed in evaluation.

For SIP invite message
- Payload of 1500 bytes can be a starting point.
- The assumptions (TB size, time period etc.) are reported by companies.
- Contributions R1-2003464 and R1-2005259 are taken into account for the evaluation
  - In addition, 1 second time period can also be considered.</td></tr>
<tr><td>Latency requirements for VoIP</td><td>Latency requirements assumed in VoIP evaluation for TDD and FDD are reported by companies.</td></tr>
<tr><td>Pathloss model (select from LoS or NLoS)</td><td>Urban: NLoS
Rural: NLoS and LoS</td></tr>
<tr><td>BWP</td><td>100MHz for 4GHz and 2.6GHz.
20MHz for 2GHz (FDD)
20MHz (optional for 10MHz) for 700MHz. (FDD)</td></tr>
</table>

Channel model for link-level simulation	TDL-C for NLOS, TDL-D for LOS.
Delay spread	Urban: 300ns Rural: 300ns Rural with long distance: 30ns
UE velocity	Urban: 3km/h for indoor Rural: 3km/h for indoor, 120km/h (optional 30km/h) for outdoor
Number of antenna elements for BS	- Urban: 192 antenna elements for 4GHz and 2.6GHz, (M,N,P,Mg,Ng) = (12,8,2,1,1) (optional) 128 antenna elements for 4GHz, (M,N,P,Mg,Ng) = (8,8,2,1,1) - Rural: 64 antenna elements for 4GHz and 2.6GHz (M,N,P,Mg,Ng) = (8,4,2,1,1) 32 antenna elements for 2GHz (M,N,P,Mg,Ng) = (8,2,2,1,1) 16 antenna elements for 700MHz (M,N,P,Mg,Ng) = (4,2,2,1,1)
Number of TxRUs for BS	gNB architectures to study: - 2 or 4 TXRUs for 2GHz, 700 MHz - 64TxRUs for 2.6 and 4 GHz. - Optional: 32 TXRUs at 2 GHz gNB modeling in LLS for TDL: - Option 1: 2 or 4 gNB RF chains in LLS. - Option 2 (Optional): Number of gNB RF chains = number of TXRUs in LLS. - Companies can report if and how correlation is modelled.

Table A.1-2: Channel-specific parameters for PUSCH for FR1

Parameter	Value
Frequency hopping	w/ or w/o frequency hopping
BLER	For eMBB, w/ HARQ, 10% iBLER; w/o HARQ, 10% iBLER. For VoIP, 2% rBLER.
Number of UE transmit chains	1, 2 (optional)
DMRS configuration	For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data. For 120km/h, (Optional: 30km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data. For frequency hopping: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data. PUSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies.
Waveform	DFT-s-OFDM, CP-OFDM (optional)
SCS	30kHz for TDD, 15kHz for FDD.

PUSCH duration	14 OS
Repetitions	For eMBB, w/o repetition as baseline, w/ repetition (optional). For VoIP, w/ type A repetition, optional for type B repetition. The actual number of repetitions is reported by companies.
HARQ configuration	For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ. The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies.
PRBs/TBS/MCS for eMBB	Any value of PRBs, and corresponding MCS index, reported by companies will be considered in the discussion. Companies are encouraged to use 30 PRBs for 1Mbps, 4 PRBs for 100kbps, 1 PRB for 30kbps as a starting point. TBS can be calculated based on e.g. the number of PRBs, target data rate, frame structure and overhead.
PRBs/MCS for VoIP	4 PRBs for VoIP as starting point. Other values of PRBs can be reported by companies. QPSK, pi/2 BPSK (optional)

Table A.1-3: Channel-specific parameters for PUCCH for FR1

Parameter	Value
PUCCH format	Format 1, 2bits UCI. Format 3, 4bits (3 bits A/N + 1 bit SR)/11/22 bits UCI
Frequency hopping	w/ frequency hopping
BLER	- For PUCCH format 1: DTX to ACK probability: 1%. NACK to ACK probability: 0.1%. ACK missed detection probability: 1%. - For PUCCH format 3: BLER for Ack/Nack, SR: 1% BLER for CSI: 1%, optional for 10%.
Number of UE transmit chains	1
DMRS configuration	Number of DMRS symbols for PUCCH Format 3: Reported by companies
SCS	30kHz for TDD, 15kHz for FDD.
Repetitions	w/ repetition (optional), w/o repetition for PUCCH. The maximum number of repetitions is 8.
PUCCH duration	14 OS
Number of PRBs	1 PRB

Table A.1-4: Channel-specific parameters for PRACH for FR1

Parameter	Value
Format	Format 0, Format B4, or Format C2
SCS	Reported by companies.
Performance metric	1% missed detection at 0.1% false alarm probability

	10% missed detection: reported by companies if this value is used
Number of UE transmit chains	1, 2 (optional)
Other parameters	Reported by companies.

Table A.1-5: Channel-specific parameters for PUSCH of Msg.3 for FR1

Parameter	Value
Frequency hopping	w/ or w/o frequency hopping
Number of UE transmit chains	1, 2 (optional)
Number of DMRS symbol	w/o frequency hopping: 3, w/ frequency hopping: 2 for each hop
Waveform	DFT-s-OFDM
SCS	30kHz for TDD, 15kHz for FDD.
HARQ configuration	For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ. The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies.
PUSCH duration	14 OS
Number of PRBs	2
TBS	56 bits
Other parameters	Reported by companies.

Table A.1-6: Channel-specific parameters for PDSCH for FR1

Parameter	Value
BLER	For eMBB, w/ HARQ, 10% iBLER; w/o HARQ, 10% iBLER. For VoIP, 2% rBLER.
Waveform	CP-OFDM
Number of UE receive chains	4 for 4GHz/2.6GHz, 2 or 4 for 2GHz, 2 for 700MHz
SCS	30kHz for TDD, 15kHz for FDD.
HARQ configuration	For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ. The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies.
DMRS configuration	3 DMRS symbols is used for PDSCH of Msg.2. For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data. For 120km/h, (Optional: 30km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data. For frequency hopping: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data. PDSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies.
PRBs/MCS/TBS	Reported by companies.
PDSCH duration	12 OS For PDSCH of Msg.4, 12 OS

Payload size for PDSCH of Msg.4	1040 bits
Other parameters	Reported by companies.

Table A.1-7: Channel-specific parameters for PDCCH for FR1

Parameter	Value
Number of UE receive chains	4 for 4GHz/2.6GHz, 2 or 4 for 2GHz, 2 for 700MHz
SCS	30kHz for TDD, 15kHz for FDD.
Aggregation level	16
Payload	40 bits
CORESET size	2 symbols, 48 PRBs
Tx Diversity	Reported by companies
BLER	1% BLER optional for 10% BLER
Number of SSB for broadcast PDCCH of Msg.2	Reported by companies
Other parameters	Reported by companies

Table A.1-8: Channel-specific parameters for SSB for FR1

Parameter	Value
Number of UE receive chains	4 for 4GHz/2.6GHz, 2 or 4 for 2GHz, 2 for 700MHz
SCS	30kHz for TDD, 15kHz for FDD.
Periodicity	20ms
Performance metric	Combination of 4 SSBs in 80ms. Note: UE is not assumed to know the SS/PBCH block index
Other parameters	Reported by companies.

A.2 Simulation assumptions for FR2

This clause describes the link-level simulation assumptions for FR2. Table A.2-1 shows the general parameters for all channels. Table A.2-2~Table A.2-8 shows the channel-specific parameters for each channel respectively.

Table A.2-1: General parameters for FR2

Parameter	Value
Scenario and frequency	Indoor: 28GHz (TDD) Urban: 28GHz (TDD) Suburban: 28GHz (TDD)
Frame structure for TDD	DDDSU (S: 10D:2G:2U) DDSU (S: 11D:3G:0U) Other frame structures can be reported by companies.

<table>
<tr><td>Target data rates for eMBB</td><td>Indoor: DL: 25Mbps, UL:5Mbps
Urban: DL: 25Mbps, UL: 5Mbps
Suburban: DL: 1Mbps, UL: 50kbps (low priority)</td></tr>
<tr><td>Packet size for VoIP</td><td>A packet size of 320 bits with 20ms data arriving interval is adopted.
<table>
<tr><td></td><td>Size (bits)</td></tr>
<tr><td>Payload</td><td>256</td></tr>
<tr><td>CRC</td><td>16 (TBS size lower than 3824 bits)</td></tr>
<tr><td>MAC</td><td>16 (with 12 bits SN size)</td></tr>
<tr><td>RLC</td><td>8 (with 6 bits SN size)</td></tr>
<tr><td>PDCP</td><td>16</td></tr>
<tr><td>RTP/UDP/IP</td><td>24 (w RoHC)</td></tr>
</table>
If applicable, companies report TB size assumed in evaluation.

For SIP invite message
- Payload of 1500 bytes can be a starting point.
- The assumptions (TB size, time period etc.) are reported by companies.
- Contributions R1-2003464 and R1-2005259 are taken into account for the evaluation
  - In addition, 1 second time period can also be considered.</td></tr>
<tr><td>Latency requirements for VoIP</td><td>Latency requirements assumed in VoIP evaluation for TDD and FDD are reported by companies.</td></tr>
<tr><td>BWP</td><td>100MHz, [400MHz]</td></tr>
<tr><td>Channel model for link-level simulation</td><td>CDL- A, TDL-A, [urban/suburban: TDL-C]
Note: company can provide simulation results based on either TDL channel or CDL model</td></tr>
<tr><td>Delay spread</td><td>Indoor scenario: 30ns
Urban scenario: 100ns
Suburban scenario: 100ns</td></tr>
<tr><td>UE velocity</td><td>Indoor scenario:3km/h
Urban scenario: 3km/h for indoor, 30km/h for outdoor.
Suburban scenario: 3km/h for indoor, 30km/h, (optional: 120km/h) for outdoor.</td></tr>
<tr><td>Number of antenna elements for BS</td><td>Indoor scenario: 128
(M, N, P, Mg, Ng) = (8, 8, 2, 1, 1)
Urban/suburban scenario:
256, (M,N,P,Mg,Ng) = (4, 8, 2, 2, 2)
Optional: 512, (M,N,P,Mg,Ng) = (8,8,2,2,2)</td></tr>
<tr><td>Number of TxRUs for BS</td><td>2
Note: Analog beamforming is assumed.</td></tr>
<tr><td>Number of UE antenna elements</td><td>8, one panel:(M, N, P) = (2,2,2),</td></tr>
</table>

Table A.2-2: Channel-specific parameters for PUSCH for FR2

Parameter	Value
Frequency hopping	w/ or w/o frequency hopping
BLER	For eMBB, w/ HARQ, 10% iBLER, Optional: companies report rBLER. w/o HARQ, 10% iBLER. For VoIP, 2% rBLER.
Number of UE Tx/Rx chains	1T2R, 2T2R
DMRS configuration	For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data. For 30km/h (optional: 120km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data. For frequency hopping for PUSCH: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data. PUSCH/PDSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies.
Waveform	DFT-s-OFDM
SCS	120kHz.
PUSCH duration	14 OS
Repetitions	For eMBB, w/o repetition as baseline, w/ repetition (optional). For VoIP, w/ repetition. The actual number of repetitions is reported by companies. Only PUSCH repetition type A is considered for baseline performance evaluation. o Note: companies are not precluded to report results for repetition type B.
HARQ configuration	For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ. The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies.
PRBs/TBS/MCS for eMBB	Any value of PRBs, and corresponding MCS index, reported by companies will be considered in the discussion. Companies are encouraged to use [30] PRBs for 5Mbps for PUSCH as a starting point. TBS can be calculated based on e.g. the number of PRBs, target data rate, frame structure and overhead.
PRBs/MCS for VoIP	[4 PRBs] for VoIP as starting point. Other values of PRBs can be reported by companies. QPSK for PUSCH Optional: pi/2 BPSK for PUSCH

Table A.2-3: Channel-specific parameters for PUCCH for FR2

Parameter	Value
PUCCH format	Format 1, 2bits UCI. Format 3, [4bits (3 bits A/N + 1 bit SR)]/11/22 bits UCI
Frequency hopping	w/ frequency hopping
BLER	- For PUCCH format 1: DTX to ACK probability: 1%. NACK to ACK probability: 0.1%. ACK missed detection probability: 1%.

	- For PUCCH format 3: BLER: 1%
Number of UE transmit chains	1
DMRS configuration for	4 DMRS symbols for PUCCH Format 3.
SCS	120kHz
Repetitions	w/ repetition (optional), w/o repetition for PUCCH. The maximum number of repetitions is 8.
PUCCH duration	14 OFDM symbols
Number of PRBs	1 PRB

Table A.2-4: Channel-specific parameters for PRACH for FR2

Parameter	Value
Format	Format B4, (Optional: Format C2)
SCS	Reported by companies.
Performance metric	0.1% false alarm, 1% miss-detection
Number of UE Tx chains	1T, 2T
Number of SSB beams	Reported by companies
Other parameters	Reported by companies.

Table A.2-5: Channel-specific parameters for PUSCH of Msg.3 for FR2

Parameter	Value
Frequency hopping	w/ or w/o frequency hopping
Number of UE Tx chains	1T, 2T
Number of DMRS symbol	w/o frequency hopping: 3, w/ frequency hopping: 2 for each hop
Waveform	DFT-s-OFDM
SCS	120kHz
HARQ configuration	For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ. The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies.
TBS	56 bits
PUSCH duration	14 OS
Number of PRBs	2
Other parameters	Reported by companies.

Table A.2-6: Channel-specific parameters for PDSCH for FR2

Parameter	Value
BLER	For eMBB, w/ HARQ, 10% iBLER, Optional: companies report rBLER. w/o HARQ, 10% iBLER. For VoIP, 2% rBLER.
Waveform	CP-OFDM
Number of UE receive chains	2
SCS	120kHz
HARQ configuration	For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ. The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies.
DMRS configuration	For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data. For 30km/h (optional: 120km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data. For frequency hopping for PUSCH: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data. PUSCH/PDSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies.
PRBs/TBS/MCS for eMBB	Any value of PRBs, and corresponding MCS index, reported by companies will be considered in the discussion. Companies are encouraged to use full bandwidth for 25Mbps for PDSCH as a starting point. TBS can be calculated based on e.g. the number of PRBs, target data rate, frame structure and overhead.
PRBs/MCS for VoIP	[4 PRBs] for VoIP as starting point. Other values of PRBs can be reported by companies. QPSK for PDSCH
PDSCH duration	12 OS For PDSCH of Msg.4, 12 OS
Payload size for PDSCH of Msg.4	1040 bits

Table A.2-7: Channel-specific parameters for PDCCH for FR2

Parameter	Value
Number of UE receive chains	2
SCS	120kHz
Aggregation level	16
Payload	40 bits
CORESET size	2 symbols, 48 PRBs
Tx Diversity	Reported by companies
BLER	1% BLER
Number of SSB for broadcast PDCCH of Msg.2	Reported by companies
Other parameters	Reported by companies

Table A.2-8: Channel-specific parameters for SSB for FR2

Parameter	Value
Number of UE Tx/Rx chains	1T2R, 2T2R
SCS	120kHz
Periodicity	20ms
Performance metric	Combination of 4 SSBs in 80ms. Note: UE is not assumed to know the SS/PBCH block index
Other parameters	Reported by companies.

A.3 Link budget template

Table A.3: Link budget template

System configuration	
Channel for evaluation	PUSCH/ PUCCH/ Msg.3 PUSCH/ PRACH/ Broadcast PDCCH(Msg.2 PDCCH)/ Msg.2 PDSCH/ Msg.4 PDSCH/ PDSCH/ Unicast PDCCH/ SSB/ PUSCH for CSI/PUCCH with HARQ-ACK for Msg.4/ PUSCH with SIP invite
Scenarios and Carrier frequency (GHz)	For FR1: - Urban 4 GHz TDD/ 2.6 GHz TDD - Rural 4 GHz TDD/ 2.6 GHz TDD/ 2 GHz FDD/ 700 MHz FDD - Rural with long distance 700 MHz FDD/ 4 GHz TDD For FR2: - Indoor 28 GHz TDD - Urban 28 GHz TDD - Suburban 28 GHz TDD
BS antenna heights (m)	Reported by companies, 25m for urban, 35m for rural can be used as a starting point.
UT antenna heights (m)	Reported by companies, 1.5m can be used as a starting point.
Cell area reliability (%)	Reported by companies, 95% for control channel, 90% for data channel can be used as a starting point.
Lognormal shadow fading std deviation (dB)	Reported by companies
Tx Diversity	Reported by companies
Number of SSB	Reported by companies
Transmitter	
(1) Number of transmit antenna elements	For FR1 BS: - Urban: - 192 antenna elements for 4GHz and 2.6GHz - (optional) 128 antenna elements for 4GHz - Rural: - 64 for 4GHz and 2.6GHz - 32 antenna elements for 2GHz For FR2 BS: - Indoor scenario: 128 - Urban/suburban scenario: 256, Optional: 512 For FR1 UE: - 1 - 2 (optional) For FR2 UE: - 8
(2) Number of transmit TxRUs Note: this row is void (left empty) for uplink	FR1 BS: - 2 or 4 TXRUs for 2GHz, 700 MHz - 64TxRUs for 2.6 and 4 GHz - Optional: 32 TXRUs at 2 GHz FR2 BS: - 2
(2a) Number of transmit chains modelled in LLS	For FR1 BS: - Option 1: 2 or 4 gNB transmit chains in LLS. - Option 2 (optional): Number of gNB transmit chains = number of TXRUs FR2 BS: - 2 For FR1 UE: - PUSCH/ Msg.3 PUSCH/ PRACH: 1, 2 (optional) - PUCCH: 1 For FR2 UE: - Option 1: PUSCH/ Msg.3 PUSCH/ PRACH: 1, 2; PUCCH: 1 - Option 2: 8
(3) Total transmit power (dBm) Note: total transmit power for system bandwidth	For FR1 UE: - 23 dBm for UE For FR2 UE: - 23 dBm and/or 12 dBm for UE (other values can be reported by companies)

(3a) System bandwidth for downlink, or occupied bandwidth for uplink (Hz)	For downlink: System bandwidth for FR1: - 100MHz for 4GHz and 2.6GHz - 20MHz for 2GHz (FDD) - 20MHz (optional for 10MHz) for 700MHz. (FDD) System bandwidth for FR2: - 100MHz, [400MHz] For uplink: - Occupied bandwidth is reported by companies
(3b) Power Spectrum Density = (3) - 10 log((3a) / 1000000) (dBm/MHz) Note: For FR1 downlink, (3b) should satisfy the following: For 4GHz frequency, 24 and 33 For 2.6 GHz frequency, 33 For 700MH and 2GHz frequency, 36 Note: For FR2 downlink, the following should be satisfied: 40 dBm for 100 MHz Urban scenario, 23 dBm for 100 MHz Indoor scenario. Note: no PSD constraint for uplink	
(3c) Bandwidth used for the evaluated channel (Hz) Note: (3c) is identical to the number of PRBs assigned to the channel evaluated. For uplink, (3a) = (3c)	
(3bis) Total transmit power for occupied bandwidth = (3b) + 10 log ((3c) / 1000000) (dBm)	
(4) Total antenna gain at antenna gain component 3 & antenna gain component 4 of transmitter = (4a) – (4b) (dB)	
(4a) Antenna gain at antenna gain component 3 & antenna gain component 4 of transmitter = (4c) + 10 log ((1) / (2)) (dB) for downlink, and = (4c) + 10 log ((1) / (2a)) (dB) for uplink	
(4b) Antenna gain correction factor at antenna gain component 3 & antenna gain component 4 of transmitter (dB)	Reported by companies
(4c) Gain of antenna element (dBi)	For BS: - 8 dBi or reported by companies For UE: - 0 dBi for FR1 - 5 dBi for FR2
(5) Total antenna gain at antenna gain component 2 of transmitter = (5a) - (5b) (dB) Note: zero for uplink	
(5a) Antenna gain at antenna gain component 2 of transmitter = 10 log((2)/(2a)) (dB) Note: zero for uplink	
(5b) Antenna gain correction factor at antenna gain component 2 of transmitter (dB) Note: zero for uplink	Reported by companies
(8) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for downlink)	Reported by companies
(9) EIRP = (3bis) + (4) + (5) – (8) dBm	
Receiver	

(10) Number of receive antenna elements	For FR1 BS: Urban: - 192 antenna elements for 4GHz and 2.6GHz - (optional) 128 antenna elements for 4GHz Rural: - 64 for 4GHz and 2.6GHz - 32 antenna elements for 2GHz For FR2 BS: - Indoor scenario: 128 - Urban/suburban scenario: 256, Optional: 512 For FR1 UE: - 1 - (optional) 2 For FR2 UE: -8
(10a) Number of receive TxRUs Note: this row is void (empty) for downlink	FR1 BS: - 2 or 4 TXRUs for 2GHz, 700 MHz - 64TxRUs for 2.6 and 4 GHz - Optional: 32 TXRUs at 2 GHz FR2 BS: - 2
(10b) Number of receive chains modelled in LLS	For FR1 BS: - Option 1: 2 or 4 gNB receive chains in LLS. - Option 2 (optional): Number of gNB receive chains = number of TXRUs FR2 BS: - 2 For FR1 UE: - 4 for 4GHz/2.6GHz - 2 or 4 for 2GHz - 2 for 700MHz For FR2 UE: - Option 1: 2 - Option 2: 8
(11) Total antenna gain at antenna gain component 3 & antenna gain component 4 of receiver = (11a) - (11b) (dB)	
(11a) Antenna gain at antenna gain component 3 & antenna gain component 4 of receiver = (11c) + 10 log ((10)/(10a)) (dB) for uplink = (11c) + 10 log ((10)/(10b)) (dB) for downlink	
(11b) Antenna gain correction factor at antenna gain component 3 & antenna gain component 4 of receiver (dB)	Reported by companies
(11c) Gain of antenna element (dBi)	For BS: - 8 dBi or reported by companies For UE: - 0 dBi for FR1, - 5 dBi for FR2
(11bis) Total antenna gain at antenna gain component 2 of receiver = (11bis-a) - (11bis-b) (dB) Note: zero for downlink	
(11bis-a) Antenna gain at antenna gain component 2 of receiver = 10 log((10a)/(10b)) (dB) Note: zero for downlink	
(11bis-b) Antenna gain correction factor at antenna gain component 2 of receiver (dB) Note: zero for downlink	Reported by companies
(12) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for uplink)	Reported by companies

(13) Receiver noise figure (dB)	Reported by companies
(14) Thermal noise density (dBm/Hz)	Reported by companies
(15) Receiver interference density (dBm/Hz)	Reported by companies
(16) Total noise plus interference density = 10 log (10^(((13) + (14))/10) + 10^((15)/10)) (dBm/Hz)	
(18) Effective noise power = (16) + 10 log ((3c)) (dBm)	
(19) Required SNR (dB)	
(20) Receiver implementation margin (dB)	Reported by companies
(21) H-ARQ gain (dB) Note: Only applicable if HARQ is not considered in LLS	Reported by companies
(22) Receiver sensitivity = (18) + (19) + (20) – (21) (dBm)	
(22bis) MCL = (3bis) – (22) + (5) + (11bis) (dB)	(22bis) MCL = (3bis) – (22) + (5) + (11bis) (dB)
(23) Hardware link budget, a.k.a. MIL = (9) + (11) + (11bis) − (12) − (22) (dB) Note: MIL can also be derived by (22bis) + (4) – (8) + (11) − (12)	(23) Hardware link budget, a.k.a. MIL = (9) + (11) + (11bis) − (12) − (22) (dB) Note: MIL can also be derived by (22bis) + (4) – (8) + (11) − (12)
Calculation of available pathloss	
(25) Shadow fading margin (function of the cell area reliability and lognormal shadow fading std deviation) (dB)	Reported by companies
(26) BS selection/macro-diversity gain (dB)	Reported by companies
(27) Penetration margin (dB)	Reported by companies
(28) Other gains (dB) (if any please specify)	Reported by companies
(29) Available path loss = (23) – (25) + (26) – (27) + (28) (dB)	
Range/coverage efficiency calculation	
(30) Maximum range (based on (29) and according to the system configuration section of the link budget) (m)	

A.4 Derivation of target MCL for service dependent metric

Table A.4: Link budget for UMTS voice uplink

Transmitter	
(2a) Number of transmit chains modelled in LLS	1
(3) Total transmit power (dBm) Note: total transmit power for system bandwidth	23
(3a) System bandwidth for downlink, or occupied bandwidth for uplink (Hz)	3840000
(3b) Power Spectrum Density = (3) - 10 log((3a) / 1000000) (dBm/MHz) Note: For FR1 downlink, (3b) should satisfy the following: For 4GHz frequency, 24 and 33 For 2.6 GHz frequency, 33 For 700MH and 2GHz frequency, 36 Note: For FR2 downlink, the following should be satisfied: 40 dBm for 100 MHz Urban scenario, 23 dBm for 100 MHz Indoor scenario. Note: no PSD constraint for uplink	17.16
(3c) bandwidth used for the evaluated channel (Hz) Note: (3c) is identical to the number of PRBs assigned to the channel evaluated. for uplink, (3a) = (3c)	3840000
(3bis) Total transmit power for occupied bandwidth = (3b) + 10 log ((3c) / 1000000) (dBm)	23.00
(5) total antenna gain at antenna gain component 2 of transmitter = (5a) - (5b) (dB) Note: zero for uplink	0
(5a) antenna gain at antenna gain component 2 of transmitter = 10 log((2)/(2a)) (dB) Note: zero for uplink	0
(5b) antena gain correction factor at antenna gain component 2 of transmitter (dB) Note: zero for uplink	0
Receiver	
(10a) Number of receive TxRUs Note: this row is void (empty) for downlink	2
(10b) Number of receive chains modelled in LLS	2
(11bis) total antenna gain at antenna gain component 2 of receiver = (11bis-a) - (11bis-b) (dB) Note: zero for downlink	0
(11bis-a) antenna gain at antenna gain component 2 of receiver = 10 log((10a)/(10b)) (dB) Note: zero for donwlink	0
(11bis-b) antena gain correction factor at antenna gain component 2 of receiver (dB) Note: zero for downlink	0
(13) Receiver noise figure (dB)	5
(14) Thermal noise density (dBm/Hz)	-174
(15) Receiver interference density (dBm/Hz)	-165.7
(16) Total noise plus interference density = 10 log (10^(((13) + (14))/10) + 10^((15)/10)) (dBm/Hz)	-164.0
(18) Effective noise power = (16) + 10 log((3c)) (dBm)	-98.2
(19) Required SNR (dB)	5
(20) Receiver implementation margin (dB)	2
(21) H-ARQ gain (dB) or Process gain for UMTS Note: Only applicable if HARQ is not considered in LLS	25
(22) Receiver sensitivity = (18) + (19) + (20) – (21) (dBm)	-116.2
(22bis) MCL = (3bis) - (22) + (5) + (11bis) (dB)	139.2

Annex <B>: Simulation results for baseline coverage performance

The simulation results for baseline coverage performance can be found in the attached document "B_SimulationResults_baseline.zip".

Annex <C> (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2020-05	RAN1#101e	R1-2004753				Skeleton TR	0.0.1
2020-08	RAN1#102e	R1-2005730				Inclusion of agreements made at RAN1#101e on evaluation methodology and simulation assumptions	0.0.2
2020-10	RAN1#103e	R1-2007992				Inclusion of agreements made at RAN1#102e and post email discussion	0.0.3
2020-11	RAN1#103e	R1-2009461				Updated based on R1-2007992 with some corrections	0.1.0
2020-11	RAN1#103e	R1-2009851				Inclusion of agreements made at RAN1#103e	0.2.0
2020-12	RAN#90e	RP-202307				MCC clean-up – for approval by RAN plenary	1.0.0
2020-12	RAN#90e					TR under change control (Release 17) – approved by RAN plenary	17.0.0