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Technical Report

3rd Generation Partnership Project;
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Study on New Radio Access Technology
Physical Layer Aspects
(Release 14)

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Postal address

3GPP support office address
650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet
http://www.3gpp.org

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Contents

Foreword

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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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1 Scope

This document is related to the technical report for physical layer aspect of the study item “Study on New Radio Access Technology” [2]. The purpose of this TR is to help TSG RAN WG1 to define and describe the potential physical layer evolution under consideration and compare the benefits of each evolution techniques, along with the complexity evaluation of each technique.

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

This document is intended to gather all information in order to compare the solutions and gains vs. complexity, and draw a conclusion on way forward.

This document will be kept up-to-date via CRs in the future.

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-161596, "New SID Proposal: Study on New Radio Access Technology".

[3] 3GPP TR 38.913: "Study on Scenarios and Requirements for Next Generation Access Technologies".

[4] 3GPP TR 36.885: "Study on LTE-based V2X services".

[5] 3GPP TR 36.897: "Study on Elevation Beamforming/Full-Dimension (FD) MIMO for LTE".

[7] 3GPP TR 25.996: "Spatial channel model for Multiple Input Multiple Output (MIMO) simulations".

[8] 3GPP TR 38.900: "Study on channel model for frequency spectrum above 6 GHz".

[9] 3GPP TR 36.873: "Study on 3D channel model for LTE".

[10] 3GPP TR 36.814: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects".

[11] 3GPP TR 36.872: "Small cell enhancements for E-UTRA and E-UTRAN - Physical layer aspects".

[12] 3GPP TR 45.820: "Cellular system support for ultra-low complexity and low throughput Internet of Things (CIoT) ".

[13] 3GPP TR 36.843: "Study on LTE device to device proximity services; Radio aspects".

[14] 3GPP TR 36.828: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further enhancements to LTE Time Division Duplex (TDD) for Downlink-Uplink (DL-UL) interference management and traffic adaptation".

[15] 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR21.905[1] and the following apply.

5GCM: The channel model applicable above 6 GHz in TR 38.900 [8] subsequently expanded in scope to 0.5-100 GHz in TR 38.901 [15]. NOTE: The evaluations reported in the present document were performed before TR 38.901 was available.

3.2 Symbols

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

$L_{\mathrm{TB,CRC}}$	Number of bits for TB-level CRC(Cyclic Redundancy Check) before code block segmentation
T_s	Basic time unit

3.3 Abbreviations

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

CB	Code Block
CBG	Code Block Group
CC	Chase Combining, Component Carrier
CSI-RS	Channel State Information-Reference Signal
DC	Dual Connectivity, Direct Conversion
DM-RS	DeModulation-Reference Signal
eIMTA	Enhanced Interference Management and Traffic Adaptation
eMBB	Enhanced Mobile BroadBand
eV2X	Enhanced Vehicule to Everything
gNB	NR Node B
GT	Guard Time
IMR	Interference Measurement Resource
IR	Incremental Redundancy
LBRM	Limited Buffer Rate Matching
LDPC	Low-Density Parity-Check
MCL	Minimum Coupling Loss
MIB	Master Information Block
MU-MIMO	Multi-User Multiple Input Multiple Output
mMTC	Massive Machine Type Communication
NR	NR Radio Access
NR-PSS	NR-Primary Synchronization Signal
NR-SSS	NR-Secondary Synchronization Signal
NZP	Non Zero Power
PT-RS	Phase Tracking Reference Signal
QCL	Quasi-colocation
QC-LDPC	Quasi-Cyclic Low Density Parity Check
RAR	Random Access Response
SRI	SRS Resource Indicator
TRI	Transmit Rank Indicator
TRxP	Transmission Reception Point
UCI	Uplink Control Information
URLLC	Ultra-Reliable and Low Latency Communications

4 Introduction

At the 3GPP TSG RAN #71 meeting, the Study Item description on "Study on New Radio Access Technology " was approved [2]. The study item covers technology components to be considered for new radio access technologies, e.g. to fulfil the requirements on IMT-2020. This technical report covers the physical-layer aspects of these technology components.

5 General description of layer 1

5.1 Duplexing

NR supports paired and unpaired spectrum and strives to maximize commonality between the technical solutions, allowing FDD operation on a paired spectrum, different transmission directions in either part of a paired spectrum, TDD operation on an unpaired spectrum where the transmission direction of time resources is not dynamically changed, and TDD operation on an unpaired spectrum where the transmission direction of most time resources can be dynamically changing. DL and UL transmission directions at least for data can be dynamically assigned on a per-slot basis at least in a TDM manner. It is noted that transmission directions include all of downlink, uplink, sidelink, and backhaul link. NR supports at least semi-statically assigned DL/UL transmission direction as gNB operation, i.e., the assigned DL/UL transmission direction can be signaled to UE by higher layer signaling.

5.2 Forward compatibility

Forward compatibility of NR shall ensure smooth introduction of future services and features while efficient access of the earlier services and UEs in the same spectrum is still ensured.

In order to ensure forward compatibility of NR, explicit signaling to NR UEs can indicate reserved resources. At least some reserved resources are indicated by using at least RRC signaling.

5.3 Numerologies and frame structure

Multiple numerologies are supported. A numerology is defined by sub-carrier spacing and CP overhead. Multiple subcarrier spacings can be derived by scaling a basic subcarrier spacing by an integer N. The numerology used can be selected independently of the frequency band although it is assumed not to use a very low subcarrier spacing at very high carrier frequencies. Flexible network and UE channel bandwidth is supported.

From RAN1 specification perspective, maximum channel bandwidth per NR carrier is 400MHz in Rel-15. Note that all details for channel bandwidth at least up to 100 MHz per NR carrier are to be specified in Rel-15. At least for single numerology case, candidates of the maximum number of subcarriers per NR carrier is 3300 or 6600 in Rel-15 from RAN1 specification perspective. NR channel designs should consider potential future extension of these parameters in later releases, allowing Rel-15 UE to have access to NR network on the same frequency band in later release

A subframe duration is fixed to 1ms and frame length is 10ms. Scalable numerology should allow at least from 15kHz to 480kHz subcarrier spacing. All numerologies with 15 kHz and larger subcarrier spacing, regardless of CP overhead, align on symbol boundaries every 1ms in NR carrier. More specifically, for the normal CP family, the following is adopted.

- For subcarrier spacing of 15 kHz * 2^n (n is non-negative integer),
  - Each symbol length (including CP) of 15 kHz subcarrier spacing equals the sum of the corresponding 2^n symbols of the scaled subcarrier spacing.
  - Other than the first OFDM symbol in every 0.5ms, all OFDM symbols within 0.5ms have the same size
  - The first OFDM symbol in 0.5ms is longer by $16T_s$ (assuming 15 kHz and FFT size of 2048) compared to other OFDM symbols.
    - 16 T_s is used for CP for the first symbol.

- For subcarrier spacing of 15 kHz * 2^n (n is a negative integer)
  - Each symbol length (including CP) of the subcarrier spacing equals the sum of the corresponding 2^{-n} symbols of 15 kHz.

Resource defined by one subcarrier and one symbol is called as resource element (RE).

The physical layer design supports an extended CP. Extended CP will be only one in given subcarrier spacing in Rel-15. LTE scaled extended CP is supported at least for 60 kHz subcarrier spacing in Rel-15. The CP type can be semi-static configured with UE-specific signaling. UE supporting the extended CP may depend on UE type/capability.

The number of subcarriers per PRB is 12.

No explicit DC subcarrier is reserved both for downlink and uplink. Regarding DC present within the transmitter, DC handling of DC subcarrier in transmitter side is specified as follows:

- Receiver knows where DC subcarrier is or is informed (e.g., by specification or signaling) of where DC subcarrier is or if DC subcarrier is not present within receiver bandwidth.
- For the downlink, UE may assume transmitted DC subcarrier at the transmitter (gNB) side is modulated i.e., data is neither rate-matched nor punctured.
  - Signal quality requirement (e.g., EVM) corresponding to DC subcarriers is up to RAN4.
- For the uplink, transmitted DC subcarrier at the transmitter (UE) side is modulated i.e., data is neither rate-matched nor punctured.
  - Signal quality requirement (e.g., EVM) corresponding to DC subcarriers is up to RAN4.
- For the uplink, the transmitter DC subcarrier at the transmitter (UE) side should avoid collisions at least with DMRS if possible.
- For the uplink the specification should define at least one particular subcarrier as the candidate position of DC subcarrier, e.g., DC subcarrier is located at the boundary of PRBs
- For the uplink, means for the receiver to determine DC subcarrier location should be specified.
  - This involves semi-static signalling from UE and also standard specified DC subcarrier location.
- When DC subcarrier is not present, all subcarriers within the receiver bandwidth are transmitted.

Note that above DC subcarrier can be interpreted as DC subcarrier candidate.

On the other hand, at the receiver side, no special handling of the DC subcarrier(s) on the receiver side is specified in RAN1. Behavior is left to implementation, i.e., the receiver may for example puncture data received on the DC subcarrier.

A slot is defined as 7 or 14 OFDM symbols for the same subcarrier spacing of up to 60kHz with normal CP and as 14 OFDM symbols for the same subcarrier spacing higher than 60kHz with normal CP. A slot can contain all downlink, all uplink, or {at least one downlink part and at least one uplink part}. Slot aggregation is supported, i.e., data transmission can be scheduled to span one or multiple slots.

Mini-slots having the following lengths are defined.

- At least above 6 GHz, mini-slot with length 1 symbol supported.
- Lengths from 2 to slot length -1
  - For URLLC, at least 2 is supported

The following should be taken into account for designing slot-level channels/signals/procedures:

- Possible occurrence of mini-slot/slot transmission(s) occupying resources scheduled for ongoing slot transmission(s) of a given carrier for the same/different UEs
- At least one of DMRS format/structure/configuration for slot-level data channel is re-used for mini-slot-level data channel

- At least one of DL control channel format/structure/configuration for slot-level data scheduling is designed to be applicable to mini-slot-level data scheduling
- At least one of UL control channel format/structure/configuration for slot-level UCI feedback is designed to be applicable to mini-slot-level UCI feedback

Note that some UEs targeting certain use cases may not support all mini-slot lengths and all starting positions. Mini-slot can start at any OFDM symbol, at least above 6 GHz. A mini-slot contains DMRS at position(s) relative to the start of the mini-slot.

The following targets/use-cases to design mini-slots should be taken into account.

- Support of very low latency including URLLC for certain slot lengths
  - Target slot lengths are at least 1ms, 0.5ms.
- Support of finer TDM granularity of scheduling for the same/different UEs within a slot, especially if TxRP uses beam-sweeping (e.g., above 6GHz).
- NR-LTE co-existence
  - Note that this use case also exists for slot-based scheduling
- Forward compatibility towards unlicensed spectrum operation

The following should be taken into account as starting point for designing mini-slot-level channels/signals/procedures:

- Possible occurrence of mini-slot/slot transmission(s) occupying resources scheduled for ongoing slot transmission(s) of a given carrier for the same/different UEs
- DMRS for mini-slot-level data channel is just a re-use of that for slot-level data channel
- DL control channel for mini-slot-level data scheduling is just a re-use of that for slot-level data scheduling
- UL control channel for mini-slot-level UCI feedback is just a re-use of that for slot-level UCI feedback
- Scheduling/HARQ timelines for a mini-slot can be based on scheduling/HARQ timelines for a slot
- Scheduling/HARQ timelines for a mini-slot can be based on scheduling/HARQ timelines shorter than those for a slot

At least for single carrier operation, NR should allow a UE to operate in a way where it receives at least downlink control information in a first RF bandwidth and where the UE is not expected to receive downlink control information or data in a second RF bandwidth that is larger than the first RF bandwidth within less than X µs.

5.4 LTE-NR co-existence

To support the efficient coexistence between NR and LTE operating in the same licensed frequency band, at least legacy LTE features should be considered in the NR study, e.g.:

- MBSFN configuration (for LTE Rel-8 and beyond)
- TDD UL subframe (for LTE Rel-8 and beyond)
- SCell activation/deactivation (for LTE Rel-10 and beyond)
- TDD UL subframe configured by eIMTA feature (for LTE Rel-12 and beyond)

For LTE and NR coexistence, support the following features in NR design.

- Adapting the bandwidth occupied by NR carrier(s) at least as fast as LTE carrier aggregation schemes
- Allowing NR transmissions while avoiding OFDM symbols carrying SRS on an UL LTE subframe

For LTE and NR coexistence, in NR design, support of flexible starting point and duration of scheduled resources are considered as a tool to avoid for example the control region of MBSFN subframes and be able to use resources in the unused MBSFN subframes of an LTE carrier.

Note: these mechanisms may be reused from forward compatibility mechanisms

NR downlink is supported in MBSFN subframes of LTE.

For adjacent channel/band operation of NR and LTE in the unpaired spectrum, NR supports efficient adjacent channel co-existence with LTE-TDD using UL-DL configurations 0,1,2,3,4,5 in unpaired spectrum. NR also supports efficient adjacent channel co-existence with LTE-TDD using all the special subframe configurations in unpaired spectrum. The above adjacent channel co-existence with LTE-TDD does not necessarily imply that two or more frame structures are to be defined for NR. The wording “efficient” in the above two bullets does not imply exact alignment of configurations.

Note that DL/UL interference also can be avoided by using dynamically assigned DL/UL transmission direction in some cases.

It is noted that support or design for the above features do not imply that UE has to support simultaneous connection of NR and LTE in the same or overlapping carrier. Also note that the above mechanisms may be reused from forward compatibility mechanisms, or mechanisms for multiplexing eMBB and URLLC on the DL, or mini-slot.

NR supports the case when an NR UE is not expected to understand or detect LTE signals/channels in the frequency band shared by NR and LTE. Initial access procedure design for NR should be used as a baseline for the case of NR-LTE coexisting.

LTE-NR co-existence should support the following UL sharing scenarios. Collocated LTE and NR base stations with network operating UL on frequency F1 where LTE UL and NR UL share UL subframes of LTE. LTE DL on a paired frequency F3 NR DL transmission on frequency F2 (different than LTE DL frequency). NR UE operates in either of the following cases based on a common NR design:

- Standalone NR: UE accesses standalone NR carrier on F2. The UE may not be connected to an LTE carrier (some UE may not even support LTE).
- Dual connectivity of LTE and NR: UE accesses LTE PCell (with LTE UL on F1), then is configured by dual connectivity to also operate NR on F1 (UL) and F2 (DL).
    - NR DL and UL frequencies (and/or NR band number) are signaled by RRC

5.5 Carrier aggregation / Dual connectivity

For phase 1, carrier aggregation/dual connectivity operation within NR carriers over e.g. around 1GHz contiguous and non- contiguous spectrum from both NW and UE perspectives is supported. Carrier aggregation including different carriers having same or different numerologies is supported. From RAN1 specification perspective, the maximum number of NR carriers for CA and DC is 16. The number of NR CCs in any aggregation is independently configured for downlink and uplink. NR channel designs should consider potential future extension of the maximum number of NR carriers in later releases, allowing Rel-15 UE to have access to NR network on the same frequency band in later release.

Cross-carrier scheduling and joint UCI feedback are supported.

Per-carrier TB mapping is supported.

6 DL concepts

6.1 Basic transmission scheme

6.1.1 Modulation scheme

QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported.

6.1.2 Physical layer channel

NR defines physical resource block (PRB) where the number of subcarriers per PRB is the same for all numerologies. Note that the number of subcarriers per PRB is 12.

6.1.2.1 Physical resource multiplexing

Multiplexing different numerologies within a same NR carrier bandwidth (from the network perspective) is supported in TDM and/or FDM manner for both downlink and uplink. From UE perspective, multiplexing different numerologies is performed in TDM and/or FDM manner within/across (a) subframe duration(s). For subcarrier spacing of $2^m \times 15$ kHz, subcarriers are mapped on the subset/superset of those for subcarrier spacing of 15kHz in a nested manner in the frequency domain and the PRB grids are defined as the subset/superset of the PRB grid for subcarrier spacing of 15kHz in a nested manner in the frequency domain.

From network perspective, multiplexing of transmissions with different latency and/or reliability requirements for eMBB/URLLC in DL is supported by using the same subcarrier spacing with the same CP overhead or using different subcarrier spacing. In the specification, both approaches are to be supported. NR supports dynamic resource sharing between different latency and/or reliability requirements for eMBB/URLLC in DL. Dynamic resource sharing between URLLC and eMBB is supported by transmitting URLLC scheduled traffic where URLLC transmission may occur in resources scheduled for ongoing eMBB traffic. DL dynamic resources sharing between eMBB and URLLC is enabled without pre-emption by scheduling the eMBB and URLLC services on non-overlapping time/frequency resources (No specific specification work is expected).

NR supports indication of time and/or frequency region of impacted eMBB resources to respective eMBB UE(s).

6.1.2.2 Data channel

NR supports at least functionality where for DL data scheduled for a slot, the DL data DMRS location in time is not dynamically varying relative to the start of slot.

6.1.2.3 Control channel

At least QPSK is supported for the modulation of the NR-PDCCH. For single stage DCI, modulation scheme for NR-PDCCH is only QPSK. In frequency-domain, a PRB (or a multiple of PRBs) is the resource unit size (may or may not including DM-RS) for control channel. A NR-PDCCH candidate consists of a set of NR-CCEs. A NR-CCE consists of a fixed number of resource element groups (REGs). A REG is one RB during one OFDM symbol which may or may not include DM-RS. This is at least for the case where the DL control region consists of one or a few OFDM symbol(s) of a slot or a mini-slot. At least for eMBB, in one OFDM symbol, multiple NR-CCEs cannot be transmitted on the same REG except for spatial multiplexing to different UEs (MU-MIMO).

At least for single stage DCI design, a UE monitors for downlink control information in one or more control resource sets where a control resource set is defined as a set of REGs under a given numerology. The BW for control resource set is smaller than or equal to the carrier bandwidth (up to a certain limit). The control resource set is a set of REGs within which the UE attempts to blindly decode downlink control information. The REGs may or may not be frequency contiguous. When the control resource set spans multiple OFDM symbols, a control channel candidate is mapped to multiple OFDM symbols or to a single OFDM symbol. The gNB can inform UE which control channel candidates are mapped to each subset of OFDM symbols in the control resource set. This does not preclude that UE may receive additional control information elsewhere within or outside the control resource set in the same or different OFDM symbol(s). A UE may have one or more control resource sets. NR should support dynamic reuse of at least part of resources in the control resource sets for data for the same or a different UE, at least in the frequency domain. From gNB perspective, DL control channel can be located at the first OFDM symbol(s) in a slot and/or mini-slot. UE-specific DL control information monitoring occasions at least in time domain can be configured. At least for single-stage DCI design, for slots, minimum granularity of DCI monitoring occasion is once per slot.

The time/frequency resource containing at least one search space is obtained from MIB/system information/implicitly derived from initial access information. Time/frequency resource containing additional search spaces, can be configured using dedicated RRC signaling. NR-PDCCH can be mapped contiguously or non-contiguously in frequency. Multiple control resource sets can be overlapped in frequency and time for a UE. A search space in NR is associated with a single control resource set. The search spaces in different control resources sets are defined independently. Each candidate of NR DL control channel search space is composed by K NR-CCE(s). Control search space includes at least, aggregation level(s), number of decoding candidates for each aggregation level, and the set of CCEs for each decoding candidate.

The max number of blind decoding candidates for a UE is defined independently of the number of control resource sets and the number of search spaces.

NR supports a group common PDCCH carrying at least slot format related information. If the UE does not receive the group common PDCCH the UE should be able to receive at least PDCCH in a slot, at least if the gNB did not transmit the group common PDCCH. The network will inform through RRC signalling the UE whether to decode the group common PDCCH or not. Note that common does not necessarily imply common per cell. Also, the term group common PDCCH refers to a channel (either a PDCCH or a separately designed channel) that carries information intended for the group of UEs. Slot format related information and defined as information from which the UE can derive at least which symbols in a slot that are DL, UL (for Rel-15), and other, respectively. The UE will have the possibility to determine whether some blind decodings can be skipped based on information on a group common PDCCH (if present). When monitoring for a PDCCH, the UE should be able to process a detected PDCCH irrespective of whether the group common PDCCH is received or not.

UE/NR-PDCCH-specific DM-RS and shared/common RS are supported for NR-PDCCH reception. At least for beamforming, UE may assume the same precoding operation for NR-PDCCH and associated DM-RS for NR-PDCCH. The reference signals in at least one search space do not depend on the RNTI or UE-identity. In an additional search space, reference signals can be configured. A UE assumes fixed number of RS REs per REG for control channel rate matching when the REG contains RS REs. For one UE, the channel estimate obtained for one RE should be reusable across multiple blind decodings involving that RE in at least the same control resource set and type of search space (common or UE-specific).

Transmit diversity is supported for NR-PDCCH.

The starting position of downlink data in a slot can be explicitly and dynamically indicated to the UE.

6.1.3 Waveform

OFDM-based waveform is supported. At least up to 40 GHz for eMBB and URLLC services, CP-OFDM based waveform supports spectral utilization of Y greater than that of LTE (assuming Y=90% for LTE) where Y (%) is defined as transmission bandwidth configuration / channel bandwidth * 100%. From RAN1 perspective, spectral confinement technique(s) (e.g. filtering, windowing, etc.) for a waveform at the transmitter is transparent to the receiver.

6.1.4 Multiple access scheme

Synchronous/scheduling-based orthogonal multiple access is at least supported for DL transmissions, at least targeting for eMBB.

6.1.5 Channel coding

The channel coding scheme for data for eMBB is flexible LDPC as the single channel coding scheme for all block sizes.

The channel coding scheme for DCI for eMBB is Polar Coding (except for very small block lengths where repetition/block coding may be preferred).

Channel coding techniques for NR should support info block size K flexibility and codeword size flexibility where basic code design with rate matching (i.e., puncturing and/or repetition) supports 1-bit granularity in codeword size. Channel coding technique(s) designed for data channels of NR support both Incremental Redundancy (IR) (or similar) and Chase Combining (CC) HARQ.

6.1.5.1 LDPC

Code extension of a parity-check matrix is used for IR HARQ/rate-matching support. Lower-triangular extension, which includes diagonal-extension as a special case, is used. For the QC-LDPC design, the non-zero sub-blocks have circulant weight = 1. Circulant weight is the number of superimposed circularly shifted Z×Z identity matrices. In parity check matrix design, the highest code rate ($R_{\max,j}$) to design j-th H matrix for is $R_{\max,j}$ <=8/9, where $R_{\max,j}$ is the code rate of the j-th H matrix before code extension is applied ($0 \leq j < J$). $R_{\max,j}$ is the code rate after accounting for the built-in puncturing in H matrix design. Base graph for supporting $K_{\max}$ has minimum code rate $R_{\min,\mathrm{kmax}}$ of approximately 1/3. Base graph for any info block sizes K has $R_{\min,k}$ >= ~1/5, provided that $N_{\max}$ is not exceeded. At least 20Gbps decoder information throughput with code rate 8/9 is supported.

For a given shift size Z, a QC-LDPC code can be defined by a parity check matrix which is defined by its base graph and shift values. Element 1s and 0s in the base graph is replaced by a circulant permutation matrix of size ZxZ and zero matrix of size ZxZ, respectively. The shift values of a circulant permutation matrix can be calculated by a function $P_{i,j} = f(V_{i,j}, Z)$ where $V_{i,j}$ is an integer corresponding to the (i,j)-th non-zero element in a base matrix. The shift value $P_{i,j}$ is circularly shifted value from the identity matrix for the (i,j)-th non-zero element in a base matrix. The ZxZ circulant permutation matrix which shifts the ZxZ identity matrix I to the right by $P_{i,j}$ times for the (i,j)-th non-zero element in a base matrix.

Shortening is applied before LDPC encoding when necessary. Built-in puncturing of systematic bits is supported for LDPC coding, i.e., at least for the initial transmission, the coded bits are taken after skipping the first $N_{sys,punct}$ systematic bits.

For at least one base graph, the base matrix consists of five sub-matrices (A, B, C, D, E) as shown in Fig. 6.1.5.1-1. A corresponds to systematic bits. B is square and corresponds to parity bits. The first or last column may be weight 1. The non-zero value is in the last row and this row is weight 1 in B. If there is a weight 1 column, then the remaining columns contain a square matrix such that the first column has weight three. The columns after the weight three column have a dual diagonal structure (i.e., main diagonal and off diagonal). If there is no weight 1 column, B consists of only a square matrix such that the first column has weight three. The columns after the weight three column have a dual diagonal structure (i.e., main diagonal and off diagonal). C is a zero matrix. E is an identity matrix for the above base graph. These examples are shown in Fig. 6.1.5.1-2.

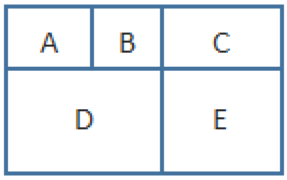


Figure 6.1.5.1-1: Base matrix.

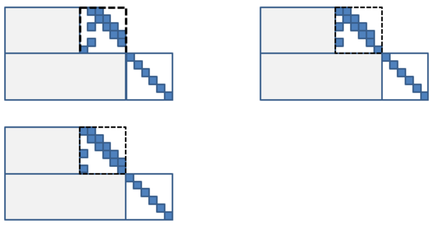


Figure 6.1.5.1-2: Examples of dual diagonal structure.

The rate matching for LDPC code is circular buffer based (same concept as in LTE). The circular buffer is filled with an ordered sequence of systematic bits and parity bits. For IR-HARQ, each Redundancy Version (RV), RV_i, is assigned a starting bit location S_i on the circular buffer. For IR retransmission of RV_i, the coded bits are read out sequentially from the circular buffer, starting with the bit location S_i. Limited buffer rate matching (LBRM) is supported

Before code block segmentation, $L_{TB,CRC}$ bit TB-level CRC are attached to the end of the transport block, where $L_{TB,CRC}$ <=24 bits, $L_{TB,CRC}$ value is determined to satisfy probability of misdetection of TB error $<=10^{-6}$ and, inherent error detection of LDPC codes is taken into account in determining the $L_{TB,CRC}$ value.

6.1.5.2 Polar coding

Maximum mother code size of Polar code, $N=2^n$, is $N_{max,DCI}$ =512 for downlink control information.

6.1.6 Multi-antenna scheme

6.1.6.1 Beam management

In NR, beam management is defined as follows:

- **Beam management:** a set of L1/L2 procedures to acquire and maintain a set of TRP(s) and/or UE beams that can be used for DL and UL transmission/reception, which include at least following aspects:

- **Beam determination:** for TRP(s) or UE to select of its own Tx/Rx beam(s).
- **Beam measurement:** for TRP(s) or UE to measure characteristics of received beamformed signals
- **Beam reporting:** for UE to report information of beamformed signal(s) based on beam measurement
- **Beam sweeping:** operation of covering a spatial area, with beams transmitted and/or received during a time interval in a predetermined way.

Also, the followings are defined as Tx/Rx beam correspondence at TRP and UE:

- Tx/Rx beam correspondence at TRP holds if at least one of the following is satisfied:
  - TRP is able to determine a TRP Rx beam for the uplink reception based on UE's downlink measurement on TRP's one or more Tx beams.
  - TRP is able to determine a TRP Tx beam for the downlink transmission based on TRP's uplink measurement on TRP's one or more Rx beams
- Tx/Rx beam correspondence at UE holds if at least one of the following is satisfied:
  - UE is able to determine a UE Tx beam for the uplink transmission based on UE's downlink measurement on UE's one or more Rx beams.
  - UE is able to determine a UE Rx beam for the downlink reception based on TRP's indication based on uplink measurement on UE's one or more Tx beams.
  - Capability indication of UE beam correspondence related information to TRP is supported.

Note that definition/terminology of Tx/Rx beam correspondence is for convenience of discussion. The detailed performance conditions are up to RAN4.

The following DL L1/L2 beam management procedures are supported within one or multiple TRPs:

- P-1: is used to enable UE measurement on different TRP Tx beams to support selection of TRP Tx beams/UE Rx beam(s)
  - For beamforming at TRP, it typically includes a intra/inter-TRP Tx beam sweep from a set of different beams. For beamforming at UE, it typically includes a UE Rx beam sweep from a set of different beams.
- P-2: is used to enable UE measurement on different TRP Tx beams to possibly change inter/intra-TRP Tx beam(s)
  - From a possibly smaller set of beams for beam refinement than in P-1. Note that P-2 can be a special case of P-1.
- P-3: is used to enable UE measurement on the same TRP Tx beam to change UE Rx beam in the case UE uses beamforming

At least network triggered aperiodic beam reporting is supported under P-1, P-2, and P-3 related operations.

UE measurement based on RS for beam management (at least CSI-RS) is composed of K (= total number of configured beams) beams, and UE reports measurement results of N selected Tx beams, where N is not necessarily fixed number. Note that the procedure based on RS for mobility purpose is not precluded. Reporting information at least include measurement quantities for N beam (s) and information indicating N DL Tx beam(s), if $N < K$. Specifically, when a UE is configured with $K' > 1$ non-zero power (NZP) CSI-RS resources, a UE can report N' CRIs (CSI-RS Resource Indicator).

A UE can be configured with the following high layer parameters for beam management:

- $N \geq 1$ reporting settings, $M \geq 1$ resource settings
  - The links between reporting settings and resource settings are configured in the agreed CSI measurement setting
  - CSI-RS based P-1 & P-2 are supported with resource and reporting settings

  - P-3 can be supported with or without reporting setting
- A reporting setting at least including
  - Information indicating selected beam(s)
  - L1 measurement reporting
  - Time-domain behavior: e.g. aperiodic, periodic, semi-persistent
  - Frequency-granularity if multiple frequency granularities are supported
- A resource setting at least including
  - Time-domain behavior: e.g. aperiodic, periodic, semi-persistent
  - RS type: NZP CSI-RS at least
  - At least one CSI-RS resource set, with each CSI-RS resource set having K≥1 CSI-RS resources
    - Some parameters of *K* CSI-RS resources can be the same, e.g. port number, time-domain behavior, density and periodicity if any

At least one of these two alternatives of beam reporting is supported.

- Alt 1:
  - UE reports information about TRP Tx Beam(s) that can be received using selected UE Rx beam set(s) where a Rx beam set refers to a set of UE Rx beams that are used for receiving a DL signal. Note that it is UE implementation issues on how to construct the Rx beam set. One example is that each of Rx beam in a UE Rx beam set corresponds to a selected Rx beam in each panel. For UEs with more than one UE Rx beam sets, the UE can report TRP Tx Beam(s) and an identifier of the associated UE Rx beam set per reported TX beam(s).
    - NOTE: Different TRP Tx beams reported for the same Rx beam set can be received simultaneously at the UE.
    - NOTE: Different TRP TX beams reported for different UE Rx beam set may not be possible to be received simultaneously at the UE
- Alt 2:
  - UE reports information about TRP Tx Beam(s) per UE antenna group basis where UE antenna group refers to receive UE antenna panel or subarray. For UEs with more than one UE antenna group, the UE can report TRP Tx Beam(s) and an identifier of the associated UE antenna group per reported TX beam.
    - NOTE: Different TX beams reported for different antenna groups can be received simultaneously at the UE.
    - NOTE: Different TX beams reported for the same UE antenna group may not be possible to be received simultaneously at the UE

NR also supports the following beam reporting considering L groups where L>=1 and each group refers to a Rx beam set (Alt1) or a UE antenna group (Alt2) depending on which alternative is adopted. For each group l, UE reports at least the following information:

- Information indicating group at least for some cases
- Measurement quantities for N_l beam (s)
  - Support L1 RSRP and CSI report (when CSI-RS is for CSI acquisition)
- Information indicating N_l DL Tx beam(s) when applicable

This group based beam reporting is configurable per UE basis. This group based beam reporting can be turned off per UE basis e.g., when L=1 or N_l=1. Note that no group identifier is reported when it is turned off.

NR supports that UE can trigger mechanism to recover from beam failure. Beam failure event occurs when the quality of beam pair link(s) of an associated control channel falls low enough (e.g. comparison with a threshold, time-out of an associated timer). Mechanism to recover from beam failure is triggered when beam failure occurs. Note that here the beam pair link is used for convenience, and may or may not be used in specification. Network explicitly configures to UE with resources for UL transmission of signals for recovery purpose. Configurations of resources are supported where the base station is listening from all or partial directions, e.g., random access region. The UL transmission/resources to report beam failure can be located in the same time instance as PRACH (resources orthogonal to PRACH resources) or at a time instance (configurable for a UE) different from PRACH. Transmission of DL signal is supported for allowing the UE to monitor the beams for identifying new potential beams.

NR supports beam management with and without beam-related indication. When beam-related indication is provided, information pertaining to UE-side beamforming/receiving procedure used for CSI-RS-based measurement can be indicated through QCL to UE. NR supports using the same or different beams on control channel and the corresponding data channel transmissions.

For NR-PDCCH transmission supporting robustness against beam pair link blocking, UE can be configured to monitor NR-PDCCH on M beam pair links simultaneously, where $M \geq 1$ and the maximum value of M may depend at least on UE capability. UE can be configured to monitor NR-PDCCH on different beam pair link(s) in different NR-PDCCH OFDM symbols. Parameters related to UE Rx beam setting for monitoring NR-PDCCH on multiple beam pair links are configured by higher layer signaling or MAC CE and/or considered in the search space design. At least, NR supports indication of spatial QCL assumption between an DL RS antenna port(s), and DL RS antenna port(s) for demodulation of DL control channel. Candidate signaling methods for beam indication for a NR-PDCCH (i.e. configuration method to monitor NR-PDCCH) are MAC CE signaling, RRC signaling, DCI signaling, specification-transparent and/or implicit method, and combination of these signaling methods. Note that indication may not be needed for some cases.

For reception of unicast DL data channel, NR supports indication of spatial QCL assumption between DL RS antenna port(s) and DMRS antenna port(s) of DL data channel. Information indicating the RS antenna port(s) is indicated via DCI (downlink grants). The information indicates the RS antenna port(s) which is QCL-ed with DMRS antenna port(s). Different set of DMRS antenna port(s) for the DL data channel can be indicated as QCL with different set of RS antenna port(s). Note that indication may not be needed for some cases.

6.1.6.2 MIMO schemes

For NR, the number of codewords per PDSCH assignment per UE is 1 codeword for 1 to 4-layer transmission and 2 codewords for 5 to 8-layer transmission.

DL DMRS based spatial multiplexing (SU-MIMO/MU-MIMO) is supported. At least, the 8 orthogonal DL DMRS ports are supported for SU-MIMO and maximum 12 orthogonal DL DMRS ports are supported for MU-MIMO. At least the following DMRS based DL MIMO transmissions are supported for data in NR.

- Scheme 1: Closed-loop transmission where data and DMRS are transmitted with the same precoding matrix
  - Demodulation of data at the UE does not require knowledge of the precoding matrix used at the transmitter
  - Note: spatial multiplexing and rank-1 are included
- Scheme 2: Open loop and Semi-open loop transmissions where data and DMRS may or may not be restricted to be transmitted with the same precoding matrix
  - Demodulation of data at the UE may or may not require knowledge of the relation between DMRS ports and data layers
  - Note: DMRS can be precoded or not precoded

For the downlink data, at least a Precoding Resource block Group (PRG) size for PRB bundling equal to a specified value is supported. Configurable PRG size is also supported for data DMRS.

Dynamic switching between transmission methods/schemes is supported. The following two sets of transmission parameters are at least supported.

- Transmission parameter set 1: parameters configured
  - For default transmission scheme, specify default values of parameters in the Transmission parameter set 1

    - Note that depending on parameter settings in transmission parameter set 1, the size of transmission parameter set 2, i.e. DCI size, may vary.
- Transmission parameter set 2: parameters indicated by physical layer (e.g. NR PDCCH channel)
    - Note: some transmission parameter may belong to both set-1 and set-2

Downlink transmission scheme(s) achieving diversity gain at least for some control information transmission is supported.

6.1.6.3 CSI measurement and reporting

For NR, DL CSI measurement with X antenna ports is supported. At least for CSI acquisition, NR supports CSI-RS and SRS.

NR supports aperiodic, semi-persistent, and periodic CSI reporting.

- Periodic CSI reporting
    - It can be configured by higher layer. Higher-layer configuration includes at least reporting periodicity and timing offset.
- Semi-persistent CSI reporting
    - Configuration of CSI reporting can be activated or de-activated.

CSI reporting with two types of spatial information feedback is supported.

- Type I feedback: Normal
    - Type I feedback is codebook-based PMI feedback with normal spatial resolution. PMI codebook has at least two stages, i.e., $\mathbf{W} = \mathbf{W}_1\mathbf{W}_2$ where $\mathbf{W}_1$ codebook comprises of beam groups/vectors.
    - Type I feedback supports at least the following (DL) CSI reporting parameters.
        - Resource selection indicator (Examples for further study are reference signal resource, port, reference signal sequence, beam)
        - RI (rank indicator)
        - PMI (precoding matrix indicator)
        - Channel quality feedback
    - At least, for single panel case, codebook-based PMI feedback has two-stage, i.e., $\mathbf{W}=\mathbf{W}_1\mathbf{W}_2$,
    - At least for type I CSI feedback, support multi-panel scenarios by having co-phasing factor across panels.
        - Alt1: only wideband co-phasing factor across panels
        - Alt2: wideband and subband co-phasing factor across panels
- Type II feedback: Enhanced
    - Explicit feedback and/or codebook-based feedback with higher spatial resolution
    - At least, one scheme is supported from the following Category 1, 2, and/or 3 for Type II CSI.
        - Category 1: precoder feedback based on linear combination codebook
            - Dual-stage $\mathbf{W} = \mathbf{W}_1\mathbf{W}_2$ codebook
                - $\mathbf{W}_1$ consists of a set of L orthogonal beams taken from 2D DFT beams
                    - The set of L beams is selected out of a basis composed of oversampled 2D DFT beams
                        - $L \in \{2, 3, 4\}$ (L is configurable)

                - Beam selection is wideband

            - $\mathbf{W}_2$: L beams are combined in $\mathbf{W}_2$ with common $\mathbf{W}_1$

                - Subband reporting of phase quantization of beam combining coefficients

                    - Configurable between QPSK and 8-PSK phase related information quantization

                - Beam amplitude scaling quantization can be configured for wideband or subband reporting

    - Category 2: covariance matrix feedback

        - The feedback of channel covariance matrix is long term and wideband

            - A quantized/compressed version of covariance matrix is reported by the UE

                - Quantization/compression is based on a set of M orthogonal basis vectors

                - Reporting can include indicators of the M basis vectors along with a set of coefficients

            - Other quantized/compressed versions of channel covariance matrix are not precluded

    - Category 3: Hybrid CSI feedback

        - Type II Category 1 or 2 CSI codebook can be used in conjunction with LTE-Class-B-type-like CSI feedback (e.g. based on port selection/combination codebook)

        - The LTE-Class-B-type-like CSI feedback can be based on either Type I or Type II CSI codebook

For Type I and II, CSI feedback per subband as well as partial band and/or wideband feedback are supported. For Type I and II, beam-related feedback can be also included. For CSI reporting for a component carrier, at least three different frequency granularities are supported.

- Wideband CSI

    - Wideband size is determined by UE RF capability of receiving DL signal. Location of wideband could be configurable by network. For example, wideband CSI is used for analog beam management at least.

- Partial band CSI

    - Alt1. UE-specifically configurable bandwidth

    - Alt2. The size is determined by the composition of numerologies or scheduling time units within the UE-specific wideband.

        - Applicable only when different numerology or scheduling time unit are multiplexed within wideband.

    - For example, partial band CSI is used for analogue beam management and for managing CSI per service at least.

- Subband CSI

    - The band size is determined by dividing wideband or partial band to multiple bands. For example, subband CSI is used for frequency selective scheduling and subband precoding at least.

With regard to relating CSI-RS transmission and CSI reporting, the following combinations are supported at least

- For periodic CSI-RS,

    - Semi-persistent CSI reporting is activated/deactivated by MAC CE and/or DCI

    - Aperiodic CSI reporting is triggered by DCI

- For semi-persistent CSI-RS,

    - Periodic CSI reporting is not supported

    - Semi-persistent CSI reporting is activated/deactivated by MAC CE and/or DCI

        - Semi-persistent CSI-RS is activated/deactivated by MAC CE and/or DCI
    - Aperiodic CSI reporting is triggered by DCI
        - Semi-persistent CSI-RS is activated/deactivated by MAC CE and/or DCI
- For aperiodic CSI-RS,
    - Periodic CSI reporting is not supported
    - Aperiodic CSI reporting is triggered by DCI
        - Aperiodic CSI-RS is triggered by DCI and/or MAC CE

Note that it is possible to dynamically trigger RS and reports through links in the measurement setting. To support combinations above more flexibly, NR should allow independent control of CSI-RS indication and CSI reporting indication timings. The indication may refer to triggering, activation, and deactivation depending on type of RS/reporting. Also, NR supports mechanism(s) to trigger aperiodic CSI-RS and aperiodic CSI reporting simultaneously. For aperiodic CSI-RS timing offset X, support X=0 at least, if aperiodic CSI-RS triggering is done by DCI. Note that aperiodic CSI-RS timing offset X refers to the time gap between aperiodic CSI-RS triggering and aperiodic CSI-RS transmission with regard to the number of slots. For CSI reporting timing offset Y that is fixed or configurable by the network but with certain restriction on lower limit of Y to provide sufficient CSI computation time. Note that aperiodic CSI reporting timing offset Y refers to the time gap between aperiodic CSI reporting triggering and aperiodic CSI reporting with regard to the number of slots.

Interference measurement under different interference hypothesis should be supported in NR. For interference measurement, at least one of the following schemes is supported.

- Measurement subsets in both time and frequency domain
- Interference measurement restriction in both time and frequency domain

At least two types of resources used for interference measurement in CSI configuration is supported based on the candidates, i.e., ZP CSI-RS, NZP CSI-RS, and DMRS, including independent or joint usage of any combination of these three candidates, where ZP CSI-RS based interference measurement is to be supported among the three candidates. NR supports aperiodic IMR, semi-persistent IMR and periodic IMR based on ZP CSI-RS for interference measurement for CSI feedback. For IMR based on ZP CSI-RS, the three different time-domain behaviors are configured in the resource setting(s).

A UE can be configured with $N\geq1$ CSI reporting settings, $M\geq1$ Resource settings, and 1 CSI measurement setting, where the CSI measurement setting includes $L \geq1$ links and value of L may depend on the UE capability. The CSI acquisition framework (including CSI measurement, Resource, and CSI reporting settings) supports configurations that provide CSI similar to Rel.14 eFD-MIMO hybrid CSI mechanisms 1 and 2, e.g.

- Long-term CSI for a number of antenna ports or multiple NZP CSI-RS resources
- Short-term CSI for a number of antenna ports with one or more NZP CSI-RS resources
- The number of ports for long-term and short-term CSIs can be the same or different

At least the following configuration parameters are signaled via RRC at least for CSI acquisition.

- N, M, and L are indicated either implicitly or explicitly
- In each CSI reporting setting, at least: reported CSI parameter(s), CSI Type (I or II) if reported, codebook configuration including codebook subset restriction, time-domain behavior, frequency granularity for CQI and PMI, measurement restriction configurations.
- CSI parameter CRI is supported. CRI functionality includes selection and reporting of indices for N out K NZP CSI-RS resources. If $N_{max} > 1$ is supported, the value of N is included in the associated CSI reporting setting, where the maximum value of $N \in \{1,2,\ldots,K\}$ may be a UE capability.
    - CSI reporting band is defined as a collection of (contiguous or non-contiguous) subbands pertinent to a CSI reporting setting. Three frequency granularities are supported, i.e., wideband reporting, partial band reporting, and subband reporting. At least some combination(s) of the CSI parameters (e.g., CRI, RI, PMI, CQI, etc.) can be configured to be omitted from reporting within a CSI reporting setting.

- In each Resource setting:
  - A configuration of $S \geq 1$ CSI-RS resource set(s)
    - Note: each set corresponds to different selections from a “pool” of all configured CSI-RS resources to the UE
  - A configuration of $K_s \geq 1$ CSI-RS resources for each set s, including at least: mapping to REs, the number of ports, time-domain behavior, etc.
  - Time domain behavior: aperiodic, periodic or semi-persistent
    - In each semi-persistent or periodic resource setting, periodicity is included in the configuration information
- In each of the L links in CSI measurement setting: CSI reporting setting indication, Resource setting indication, quantity to be measured (either channel or interference)
  - One CSI reporting setting can be linked with one or multiple Resource settings
  - Multiple CSI reporting settings can be linked

In each resource setting, RS type which encompasses at least CSI-RS is also included.

At least, the following are dynamically selected by L1 or L2 signaling, if applicable.

- One or multiple CSI reporting settings within the CSI measurement setting
- One or multiple CSI-RS resource sets selected from at least one Resource setting
- One or multiple CSI-RS resources selected from at least one CSI-RS resource set

6.1.6.4 Reference signal related to multi-antenna scheme

At least the following RSs are supported for NR downlink

- CSI-RS: Reference signal with main functionalities of CSI acquisition, beam management
- DM-RS: Reference signal with main functionalities of data and control demodulation
- Reference signal for phase tracking
- Reference signal for time/freq. tracking
- Reference signal for Radio link monitoring
- RS for RRM measurement

6.1.6.4.1 CSI-RS

NR supports periodic, aperiodic, and semi-persistent transmissions of CSI-RS as follows.

- Semi-persistent transmission
  - Activation(s)/de-activation(s) of CSI-RS resource is triggered dynamically
- Preconfigured CSI-RS resources can be activated or de-activated
- Periodic transmission
  - Periodic transmission can be configured by higher layer signaling
  - Periodic CSI-RS transmissions are semi-statically configured/re-configured.

NR CSI-RS pattern with at least the following properties is supported.

- CSI-RS mapped in one or multiple symbols

The following configurations of NR CSI-RS are supported.

- UE-specific configuration to support
  - Wideband CSI-RS, i.e. from UE perspective, the full bandwidth the UE is configured to operate with
  - Partial-band CSI-RS, i.e. from UE perspective, part of the bandwidth the UE is configured to operate with

CSI-RS configuration for NR also includes at least 'number of antenna ports'. Configuration can be explicit or implicit. The number of CSI-RS antenna ports can be independently configured for periodic/semi-persistent CSI reporting and aperiodic CSI reporting. A UE can be configured with a CSI-RS resource configuration with at up to at least 32 ports. UE is configured by RRC signaling with one or more CSI-RS resource sets and CSI-RS resources is dynamically allocated from the one or more sets to one or more users. Allocation can be aperiodic (single-shot) and can be on a semi-persistent basis. Note that semi-persistent CSI-RS transmission is periodic while allocated.

CSI-RS supports the downlink Tx beam sweeping and UE Rx beam sweeping. Note that CSI-RS can be used in P1, P2, P3. NR CSI-RS supports the following mapping structure.

- N_P CSI-RS port(s) can be mapped per (sub)time unit
  - Across (sub)time units, same CSI-RS antenna ports can be mapped
- Each time unit can be partitioned into sub-time units
- Mapping structure can be used for supporting multiple panels/Tx chains

For beam management overhead and latency reduction, NR also considers beam sweeping for CSI-RS within an OFDM symbol. Note that the symbol duration is based on a reference numerology.

NZP CSI-RS resource is defined in NR, as a set of NZP CSI-RS port(s) mapped to a set of REs within a frequency span/a time duration which can be measured at least to derive a CSI. Multiple NZP CSI-RS resources can be configured to UE at least for supporting CoMP and multiple beamformed CSI-RS based operations, where each NZP CSI-RS resource at least for CoMP can have different number of CSI-RS ports.

The RE pattern for an X-port CSI-RS resource spans $N \geq 1$ OFDM symbols in the same slot and is comprised of one or multiple component CSI-RS RE patterns where a component CSI-RS RE pattern is defined within a single PRB as Y adjacent REs in the frequency domain and Z adjacent REs in the time domain. Note that, depending on the density reduction approach, the Y REs of a component CSI-RS RE pattern may be non-adjacent in the frequency domain. The multiple component CSI-RS RE patterns can be extended across the frequency domain within the configured CSI-RS bandwidth. At least, the numbers of OFDM symbols for a CSI-RS resource, $N = \{1, 2, 4\}$, are supported. The N OFDM symbols can be adjacent/non-adjacent. OFDM symbol(s) can be configured to contain CSI-RS only. Density per port in terms of RE per port per PRB is configurable.

6.1.6.4.2 DMRS

Variable/configurable DMRS patterns for data demodulation are supported. At least, one configuration supports front-loaded DMRS pattern. Front-loaded DMRS is mapped over 1 or 2 adjacent OFDM symbols. Additional DMRS can be configured for the later part of the slot. NR aims for performance at least comparable to DM-RS of LTE in scenarios where applicable for both LTE and NR.

DMRS configuration can be up to the maximum number of DMRS ports. At least, the 8 orthogonal DL DMRS ports are supported for SU-MIMO and the maximal 12 orthogonal DL DMRS ports are supported for MU-MIMO. At least for CP-OFDM, NR supports a common DMRS structure for DL and UL where the exact DMRS location, DMRS pattern, and scrambling sequence can be the same or different. DMRS for same or different links can be configured to be orthogonal to each other.

For DL DMRS port multiplexing, FDM (including comb), CDM (including OCC and Cyclic shift) and TDM are considered. PN sequence is supported for CP-OFDM. DMRS bundling is supported in time domain. At least time domain bundling with slot aggregation of DL-only slots is supported. DMRS pattern within the first slot is not impacted by the time domain DMRS bundling.

6.1.6.4.3 Phase-tracking RS (PT-RS)

For CP-OFDM, time-domain density mapped on every other symbol and/or every symbol and/or every 4-th symbol is supported. For a given UE, the designated PT-RS is confined in scheduled resource as a baseline. Presence/patterns of PT-RS in scheduled resource are UE-specifically configured by a combination of RRC signaling and association with parameter(s) used for other purposes (e.g., MCS) which are (dynamically) indicated by DCI. Whether PT-RS can be present or not depends on RRC configuration. When configured, the dynamic presence is associated with DCI parameter(s) including at least MCS. Multiple PT-RS densities defined in time/frequency domain are supported. When present, frequency domain density is associated with at least dynamic configuration of the scheduled BW. UE can assume the same precoding for a DMRS port and a PT-RS port. Number of PT-RS ports can be fewer than number of DM-RS ports in scheduled resource.

6.1.6.5 Quasi-colocation (QCL)

Definition of QCL is that two antenna ports are said to be quasi co-located if properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed. QCL supports the following functionalities at least

- Beam management functionality: at least including spatial parameters
- Frequency/timing offset estimation functionality: at least including Doppler/delay parameters
- RRM management functionality: at least including average gain

For DM-RS antenna ports, NR supports:

- All ports are quasi-collocated.
- Not all ports are quasi-collocated.

DMRS ports grouping is supported, and DMRS ports within one group are QCL-ed, and DMRS ports in different groups are non-QCLed. NR supports with and without a downlink indication to derive QCL assumption for assisting UE-side beamforming for downlink control channel reception.

For CSI-RS antenna ports,

- Indication of QCL between the antenna ports of two CSI-RS resources is supported.
  - By default, no QCL should be assumed between antenna ports of two CSI-RS resources.
  - Partial QCL parameters (e.g., only spatial QCL parameter at UE side) should be considered.
- For downlink, NR supports CSI-RS reception with and without beam-related indication,
  - When beam-related indication is provided, information pertaining to UE-side beamforming/receiving procedure used for CSI-RS-based measurement can be indicated through QCL to UE
  - QCL information includes spatial parameter(s) for UE side reception of CSI-RS ports

Indication of QCL assumption associated with subset of QCL parameters between the antenna ports of two RS resources is supported.

By default (i.e., the UE is not indicated), antenna port(s) transmitted on different CCs can't be assumed to be quasi-collocated except for spatial domain QCL assumptions.

6.1.6.6 Network coordination and advanced receiver

For coordinated transmission schemes for NR, both the case of co-located TRPs and the case of non-co-located TRPs are considered. For coordinated transmission schemes for NR, different types of coordinated transmission schemes for NR are supported. Both semi-static and dynamic network coordination schemes are considered. In supporting semi-static and dynamic network coordination schemes in NR, different coordination levels should be considered, e.g., centralized and distributed scheduling, the delay assumption used for coordination schemes, etc.

NR supports downlink transmission of the same NR-PDSCH data stream(s) from multiple TRPs at least with ideal backhaul, and different NR-PDSCH data streams from multiple TRPs with both ideal and non-ideal backhaul. Note that the case of supporting the same NR-PDSCH data stream(s) may or may not have spec impact.

6.2 Physical layer procedure

6.2.1 Scheduling

NR supports both data and control with the same numerology. NR supports at least same-slot and cross-slot scheduling for both DL and UL. Timing between DL assignment and corresponding DL data transmission is indicated by a field in the DCI from a set of values and the set of values is configured by higher layer. The timing(s) is (are) defined at least for the case where the timing(s) is (are) unknown to the UE. Both contiguous and non-contiguous resource allocation for data with CP-OFDM is supported. Resource allocation for data transmission for a UE not capable of supporting the carrier bandwidth can be derived based on a two-step frequency-domain assignment process, i.e., indication of a bandwidth part (the 1st step) and indication of the PRBs within the bandwidth part (2nd step).

Indication of URLLC transmission overlapping the resources scheduled for an eMBB UE in downlink can be dynamically signaled to the eMBB UE to facilitate demodulation and decoding. Indication can be dynamically signaled to a UE, whose assigned downlink resources have partially been preempted by another downlink transmission, to increase the likelihood of successful demodulation and decoding of the TB(s) transmitted within the above mentioned assigned resource. The indication may be used to increase the likelihood of successful demodulation and decoding of the transport block based on the pre-empted transmission and/or subsequent (re)-transmissions of the same TB.

6.2.2 HARQ

HARQ-ACK feedback with one bit per TB is supported. Operation of more than one DL HARQ processes is supported for a given UE while operation of one DL HARQ process is supported for some UEs. UE supports a set of minimum HARQ processing time. NR also supports different minimum HARQ processing time at least for across UEs. The HARQ processing time at least includes delay between DL data reception timing to the corresponding HARQ-ACK transmission timing and delay between UL grant reception timing to the corresponding UL data transmission timing. UE is required to indicate its capability of minimum HARQ processing time to gNB.

Asynchronous and adaptive DL HARQ is supported at least for eMBB and URLLC. From UE perspective, HARQ ACK/NACK feedback for multiple DL transmissions in time can be transmitted in one UL data/control region. Timing between DL data reception and corresponding acknowledgement is indicated by a field in the DCI from a set of values and the set of values is configured by higher layer. The timing(s) is (are) defined at least for the case where the timing(s) is (are) unknown to the UE.

Code Block Group (CBG)-based transmission with single/multi-bit HARQ-ACK feedback is supported, which shall have the following characteristics:

- Only allow CBG based (re)-transmission for the same TB of a HARQ process
- CBG can include all CB of a TB regardless of the size of the TB. In such case, UE reports single HARQ ACK bit for the TB
- CBG can include one CB
- CBG granularity is configurable

6.2.3 Initial access and mobility

6.2.3.1 Synchronization signal and DL broadcast signal/channel structure

NR synchronization signal is based on CP-OFDM. NR defines at least two types of synchronization signals; NR-PSS and NR-SSS. NR-PSS is defined at least for initial symbol boundary synchronization to the NR cell. NR-SSS is defined for detection of NR cell ID or at least part of NR cell ID. The number of NR cell IDs is targeted to be approximately 1000. NR-SSS detection is based on the fixed time/frequency relationship with NR-PSS resource position irrespective of duplex mode and beam operation type at least within a given frequency range and CP overhead. At least, normal CP is supported for NR-PSS/SSS.

The raster for NR synchronization signals can be different per frequency range. At least for frequency ranges where NR supports a wider carrier bandwidth and operation in a wider frequency spectrum (e.g. above 6 GHz), the NR synchronization signals raster can be larger than the 100 kHz raster of LTE. When the synchronization signal bandwidth is the same as the minimum system bandwidth for a given frequency band which UE searches, synchronization signal frequency raster is the same as the channel raster. For carrier supporting initial access, for frequency range up to 6 GHz, minimum carrier bandwidth for NR can be either 5 or 10 MHz and is frequency band dependent. For frequency range from 6 GHz to 52.6 GHz, minimum carrier bandwidth for NR can be either 40 or 80 MHz and is frequency band dependent.

At least one broadcast channel (NR-PBCH) is defined. NR-PBCH decoding is based on the fixed relationship with NR-PSS and/or NR-SSS resource position irrespective of duplex mode and beam operation type at least within a given frequency range and CP overhead. NR-PBCH is a non-scheduled broadcast channel carrying at least a part of minimum system information with fixed payload size and periodicity predefined in the specification depending on carrier frequency range.

In both single beam and multi-beam scenario, time division multiplexing of NR-PSS, NR-SSS, and NR-PBCH is supported. NR-PSS, NR-SSS and/or NR-PBCH can be transmitted within an SS block. For a given frequency band, an SS block corresponds to *N* OFDM symbols based on the default subcarrier spacing, and *N* is a constant. The signal multiplexing structure is fixed in a specification. UE shall be able to identify at least OFDM symbol index, slot index in a radio frame and radio frame number from an SS block.

One or multiple SS block(s) compose an SS burst. One or multiple SS burst(s) further compose an SS burst set where the number of SS bursts within a SS burst set is finite. From physical layer specification perspective, at least one periodicity of SS burst set is supported. From UE perspective, SS burst set transmission is periodic and UE may assume that a given SS block is repeated with a SS burst set periodicity. Note that NR-PBCH contents in a given repeated SS block may change. A single set of possible SS block time locations is specified per frequency band. The maximum number of SS-blocks within SS burst set may be carrier frequency dependent. The position(s) of actual transmitted SS-blocks can be informed for helping CONNECTED/IDLE mode measurement, for helping CONNECTED mode UE to receive DL data/control in unused SS-blocks and potentially for helping IDLE mode UE to receive DL data/control in unused SS-blocks. By default, the UE may neither assume the gNB transmits the same number of physical beam(s), nor the same physical beam(s) across different SS-blocks within an SS burst set. For initial cell selection, UE may assume default SS burst set periodicity which may be frequency band-dependent. At least for multi-beams case, at least the time index of SS-block is indicated to the UE.

For CONNECTED and IDLE mode UEs, NR supports network indication of SS burst set periodicity and information to derive measurement timing/duration (e.g., time window for NR-SS detection). The network provides one SS burst set periodicity information per frequency carrier to UE and information to derive measurement timing/duration if possible. In case that one SS burst set periodicity and one information regarding timing/duration are indicated, UE assumes the periodicity and timing/duration for all cells on the same carrier. If the network does not provide indication of SS burst set periodicity and information to derive measurement timing/duration the UE should assume 5 ms as the SS burst set periodicity. NR supports set of SS burst set periodicity values for adaptation and network indication.

For initial access, UE can assume a signal corresponding to a specific subcarrier spacing of NR-PSS/SSS in a given frequency band given by specification.

For NR-PSS, ZC-sequence can be used as the baseline sequence for NR-PSS for study. At least one basic sequence length is defined for each synchronization signal in case of sequence-based synchronization signal design. The number of antenna port of NR-PSS is 1.

For NR-PBCH transmission, a single fixed number of antenna port(s) is supported. No blind detection of NR-PBCH transmission scheme or number of antenna ports is required by the UE. UE assumes the same PBCH numerology as that of NR-SS. For the minimum system information delivery, part of minimum system information is transmitted in NR-PBCH. NR-PBCH contents shall include at least part of the SFN (system frame number), and CRC. The remaining minimum system information is transmitted in shared downlink channel via NR-PDSCH.

6.2.3.2 Mobility

For RRM measurement in NR, DL measurement is supported with the consideration on both single-beam based operation and multi-beam based operation. NR supports cell-level mobility based on DL cell-level measurement (e.g. RSRP for each cell) in IDLE mode UE. Note that IDLE mode refers to a UE state similar to LTE IDLE state, whose exact definition is up to RAN2 and CONNECTED mode refers to a UE state similar to LTE CONNECTED state, whose exact definition is up to RAN2. Also, note that cell refers to NR cell which is tied to a same ID carried by NR-SS. At least NR-SSS is used for DL based RRM measurement for L3 mobility in IDLE mode. For CONNECTED mode RRM measurement for L3 mobility, CSI-RS can be used, in addition to IDLE mode RS. Detection of neighbor cell for measurement is based on NR-SS.

Adaptation and network indication of the valid time and frequency resources are supported which may be used for inter-/intra-frequency RRM measurements and reports for ‘CONNECTED’ mode UEs.

RSRP(s) can be measured from the IDLE mode RS. One RSRP value is measured from the IDLE mode RS per SS block. The measured values are referred to “SS-block-RSRP”. It is RAN1’s understanding that “SS-block-RSRP” may correspond to the “beam quality” in RAN2 agreements in multi-beam case, at least in IDLE mode.

At least one of cell-level and beam-level measurement quantities is supported for RRM reporting.

6.2.3.3 Paging

For paging in multi-beam operation, beam sweeping is supported for paging. For the paging channel design at least for RRC idle mode, paging message is scheduled by DCI carried by NR-PDCCH and is transmitted in the associated NR-PDSCH.

7 Evaluation of DL techniques

7.1 Performance evaluation

7.1.1 Performance evaluation of waveform

Four evaluation cases for the downlink and uplink are used in link level simulation depending on evaluation purposes of each usage scenario, which are

- Case 1a, 1b: single numerology case
    - 1a: Downlink
    - 1b: Uplink, only one UE with narrow bandwidth is located at the edge of wide frequency band. It is assumed that no wide-band filter upon the whole frequency band.
- Case 2: DL mixed numerology case
- Case 3: UL single numerology case (asynchronous reception between UEs)
- Case 4: UL mixed numerology case (synchronous reception between UEs)

  (also refer to these illustrations in pages 5 – 9 in R1-163558)

For each waveform, the RF nonlinearity (refer to R1-167297) is considered in the evaluation. General evaluation assumptions are provided in Annex. A.1. In order to assess the candidate techniques, the following performance metrics are considered.

- User spectrum efficiency as performance metric
- Take into account guard band and time domain overhead. The values and their calculation method of guard band and time domain overhead should be reported.
- BLER vs SNR should be reported for calibration
- OOBE level is reported (Similar to ACLR but applied to adjacent sub-band/UE instead of carrier)
- EVM
- PAPR/Cubic metric
- UE Complexity
- The following is also reported

- Receiver waveform design
- Rx processing delay
- Power spectral density

UE spectrum efficiency is defined as follows.

$$\eta = \frac{\chi}{T \cdot \omega}$$

where χ denotes the number of correctly received information bits by target user, T is the transmission time of the target user.For Case 1a, $\omega = BW_{\text{carrier}}$ is the whole bandwidth including system guard band. For Case 1b, 2, 3, and 4, ω is the data bandwidth plus guard tone of the target UE. General evaluation assumptions are provided in Annex. A.1

Evaluation observations for the downlink are summarized as below.

- Some evaluations in RAN1 show that Y for a NR carrier can be up to 98% of the evaluated channel bandwidths for both DL and UL without complexity and latency constraints [R1-166093]
- For in-band frequency multiplexing of different numerologies, it is expected that spectrum confinement on sub-band basis is specified as requirements on transmitter side in-band emission and EVM requirements and reception performance in presence of other-subband interferer.
- From RAN1 perspective, spectral confinement technique(s) (e.g. filtering, windowing, etc.) for a waveform at the transmitter is transparent to the receiver.

7.1.2 Performance evaluation of multiple access

Evaluation for multiple access schemes consider the following usage scenario families defined in [TR38.913].

- eMBB: dense urban, urban macro, rural, indoor
- mMTC: urban coverage for massive connection
- URLLC: urban macro, indoor

Link-level simulation and system-level simulation are used for multiple access evaluation. Link level simulation is used for feasibility investigation of new multiple access proposals, comparison of different proposals in typical scenarios. System level simulation is used for comparison of proposals, and verification with traffic/scheduling/multi-cell interference dynamics. Note that link level simulation includes link level simulation with optional analytical model. For link level simulation, the following evaluation metrics are considered.

- BLER vs SNR reported for UL and DL calibration
- BS and UE receiver complexity reported
- Sum rate region
- Optional metrics:
- Sum normalized user throughput (normalized by throughput in orthogonal case); Sum throughput with minimum throughput constraint for some users

For system level simulation, the following are used as evaluation metrics

- eMBB: TRP spectrum efficiency and 5th percentile user spectrum efficiency; user experienced data rate and area traffic capacity; signaling overhead
- mMTC: Connection density with “connection efficiency” reported; latency for infrequent small packets; signaling overhead
- URLLC: Reliability for a target latency

General evaluation assumptions are provided in Annex. A.1.

7.1.3 Performance evaluation of channel coding

Evaluations for channel coding candidates with similar code rates and block sizes.are conducted for each usage case of eMBB, mMTC and URLLC. General evaluation assumptions are provided in Annex. A.1.

LDPC, Polar and Turbo codes are studied and the following observations are made.

- **Performance**
  - At least in AWGN channels, for large information block sizes, all candidate channel coding schemes show comparable link performance.
  - The performance of LDPC, Polar and Turbo codes is captured in R1-1610600 (update of R1-1610423).
  - It has not yet been possible to draw conclusions directly from these captured results, owing to different views on the implementation complexities and possible enhancements which are discussed in more detail below.
- **Flexibility for code rate and code block size support**
  - LDPC, Polar and Turbo codes can all deliver acceptable flexibility.
- **Chase- and IR-HARQ support**
  - The proponents of LDPC and Polar have shown schemes for support of both CC- and IR-HARQ in their respective codes
    - Some companies have concerns on the incremental freezing method of HARQ support for Polar codes
    - One company has concerns on the complexity of IR-HARQ for LDPC codes
  - The ability of Turbo codes to support both CC- and IR-HARQ is well known
- **Implementation complexity**
  - LDPC:
    - LDPC codes are widely implemented in commercial hardware supporting several Gbps throughput and attractive area and energy efficiency with some flexibility, but with flexibility and features that are more limited than required for NR; in relation to NR, there are concerns summarised below.
    - The area efficiency reduces for lower coding rates
    - The complexity of LDPC increases with increasing flexibility
    - Proponents consider LDPC codes with limited flexibility to provide the most attractive area and energy efficiency, and that the characteristics of LDPC codes in area and energy efficiency remain advantageous even when supporting full flexibility, while some other companies consider the applicable flexibility to be limited, for example because a flexible switched network (if used) has an impact on increasing the power, area and latency
    - LDPC codes are amenable to parallelisation which can provide better decoding latency
      - Depending on the parity check matrix design, some of this parallelism may not be exploited for all code block lengths for NR, and some companies have a concern with this and its impact on energy and area efficiency
    - Some variants of min-sum based iterative decoders are considered implementable, and allow a trade-off between complexity and performance
    - Two proponents consider quasi-ML decoders (e.g. list 32, ordered stochastic decoding) implementable for codeword sizes up to 1k
    - BP and sum-product decoders are not considered implementable for NR by some companies
    - For LDPC there are concerns that implementation with attractive area and energy efficiency may be challenging when simultaneously targeting the peak throughput and flexibility requirements of NR

- Polar:
  - Polar codes are implementable, although there are currently no commercial implementations, and in relation to NR, there are some concerns as summarised below.
  - The area efficiency reduces for shorter block lengths and lower coding rates
  - For list decoders, the implementation complexity increases with increasing list size, especially with larger block sizes
    - Some companies consider that a List 32 decoder is implementable up to a codeword size N of at least 1k (with larger codeword sizes requiring a segmented design), although some other companies have concerns on the achievable performance (including area efficiency, hardware throughput)
    - Some companies consider that a List 8 decoder is implementable for codeword sizes N up to 4k (with larger codeword sizes requiring a segmented design)
    - List 4 decoder is considered implementable for codeword sizes N up to at least 2k, with some companies considering it implementable up to 8k (with larger codeword sizes requiring a segmented design)
    - List 1 is considered implementable
  - For decoding hardware that can achieve acceptable latency, performance and flexibility, there are some concerns about the area efficiency and energy efficiency that are achievable with polar codes
- Turbo:
  - Turbo codes are widely implemented in commercial hardware, supporting HARQ and flexibility similar to what is required for NR, but not at the high data rates or low latencies required for NR; in relation to NR, there are concerns summarised below.
  - Proponents consider some implementations of turbo codes to meet the flexibility requirements of NR with the most attractive area and energy efficiency except at higher throughputs, and particularly at lower code rates and lower block lengths
    - Other companies consider that the latency and area and energy efficiency are not adequate for NR, and that the area and energy efficiency reduces at lower block lengths
    - Only two of the proponents of turbo codes propose turbo codes for the higher throughputs for NR
  - In some implementations suitable for lower throughputs, the area and energy efficiency is constant when varying the puncturing and repetition rate.
    - Otherwise, this is not the case, e.g. in some implementations designed for higher data rates
  - The decoding complexity increases linearly with the information block size for a given mother code rate
  - The decoding complexity increases as the contraint length increases, and to a lesser extent as the mother code rate reduces
  - For turbo codes, there are concerns that implementation with attractive area and energy efficiency is challenging when targeting the higher throughput requirements of NR
  - Some advanced turbo decoders are considered implementable, and allow a tradeoff between complexity and performance.
  - Some companies consider quasi-ML decoders are implementable for shorter information block lengths and codeword sizes up to 1k
  - The proponents consider that a turbo decoder could be designed that would be capable of decoding both LTE and at least small information block sizes (K<=6144) of NR
    - Other companies consider that such reuse would be subject to multiple concerns or would not be possible

- **Latency**
  - The proponents of all three coding families consider that their respective codes can fulfil the NR latency requirements
    - Latency-wise, highly-parallelised decoders, as applicable for LDPC, and turbo according to some proponents, can help to reduce latency
    - Although polar codes are not highly parallelisable, proponents consider that there are other design techniques that can help to reduce latency for polar decoders
    - Some companies consider that polar codes may be able to achieve lower latency for decoding of small (around 1000 bits) blocks if capability of decoding large blocks is not considered; however, some other companies consider that polar decoders incurs longer latency than turbo decoders
- **Other considerations**
  - Turbo and LDPC are similarly well established, while Polar is less well established, being the newest among the three. All of the code families require effort at least in specification design, in order to meet the NR requirements. Some companies consider that less well established technologies require more effort.

7.1.4 Performance evaluation of network coordination and advanced receiver

For system-level simulations of advanced receiver based on network coordination, urban macro scenario, dense urban scenario excluding small cells, indoor hotspot scenario, and dense urban scenario including small cells with the same carrier frequency are encouraged to be evaluated.

Table 7.1.4-1 provides the evaluation assumptions for advanced receivers based on network coordination. The other parameters not covered by Table 7.1.4.-1 follow Table A.2.1-1 in Annex A.

Table 7.1.4-1: Evaluation assumptions for advanced receivers based on network coordination

Parameters	Urban Macro	Dense urban (Single or Dual layer)	Indoor hotspot
Carrier frequency	4GHz	Macro layer: 4GHz Small cell layer: 4GHz (co-channel)	4GHz, 30GHz
TP antenna configuration (M, N, P, M_g, N_g) (Optional parameters)	(8, 8, 2, 1, 1) (8, 4, 2, 1, 1) (8, 2, 2, 1, 1) (8, 1, 2, 1, 1) (1, 1, 2, 1, 1)	(8, 8, 2, 1, 1) (8, 4, 2, 1, 1) (8, 2, 2, 1, 1) (8, 1, 2, 1, 1) (1, 1, 2,1 ,1)	(4, 4, 2, 1, 1) (1, 1, 2, 1, 1) for 4GHz (4, 8, 2, 1, 1) for 30GHz
	(d_H, d_V) = (0.5, 0.8)λ	(d_H, d_V) = (0.5, 0.8)λ	
UE receiver	Baseline for calibration purpose : MMSE-IRC Advanced receiver : advanced receivers can be provided by each company		
Transmission scheme	closed-loop rank 1 and 2 SU-MIMO with rank adaptation, open-loop rank 1 and 2 SU-MIMO with rank adaptation (optional), other ranks are not precluded. MU-MIMO are not precluded		
Coordination cluster size for ideal backhaul	Provided by each company		
Coordinated TP measurement set size	Provided by each company		
Feedback assumption (Optional parameters)	Non-ideal CSI-RS/IMR channel/interference estimation (Number of CSI-RS ports = 16, 32 for (M, N, P, M_g, N_g) = (8, 8, 2, 1, 1), (4, 4, 2, 1, 1), (4, 8, 2, 1, 1) Number of CSI-RS ports = 8 for (M, N, P, M_g, N_g) = (8, 4, 2, 1, 1), Number of CSI-RS ports = 4 for (M, N, P, M_g, N_g) = (8, 2, 2, 1, 1), Number of CSI-RS ports = 2 for (M, N, P, M_g, N_g) = (8, 1, 2, 1, 1), Number of CSI-RS ports = 2 for (M, N, P, M_g, N_g) = (1, 1, 2, 1, 1))		
Feedback assumption	Non-ideal CSI-RS/IMR channel/interference estimation (# of CSI ports = 32)		
Traffic model	Non full buffer FTP traffic model 1/3, S = 0.1Mbytes (optional) or 0.5Mbytes		
Traffic load (Resource utilization)	20%, 40%, 60%, Optional 80%		
Backhaul link delay	0ms, 2ms (optional), 5ms, 50ms (optional). Other values are not precluded. Report by each company		
Coordination assumptions	Complexity of coordination / information exchange shall be taken into account		

It is observed that network coordination with/without advanced UE-side receivers has been shown to provide 5%-tile cell edge throughput gains over baseline schemes without network coordination in the evaluated scenarios

Table 7.1.4-2: Evaluation results for NW coordination schemes with linear receivers

		Samsung (R1-1702923)		Huawei (R1-1703340)		Nokia (R1-1703158)		Huawei (R1-1703339)			
UE Receiver		Single Antenna		MMSE-IRC Receiver		MMSE-IRC Receiver		MMSE-IRC Receiver			
TP transmission type based on network coordination		Intra-Site CJT		NCJT		DPS		DPS			
						SE-based DPS	Load and SE-based DPS				
Scenarios		Urban Macro		Urban Macro	Dense Urban (single layer)	Urban Macro		Urban Macro		Dense Urban (single layer)	
Carrier frequency		4GHz		4GHz		4 GHz		4GHz			
TP antenna configuration (M, N, P, M_g, N_g)		(8, 1, 2, 1, 1)	(8, 2, 2, 1, 1)	(8, 2, 2, 1, 1)		(8, 4, 2, 1, 1)		(8, 2, 2, 1, 1)		(8, 2, 2, 1, 1)	
		$(d_H, d_V) = (0.5, 0.8)\lambda$		$(d_H, d_V) = (0.5, 0.8)\lambda$		$(d_H, d_V) = (0.5, 0.8)\lambda$		$(d_H, d_V) = (0.5, 0.8)\lambda$			
Transmission scheme		Single TRP Transmission vs intra-site coherent JT		rank 1 OL SU-MIMO		SU-MIMO with rank adaptation		rank1 OL SU-MIMO	rank 1 CL MU-MIMO	rank 1 OL SU-MIMO	rank 1 CL MU-MIMO
Coordination cluster size for ideal backhaul		1 macro site		_		Liquid clusters		3			
Coordinated TP measurement set size		3		_		3		3			
Feedback assumption		PUSCH 3-2; 5 ms periodicity; 6 ms delay		# of CSI-RS ports = 4		2 CSI-RS ports; Wideband PMI; Subband CQI; 5 ms periodicity		CQI Reporting every 5 ms			
Traffic model		Non full buffer FTP traffic model 1, S = 0.1Mbytes		Non full buffer FTP traffic model 3, S = 0.5 Mbytes		Non full buffer FTP traffic model 1, S = 0.5Mbytes		Full Buffer			
Backhaul link delay		0ms		0ms		0ms		0ms			
5%-tile throughput gain over baseline	RU=20%	15% @λ = 0.5 s-1	18.1% @λ = 0.5 s-1	63.8%	83.7%	8.5% @RU=25%	10.8% @RU=25%	19.1% @Full buffer	20.9% @Full buffer	22.0% @Full buffer	23.0% @Full buffer
	RU=40%	11.2% @λ = 1.0 s-1	16.1% @λ = 1.0 s-1	34.2%	68.4%	33.2% @RU=45%	35.2% @RU=45%				
	RU=60%	6.8% @λ = 1.5 s-1	9.3% @λ = 1.5 s-1	37.4%	51.8%	60.6% @RU=45%	68.9% @RU=45%				

Table 7.1.4-3: Evaluation results for NW coordination schemes with advanced receivers

	Samsung (R1-1702928)				Huawei (R1-1703340)				Nokia (R1-1703157)	ZTE (R1-1701795)
UE Receiver	CIC Codeblock-level				SIC Codeword-level				IAD Symbol-level	SIC Codeword-level
TP transmission type based on network coordination	Diagonal CW2L mapping				NCJT				Modulation coordination	NCJT
Scenarios	Urban Macro		Dense Urban (single layer)		Urban Macro		Dense Urban (single layer)		Urban Macro	Indoor Hotspot
Carrier frequency	4GHz				4GHz				2GHz	3.5GHz
TP antenna configuration (M, N, P, M_g, N_g)	(1, 1, 2, 1, 1)	(8, 8, 2, 1, 1)	(1, 1, 2, 1, 1)	(8, 8, 2, 1, 1)	(8, 2, 2, 1, 1)	(2, 4, 2, 1, 1)	(8, 2, 2, 1, 1)	(2, 4, 2, 1, 1)	(1, 1, 2, 1, 1)	(1, 1, 2, 1, 1)
	$(d_H, d_V) = (0.5, 0.8)\lambda$				$(d_H, d_V) = (0.5, 0.8)\lambda$				$(d_H, d_V) = (0.5, 0.8)\lambda$	$(d_H, d_V) = (0.5, 0.8)\lambda$
Transmission scheme	ranks 1, 2 OL SU-	ranks 1, 2 CL SU-	ranks 1, 2 OL SU-	ranks 1, 2 CL SU-	Co-existing layers with	ranks 1, 2 CL SU-	Co-existing layers with	ranks 1, 2 CL SU-	SU-MIMO with rank adaptation	TM10 with rank adaptation

<table>
<tr><td colspan="2"></td><td>MIMO</td><td>MIMO</td><td>MIMO</td><td>MIMO</td><td>rank 1 OL SU-MIMO</td><td>MIMO</td><td>rank 1 OL SU-MIMO</td><td>MIMO</td><td></td><td></td></tr>
<tr><td colspan="2">Coordination cluster size for ideal backhaul</td><td colspan="4">Depending on one dominant interferer on the UE side</td><td>3</td><td>2</td><td>3</td><td>2</td><td>Liquid clusters</td><td>–</td></tr>
<tr><td colspan="2">Coordinated TP measurement set size</td><td colspan="4">Size of one TP measurement, but semi-static</td><td>3</td><td>2</td><td>3</td><td>2</td><td>–</td><td>–</td></tr>
<tr><td colspan="2">Feedback assumption</td><td colspan="4">Non-ideal CSI-RS/IMR channel/interference estimation
# of CSI-RS ports = 2 and 32 for (M, N, P, M_g, N_g) = (8, 8, 2, 1, 1) and (1, 1, 2, 1, 1), respectively</td><td colspan="4"># of CSI-RS ports = 4 and 16 for (M, N, P, M_g, N_g) = (8, 2, 2, 1, 1) and (2, 4, 2, 1, 1), respectively</td><td># of CSI-RS ports = 2</td><td>Rel-12 enhanced CSI feedback, PUSCH mode 3-2
2Tx codebook, 16Tx FD-MIMO codebook</td></tr>
<tr><td colspan="2">Traffic model</td><td colspan="4">Non full buffer FTP traffic model 1, S = 0.5Mbytes</td><td colspan="4">NC-JT with CL: Non full buffer FTP traffic model 1, S=0.5Mbytes
NC-JT with OL: Full Buffer</td><td>Full Buffer</td><td>Non full buffer FTP traffic model 1, S = 0.5 Mbytes</td></tr>
<tr><td colspan="2">Backhaul link delay</td><td colspan="4">0ms</td><td colspan="4">0ms</td><td>0ms</td><td>0ms</td></tr>
<tr><td rowspan="3">5%-tile throughput gain over MMSE-IRC</td><td>RU=20%</td><td>73.70%</td><td>37.40%</td><td>195.70%</td><td>41.60%</td><td rowspan="3">96.69% @ Full buffer</td><td>61.4% @rank 1 76.50% @rank 2</td><td rowspan="3">91.72% @ Full buffer</td><td>80.3% @rank 1 85.50% @rank 2</td><td rowspan="3">–</td><td>18.5% (over DPS/DPB)</td></tr>
<tr><td>RU=40%</td><td>66.60%</td><td>51.70%</td><td>171.60%</td><td>94.50%</td><td>49.1% @rank 1 69.5% @rank 2</td><td>56/0% @rank 1 68.4% @rank 2</td><td>19.9% (over DPS/DPB)</td></tr>
<tr><td>RU=60%</td><td>41.20%</td><td>50.30%</td><td>100.50%</td><td>138.80%</td><td>23.5% @rank 1 47.5% @rank 2</td><td>38.3% @rank 1 45.4% @rank 2</td><td>16.0% @RU=70% (over DPS/DPB)</td></tr>
<tr><td rowspan="3">5%-tile throughput gain over IAD wo/ coordination</td><td>RU=20%</td><td>4.70%</td><td>8.00%</td><td>9.20%</td><td>2.20%</td><td colspan="4" rowspan="3">–</td><td rowspan="3">17.2% @Full buffer</td><td rowspan="3">–</td></tr>
<tr><td>RU=40%</td><td>12.10%</td><td>6.70%</td><td>8.90%</td><td>3.40%</td></tr>
<tr><td>RU=60%</td><td>12.20%</td><td>7.70%</td><td>14.00%</td><td>6.60%</td></tr>
</table>

7.1.5 Performance evaluation related to initial access

The following target requirements should be taken into account in NR-PSS/SSS design

- Robustness against initial frequency offset up to 5 ppm
  - 10 ppm as optional requirement
- Reasonable complexity for NR-PSS/SSS detection
- Good one-shot detection probability at -6 dB received baseband SNR condition with less than 1% false alarm rate
  - Companies report detection probability, the residual timing error and frequency error
- Good detection performance in multi-cell scenario
- Note: for mMTC, different target requirements may be considered

The following aspects can be considered (not an exhaustive list)

- Low system overhead due to NR-PSS/SSS transmission
- Low PAPR of waveform for possible power boosting transmission
- Multiplexing with other signal/channel for efficient operation
- Utility of NR-PSS/SSS as reference signal for other channels, e.g., PBCH

The following target requirements should be taken into account in the NR-PBCH design

- Detectable at low received baseband SNR condition
- Note: it does not mean NR-PBCH should be detectable by one-shot

Use of PBCH for frequency offset estimation and necessity of use of the PBCH for frequency offset estimation is also studied.

7.1.6 Performance evaluation related to MIMO

System level and link level NR MIMO calibration has been conducted through the following phased approaches:

- Phase 1: Calibration is to check the link and system level channel models with basic beamforming behavior in terms of SNR/SINR distribution. Link level evaluation assumptions for this item can be found in R1-1701823. Link level calibration results for this item can be found in R1-1715252. System level evaluation assumptions for this item can be found in R1-1703534. System level calibration results for this item can be found in R1-1715251.
- Phase 2: Calibration is to check the link/system level performance through observing the metrics of BLER, spectrum efficiency and outage. Link level evaluation assumptions for this item can be found in R1-1703535. Link level calibration results for this item can be found in R1-1715254. System level evaluation assumptions for this item can be found in R1-1703536. System level calibration results for this item can be found in R1-1715253.
- Phase 3: Calibration is to check the additional link (if necessary)/system-level features including UE movement, UE rotation and channel blockage in terms of coupling loss, ASA, SINR and spectral efficiency. System level evaluation assumptions for this item can be found in R1-1701828. System level calibration results for this item can be found in R1-1715255.

The following aspects of beam management are considered for evaluation:

- Overall beam management procedures P1, P2, P3 considering different number of beams and panels
- Beam reporting including at least the following aspects:
  - Number of beam related IDs, number of beam groups and related overhead considering different criteria of beam selection e.g. panel/subarray basis or UE Rx beam basis

- whether to report information related to spatial parameters, e.g. QCL, spatial correlation
- Reporting frequency
- CSI-RS pattern and density for beam management CSI-RS (including typical required periodicity) considering maximum or typical number of beams for beam management CSI-RS
  - Other RS for beam management can be evaluated
- Beam indication including at least the following aspects:
  - Beam indication frequency
  - Beam indication latency
- Blocking with different number of beam pair links

Note: Beam management procedures should flexibly support different antenna configurations. The evaluation assumptions for link level and system level evaluation are shown in Table A.1.6-4 and Table A.2.5-2 respectively.

8 UL concepts

8.1 Basic transmission scheme

8.1.1 Modulation scheme

QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported. 0.5 pi-BPSK is also supported for DFT-s-OFDM.

8.1.2 Physical layer channel

8.1.2.1 Data channel

UL transmission is based on scheduling.

In URLLC, for an UL transmission scheme without grant, at least semi-static resource (re-)configuration is supported. RS is transmitted together with data. For an UL transmission scheme with/without grant, *K* repetitions including initial transmission (K>=1) for the same transport block are supported.

8.1.2.2 Control channel

Physical uplink control signaling should be able to carry at least hybrid-ARQ acknowledgements, CSI reports (possibly including beamforming information), and scheduling requests.

At least two ways of transmissions are supported for NR UL control channel

- UL control channel can be transmitted in short duration around the last transmitted UL symbol(s) of a slot. UL control channel is time-division-multiplexed and/or frequency-division-multiplexed with UL data channel within a slot. For UL control channel in short duration, transmission over one symbol duration of a slot is supported.
  - Short UCI and data are frequency-division-multiplexed both within a UE and between UEs, at least for the case where the PRBs for short UCI and data are non-overlapping.
  - In order to support TDM of short PUCCH from different UEs in the same slot, a mechanism to tell the UE in which symbol(s) in a slot to transmit the short PUCCH on is supported at least above 6 GHz.
  - At least following is supported for PUCCH in 1-symbol duration:
    - UCI and RS are multiplexed in the given OFDM symbol in FDM manner if RS is multiplexed.

    - Same subcarrier spacing between DL/UL data and PUCCH in short-duration in the same slot.
- At least a PUCCH in short-duration spanning 2-symbol duration of a slot is supported.
    - Same subcarrier spacing between DL/UL data and PUCCH in short-duration in the same slot.
- At least semi-static configuration for the following is supported.
    - A PUCCH resource of a given UE within a slot. i.e., short-PUCCHs of different UEs can be time-division multiplexed within the given duration in a slot.
- The PUCCH resource includes time, frequency and, when applicable, code domains.
- PUCCH in short-duration can span until the end of a slot from UE perspective
    - No explicit gap symbol is necessary after the PUCCH in short-duration.
- For a slot having short UL-part (i.e., DL-centric slot):
    - 'Short UCI' and data can be frequency-division multiplexed by one UE if a data is scheduled on the short UL-part.

UL control channel can be transmitted in long duration over multiple UL symbols to improve coverage. UL control channel is frequency-division-multiplexed with UL data channel within a slot.

- A UCI carried by long duration UL control channel at least with low PAPR design can be transmitted in one slot or multiple slots.
- Transmission across multiple slots should allow a total duration, e.g., 1ms, at least for some cases.
- For UL control channel with long duration, TDM between RS and UCI is supported at least for DFT-S-OFDM.
- Long UL-part of a slot can be used for transmission of PUCCH in long-duration, i.e., PUCCH in long-duration is supported for both UL-only slot and a slot with variable number of symbols with a minimum of 4 symbols for PUCCH transmission..
- At least for 1 or 2 UCI bits, the UCI can be repeated within N slots (N>1) where the *N* slots may or may not be adjacent in slots where PUCCH in long duration is allowed.
- Simultaneous transmission of PUSCH and PUCCH at least for the long PUCCH format is supported, i.e., transmit uplink control on PUCCH resources even in presence of data. In addition to simultaneous PUCCH-PUSCH transmission, UCI on PUSCH is supported.
- Intra-TTI slot frequency-hopping is supported.
- DFT-s-OFDM waveform is supported.
- Transmit antenna diversity is supported.

Both TDM and FDM between short duration PUCCH and long duration PUCCH are supported at least for different UEs in one slot. In frequency-domain, a PRB (or multiple PRBs) is the minimum resource unit size for UL control channel. The frequency resource and hopping, if hopping is used, may not spread over the carrier bandwidth. UE-specific RS is used for NR-PUCCH transmission. A set of PUCCH resources is configured by high layer signaling and a PUCCH resource within the configured set is indicated by DCI.

It should be possible to dynamically indicate (at least in combination with RRC) the timing between data reception and hybrid-ARQ acknowledgement transmission as part of the DCI. A combination of semi-static configuration and (at least for some types of UCI information) dynamic signaling is used to determine the PUCCH resource both for the 'long and short PUCCH formats', where the PUCCH resource includes time, frequency and, when applicable, code domains. UCI on PUSCH, i.e., using some of the scheduled resources for UCI is supported in case of simultaneous UCI and data.

At least UL transmission of at least single HARQ-ACK bit is supported.

Mechanism enabling frequency-diversity is supported.

For URLLC, time interval between SR resources configured for a UE can be smaller than a slot.

8.1.3 Waveform

OFDM-based waveform is supported. At least up to 40 GHz for eMBB and URLLC services, CP-OFDM based waveform supports spectral utilization of Y greater than that of LTE (assuming Y=90% for LTE) where Y (%) is defined as transmission bandwidth configuration / channel bandwidth * 100%. From RAN1 perspective, spectral confinement technique(s) (e.g. filtering, windowing, etc.) for a waveform at the transmitter is transparent to the receiver.

DFT-S-OFDM based waveform is also supported, complementary to CP-OFDM waveform at least for eMBB uplink for up to 40GHz. CP-OFDM waveform can be used for a single-stream and multi-stream (i.e. MIMO) transmissions, while DFT-S-OFDM based waveform is limited to a single stream transmissions (targeting for link budget limited cases). Network can decide and communicate to the UE which one of CP-OFDM and DFT-S-OFDM based waveforms to use Note that both CP-OFDM and DFT-S-OFDM based waveforms are mandatory for UEs.

8.1.4 Multiple access scheme

Synchronous/scheduling-based orthogonal multiple access is at least supported for UL transmissions, at least targeting for eMBB. Note that synchronous means that timing offset between UEs is within cyclic prefix by e.g. timing alignment.

NR targets to support UL non-orthogonal multiple access, in addition to the orthogonal approach, targeting at least for mMTC.

8.1.5 Channel coding

The channel coding scheme for data for eMBB is flexible LDPC as the single channel coding scheme for all block sizes.

The channel coding scheme for UL control information for eMBB is Polar Coding (except for very small block lengths where repetition/block coding may be preferred).

8.1.5.1 LDPC

See subclause 6.1.5.1.

8.1.5.1 Polar coding

See subclause 6.1.5.2. Maximum mother code size of Polar code, $N=2^n$, is $N_{\max,\mathrm{UCI}} = 1024$ for uplink control information.

8.1.6 Multi-antenna scheme

8.1.6.1 Beam management and CSI acquisition

For UL CSI acquisition, UE can be configured with multiple SRS resources, where UE can be configured to transmit SRS in each configured SRS resource. In NR, UE reports its capability regarding the max number of spatial layers for UL transmission. NR supports UL codebook for an UE based on the reported capability. At least, one of the followings is supported.

- Alt1: Network configures multiple codebooks each corresponding to the number of antenna ports
- Alt2: Network configures a scalable/nested codebook supporting the variable number of antenna ports
- Alt3: Network configures a codebook same as UE capability
- Alt 4: UE recommends a subset of codebook(s)
    - This alternative may be absorbed into one or more the above alternatives

As for the UL codebook structure, at least one of the following two is supported

- Alt 0: single-stage codebook

- Alt 1: dual-stage codebook

8.1.6.2 MIMO schemes

For NR, the number of codewords per PUSCH assignment per UE is 1 codeword for 1 to 4-layer transmission.

The following aspects for UL MIMO transmission should be supported. Transmission schemes/methods for reciprocity calibrated UEs, reciprocity non-calibrated UEs, and non-reciprocity/partial reciprocity cases are considered.

- At least the following candidate schemes/methods are supported for data.
  - Candidate 1: Codebook based transmission
    - Frequency selective precoding is supported for CP-OFDM when the number of transmission port(s) is equal to or greater than X.
  - Candidate 2: Non-codebook based transmission
    - Frequency selective precoding is supported for CP-OFDM when the number of transmission port(s) is equal to or greater than Y.
    - The indication of DL measurement RS is supported for UE to calculate candidate precoder
  - Diversity-based transmission schemes
    - For DFT-S-OFDM, CDD, precoder cycling, antenna port switching, SFBC, and STBC can be the candidates for UL diversity schemes for UL data

Dynamic switching between transmission methods/schemes is supported. Rank determination is performed by gNB. PRB bundling is supported for CP-OFDM and for DFT-s-OFDM based transmission. For CP-OFDM based transmission, PRB bundling is supported for both codebook based and non-codebook based transmissions. For DFT-S-OFDM based transmission, PRB bundling size is the whole scheduled bandwidth if the scheduled bandwidth comprises a single cluster. Note that UE shall apply the precoder in a way that the gNB may assume that UE uses the same precoder for all scheduled PRBs.

UL DMRS based spatial multiplexing (SU-MIMO/MU-MIMO) is supported. At least a maximum of 4 layers uplink SU-MIMO transmission is supported.

At least one of precoded and non-precoded SRS based UL link adaptation procedure is supported in NR, with at least following three different procedures:

- UL data scheduling (MCS/precoder/rank) is based on non-precoded SRS transmission by UE
  - Configurable number of SRS ports are 1, 2, or 4 at least.
- UL data scheduling (MCS/precoder/rank) is based on precoded SRS(s) transmission by UE
  - Configurable number of SRS ports are 1, 2, or 4 at least.
  - Multiple precoded SRS resources can be configured.
  - The followings are supported
    - Precoder for SRS can be determined by UE based on measurement on DL RS and
    - Precoder for SRS can be indicated by gNB
- UL data scheduling (MCS/precoder/rank) is based on a combination of non-precoded and precoded SRS transmission by UE

Note that some parts of above procedures might be transparent to UE.

NR supports UL-MIMO scheduling by DCI, which includes at least some of

- Indication of a SRS resource (SRI) which has been transmitted by UE in previous time instance
    - Each configured SRS resource is associated with at least one UL Tx beam/precoder

- Transmit Rank indicator (TRI)
    - Possible values are up to the number of SRS ports configured in the indicated SRI
- Wideband transmit PMI (TPMI)
- UL MCS indication
- UL HARQ related information
- UL Resource allocation

8.1.6.3 Reference signal related to multi-antenna scheme

The following RSs are at least supported for NR uplink.

- SRS: Reference signal with main functionalities of CSI acquisition, beam management
- DM-RS: Reference signal with main functionalities of data and control demodulation
- Reference signal for phase tracking

8.1.6.3.1 SRS

NR SRS design should not assume a particular antenna configuration at UE and should support dynamic port/antenna/resource selection by gNB and UE. In the case of UE selection, it can be disabled/enabled by gNB (if the UE selection is not transparent).

NR UL supports transmissions of SRS precoded with same and different UE Tx beams within a time duration. NR supports the following Tx beamformer determination for SRS.

- UE applies gNB-transparent Tx beamformer to SRS, e.g., UE determines Tx beam for each SRS port/resource
- Based on gNB indication, e.g. via SRI

NR supports SRS transmission including number of SRS ports are 1, 2, and 4 at least, Comb levels of 2 and 4, and configurable frequency hopping.

Configurable SRS bandwidth is supported. SRS can be configurable with regard to density in frequency domain (e.g., comb levels) and/or in time domain (including multi-symbol SRS transmissions). Partial band size and full band size can be configured. Partial-band is smaller than the largest transmission bandwidth supported by the UE. Within a partial-band, the PRBs for SRS transmission can at least be consecutive in the frequency domain. Frequency hopping is supported within a partial-band for a UE where at least hopping with a granularity of subband is supported. For the full band size, the size is equal to the largest transmission bandwidth supported by the UE. The numerology(ies) for the SRS transmissions can be also configurable for a UE.

An NR-SRS resource comprises of a set of resource elements (RE) within a time duration/frequency span and N antenna ports ($N \geq 1$). A UE can be configured with $K \geq 1$ NR-SRS resources. The maximum value of K is considered to be a UE capability to avoid mandatory support for large values of K. Out of $K \geq 1$ configured NR-SRS resources, for aperiodic transmission, the UE can be configured to transmit a subset of or all K NR-SRS resources with no precoding, the same, or different precoding. For periodic and semi-persistent transmission, out of $K \geq 1$ configured NR-SRS resources, the UE can be configured to transmit K NR-SRS resources with no precoding, the same, or different precoding.

SRS transmissions with sequences achieving low-PAPR and possible multiplexing of SRS with different SRS bandwidths in the same symbol are considered.

Aperiodic SRS transmission triggered by the network is supported. Periodic and semi-persistent NR-SRS transmissions are also supported.

8.1.6.3.2 PT-RS

For CP-OFDM, time-domain density mapped on every other symbol and/or every symbol and/or every 4-th symbol is supported. At least for UL, the presence of PT-RS is UE-specifically configured .PT-RS is confined in the scheduled time/frequency duration for a UE. For a given UE, the designated PT-RS is confined in scheduled resource as a baseline. Presence/patterns of PT-RS in scheduled resource are UE-specifically configured by a combination of RRC signaling and association with parameter(s) used for other purposes (e.g., MCS) which are (dynamically) indicated by DCI. Whether PT-RS can be present or not depends on RRC configuration. When configured, the dynamic presence is associated with DCI parameter(s) including at least MCS. Multiple PT-RS densities defined in time/frequency domain are supported. When present, frequency domain density is associated with at least dynamic configuration of the scheduled BW. UE can assume the same precoding for a DMRS port and a PT-RS port. Number of PT-RS ports can be fewer than number of DM-RS ports in scheduled resource.

In NR, frequency offset and PN compensation for DFT-s-OFDM are also considered.

8.2 Physical layer procedure

8.2.1 Random access procedure

8.2.1.1 Preamble

NR defines that

- a random access preamble format consists of one or multiple random access preamble(s),
- a random access preamble consists of one preamble sequence plus CP, and
- one preamble sequence consists of one or multiple RACH OFDM symbol(s)

UE transmits PRACH according to the configured random access preamble format.

NR supports multiple RACH preamble formats, including at least RACH preamble formats with longer preamble length and shorter preamble length. Multiple/repeated RACH preambles in a RACH resource are supported. Numerology for RACH preamble can be different depending on frequency ranges. Numerology for RACH preamble can be different from or the same as that for the other UL data/control channels.

For a single RACH preamble transmission, CP/GT are required. For example, the single RACH preamble would be used when Tx/Rx beam correspondence held at both TRP and UE for multi-beam operation.

For single/multi-beam operation, the following multiple/repeated RACH preamble transmission is at least supported.

- CP is inserted at the beginning of the consecutive multiple/repeated RACH OFDM symbols, CP/GT between RACH symbols is omitted and GT is reserved at the end of the consecutive multiple/repeated RACH symbols

The region for PRACH transmission is aligned to the boundary of uplink symbol/slot/subframe. For supporting various coverage and forward compatibility, flexibility in the length of CP/GT and the number of repeated RACH preambles and RACH symbols is supported. Note that specific use of the RACH preamble transmission may depend on RACH subcarrier spacing and TRP beam correspondence.

8.2.1.2 Procedure

RACH procedure including RACH preamble (Msg. 1), random access response (Msg. 2), message 3, and message 4 is assumed for NR from physical layer perspective. Random access procedure is supported for both IDLE mode and CONNECTED mode UEs. For 4-step RACH procedure, a RACH transmission occasion is defined as the time-frequency resource on which a PRACH message 1 is transmitted using the configured PRACH preamble format with a single particular tx beam

RACH resource is also defined as a time-frequency resource to send RACH preamble. Whether UE needs to transmit one or multiple/repeated preamble within a subset of RACH resources can be informed by broadcast system information, e.g., to cover gNB RX beam sweeping in case of NO Tx/Rx beam correspondence at the gNB.

Regardless of whether Tx/Rx beam correspondence is available or not at gNB at least for multiple beams operation, the following RACH procedure is considered for at least UE in idle mode. Association between one or multiple occasions for DL broadcast channel/signal and a subset of RACH resources is informed to UE by broadcast system information or known to UE. Based on the DL measurement and the corresponding association, UE selects the subset of RACH preamble indices. UE Tx beam(s) for preamble transmission(s) is selected by the UE. During a RACH transmission occasion of single or multiple/repeated preamble(s) as informed by broadcast system information, UE uses the same UE Tx beam. NR at least supports transmission of a single Msg.1 before the end of a monitored RAR window.

At least for the case without gNB Tx/Rx beam correspondence, gNB can configure an association between DL signal/channel, and a subset of RACH resources and/or a subset of preamble indices, for determining Msg2 DL Tx beam. Based on the DL measurement and the corresponding association, UE selects the subset of RACH resources and/or the subset of RACH preamble indices. A preamble index consists of preamble sequence index and OCC index, if OCC is supported. Note that a subset of preambles can be indicated by OCC indices.

Regardless of whether Tx/Rx beam correspondence is available or not at gNB at least for multiple beams operation, at gNB, the DL Tx beam for message 2 can be obtained based on the detected RACH preamble/resource and the corresponding association. UL grant in message 2 may indicate the transmission timing of message 3. As baseline UE behavior, UE assumes single RAR reception within a given RAR window.

At least for UE in idle mode, UL Tx beam for message 3 transmission is determined by UE. UE may use the same UL Tx beam used for message 1 transmission.

Different PRACH configurations will be supported, e.g., considering different numerologies case and whether Tx/Rx beam correspondence is available or not at gNB.

For NR RACH Msg. 1 retransmission at least for multi-beam operation, NR supports power ramping. If UE doesn't change beam, the counter of power ramping keeps increasing. Note that UE may derive the uplink transmit power using the most recent estimate of path loss. Whether UE performs UL Beam switching during retransmissions is up to UE implementation. Note that which beam UE switches to is up to UE implementation.

8.2.2 Scheduling

NR supports both data and control with the same numerology. The same-slot and cross-slot scheduling for UL is supported. Timing between UL assignment and corresponding UL data transmission is indicated by a field in the DCI from a set of values and the set of values is configured by higher layer. For slot-based scheduling, UL assignment in slot N and corresponding uplink data transmission in slot $N+K2$ is to be specified. The timing(s) is (are) defined at least for the case where the timing(s) is (are) unknown to the UE. Both contiguous and non-contiguous resource allocation for data with CP-OFDM is supported.

At least an UL transmission scheme without grant is supported for URLLC. Resource may or may not be shared among one or more users. Also, an UL transmission scheme without grant is targeted to be supported for mMTC. For UL transmission without grant, the resource configuration includes at least time and frequency resources, modulation and coding scheme(s), possibly including RV, implicitly or explicitly, and reference signal parameters. For UE configured with K repetitions for a TB transmission with/without grant, the UE can continue repetitions for the TB until one of the following conditions is met.

- If an UL grant is successfully received for a slot/mini-slot for the same TB
- The number of repetitions for that TB reaches K
- Note that this does not assume that UL grant is scheduled based on the slot whereas grant free allocation is based on mini-slot (vice versa)

8.2.3 Power control

For NR-PUSCH at least targeting eMBB, both open-loop and closed-loop power controls are supported. Open-loop based on pathloss estimate is supported where pathloss measurement for UL power control is to be based on at least one type of DL RS for beam measurement. Note that beam measurement RS includes CSI-RS, RS defined for mobility purpose. The same gNB antenna port can be used for pathloss measurement for multiple processes.

Fractional power control is supported. Closed-loop power control is based on NW signaling. Dynamic UL-power adjustment is considered.

Separate power control process can be supported for transmission of different channel/RS (i.e., PUSCH, PUCCH, SRS).

NR supports beam specific power control as baseline. Power control for UE side multiple panel transmission is supported.

8.2.4 HARQ

Operation of more than one UL HARQ processes is supported for a given UE while operation of one UL HARQ process is also supported for some UEs. Asynchronous and adaptive UL HARQ is supported at least for eMBB.

9 Evaluation of UL techniques

9.1 Performance evaluation

9.1.1 Performance evaluation of waveform

Evaluation cases, i.e., Case 3 and 4, and performance metrics for the uplink are described in subclause 7.1.1. General evaluation assumptions are provided in Annex. A.1.

Evaluation observations for the uplink are summarized as below.

- Some evaluations in RAN1 show that Y for a NR carrier can be up to 98% of the evaluated channel bandwidths for both DL and UL without complexity and latency constraints [R1-166093]
- For in-band frequency multiplexing of different numerologies, it is expected that spectrum confinement on sub-band basis is specified as requirements on transmitter side in-band emission and EVM requirements and reception performance in presence of other-subband interferer.
- From RAN1 perspective, spectral confinement technique(s) (e.g. filtering, windowing, etc.) for a waveform at the transmitter is transparent to the receiver.

9.1.2 Performance evaluation of multiple access

Evaluation cases and performance metrics for the uplink are followed by those for the downlink described in subclause 7.1.2. For link level simulation, the following evaluation metrics are considered.

- BLER vs SNR reported for UL and DL calibration
- BS and UE receiver complexity reported
- Sum throughput v.s. SNR at given BLER level under different overloading factor.
  - Overload factor is defined as
    - For spreading case: number of data layers (users) / spreading length (number of REs)
    - For non-spreading case: number of data layers (users) on each RE
- Link budget (MCL with specific data rate)

For system level simulation, the same evaluation metrics described in subclause 9.1.2 are applicable. General evaluation assumptions are provided in Annex. A.1. For the SLS evaluation for grant-free UL multiple access schemes applied to mMTC, packet drop rate vs. packet arrival rate per cell curve is used, where grant-free UL multiple access schemes has the following characteristics

- A transmission from UE does not need the dynamic and explicit scheduling grant from eNB
- Multiple UEs can share the same time and frequency resources

and packet drop rate is defined as (Number of packet in outage) / (number of generated packets), where a packet is in outage if this packet failed to be successfully received by destination receiver beyond "Packet dropping timer" The UL traffic model to use for evaluation of grant-free UL multiple access applied to mMTC is also shown in Annex A.2.

A MA physical resource for "grant-free" UL transmission is comprised of a time-frequency block. Note that spatial dimension is not considered as a physical resource in this context. A MA resource is comprised of a MA physical resource and a MA signature, where a MA signature includes at least one of the following:

- Codebook/Codeword
- Sequence
- Interleaver and/or mapping pattern
- Demodulation reference signal
- Preamble
- Spatial-dimension
- Power-dimension
- Others are not precluded

The baseline multiple access scheme to assess the candidate techniques is described in Table A.9.1.2-1.

Table 9.1.2-1: Baseline scheme of calibration purpose for evaluation of grant-free UL multiple access schemes.

Attributes	Assumptions
Waveform	CP-OFDM as the UL waveform • UL DMRS overhead, 1 OFDM symbol out of 7 OFDM symbols
Resource allocation	A UE selects a MA physical resource randomly from a pool of orthogonal MA physical resources There is no partial overlapping between the MA physical resources selected by more than one UE All orthogonal MA physical resources are of same size Total allocated bandwidth: 6RB, 4RB (optional) for calibration purpose only Bandwidth per user per transmission: 1 RB
Receiver	MMSE-IRC, assuming ideal channel estimation for calibration purpose only • 2Rx • No blind decoding assumed
MCS	Same for all UEs •Derived by the bandwidth per user of 1 RB and TB size of 160 bits per transmission •QPSK
Power control	Open loop power control: Alpha=1, P0= -90 dBm
Packet size	Fixed by 20 bytes TB size with CRC included
HARQ retransmission	No. of transmission is 1 (i.e., no repetition or retransmission)
Traffic model	FTP 3 with fixed TB size
Average no. of users per sector	20 assuming 3 sectors/cell, total 57 sectors
Channel code	LTE Turbo

All proposed non-orthogonal MA schemes studied for UL transmission share the following common features:

- At the transmitter side: using MA signature(s)
- At the receiver side: allowing multi-user detector

All proposed non-orthogonal MA schemes for UL transmission on a high level follow the following basic diagram as shown in Figure 9.1.2-1. Note that the basic diagram is not intended to capture all the details or to be a complete diagram.

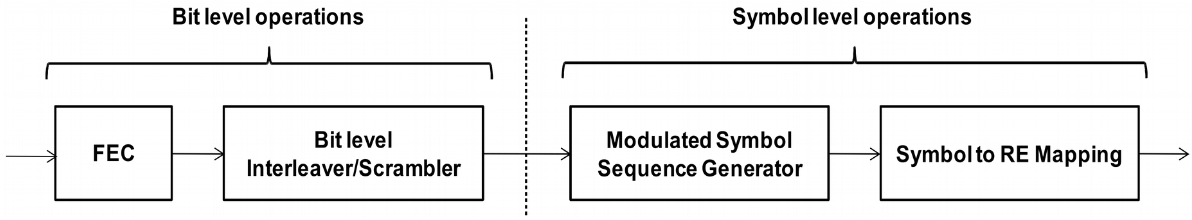


Figure 9.1.2-1: High level block diagram for UL non-orthogonal MA schemes.

Tables 9.1.2-2 and 9.1.2-3 provide the link-level simulation assumptions for evaluating various UL non-orthogonal multiple access schemes. Tables 9.1.2-4 to 9.1.2-6 provide summary of link level simulation results comparing non-orthogonal multiple access schemes with OFDMA. In the table, each source corresponds to the following references.

- Source1: R1-164037, R1-166094, R1-1608853, R1-162153
- Source2: R1-166404, R1-1608953
- Source3: R1-167870, R1-1608755
- Source4: R1-164329, R1-166670, R1-1610478
- Source5: R1-163992, R1-166750, R1-1609041, R1-1612574
- Source6: R1-164557, R1-166876, R1-1609223
- Source7: R1-167340, R1-1609548
- Source8: R1-1610078
- Source9: R1-167537, R1-167536, R1-1609332, R1-167872, R1-1609613, R1-1609333, R1-167872
- Source10: R1-167602, R1-165287, R1-167602
- Source11: R1-167700, R1-1609497, R1-1610918, R1-1610375
- Source12: R1-167105
- Source13: R1-1610118
- Source14: R1-165019, R1-1609651
- Source15: R1-165435, R1-165435

Based on the contributions and the assumptions listed in Tables 9.1.2-2 and 9.1.2-3, and evaluation results shown in Tables 9.1.2-4 to 9.1.2-6, it is observed

- Non-orthogonal MA, in some of the evaluated scenarios, provides significant gain in terms of UL link-level sum throughput and overloading capability with ideal and realistic channel estimation.
- Some non-orthogonal MA results combined with narrowband and/or repetition operations can reach -164 dB MCL @160bps data rate, which meets the coverage requirement for NR.
- Non-orthogonal MA schemes using an advanced receiver have little or no performance loss due to MA signature (except RS) collision.

Table 9.1.2-2: Link-level evaluation assumptions

Parameters	Values or assumptions	Further specified values reported
Carrier Frequency	2 GHz	
Waveform	OFDM /SC-FDMA Other waveform is not precluded	OFDMA with equal bandwidth and distributed subcarrier allocation or OFDMA with orthogonal Walsh code
Numerology	Same as Release 13	

System Bandwidth	10 MHz	Allocated bandwidth reported: 4RB, 6RB, 12RB The same for non-orthogonal MA and OFDMA
Target spectral efficiency	Proponents report per UE spectral efficiency and the number of UEs multiplexed if multi-UEs LLS is assumed	The same target per UE spectral efficiency for non-orthogonal MA and OFDMA Without short-term (per TTI) MCS adaptation Detail of reported target SE per user and the number of users are listed in Table 9.1.2-3
BS antenna configuration	2/4 Rx as baseline 8Rx optional	See Table 9.1.2-3
UE antenna configuration	1Tx	
Transmission mode	TM1 (refer to TS36.213)	
SNR distribution of Multiple UEs	Proponents report if single-user or multi-user LLS is used, and what SNR distribution is assumed.	Either equal long-term SNR and/or unequal long-term SNR has been considered Detail of assumptions listed in Table 9.1.2-3
Propagation channel & UE velocity	TDL for in TR 38.901 [15] as mandatory EPA, EVA, ETU as optional 3km/h, 30km/h, 120km/h	See Table 9.1.2-3
Max number of HARQ transmission	1, 4	1
Channel estimation		Either ideal and/or realistic channel estimation has been considered Detail of assumptions listed in Table 9.1.2-3
MA signature allocation		Either fixed and/or random MA signature (e.g., codebook, sequence, interleaver, etc.) allocation has been considered Detail of assumptions listed in Table 9.1.2-3
Timing/frequency offset		Frequency offset not considered Timing offset of either within CP and/or beyond CP has been considered Detail of assumptions listed in Table 9.1.2-3
SNR definition		SNR is either defined at the transmitter per layer or at the receiver as the sum per RE

Table 9.1.2-3: Assumptions of preliminary link-level simulation results for non-orthogonal multiple access schemes comparing with OFDMA

Source	Source 1, Source 10, Source 12, Source 15	Source 2	Source 3, Source 10, Source 15	Source 4	Source 5	Source 6	Source 7	Source 8, Source 9	Source 9	Source 9	Source 11	Source 9	Source 13	Source 14
Multiple access scheme	SCMA	MUSA	PDMA	LDS-SVE	IGMA	NCMA	LSSA	NOMA	GOCA	RDMA	LCRS	MU-MIMO	RSMA	NOCA
Spectral efficiency (Bit/RE per UE)	0.05~0.5	0.125, 0.25	0.0417,0.0833, 0.2083, 0.3333	0.33, 0.35	0.083,0.171, 0.222	0.0625, 0.25	0.0833, 0.0926, 0.111, 0.166, 0.375	0.144, 0.25, 0.5	0.157, 0.222	0.157, 0.222	0.001~0.33	1.25, 0.625	0.25, 0.375. 0.5, 0.75, 1	0.069
Number of UEs	4, 6, 8, 12	4~40	4, 8, 12	6	6,8 (10~16 not compared with OFDMA)	4, 6, 8	4, 6, 8, 12, 24	2, 4, 8, 12	6, 8, 12	6, 8, 12	1, 8	2	4	12, 18
Channel Type	TDL-A, TDL-C, EPA	TDL-A, TDL-C	TDL-A, TDL-C, EPA	TDL-A, TDL-B, TDL-C	TDL-A, TDL-C,	TDL-C	TDL-C	TDL-C	TDL-A,TDL-C	TDL-A,TDL-C	EPA, EVA,TDL-A, TDL-C	TDL-C	TDL-A,TDL-C	TDL-A,TDL-C
Antenna Config.	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R, 1T4R	1T2R
SNR distribution	Equal /unequal	Equal /unequal	Equal	Equal	Equal	Equal	Equal	Equal /unequal	Equal /unequal	Equal /unequal	Equal	Equal	Equal /unequal	Equal / unequal
MA signature allocation	Fixed /random	Random, No dedicate RS	Fixed	Fixed	Fixed /random	Fixed	Fixed	Fixed	Fixed /random	Fixed /random	Fixed	Fixed	Fixed	Fixed
Channel estimation	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal	Ideal /realistic
Timing offset	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP

Table 9.1.2-4: Range of SNR gain of non-orthogonal multiple access over OFDMA with ideal channel estimation

Source		Source 1]	Source 3	Source 9	Source 9	Source 4	Source 6	Source 13	Source 2	Source 5]	Source 7]	Source 11	Source 9	Source 8	Source 14
Multiple access scheme		SCMA	PDMA	GOCA	RDMA	LDS-SVE	NCMA	RSMA	MUSA	IGMA	LSSA	LCRS	MU-MIMO	NOMA	NOCA
Receiver type		MPA	MPA	MF-based SIC	MF-based SIC	MPA w/o iterative decoding	MMSE-IRC w/ SIC	Iterative Demapper	MMSE-SIC	Chip-by chip MAP	Iterative MMSE-PIC	MMSE-PIC	SIC	MMSE-CWIC	MMSE-PIC
whether CRC is included		excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded	included	excluded	excluded	excluded	excluded
MA signature setting		fixed & random	fixed	Fixed	fixed	fixed	fixed	fixed	random	fixed	fixed	fixed	fixed	fixed	fixed
# of UEs	**SE Range (bits/RE per UE)**	**Range/value of SNR gain (dB)**													
2	(0.2, 1.0]												[0.1, 3.7)		
4	[0.05, 0.1]	[0.0, 0.8]	0.3[SE = 0.0833]	-	-	-	0.7	-		-	-				
	(0.1, 0.2]	[1.3, 1.8]	0.3[SE =0.2083]	-	-	-	-	-		-	-				
	(0.2, 1.0]	[1.9, 2.5]	0.8 [SE = 0.3333]	-	-	-	1.7	[0.9, 6.5]	[0, 0.1]	-	-	[0.5, 2.2]			
6	[0.05, 0.1]	[0.1, 1.5]	-	-	-	-	0.7	-		0.8	-				
	(0.1, 0.2]	[2.5, 2.7]	-	-	-	-	-	-		1.6	-				
	(0.2, 1.0]	[3.3, 4.9]	-	[0.9, 1.8]	[0.7, 2.0]	1	2.8	-	[0.8,1]	2.5	-				
8	[0.05, 0.1]	[0.6, 2.6]	1.1 [SE = 0.0833]	-	-	-	0.6	-		0.9	-				
	(0.1, 0.2]	[3.4, 4.7]	2.6[SE =0.2083]	[0.8, 2.0]	[0.8, 2.2]	-	-	-		3.1	-				
	(0.2, 1.0]	[3.4, 7.0]	3.2 [SE = 0.3333]	[0.7, 2.2]	[0.6, 2.1]	-	3.6	-	[2.3,2.5]	-	-				
12	[0.05, 0.1]	[1.4, 4.2]	-	-	-	-	-	-		-	-				2.5, 2.7 (SE=0.069)
	(0.1, 0.2]	[5.2, 6.4]	4.5[SE =0.2083]	[1.3, 2.7]	[1.0, 2.7]	-	-	-		-	-				
	(0.2, 1.0]	[6.3, 12.3]	5.0[SE = 0.3333]	-	-	-	-	-	4.1	-	-				
18	[0.05, 0.1]	-	-	-	-	-	-	-		-	3.5				-0.3, 0.29 (SE=0.069)

	(0.1, 0.2]	-	-	-	-	-	-	-		-	3.1				
	(0.2, 1.0]	-	-	-	-	-	-	-		-	-				
20	[0.2,1.0]								[5.6,8.4]						
40	[0.2,1.1]								14.6						
Note 1: SNR is defined as total received SNR per RE per Rx antenna at eNB. Note 2: The empty entries in the table are due to absence of simulation data.															

Table 9.1.2-5: Range of SNR gain of non-orthogonal multiple access over OFDMA with realistic channel estimation

Source		Source 1	Source 3	Source 9	Source 9	Source 4	Source 6	Source 2	Source 5	Source 7	Source 8	Source 9	Source 11
Multiple access scheme		SCMA	PDMA	GOCA	RDMA	LDS-SVE	NCMA	MUSA	IGMA	LSSA	NOMA	NB-IoT MU	LCRS
Receiver type		MPA	MPA	MF-based SIC	MF-based SIC	MPA w/o iterative decoding	MMSE-IRC w/ SIC	MMSE-SIC	Chip-by chip MAP	Iterative MMSE-PIC	MMSE-CWIC	SIC	MMSE-PIC
whether CRC is included		excluded	excluded	excluded	excluded	excluded	excluded	excluded	Excluded	included	excluded	excluded	excluded
MA signature setting		fixed & random	fixed	fixed	fixed	fixed	fixed	random	Fixed	fixed	fixed	fixed	fixed
# of UEs	SE Range (bits/RE per UE)	Range/value of SNR gain (dB)											
2	(0.2, 1.0]											[-1.3, 3.3]	
4	[0.05, 0.1]	[0, 0.4]	0.1[SE = 0.0833]	-	-	-	-1.4		-	-	-		
	(0.1, 0.2]	[0.8, 1.4]	0.2[SE = 0.2083]	-	-	-	-	[0.6,1]	-	-	0.2		
	(0.2, 1]	[1.6, 2.2]	0.5[SE = 0.3333]	-	-	-	0.3		-	-	-		[0.5, 1.5]
6	[0.05, 0.1]	[0, 1.1]	-	-	-	-	-1.7		0	-	-		
	(0.1, 0.2]	[2.2, 2.4]	-	-	-	-	-	[1.1,2.5]	0.6	-	-		
	(0.2, 1]	[3.1, 4.5]	-	[0.4, 0.8]	[0.2, 0.6]	[0.8,1.2]	1.1		1.7	-	-		
8	[0.05, 0.1]	[0.1, 1.8]	0.5[SE = 0.0833]	-	-	-	-1.9		0.4	-	-		
	(0.1, 0.2]	[2.5, 3.4]	2.2[SE = 0.2083]	[0.1, 0.7]	[-0.1, 0.5]	-	-	[0.5,1]	1.9	-	4.6		
	(0.2, 1]	[2.9, 6.7]	2.9[SE = 0.3333]	[0.5, 1.2]	[0.2, 0.8]	-	1.7		-	-	-		
12	[0.05, 0.1]	[1.0, 2.7]	-	-	-	-	-		-	-	-		
	(0.1, 0.2]	[5.1, 6.0]	-	[0.6, 1.5]	[0.1, 1.1]	-	-	[0.5,2.2]	-	-	4.6		
	(0.2, 1]	[7.2, 13.2]	-	-	-	-	-		-	-	-		
18	[0.05, 0.1]	-	-	-	-	-	-		-	4.6	-		
	(0.1, 0.2]	-	-	-	-	-	-		-	4.2	-		
	(0.2, 1]	-	-	-	-	-	-		-	-	-		
24	[0,1,0.2]							[0.9,1.4]					
26	[0.1, 0.2]							[1.6,1.7]					
Note 1: SNR is defined as total received SNR per RE per Rx antenna at eNB. Note 2: The empty entries in the table are due to absence of simulation data.													

Table 9.1.2-6: MCL calculation of multiple access schemes with ideal and/or realistic channel estimation

Source	Multiple access scheme	number of supported UEs	SE region (bits/RE)	Antenna Configuration	Bandwidth (kHz)	MCL range (dB) (Ideal Channel Estimation)	MCL range (dB) (Realistic Channel Estimation)
Source 9	NB-IoT OFDMA	1	0.072/1.23/1.77	1T2R	3.75		165.13/155.07/151.18
		1	0.01/0.43/1.77	1T2R	15		164.18/154.19/145.26
		1	0.375/0.625	1T2R	180	143.1/139.4	142.0/138.0
		1	0.375/0.625	1T2R	45	147.3/143.3	146.1/141.6
Source 9	NB-IoT MU MIMO	2	0.375/0.625	1T2R	90	147.3/145.8	141.4/144.8
		2	0.3750.625	1T2R	180	145.8/143.3	144.3/141.3
Source 1	SCMA	4	0.0133	1T2R	15	-	[165.24, 166.84]
Source 9	GOCA	6	0.222	1T2R	1080	135.77	135.27
		8	0.222	1T2R	1080	135.27	134.67
		8	0.157	1T2R	1080	137.27	136.57
		12	0.157	1T2R	1080	136.57	135.87
Source 9	RDMA	6	0.222	1T2R	1080	135.57	135.07
		8	0.222	1T2R	1080	134.87	134.27
		8	0.157	1T2R	1080	137.07	136.37
		12	0.157	1T2R	1080	136.17	135.37
Source 4	LDS-SVE	6	0.33	1T2R	360	[134.24, 134.44]	[132.84, 133.34]
		6	0.35	1T2R	1080	[129.87, 130.87]	[128.97, 129.27]
Source 6	NCMA	4	0.0625	1T2R	720	145.13	-
		6	0.0625	1T2R	720	145.03	-
		8	0.0625	1T2R	720	144.93	-
		4	0.25	1T2R	720	138.83	-
		6	0.25	1T2R	720	138,66	-
		8	0.25	1T2R	720	138.43	-
Source 13	RSMA	2	0.5	1T2R	360	136.14	-
		2	0.75	1T2R	360	133.64	-
		2	1	1T2R	360	131.64	-
Source 2	MUSA	20	0.0078	1T2R	15	-	165.74
		20	0.0313	1T2R	15	-	159.74
		20	0.125	1T2R	180	-	142.95
		24	0.0156	1T4R	15	-	165.74
		24	0.125	1T4R	15	-	156.74
		24	0.125	1T4R	180	-	145.95
Source 7	LSSA	4	0.166	1T2R	960	140.21	-
		8	0.166	1T2R	2160	139.16	-
		12	0.375	1T2R	480	138.19	-
		12	0.0011	1T2R	180	166.23	-
Source 11	LCRS	1	[0.00163, 0.208]	1T2R	180	[142.55, 167.35]	[142.25, 161.75]
		8	[0.00163, 0.208]	1T2R	180	[141.85, 167.45]	[141.45, 161.75]
Source 8	NOMA	4	0.144	1T2R	180	-	143.89
Source 5	IGMA	6	0.083	1T2R	1080	141.17	
		6	0.014	1T2R	1080	143.47	
		6	0.0313	1T2R	15	164.04	
Source 3	PDMA	8	0.0417	1T2R	720	137.03	136.48
		8	0.0833	1T2R	720	135.33	134.53
		8	0.2083	1T2R	720	131.53	130.88
		8	0.3333	1T2R	720	128.38	127.53
Source 14	NOCA	12	0.069	1T2R	2160	137.15 / 137.95	136.45/136.02
		18	0.069	1T2R	2160	137.04/137.72	136.04/135.12

Table 9.1.2-7 provides summary of system level simulation results for non-orthogonal multiple access schemes. The candidate PHY abstraction methods can be found in [R1-168076 and R1-1610626]. In the table, each source corresponds to the following references.

- Source1: R1-1608854

- Source2: R1-1608952
- Source3: R1-1608756
- Source5: R1-1609042
- Source6: R1-1609224
- Source7: R1-1609549, R1-1611023
- Source8: R1-1610078, R1-1610077
- Source9: R1-1609334, R1-1609335
- Source10: R1-1609581
- Source11: R1-1611008
- Source13: R1-1610120

Based on system-level simulation results and assumptions summarized in [R1-1610531], it is observed that

- All simulated non-orthogonal MA schemes with grant-free with advanced receivers (some with ideal channel estimation while others with realistic channel estimation) provide significant capacity gain in terms of packets arrivals rate (packets/s/sector) at a given system outage (e.g, 1% target packet drop rate), compared to a respective grant-free reference scheme assumed by each company.
- Evaluation simulators have been calibrated with agreed simulation assumptions (R1-1609442)

Table 9.1.2-7: System-level evaluation results

Source	Source 1	Source 13	Source 2	Source 3	Source 5	Source 10	Source 11	Source 7	Source 8	Source 9	Source 14	Source 6
Multiple access scheme	SCMA	RSMA	MUSA	PDMA	IGMA	SCMA	LCRS	LSSA	NOMA	RDMA, GOCA	NOCA	NCMA
Inter-BS distance	1732m	1732m	1732m	1732m	1732m	1732m	1732m	1732m	1732m	1732m	ISD=500m	200m, 1732m
Simulation bandwidth	6 PRB	1.08MHz	6 PRB	4 PRB	6PRB	4 PRB	6PRB	6RB	6 PRB	6PRB	72 PRBs	6PRB
BS antenna tilt	92 degrees	6 degrees	No Mechanical downtilt	12 degree	6 degrees	100 degree	96 degree	102 degree	No Mechanical downtilt	96 degree	_	102 degree
BS antenna element gain + connector loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable los
BS antenna configuration	(M, N, P, M_g, N_g) = (10, 1, 2, 1, 1), dv = dh = 0.5 λ, 2 TXRU, TXRU to antenna element mapping: (MTXRU, N, P, Mg, Ng) = (1, 1, 2, 1,1)	1x2 (M, N, P, M_g, N_g) = (10, 1, 2, 1, 1), 2 TXRU, one TXRU maps to 10 antenna element (50% indoor users has additional 10dB penetration loss)	(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1), 2 TXRU, one TXRU maps to one antenna element	(M, N, P, M_g, N_g) = (10, 1, 2, 1, 1), TXRU to antenna element mapping: (M, N, P, Mg, Ng) = (10, 1, 1, 1,1)	(M, N, P, M_g, N_g) = (10, 1, 2, 1, 1), dv = dh = 0.5 λ 2 TXRU, TXRU to antenna element mapping: (MTXRU, N, P, Mg, Ng) = (1, 1, 2, 1,1)	1x2 (M, N, P, M_g, N_g) = (10, 1, 2, 1, 1), 2 TXRU, one TXRU maps to 10 antenna element	(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1), 2 TXRU, one TXRU maps to one antenna element	(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1), 2 TXRU, one TXRU maps to one antenna element	(M, N, P, M_g, N_g) = (10, 1, 2, 1, 1), 2 TXRU, one TXRU maps to one antenna element	1x2 (M, N, P, M_g, N_g) = (10, 1, 2, 1, 1), 2 TXRU, one TXRU maps to 10 antenna element	(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1), 2 TXRU, one TXRU maps to one antenna element	(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1), 2 TXRU, one TXRU maps to one antenna element
UE antenna gain	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi
UL power control	P0= -97.8dBm, alpha=0.9	P0 = -126.4dBm ,Alpha = 1	Po = -100 dBm, alpha = 1	P0=-95dBm and alpha = 1	P0=-90 dBm, alpha=1	OFDMA: alpha=1, P0= -90 dBm SCMA: alpha = 1, P0=- 95dBm	Alpha = 0.8, fixed target SNR = 3 dB	Alpha=1, P0= -90 dBm	Alpha=1, P0= -90 dBm	Alpha = 1, P0 = -95dBm	Alpha = 0.8, P0 = -80dBm	Alpha=1, P0= -90 dBm
Channel estimation	Ideal | realistic	ideal	ideal	ideal	ideal, realistic	ideal	ideal	ideal	ideal	ideal	ideal	ideal
Packet size	Fixed to 40 bytes as TBS, and the reference scheme is segmented to 2 packets	Follow TR45.820, TBS of 200 bit is used to segment the packet	Fixed 40 bytes, with segmentation to 2 packets	Fixed 40 bytes, with segmentation to 2 packets for ODFMA and PDMA.	Fixed by 40 bytes, No segmentation	Fixed by 20 bytes	20 bytes	20 bytes	Fixed to 40 bytes as TBS, and the reference scheme is segmented to 2 packets	Fixed 40 Bytes, segmented into 2 20Bytes packets.	100bytes by using 72 PRB	20 bytes (no segmentation)
Packet dropping timer	1s	10s	1s	_	1s and 10s	_	128ms	_	1s	1 s	_	-

NoMA receiver type	MPA		MMSE-IRC	MMSE-SIC	MPA	Chip-by-chip MAP		MPA	MMSE-PIC	MMSE-PIC (selective)	MMSE-IRC + SIC	MF-SIC+MMSE-IRC	MMSE PIC	MMSE IRC+SIC
HARQ signaling combining or not?	Yes		Yes	No HARQ combine	Yes	Yes (repetition and combining)		No HARQ combine	HARQ combining used	combined	Yes	No HARQ combine	No HARQ combine	No HARQ combining
HARQ/Repetition	Maximum repetition/retransmissions of 32		HARQ till packet dropping timer to mimic the TTI bundling.	HARQ with random back-off until the fixed dropping timer.	Maximal number of HARQ transmissions is 16.	HARQ until the fixed dropping timer		No repetition or retransmission	Max of 15 HARQ retransmission; synchronous HARQ	Max. 2 HARQ retransmission for comparison	HARQ random back-off until the fixed dropping timer.	HARQ random back-off until the fixed dropping timer.	No HARQ combining	Max. number of retrial : 10
	ICE	RCE												
OFDMA PAR at target PDR (Packets/ms/sector)	0.6 (@PDR = 1%)	0.5 (@PDR = 1%)	–	0.18 (@PDR = 1%)	0.6 (@PDR = 1%)	0.052 (@PDR = 10%, 1s dropping timer) Reference scheme is only with ideal CE		0.1 (@PDR = 1%)	0.9 @PDR 4%	0.25 @ PDR 1%	1 (@PDR = 1%)	PDR floor at 2.5%	1.2 (PDR@ 10%)	ISD 200m: 4.1 (PDR@1%); ISD 1732m: - (PDR@10%)
						ICE	RCE							
Reported scheme PAR at target PDR (Packets/ms/sector)	2.1 (@PDR = 1%)	1.5 (@PDR = 1%)	0.68 (@PDR = 1%)	without secondary spreading: 2, with secondary spreading: 8 (@PDR = 1%)	1.8 (@PDR = 1%)	0.116 (@PDR = 1%, 1s); 0.44 (@PDR = 10%, 1s)	0.08 (@PDR = 1%, 1s); 0.34 (@PDR = 10%, 1s)	0.2 (@PDR = 1%)	2.5 @PDR 4%	0.8 @ PDR 1%	3.2 (@PDR = 1%)	RDMA:0.7 (PDR@ 1%); GOCA: 0.75 (PDR@ 1%)	6.2 (PDR@ 10%)	ISD 200m: 7.3 (PDR@1%); ISD 1732m: 1.3 (PDR@10%)
MA signature setting	Random		Random	Random	Random	Random		Random	Random	Random	Random	Random		Random
Gain (reported scheme divided by its reference scheme)	350%	300%	–	without secondary spreading: 1100%, with secondary spreading: 4400%	300%	860%@PDR 10% with ICE of IGMA; 680%@PDR 10% with RCE of IGMA;		200% (@PDR = 1%) 250% (@PDR = 10%)	278%	320% @ PDR 1%	320%	RDMA: 215% (@PDR 10%) GOCA: 218% (@PDR 10%)	516% @PDR 10%	ISD 200m: 178% (PDR@1%) ISD 1732m: - (PDR@10%)
Note 1: The empty entries in the table are due to absence of simulation data.														

9.1.3 Performance evaluation of channel coding

See subclause 7.1.3.

9.1.4 Performance evaluation of mobility

Evaluation cases and simulation assumptions are provided Annex A.2.3. For mobility, the following evaluation metrics are considered.

- Paging miss probability in RRC Connected Inactive state
- UE power consumption in RRC Connected Inactive state
- UE power consumption in RRC Connected Active state

Tables 9.1.4-1, 9.1.4-2 and 9.1.4-3 provide summary of evaluation results of both DL measurement based mobility and UL measurement based mobility. In the table, each source corresponds to the following references.

- Source1: R1-1702595, R1-1700739, R1-1612039, R1-1610166, R1-1610167 and R1-166393
- Source2: R1-1703130
- Source3: R1-1609437
- Source4: R1-1702911, R1-1700893 and R1-1612473
- Source5: R1-1703096, R1-1701062 and R1-1612810

Based on the evaluation results summarized in Tables 9.1.4-1, 9.1.4-2 and 9.1.4-3, the following observations were made by some sources.

- For CONNECTED_ACTIVE state, compared to LTE DL measurement baseline with 5 ms SS (Synchronization Signal) periodicity and CRS:
  - In synchronized deployment, UL measurements can provide a handover performance and / or potential UE power consumption gain in some scenarios, e.g. dense deployments with low number of UE's per TRP, high speed, with a potential cost of increased UL resource and potential NW backhaul signaling overhead depending on NW architecture and potential reduction in over the air signaling overhead,
- For CONNECTED_INACTIVE state, compared to LTE DL measurement baseline with 5 ms SS (Synchronization Signal) periodicity and CRS
  - In synchronized deployment, UL measurements with synchronization signals transmitted in SFN mode can provide a paging reliability performance and / or UE power consumption gain in some scenarios, , e.g. dense deployments, rural high way, with a cost of increased UL resource and potential NW backhaul signaling overhead depending on NW architecture and potential reduction in over the air signaling overhead.

Table A.9.1.4-1: System-level evaluation results: RRC Connected Inactive State Paging Miss Probability

RRC Connected Active State		Paging Miss Probability				
Scenario	Mobility Schemes	Source 1	Source 3	Source 5		
				Low Load	Intermediate Load	High Load
Rural 120km/hr UE	DL Measurement Based Mobility DRX cycle (0.32seconds)	4.0%				
	DL Measurement Based Mobility DRX cycle (0.375seconds)	2.0%		0.0%	0.3%	0.8%
	DL Measurement Based Mobility DRX cycle (0.75seconds)			0.0%	0.6%	1.5%
	DL Measurement Based Mobility DRX cycle (1.28seconds)	8.0%		0.0%	1.4%	2.8%
	DL Measurement Based Mobility DRX cycle (1.5 seconds)	8.0%				
	UL Measurement Based Mobility DRX cycle (1.28seconds)	3.0%				
	UL Measurement Based Mobility DRX cycle (1.5seconds)	1.0%				
Dense Urban 30km/hr UE	DL Measurement Based Mobility DRX cycle (0.16seconds)	12.0%				
	DL Measurement Based Mobility DRX cycle (1.28seconds)	26.0%				
	UL Measurement Based Mobility DRX cycle (1.28seconds)	6.0%				
	DL Measurement Based Mobility DRX cycle (0.375seconds)		16%			
	DL Measurement Based Mobility DRX cycle (1.5 seconds)		32%			
	UL Measurement Based Mobility DRX cycle (1.5 seconds)		1%			
High speed train 480km/hr UE	DL Measurement Based Mobility DRX cycle (0.375seconds)	7.6%		0.0%	1.7%	3.1%
	DL Measurement Based Mobility DRX cycle (0.75seconds)			0.0%	4.3%	6.9%
	DL Measurement Based Mobility DRX cycle (1.5 seconds)	27.8%		0.2%	11.5%	16.5%
	UL Measurement Based Mobility DRX cycle (1.5 seconds)	2.3%				

Table A.9.1.4-2: System-level evaluation results: RRC Connected Inactive State UE Power Consumption

RRC Connected Active State		UE Power Consumption		
Scenario	Mobility Schemes	Source 1	Source 4	
			5 Tracking Areas per cell	0.2 Tracking Areas per cell
Benign Mobility semi-static UE	DL Measurement Based Mobility	6.7mW		
Rural 120km/hr UE	DL Measurement Based Mobility	15.5mW		
Dense Urban 30km/hr	DL Measurement Based Mobility	29.2mW		
All	UL Measurement Based Mobility	7.4mW		
3km/hr DRX 640ms	DL Measurement Based Mobility		3793 mW.ms per DRX	
	UL Measurement Based Mobility		4346 mW.ms per DRX	4333 mW.ms per DRX
60km/hr DRX 640ms	DL Measurement Based Mobility		3846 mW.ms per DRX	
	UL Measurement Based Mobility		4610 mW.ms per DRX	4344 mW.ms per DRX
120km/hr DRX 640ms	DL Measurement Based Mobility		3901 mW.ms per DRX	
	UL Measurement Based Mobility		4887 mW.ms per DRX	4355 mW.ms per DRX
3km/hr DRX 2560ms	DL Measurement Based Mobility		9562 mW.ms per DRX	
	UL Measurement Based Mobility		10148 mW.ms per DRX	10095 mW.ms per DRX
60km/hr DRX 2560ms	DL Measurement Based Mobility		9772 mW.ms per DRX	
	UL Measurement Based Mobility		11201 mW.ms per DRX	10137 mW.ms per DRX
120km/hr DRX 2560ms	DL Measurement Based Mobility		9994 mW.ms per DRX	
	UL Measurement Based Mobility		12310 mW.ms per DRX	10181 mW.ms per DRX

Table A.9.1.4-3: System-level evaluation results: RRC Connected Active State UE Power Consumption

RRC Connected Active State		UE Power Consumption
Scenario	**mobility scheme**	**Source 2**
200m ISD with 3km/hr UE with DRX	DL measurement based mobility (40ms DRX cycle)	4.69mW
	UL measurement based mobility (80ms DRX cycle)	2.65mW
200m ISD with 120km/hr UE with DRX	DL measurement based mobility (40ms DRX cycle)	6.44mW
	UL measurement based mobility (80ms DRX cycle)	2.65mW
200m ISD with 3km/hr UE without DRX	DL measurement based mobility	23.5mW
	UL measurement based mobility (80ms UL SRS periodicity)	23.6mW
200m ISD with 120km/hr UE without DRX	DL measurement based mobility	25.3mW
	UL measurement based mobility (80ms UL SRS periodicity)	23.6mW
Note: Source 2 assumes DL and UL measurement based mobility achieve the same HO failure rate, the HO failure rate analysis was provided in R2-1701505		

10 Duplexing flexibility and cross-link interference mitigation

10.1 Performance Evaluation

The candidate schemes for cross-link interference mitigation are summarized in Table 10.1-1. A common framework for cross-link interference mitigation schemes for both paired and unpaired spectra is strived for.

Table 10.1-1: Candidate of cross link interference mitigation schemes

IM techniques		Company	Tdoc number for details	Enabler	Potential specification impact	Evaluation submission	Tdoc number for evaluation result
Advanced receiver (IC/IS)	eMMSE-IRC	Huawei	R1-1701669	Symmetric RS Timing alignment on cross-link. DL/UL subcarrier alignment	Symmetric RS design Information exchange among TRPs (e.g., DMRS port/pattern/sequence) Signaling/mechanism to facilitate interference cancellation and cross-link timing alignment	Provided	R1-1701673, R1-1701674
	Interference cancellation					Provided	R1-1700095,R1-1701672,R1-1701673, R1-1701674
	Packet exchange for interference cancellation)	Nokia	R1-1703110	Information exchange among TRPs	Information exchanging the transmitted packet (including DL packet and scheduling information) from the DL TRP to the UL TRP	Provided	R1-1703109
	MMSE-IRC	NTT Docomo	R1-1702839, R1-1700635	RS orthogonality	Design of DL/UL data DMRS	Provided	R1-1702836, R1-1702837, R1-1702838
	IS/IC receiver					Not provided	N/A
	Reduced complexity maximum likelihood (RML) receiver	MediaTek Inc.	R1-1702719, R1-1702720	Symmetric RS Fixed data DM-RS location irrespective of control region size	Common reference signal (RS) design for downlink and uplink data Location of data DM-RS Signaling of assistance information (e.g., scrambling seed) for receiver	Not provided	N/A
Hybrid dynamic/static UL/DL resource assignment	Distributed hybrid dynamic/static UL/DL resource assignment - For Macro deployment, intra-site coordination is a considered.	Ericsson	R1-1703302, R1-1703303	Implementation based	None	Provided	R1-1703299, R1-1703300, R1-1703301
	Switching/adaptation between semi-static and dynamic operations	Panasonic	R1-1701929	Not described in the contribution	1) At the case of no complaint of the interference from the neighbor gNB, just dynamic operation can be fine as semi-static adaptation can reduce the latency and efficiency. On the other hand, if gNB receives the complaint of the interference from the other gNB, semi-static coordination would be useful. 2) Another one is switching on or off dynamic operation for same gNB. If dynamic operation is switched off, then the operation follows SIB indicated UL-DL change. Still if for same gNB, it is just implementation issue. If inter-gNB, it may need to define some new inter-gNB signaling to coordinate.	Not provided	N/A
Scheduling coordination		Huawei	R1-1701669	Long-term CLI measurement Inter-TRP information exchange	RS for long-term CLI measurement Backhaul/OTA signaling to exchange information (e.g., DL/UL transmission direction, resource allocation)	Provided	R1-1701614
		Nokia	R1-1703110	UE-to-UE CLI measurement (SRS or DMRS) Inter-TRP information exchange	RS for long-term CLI measurement IMR setting Backhaul/OTA signaling	Not provided	N/A

	Samsung	R1-1703007/R1-173008	Inter-TRP information exchange Fixed/protected and flexible time resources with semi-static configuration CLI measurement and aggressor/victim identification	1) Signaling for Intended UL/DL transmission direction configuration (X2/OTA) 2) Information on set of RBs from serving gNB to interfering gNB. 3) Measurement signal to support CLI detection and source identification (existing signal preferable) 4) Inter-TRP signalling to enable scheduling of victim or aggressor to protected resources	Not provided	N/A
	LGE	R1-1702500	Long-term CLI measurement	IMR configuration	Not provided	N/A
Beam coordination	Huawei	R1-1701669	Long-term CLI measurement Inter-TRP information exchange	RS for long-term CLI measurement Backhaul/OTA signaling to exchange information (e.g., DL/UL transmission direction,beam interference indication,resource allocation)	Provided	R1-1701673, R1-1701674,R1-1701672
	Samsung	R1-1703008	Inter-TRP information exchange Dynamic selection of RS transmission direction CLI measurement	1) Signaling for Intended UL/DL transmission direction configuration (X2/OTA) 2) RS for CLI measurement 3) Information on i) Rx beam index for TRP-to-TRP CLIM and ii) Tx beam index for UE-to-UE CLIM from serving gNB to interfering gNB. 4) Support for dynamic selection of RS transmission direction	Not provided	N/A
	Panasonic	R1-1701929	Long/short-term CLI measurement	To coordinate DL transmission beam is quite useful considering multiple antenna situation in gNB site would be sufficiently available. To coordinate UL beam may not be always available as UEs may not always have directional antenna or multiple antennas. To coordinate reception beam would be implementation technique.	Not provided	N/A
	LGE	R1-1611857	CLI measurement Inter-TRP information exchange	RS for CLI measurement Backhaul/OTA signaling to exchange information (e.g., beam-level intended DL/UL transmission direction/interference indication)	Not provided	N/A
Link adaptation	Intel	R1-1702247, R1-1703446	DL and UL CLI measurement	1) IM-RS that can capture both BS-UE interference and BS to BS and UE to UE interference 2) Slot structure that enables time-aligned DL and UL IM-RS transmission 3) Physical control and scheduling mechanism that enables resource allocation and transmission rate adaption in two steps so that measurement and measurement reporting can be implemented in between	Provided	R1-1702247, R1-1703446
	ZTE	R1-1701616	None	Additional signaling overhead for DL and tell the UE how to do UL link adaptation, such as MCS, TBS information determination	Not provided	N/A
Power control	LGE	R1-1702501	Information exchange among TRPs	resource-specific power control configuration Backhaul/OTA signaling to exchange information (e.g., intended DL/UL transmission direction configuration)	Provided	R1-1702499

	Nokia	R1-1703111	Information exchange among TRPs Interferene-aware power control	Information exchanging among TRPs (e.g., DL/UL transmission direction) Interferene-aware power control(Different power control parameters are considered according to the interference condition)	Provided	R1-1703111
	Huawei	R1-1701669	Long-term/short-term CLI measurement Inter-TRP information exchange	RS for long-termshort-term CLI measurement Backhaul/OTA signaling to exchange information (e.g., DL/UL transmission direction, resource allocation)	Provided	R1-1701614,R1-1701672
	Panasonic	R1-1701929	Long/short-term CLI measurement	Both DL power control and UL power control could be considered.	Not provided	N/A
Sensing	MediaTek Inc.	R1-1703770	Busy tone for interference measurement Data transmision over mini-slot Adjusable timing for sensing opportunity	adjustable sensing slot for both DL and UL LBT busy tone signal design data transmission over mini-slot	Provided	R1-1702718
	ZTE	R1-1701617	Sensing based CLI measurements (Short-term measurement)	Frame/slot structure for sensing slot Design of Sensing signal Instantaneous measurement (energy detection, signal detection with existing RS (e.g., DMRS, CSI-RS, SRS) Detailed sensing procedure (including setting the sensing threshold values, and sensing timing, etc.)	Provided	R1-1701614
			Sensing based CLI measurements (Long-term measurement)	Statistical Measurement parameters (a busy rate of channel sensing (Rbusy), RSSI-UL, RSRP-UL)	Not provided	N/A
			Timing offset measurements	Not described in the contribution	Not provided	N/A
	Qualcomm	R1-1702649	Semi-Static OTA measurement	gNB to gNB: OTA measurement slot structure UE to UE: OTA measurement slot structure and measurement feedback	Provided	R1-1703462
			Dynamic OTA measurement	special slot structure to support gap between PDCCH and data transmission group common PDCCH	Not provided	N/A
	Huawei	R1-1701669	short-term CLI measurement	RS/channel for short-term CLI measurement	Provided	R1-1701672
	Samsung	R1-1703007	LBT-based CLI avoidance as an option	Frame support for LBT on slot subset	Not provided	N/A

Cell/TRP clustering	CATT	R1-1702113	Long-term RSRP like CLI measurement (TRP-TRP/gNB-gNB) Backhaul among TPRs/gNBs to enable a semi-static transmission direction coordination within a cluster, e.g. intended UL-DL usage OTA among TPRs/gNBs to enable a dynamic transmission direction coordination within a cluster, e.g. intended UL-DL usage	RS for TRP-TRP/gNB-gNB measurement, definition of the measurement Backhaul signaling OTA signaling	Not provided	N/A
OTA signaling	MediaTek Inc.	R1-1702719, R1-1704029, R1-1704056	Multiple mini-slot transmissions in a slot following muturally hearable TX pattern Relaying of downlink control information in the uplink transmission	OTA/backhaul signaling in general specifically Control channel design for mini-slot RX/TX mutually hearable pattern definition information relay procedure for UE	Provided	R1-1704029, R1-1704056
	Fujitsu	R1-1701922,R1-1701923	Signaling relaying via UE	Signaling decoding and relaying between two neighboring cells, where the signaling can be, e.g., transmission direction, channel information, etc.	Not provided	N/A
Co-channel multiple connectivity	Fujitsu	R1-1701923	Change the serving point of the UE	DL/UL synchronization with multiple gNBs; co-channel multiple connectivity configuration coordination among gNBs; scheduling coordination between the serving gNBs of one UE	Not provided	N/A
Dynamic TDD Type Definition	CMCC	R1-1700444	Information exchange among TRPs	Slot indicator, OTA/backhaul signaling	Not provided	N/A
Load/link-based resource/scheduling adaptation	AT&T	R1-1700296	Different categories of CLI measurements (Long term/short term, single antenna/multiple antenna, wideband/subband, etc.)	1) IM-RS that applies to both BS-UE interference and BS-BS and UE-UE interference 2) Use NZP-CSI-RS and ZP-CSI-RS for CLI measurements 3) RS design to enable load measurement over the air 4) CLI measurement content includes load, RSRP, beam ID, differential AoA, differential CQI, etc.	Not provided	N/A

The evaluation assumptions for flexible duplex are shown in Annex A.2.1. The detailed evaluation results are also summarized in Annex A.3.1. Based on the evaluation results, the following observations are made.

- Observations for indoor hotspot scenario:
  - Evaluations show that duplexing flexibility with cross-link interference mitigation schemes and on a 4GHz and 30GHz provides better UPT compared to static UL/DL resource partition and duplexing flexibility without cross-link interference mitigation schemes
  - Evaluations show that duplexing flexibility without cross-link interference mitigation schemes on a 4GHz and 30GHz provides better UPT compared to static UL/DL resource partition at least for some cases
  - The evaluated cross-link interference mitigation schemes include sensing based methods, advanced receivers (e.g. MMSE-IRC, EMMSE-IRC), coordinated scheduling/beamforming, power control, link adaptation, hybrid dynamic/static UL/DL resource assignment.
  - Additional detailed observations are provided in Table 10.1-2.
- Observations for urban macro scenario:
  - Evaluations show that duplexing flexibility with cross-link interference mitigation schemes on a 4GHz unpaired spectrum and on a 2GHz paired spectrum provides better average UPT compared to static UL/DL resource partition and duplexing flexibility without cross-link interference mitigation schemes.
    - The evaluated cross-link interference mitigation schemes include advanced receivers (e.g. MMSE-IRC, EMMSE-IRC, packet exchange for interference cancellation), coordinated scheduling/beamforming, power control, link adaptation.
  - Evaluations show that duplexing flexibility on a 2GHz paired spectrum with SRS on the DL part without dynamic DL/UL resource allocation provides better cell average/edge throughput compared to no SRS on the DL part of the spectrum.
  - Additional detailed observations are provided in Table 10.1-3 and Table 10.1-4.
- Observations for dense urban scenario,
  - Evaluations show that duplexing flexibility with cross-link interference mitigation schemes on a 4GHz and 30GHz unpaired spectrum provides better UPT compared to static UL/DL resource partition and duplexing flexibility without cross-link interference mitigation schemes
    - The evaluated cross-link interference mitigation schemes include advanced receivers (e.g. MMSE-IRC, eMMSE-IRC), sensing based schemes, coordinated scheduling/beamforming, power control, link adaptation, hybrid dynamic/static UL/DL resource assignment.
  - Additional detailed observations are provided in Table 10.1-5.

Table 10.1-2: Additional observations for Indoor Hotspot scenario

Source	Comparison Type	DL:UL traffic ratio	Is UPT improved by Duplexing flexibility?								
			Low RU			Medium RU			High RU		
			5th%-ile UPT	Mean UPT	Served /offered traffic	5th%-ile UPT	Mean UPT	Served /offered traffic	5th% -ile UPT	Mean UPT	Served / offered traffic
Source 1	Comparison B - CLI mitigation based on MMSE-IRC receiver	4:1	Yes	Yes	1.00	Yes	Yes	1.00			
Source 2	Comparison A	2:1	No	Mix(DL+)	1.00						
	Comparison B, C - CLI mitigation based on link adaptation	2:1	Yes	Yes	1.00						
	Comparison C - CLI mitigation based on link adaptation	1:1	Yes	Yes	1.00	Yes	Yes	1.00			
Source 4	Comparison A	2:1	No	Yes	0.98	No	Mix(DL+)	0.72	No	No	0.55
	Comparison B - CLI mitigation based on sensing	2:1 4:1 1:1 1:2	Yes	Yes	0.99	Yes Mix(DL+) Mix(UL+) Mix(UL+)	Yes Mix(DL+) Mix(UL+) Mix(UL+)	0.99 0.99 0.99 0.93	Mix(DL+)	Yes	0.93
	Comparison C - CLI mitigation based on sensing	2:1	Yes	Yes	0.99	Yes	Yes	0.99	Yes	Yes	0.93
Source 5	Comparison A (@30 GHz)	1:1 2:1 4:1	Yes Yes	Yes Yes	0.99 0.99	 Yes	 Yes	 0.99			
	Comparison B, C (@30 GHz) - CLI mitigation based on advanced IRC, coordinated scheduling, power control	1:1 2:1 4:1	Yes Yes	Yes Yes	0.97 0.99	 Yes	 Yes	 0.99			
	Comparison A (@4 GHz)	1:1 2:1 4:1	Yes Yes Yes	Yes Yes Yes	0.98 0.99 0.99						
	Comparison B, C (@4 GHz) - CLI mitigation based on advanced IRC, coordinated scheduling, power control	1:1 2:1 4:1	Yes Yes Yes	Yes Yes Yes	0.99 0.99 0.99						
Source 7	Comparison A	4:1	Yes	Yes	0.99	Mix(DL+)	Yes	0.99			
	Comparison B - CLI mitigation based on DL LBT	4:1	Yes	Yes	0.99	Yes	Yes	0.99			
	Comparison C - CLI mitigation based on DL LBT	4:1	Mix(UL+)	Mix(UL+)	0.99	Mix(UL+)	Mix(UL+)	0.99			
	Comparison B - CLI mitigation based on coordination over Backhaul within a cell group	4:1				No	No	0.99			
	Comparison B - CLI mitigation based on coordination OTA	4:1				Mix(DL+)	Mix(DL+)	0.99			
Source 8	Comparison A (@30GHz)	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Mix(UL+) Mix(UL+)	Yes Yes	0.98 0.99	Mix(UL+) Mix(UL+)	Mix(UL+) Mix(UL+)	0.76 0.90

Comparison B (@30GHz) - CLI mitigation based on Distributed Hybrid TDD	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Mix(UL+) Yes	Yes Yes	0.99 0.99	Mix(UL+) Mix(UL+)	Yes Yes	0.95 0.96
Comparison C (@30GHz) - CLI mitigation based on Distributed Hybrid TDD	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.99 0.99	Mix(DL+) Yes	Yes Yes	0.95 0.96
Comparison B (@30GHz) - CLI mitigation based on DL LBT	1:1 4:1	Mix(UL+) Mix(UL+)	Yes Mix(UL+)	0.99 0.99	No Mix(UL+)	No Mix(UL+)	0.99 0.99	No Mix(UL+)	No Mix(UL+)	0.79 0.89
Comparison C (@30GHz) - CLI mitigation based on DL LBT	1:1 4:1	No No	No No	0.99 0.99	No No	No No	0.99 0.99	No No	No No	0.79 0.89
Comparison B (@30GHz) - CLI mitigation based on UL LBT	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	No No	No No	0.99 0.99	No No	No No	0.95 0.93
Comparison C (@30GHz) - CLI mitigation based on UL LBT	1:1 4:1	No No	No No	0.99 0.99	No No	No No	0.99 0.99	Mix(DL+) Mix(DL+)	Mix(DL+) Mix(DL+)	0.95 0.93
Comparison A (@4GHz)	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.99 0.99	No Mix(UL+)	Mix(UL+) Mix(UL+)	0.76 0.90
Comparison B (@4GHz) - CLI mitigation based on Distributed Hybrid TDD	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.93 0.95
Comparison C (@4GHz) - CLI mitigation based on Distributed Hybrid TDD	1:1 4:1	Yes No	Yes No	0.99 0.99	Yes Yes	Yes Mix(UL+)	0.99 0.99	Yes Yes	Yes Yes	0.93 0.95
Comparison B (@4GHz) - CLI mitigation based on DL LBT	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.99 0.99	No No	No No	0.71 0.89
Comparison C (@4GHz) - CLI mitigation based on DL LBT	1:1 4:1	Mix(UL+) No	Mix(UL+) Mix(UL+)	0.99 0.99	Mix(UL+) Mix(UL+)	Mix(UL+) Mix(UL+)	0.99 0.99	No Mix(UL+)	No Mix(UL+)	0.71 0.89
Comparison B (@4GHz) - CLI mitigation based on UL LBT	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.99 0.99	No No	No No	0.94 0.93
Comparison C (@4GHz) - CLI mitigation based on UL LBT	1:1 4:1	Mix(DL+) Mix(DL+)	Mix(DL+) Mix(DL+)	0.99 0.99	Mix(DL+) Mix(DL+)	Mix(DL+) No	0.99 0.99	Mix(DL+) No	Mix(DL+) No	0.94 0.93

Notes: Comparison A: Gain in UPT with Duplexing flexibility without CLI mitigation schemes as compared to Static DL/UL resource partition
Comparison B: Gain in UPT with Duplexing flexibility with CLI mitigation schemes as compared to Static DL/UL resource partition
Comparison C: Gain in UPT with Duplexing flexibility with CLI mitigation schemes as compared to Duplexing flexibility without CLI mitigation schemes
Mix(DL+): Gain in DL UPT, Loss in UL UPT
Mix(UL+): Loss in DL UPT, Gain in UL UPT
Low, Medium, High RU: For baseline scheme: 25, 50 and 80%, respectively as in Table A.2.1.-1
Source: Sources follow the indexing in Appendix A.3.1.

Table 10.1-3: Additional observations for Urban Macro scenario

Source	Comparison Type	DL:UL traffic ratio	Is UPT improved by Duplexing flexibility?								
			Low RU			Medium RU			High RU		
			5th%-ile	Mean	Served / offered traffic	5th%-ile	Mean	Served / offered traffic	5th% -ile	Mean	Served /offered traffic
Source 1	Comparison B - CLI mitigation based on MMSE-IRC receiver	4:1	Mix(UL+)	Yes	1.00						
Source 5	Comparison A	1:1 2:1 4:1	No No No	No Mix(DL+) Mix(UL+)	1.00 1.00 1.00						
	Comparison B, C - CLI mitigation based on advanced IRC, coordinated beamforming	1:1 2:1 4:1	Yes Yes Yes	Yes Yes Yes	1.00 1.00 1.00						
	Comparison D - CLI mitigation based on advanced IRC, power control, coordinated beamforming	4:1	Mix(DL+)	Mix(DL+)	0.98						
Source 9	Comparison A	1:1 2:1 4:1				No No No	Mix(UL+) Mix(UL+) Mix(UL+)	0.53 0.75 0.86			
	Comparison B - CLI mitigation based on interference cancelation	1:1 2:1 4:1				Mix(UL+) Mix(UL+) Yes	Mix(UL+) Mix(UL+) Yes	0.7 0.92 0.97			
	Comparison C - CLI mitigation based on interference cancelation	1:1 2:1 4:1				Yes Yes Yes	Yes Yes Yes	0.7 0.92 0.97			

Notes:
Comparison A: Gain in UPT by Duplexing flexibility without CLI mitigation schemes as compared to Static DL/UL resource partition
Comparison B: Gain in UPT by Duplexing flexibility with CLI mitigation schemes as compared to Static DL/UL resource partition
Comparison C: Gain in UPT by Duplexing flexibility with CLI mitigation schemes as compared to Duplexing flexibility without CLI mitigation schemes
Comparison D: Gain in UPT by Duplexing flexibility on paired spectrum with CLI mitigation schemes as compared to fixed UL/DL allocation on paired spectrum
Mix(DL+): Gain in DL UPT, Loss in UL UPT
Mix(UL+): Loss in DL UPT, Gain in UL UPT
Low, Medium, High RU: For baseline scheme: 25, 50 and 80%, respectively as in Table A.2.1.-1
Source: Sources follow the indexing in Annex A.3.1.

Table 10.1-4: Additional observations for Urban Macro scenario with SRS on the DL part of paired spectrum

Source	Comparison Type	Is DL UPT improved by Duplexing flexibility?								
		Low RU			Medium RU			High RU		
		5th%-ile	Mean	Served / offered traffic	5th%-ile	Mean	Served / offered traffic	5th% -ile	Mean	Served /offered traffic
Source 5	Comparison A, B							Yes	Yes	1.00*

Notes:
Comparison A: Gain in DL UPT by Duplexing flexibility on paired spectrum with SRS on the DL part as compared to traditional fixed UL/DL allocation on paired spectrum, without adjacent-channel interference
Comparison B: Gain in DL UPT by Duplexing flexibility on paired spectrum with SRS on the DL part as compared to traditional fixed UL/DL allocation on paired spectrum, with adjacent-channel interference
Low, Medium, High RU: For baseline scheme: 25, 50 and 80%, respectively as in Table A.2.1.-1
1.00*: The evaluation is based on the full buffer traffic model.
Source: Sources follow the indexing in Annex A.3.1.

Table 10.1-5: Additional observations for Dense Urban scenario

Source	Comparison Type	DL:UL traffic ratio	Is UPT improved by Duplexing flexibility?								
			Low RU			Medium RU			High RU		
			5th%-ile UPT	Mean UPT	Served / offered traffic	5th%-ile UPT	Mean UPT	Served / offered traffic	5th% -ile UPT	Mean UPT	Served / offered traffic
Source 1	Comparison B - CLI mitigation based on MMSE-IRC receiver	4:1	Mix(UL+)	Yes	0.99	Mix(UL+)	Mix(UL+)	0.94			
Source 2	Comparison C - CLI mitigation based on link adaptation	1:1 2:1	Yes Yes	Yes Yes	1.00 1.00						
Source 3	Comparison A	2:1	Mix(DL+)	Mix(DL+)	0.88						
	Comparison B - CLI mitigation based on power control	2:1	Yes	Yes	0.94						
	Comparison C - CLI mitigation based on power control	2:1	Mix(UL+)	Mix(UL+)	0.94						
Source 5	Comparison A (Macro layer)	1:1 2:1 4:1	No No No	No Mix(DL+) Mix(UL+)	1.00 1.00 1.00						
	Comparison B, C (Macro layer) - CLI mitigation based on advanced IRC, coordinated beamforming	1:1 2:1 4:1	Yes Yes Yes	Yes Yes Yes	1.00 1.00 1.00						
	Comparison A (Micro layer)	1:1 2:1 4:1	No No	No Mix(DL+)	0.98 0.98	Mix(DL+)	Mix(DL+)	0.99			
	Comparison B, C (Micro layer) - CLI mitigation based on advanced IRC, coordinated beamforming	1:1 2:1 4:1	Yes Yes	Yes Yes	0.97 0.99	Yes	Yes	0.99			
Source 6	Comparison A	2:1 4:1	No Yes	Yes Yes	0.98 0.99	No No	No No	0.79 0.92	No No	No No	0.70 0.86
	Comparison B - CLI mitigation based on OTA interference measurements	2:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes No	Yes Yes	0.99 0.99	Mix(DL+) Yes	Mix(DL+) Yes	0.88 0.96
	Comparison C - CLI mitigation based on OTA interference measurements	2:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.88 0.96
Source 8	Comparison A (Macro layer)	1:1 4:1	Mix(DL+) Mix(DL+)	Yes Yes	0.99 0.99	No No	No No	0.99 0.99	No No	No Mix(UL+)	0.96 0.89
	Comparison B (Macro layer) - CLI mitigation based on Distributed Hybrid TDD	1:1 4:1	Yes Yes	Yes Yes	1.00 1.00	Mix(DL+) Mix(UL+)	Yes Mix(UL+)	1.00 0.99	Yes Yes	Mix(DL+) Yes	0.96 0.93
	Comparison C (Macro layer) - CLI mitigation based on Distributed Hybrid TDD	1:1 4:1	Mix(UL+) Yes	Mix(UL+) Yes	1.00 1.00	Yes Mix(DL+)	Yes Yes	1.00 0.99	Yes Mix(DL+)	Yes Mix(DL+)	0.96 0.93

	Comparison A (Micro layer)	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	No Yes	Mix(DL+) Mix(UL+)	0.95 0.93	Mix(DL+) No	Mix(DL+) No	0.60 0.60
	Comparison B, C (Micro layer) - CLI mitigation based on Distributed Hybrid TDD	1:1 4:1	Yes Yes	Yes Yes	0.99 0.99	Yes Yes	Yes Yes	0.96 0.94	Yes Yes	Yes Yes	0.60 0.58
	Comparison B (Micro layer) - CLI mitigation based on DL LBT	1:1 4:1	Yes Mix(UL+)	Yes Yes	0.99 0.99	No Mix(UL+)	Mix(DL+) Mix(UL+)	0.95 0.90	No Mix(UL+)	No No	0.52 0.52
	Comparison C (Micro layer) - CLI mitigation based on DL LBT	1:1 4:1	No No	No No	0.99 0.99	Mix(UL+) No	No No	0.95 0.90	No Mix(UL+)	No No	0.52 0.52
	Comparison B (Micro layer) - CLI mitigation based on UL LBT	1:1 4:1	Mix(DL+) Yes	Yes Yes	0.99 0.99	No Mix(DL+)	Mix(DL+) Yes	0.93 0.92	No No	Mix(DL+) No	0.57 0.55
	Comparison C (Micro layer) - CLI mitigation based on UL LBT	1:1 4:1	Mix(DL+) No	No No	0.99 0.99	No No	No No	0.93 0.92	No No	No No	0.57 0.55
Notes:	Comparison A: Gain in UPT by Duplexing flexibility without CLI mitigation schemes as compared to Static DL/UL resource partition Comparison B: Gain in UPT by Duplexing flexibility with CLI mitigation schemes as compared to Static DL/UL resource partition Comparison C: Gain in UPT by Duplexing flexibility with CLI mitigation schemes as compared to Duplexing flexibility without CLI mitigation schemes Mix(DL+): Gain in DL UPT, Loss in UL UPT Mix(UL+): Loss in DL UPT, Gain in UL UPT Low, Medium, High RU: For baseline scheme: 25, 50 and 80%, respectively as in Table A.2.1.-1 Source: Sources follow the indexing in Annex A.3.1.										

11 Evaluation common for UL/DL

11.1 Performance evaluation related to URLLC

Evaluation metric and evaluation method for URLLC are defined as follows.

- User plane latency:
  - Definition: Follow the definition in TR38.913, target value is 0.5ms one way, without reliability requirement.
  - Evaluation method: Analytical; re-transmission is considered, but scheduling / queuing delay is not included in analytical evaluation
- Reliability
  - Definition: Reliability is defined as the success probability R of transmitting X bits within L seconds, which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface, at a certain channel quality Q (e.g., coverage-edge).
    - Denoted as R(L, Q, SE), where SE is the required spectral efficiency and SE=X/L/B where B (in Hz) is the user bandwidth that is allocable to one device.
    - The latency bound L includes transmission latency, processing latency, retransmission latency and queuing/scheduling latency (including scheduling request and grant reception if any)
  - Evaluation method: Link level simulation as start point
- URLLC capacity and URLLC / eMBB multiplexing capacity

- Definition: URLLC system capacity is calculated as follows:
    - C(L, R) is the maximum offered cell load under which Y% of UEs in a cell operate with target link reliability R under L latency bound
    - X = (100 – Y) % is the percentage of UEs in outage
    - A UE in outage is defined as the UE can not meet latency L and link reliability R bound
    - Companies report their assumption on X
- Evaluation method: System level evaluation method is used for URLLC system capacity study to analyze impact from inter-cell interference, queueing and scheduling latency, multiplexing with other services.

The corresponding evaluation assumptions are provided in Annex A.2.

11.2 Performance evaluation related to high speed train

The optimized azimuth beam direction should be determined by observing both DL geometry and UL geometry. One option for antenna downtilt for high speed scenario is to reuse the downtilt for rural scenario, i.e., 6 degrees. One value for the optimized azimuth beam direction is 27 degrees to the railway track. This is obtained assuming that the half power beam points to the midpoint between the two adjacent sites along the railway.

Annex A: Simulation scenarios and assumptions

A.1 Link level simulation assumptions

A.1.1 Simulation assumption for evaluation of waveform

This subclause describes the link level simulation assumptions used for evaluating waveform candidates. The link level simulation assumption at the carrier frequencies of 4GHz is provided in Tables A.1.1-1 and A.1.1-2 and that for 30GHz and 70GHz is also given in Table A.1.1-3. The evaluation assumptions for high speed scenario is provided in Table A.1.1-4.

Table A.1.1-1: Evaluation assumptions for waveform (4GHz, Cases 1a, 1b and 2)

Assumptions	Value
Carrier frequency	4GHz
Duplex	FDD/TDD
System Bandwidth	10 MHz
TTI length	1 ms as baseline
Subcarrier spacing	Single numerology case: 15kHz as baseline, Mixed numerology case: one is 15kHz, and the other subcarrier spacing should be selected by companies from the agreed numerologies (30 kHz for calibration purpose).
Guard time interval	4.7us (interval of LTE normal CP) as baseline
FFT size	e.g. 1024 for 15kHz subcarrier spacing
Data transmission bandwidth	Single numerology case: 4※ and/or 1 PRBs for the bandwidth of target UE in case 1b Mixed numerology case: At least two candidate BWs for target UE. At least two candidate BWs for interfering subband At least two numerologies.
Guard tone number	[0~12] subcarriers for the mixed numerology case (60 kHz for calibration)
Antenna configuration	1T1R or 2T2R or 4T4R
MIMO mode	If companies bring results for MIMO, it is recommended to use at least one constant modulus precoding scheme in cases 1a, 1b and 2. Other precoding scheme is not precluded. Companies need to provide their CSI and precoding assumptions for MIMO evaluations. MIMO correlation matrices should be low correlation (i.e. uncorrelated) for RAN1#85 in case of MIMO simulations.
Rank per UE	Fixed rank
MCS	Fixed. 16QAM: 1/2 or 2/3; 64QAM: 1/2※ or 3/4; 256 QAM: 1/2 or 3/4
Control Overhead	Zero
Channel estimation *	Ideal
Channel Model **	- All values of DS {10, 30, 100, 300, 1000} ns are evaluated with the selected TDL-DS combinations, i.e. TDL-A for DS {10, 30} ns, TDL-B for DS {100 } ns, TDL-C for DS {300※, 1000} ns. Companies are allowed to choose additional combination(s) of other DS values and TDL–A and/or TDL-C in TR 38.901 [15]. - ETU/EPA/EVA are optional. - Mobility: 3km/h※ or 30 km/h or 120 km/h, higher speed is not precluded.
NOTE※ : All marked values are recommended for calibration purpose.	

Table A.1.1-2: Evaluation assumptions for waveform (4GHz, Cases 3 and 4)

Assumptions	Value
Carrier frequency	4GHz
Duplex	FDD /TDD
Subframe duration	1 ms as baseline
Subcarrier spacing	Case 3: 15kHz as baseline, Case 4: Target UE: 15kHz; Interferer pair: {30kHz※, 30kHz※}, {7.5kHz, 7.5kHz} other value for interferers is not precluded.
Guard time interval	6.7% overhead as baseline
System bandwidth & FFT size	10 MHz, 1024 for 15kHz subcarrier spacing
UE bandwidth (data transmission bandwidth plus guard tone bandwidth of the desired UE)	Case3: -720 kHz (48 Subcarriers per user allocated for both target UE and interferer UEs) Case4: Config1※: Target UE: - 720kHz (48 Subcarrier allocated) Interferer users: - 720kHz (per UE) Config2: Target UE: - 2880kHz (192 subcarrier allocated) Interferer users: -2880kHz (per UE)
Bandwidth of guard tones between neighboring UEs	{0, 15, 30, 45, 60※, 90, 120, 180}kHz
Number of uplink users	3 (1 target user and 2 interferer users)
Power offset of the interferer user	0 dB, 5 dB, 10 dB※, 20 dB
Antenna configuration	1T1R※
MIMO mode	If companies bring results for MIMO, it is recommended to use at least one constant modulus precoding scheme. Companies need to provide their CSI and precoding assumptions for MIMO evaluations. MIMO correlation matrices should be low correlation (i.e. uncorrelated) for RAN1#86 in case of MIMO simulations.
MCS	Fixed. 16QAM: 1/2 or 2/3; 64QAM: 1/2※ or 3/4; other is not precluded
Control overhead	Zero
Time offset of interfering user	Case 3: fixed offset {0, 128※, 512} samples (for 15 kHz subcarrier spacing with 1024 FFT size) Case 4: 0
Channel estimation *	Ideal※, realistic
Channel model **	TDL model All values of DS {10, 30, 100, 300, 1000} ns are evaluated with the selected TDL-DS combinations, i.e. TDL-A for DS {10, 30} ns, TDL-B for DS {100 } ns, TDL-C for DS {300※,1000} ns. Companies are allowed to choose additional combination(s) of other DS values and TDL–A and/or TDL-C in TR 38.901 [15]. ETU/EVA/EPA are optional. Mobility: 3km/h※ or 30 km/h or 120 km/h, higher speed is not precluded.

NOTE *: For realistic channel estimation, the current LTE DL/UL DMRS is recommended, and the applied DMRS pattern as well as CE implementation have to be described. Pilot overheads should be considered into the calculation of user spectrum efficiency.
NOTE **: Power-delay profiles of TDL-{A,B,C} are scenario agnostic.
NOTE ※ : All marked values are recommended for calibration purpose.

Table A.1.1-3: Evaluation assumptions for waveform (30 GHz and 70 GHz)

Assumptions	Value
Carrier frequency	30 GHz & 70 GHz
Duplexing	TDD
Simulation case	Case 1a /1b
System bandwidth	30 GHz: 80 MHz or above, 70 GHz: 640MHz or above, other values are not precluded.
Data bandwidth	DL: 90% of system bandwidth UL: 4PRBs (48 subcarriers) or 90% of system bandwidth
Numerology	Depend on defined numerology (subframe duration, guard time interval, # of symbols per subframe, subcarrier spacing if needed)
UE antenna model	(M, N, P, M_g, N_g) = (2, 4, 2, 1, 1) or (2, 2, 2, 1, 1)
TRP antenna model	(M, N, P, M_g, N_g) = (8, 8, 2, 1, 1) for 30GHz, (8, 16, 2, 1, 1) for 70GHz. Option 1: a single TXRU is mapped per panel per polarization. DFT vector is used to map TXRU to antenna elements. Per antenna element pattern is in [Note 1]
Phase noise model	Follow the agreement in R1-165685
Channel coding	LTE Turbo code, other coding scheme is not precluded
Rank per UE	Rank 1 or 2
MCS	BPSK(pi/2) 1/2, QPSK(pi/4) 1/3, QPSK: 1/2, 16QAM: 1/2 or 2/3; 64QAM: 1/2 or 3/4; 256QAM ¾
Channel estimation	Ideal, Realistic* (Pilot pattern to be given in the case of real channel estimation)
Channel model	CDL-{A,B,C} in TR 38.901 [15] with {50, 300***, 800} ns DS, with 15 degrees AoD spread for TRP, 45 degrees AoA for UE 3km/h, 30km/h (optional) Beam forming scheme used for spatial filtering needs to be reported
NOTE *: For realistic channel estimation, the current LTE DL/UL DMRS is recommended. Pilot overheads should be considered into the calculation of user spectrum efficiency. NOTE **: CDLs are scenario agnostic. NOTE ***: Recommended for calibration NOTE 1: TR36.873_v210 table 7.1.1 Antennal element vertical & horizontal radiation pattern	

Table A.1.1-4: Evaluation assumptions for high speed scenario for waveform

Assumptions	Value
Carrier frequency	4GHz
Duplex	FDD/TDD
System Bandwidth	10 MHz
TTI length	1 ms
Subcarrier spacing	Single numerology case. Companies should report the selected value
Guard time interval	4.7us (interval of LTE normal CP) as baseline, other interval is not precluded
FFT size	e.g. 1024 for 15kHz subcarrier spacing
Data transmission bandwidth	Single numerology case: 50, 4 PRBs
Antenna configuration	1T1R, 2T2R
MIMO mode	Open loop. Companies should describe precoding scheme
Rank per UE	Fixed rank
MCS	Fixed. QPSK: 1/2, 16QAM: 1/2
Performance metric	User Spectral efficiency (bps/Hz)*
Control Overhead	Zero
Channel estimation	Ideal, Realistic (describe pilot arrangement)
Channel Model	ITU Rural Macro CDL, other channel models not precluded
Mobility	Up to 500 Km/h
NOTE*: Computed according to R1-163897	

A.1.2 Simulation assumption for evaluation of multiple access

This subclause describes the link level simulation assumptions used for evaluating multiple access candidates. The general link level simulation assumptions for the uplink and downlink are provided in Tables A.1.2-1 and A1.2-2, respectively.

Table A.1.2-1: Simulation assumptions for UL multiple access scheme

Parameters	Values or assumptions
Carrier Frequency	2 GHz
Waveform	OFDM /SC-FDMA Other waveform is not precluded
Channel coding	LTE Turbo as start point, other coding schemes are not precluded.
Numerology	Same as Release 13
System Bandwidth	10 MHz
Total allocated bandwidth for transmission	Companies need to report this value.
Overhead	2 DMRS symbols, no SRS, i.e., 144 available RE per RB for data transmission, or equivalent overhead
Target spectral efficiency	Proponents report per UE spectral efficiency and the number of UEs multiplexed if multi-UEs LLS is assumed
BS antenna configuration	2/4 Rx as baseline 8Rx optional
UE antenna configuration	1Tx
Transmission mode	TM1 (refer to TS36.213)
SNR distribution of Multiple UEs	Proponents report if single-user or multi-user LLS is used, and what SNR distribution is assumed.
Suggested SNR distribution of multiple UEs	Equal average SNR (short-term variation remains) Unequal average SNR (the SNR distribution is, e.g., uniformly distributed within a range of 3dB, and proponents should report their assumption)
Propagation channel & UE velocity NOTE2	TDL in TR 38.901 [15] as mandatory EPA, EVA, ETU as optional 3km/h, 30km/h, 120km/h
Max number of HARQ transmission	1, 4
Given BLER level (to calculate sum throughput)	0.1 for 1 transmission as starting point, other numbers not precluded, e.g., 0.01 for 1 transmission
Overloading factor (Optional, definition refers to R1-163881)	Some example values: 100%, 150%, 200%, 300%

Table A.1.2-2: Simulation assumptions for DL multiple access scheme

Parameters	Values or assumptions
Carrier Frequency	2 GHz
Waveform	OFDM Other waveform is not precluded
Channel coding	LTE Turbo as starting point, other coding schemes are not precluded.
Numerology	Same as Release 13
System Bandwidth	10 MHz
Total allocated bandwidth for transmission	Companies need to report this value.
Overhead	2 PDCCH symbols, 2 CRS ports for TM2 , i.e., 132 REs per RB for data transmission, or equivalent overhead
Target spectral efficiency	Proponents report per UE spectral efficiency and the number of UEs multiplexed if multi-UEs LLS is assumed
BS antenna configuration	2/4 Tx as baseline 8Tx optional
UE antenna configuration	2 Rx
Transmission mode	TM2 as starting point (refer to TS36.213)
SNR distribution of Multiple UEs	Fixed gap {0, 5, 10, 15, 20} dB between UEs
Number of UEs	2 UEs as start point
SNR of the reference UE	0dB (The SNR of the other UE would be 0, 5, 10, 15, or 20dB)
Power allocation between UEs	Dynamic
Propagation channel & UE velocity NOTE2	CDL in TR 38.901 [15] as mandatory EPA, EVA, ETU as optional 3km/h, 30km/h, 120km/h
Max number of HARQ transmission	1, 4
Given BLER level (to calculate sum rate region)	0.1 for 1 transmission as starting point

A.1.3 Simulation assumption for evaluation of channel coding

This subclause describes the link level simulation assumptions used for evaluating channel coding candidates. The general link level simulation assumptions for eMBB, mMTC, and URLLC are provided in Tables A.1.3-1 and A.1.3-2 to evaluate the BLER performance versus SNR. The general link level simulation assumptions for control channel for eMBB are also provided in A.1.3-3.

Table A.1.3-1: Simulation assumptions for eMBB

Parameters	Values or assumptions		
Channel*	AWGN		
Modulation	QPSK, 64QAM		
Coding Scheme	Turbo	LDPC	Polar
Code rate	1/5, 1/3, 2/5, 1/2, 2/3, 3/4, 5/6, 8/9		
Decoding algorithm**	Max-log-MAP	min-sum	List-X
Info. block length*** (bits w/o CRC)	100, 400, 1000, 2000, 4000, 6000, 8000 Optional(12K, 16K, 32K, 64K)		

Table A.1.3-2: Simulation assumptions for URLLC and mMTC

Parameters	Values or assumptions			
Channel*	AWGN			
Modulation	QPSK, 16 QAM			
Coding Scheme	Convolutional codes	LDPC	Polar	Turbo
Code rate	1/12, 1/6, 1/3			
Decoding algorithm**	List-X Viterbi	min-sum	List-Y	Max-log-MAP
Info. block length*** (bits w/o CRC)	20, 40, 200, 600, 1000			

Table A.1.3-3: Simulation assumptions for control channel targeting eMBB

Channel	AWGN						
Modulation	QPSK						
Coding Scheme	Repetition	Simplex	TBCC	Turbo	LDPC	Reed-Muller	Polar
Code rate (for evaluation purposes)	1/24*, 1/12, 1/6, 1/3, 1/2, 2/3						
Decoding algorithm**	ML	ML	List-Viterbi	Scaled max log MAP	Adjusted min-sum	FHT	SC list
Info. block length (bits w/o CRC) (for evaluation purposes) ***	1, 2, 4, 8, 16, 32, 48, 64, 80, 120, 200						
NOTE *: Code rate 1/24 is valid for info block length of 1-2 bits NOTE **: Other variants of agreed algorithms can be used for encoding and decoding (Complexity details should be illustrated) NOTE ***: Each of these info block lengths shall be evaluated at least one of the code rates. Other info. block lengths and code rates are not precluded. Similar info and encoded block lengths should be used for the evaluation. Total coded bits = info. Block length/code rate. Note: these info block length and code rate are only for initial performance evaluations. They are not interpreted as design targets or assumptions for complexity analysis.							

A.1.4 Simulation assumption related to URLLC evaluation

This subclause describes the simulation assumptions used for evaluating URLLC capacity.

Table A.1.4-1: Simulation assumptions for URLLC

Attributes	Values or assumptions
Carrier Frequency	700MHz and 4 GHz (FDD and TDD)
Modulation and coding rate	QPSK, 16QAM, 64QAM 1/12, 1/6, 1/3 Other MCS not precluded Comparison should be made for the same spectrum efficiency
User bandwidth	Companies report
Latency bound	1ms Other values are not precluded Companies report delay assumptions according to Table 1 in R1-166485
SINR range	-5dB to 20dB Larger range is not precluded
Sub-carrier spacing	Companies report
TTI length	Companies report
OFDM symbols per TTI	Companies report
Channel model	TDL/CDL in TR 38.901 [15]; user speed = 3km/h, 15km/h (other user speed is not precluded)
BS antenna configuration	2/4/8 Tx/Rx ports as start point Other values (i.e., up to 256) are not precluded
UE antenna elements	2/4 Tx/Rx ports as start point Other values (i.e., up to 8) are not precluded
Packet arrive rate	Option 1: periodically Option 2: Poisson arrival with arrival rate λ
PHY Packet size	32 byte, 50 byte, 200 byte Other values are not precluded.
ACK Feedback assumption	Ideal as start point (Note 1)
Channel estimation	Ideal as start point; Realistic is not precluded when RS design is ready
CQI feedback assumption	Companies report the feedback scheme if any
NOTE: control channels including DL assignment/UL grant/ACK/NACK are to be evaluated further. NOTE 1: It is also possible that no ACK feedback is needed.	

A.1.5 Simulation assumption for evaluation related to initial access

This subclause describes the link level simulation assumptions used for evaluating physical layer signals/channels related to initial access. The link level evaluations for synchronization signal/channels and RACH are respectively provided in Tables A.1.5-1 and A.1.5-2. The link level evaluation for PBCH is also provided in Table A.1.5-3.

Table A.1.5-1 can also be used in link level evaluation for DL based mobility at above 6 GHz.

Table A.1.5-1: Simulation assumptions for synchronization signals/channels

	Below 6GHz	Above 6GHz
Carrier Frequency	4 GHz	30, 70 GHz
Channel Model	CDL-C for 4 and 30 GHz, and CDL-D for 70 GHz (other CDL models are not precluded), AWGN - with delay scaling values of 100ns (mandatory), 300ns (optional) and 1000ns (optional) for 4 GHz, 30 ns for 30/70 GHz - with combination of ASA and ASD scaling values in sec. 7.7.5.1 in TR 38.901 [15], for above 6 GHz cases - ZSA = 5 degree, ZSD = 1 degree - The CDL table is translated so that the strongest cluster's AoD and AoA occur at a random angle for both the antenna panels of TRP and UE in the local coordinate. The value of the random angle is selected to be uniformly distributed from +30 to -30 degree. The random value is chosen independently for both AoD and AoA	
Subcarrier Spacing(s)	15, 30, 60, 120, 240, or 480 kHz (to be clarified by each proponent; other values are not precluded)	
SNR range	> -6dB	> -18dB
UE speed	3 km/h and 120 km/h (mandatory) 30km/h and 500km/h (optional)	3 km/h
Search window	The time window to search (correlate) NR-PSS. It depends on the periodicity of NR-SS transmission. The value needs to be provided by each proponent	
Antenna Configuration at the TRP	(1, 1, 2) with omni-directional antenna element	(4, 8, 2), with directional antenna element (HPBW=65 °, directivity 8 dBi) Optional: (M, N, P, M_g, N_g) = (4, 8, 2, 2, 2). (d_V, d_H) = (0.5, 0.5)λ. ($d_{g,V}$, $d_{g,H}$) = (2.0, 4.0)λ
Antenna Configuration at the UE	(1, 1, 2) with omni-directional antenna element	(2, 4, 2), with directional antenna element (HPBW=90 ° , directivity 5 dBi)
Antenna port virtualization	Clarified by each proponent in simulation assumptions (e.g. the beamforming method, beam directions, number of beams)	

Frequency Offset	- Initial acquisition
	  - TRP: uniform distribution +/- 0.05 ppm
	  - UE: uniform distribution +/- 5, 10, 20 ppm (each company to choose one)
	- Non-initial acquisition
	  - TRP: uniform distribution +/- 0.05 ppm
	  - UE: uniform distribution +/- 0.1 ppm	

Number of interfering TRPs	1. 0 TRP: mandatory 2. 2 interfering TRPs (1st SIR = 0dB, 2nd SIR = -3dB; SIR is defined as the ratio of power between a reference cell and interfered cell) – timing arrival differences from TRPs are provided by each proponent: optional	1. 0 TRP

Table A.1.5-2: Simulation assumptions for RACH

	Below 6GHz	Above 6GHz
Carrier Frequency	4 GHz	30, 70 GHz
Channel Model	CDL-C for 4 and 30GHz, CDL-D for 70 GHz (other CDL models are not precluded), AWGN - with delay scaling values of 100ns(mandatory) for 4 GHz, 30ns (optional), and 1000ns(optional) for 30/70 GHz - with combination of ASA and ASD scaling values in sec. 7.7.5.1 in TR 38.901 [15], for above 6 GHz cases - ZSA = 5 degree, ZSD = 1 degree - The CDL table is translated so that the strongest cluster's AoD and AoA occur at a random angle for both the antenna panels of TRP and UE in the local coordinate. The value of the random angle is selected to be uniformly distributed from +30 to -30 degree. The random value is chosen independently for both AoD and AoA	
Antenna Configuration at the TRP	(1, 1, 2) with omni-directional antenna element	(4, 8, 2), with directional antenna element (HPBW=65°, directivity 8 dBi) Optional: $(M, N, P, M_g, N_g) = (4, 8, 2, 2, 2)$. $(d_V, d_H) = (0.5, 0.5)\lambda$. $(d_{g,V}, d_{g,H}) = (2.0, 4.0)\lambda$
Antenna Configuration at the UE	(1, 1, 2) with omni-directional antenna element	(2, 4, 2), with directional antenna element (HPBW=90°, directivity 5 dBi)
Antenna port virtualization	Clarified by each proponent in simulation assumptions (e.g. the beamforming method, beam directions, number of beams)	
Frequency Offset	- +/- 0.05 ppm at TRP, +/-0.1 ppm at UE	
UE speed	- 3km/h, 120km/h(mandatory) - -30km/h, 500km/h(optional)	- 3km/h - Other values are not precluded

Initial timing Offset	- Timing uncertainty derived from cell radius
	  - (e.g. for below 6 GHz, [-10us, +10us] for 3km cell radius)
	  - Companies report the assumed cell radius	

Table A.1.5-3: Simulation assumptions for PBCH

Parameter	Value
Channel coding scheme	LTE TBCC Other channel coding schemes are not precluded. (e.g. Polar coding)
Carrier frequency, Channel model, UE speed, Antenna configuration, Number of interfering TRPs	Following evaluation assumptions for initial access
Performance Target	1% BLER @ -6dB (average received SNR)

A.1.6 Simulation assumption for evaluation related to multi-antenna scheme

This subclause describes the link level simulation assumptions used for evaluating physical layer signals/channels related to multi-antenna scheme. The link level evaluation assumptions for DMRS are provided in Tables A.1.6-1 and A.1.6-2.

Table A.1.6-1: Link-level evaluation assumptions for DMRS for data channel (4 GHz)

Assumptions	Value
Carrier frequency	4GHz
Duplex	FDD/TDD
Subcarrier spacing	- 15kHz, 30kHz and 60kHz - Less than 15kHz (optional) - Other subcarrier spacing are not precluded. Note: Companies which have result for less than 15kHz subcarrier spacing are encouraged to provide use cases.
Number of TXRUs	- TRP = {2, 4, 8, 16, 32, 64} - UE = {2, 4, 8}
Transmission layers for data channel	- SU-MIMO: up to 8 layers - MU-MIMO: up to N layers Note: Companies should provide the assumptions on N and the number of paired UEs and SNR distribution for MU-MIMO simulation.
Transmission scheme	- Multi-antenna port transmission schemes Note: Companies explain details of the using transmission scheme.
CSI feedback / Beam management scheme	- Each company describes their own assumptions on CSI feedback and/or beam management
CW to layer mapping	- LTE CW to layer mapping (baseline)
Data allocation	- 1, 8, 32 RBs, and other option for maximum throughput - Co-scheduled “dummy” users allocated on neighboring RBs. (optional) - FDD: First 2 OFDM symbols for PDCCH, and following 12 OFDM symbols for data channel - TDD: First 2 OFDM symbols for PDCCH, 10 OFDM symbols for data channel, last 2 OFDM symbols for guard and UL symbol. Note: Error free PDCCH decoding is assumed.
PRB bundling	- 1, N RBs as in LTE (baseline) - Other N (optional)
Modulation order, Coding rate	- QPSK (1/3, 1/2), 16QAM (1/2, 3/4), 64QAM (2/3, 5/6), 256QAM (3/4, 5/6), - QPSK (1/5) (optional) - Other MCS are not precluded Note: Companies are allowed to choose the more appropriate MCS(s) for DM-RS evaluation in the selected channel model.
Channel coding scheme	- LTE turbo coding (baseline) - Other channel coding schemes are not precluded.
Link adaptation / HARQ	- No link adaptation and no HARQ - Evaluation with HARQ and/or link adaptation
Channel estimation	- Real estimation Note: Companies provide the channel estimation method. Note: An ideal estimation based LLS performance result can be reported as a reference performance.
Performance metric	- BLER - Spectral efficiency
Frequency offset model (optional)	- Evaluate with and without frequency tracking with the model in table 1 in [Note 1]
Interference limited scenario (optional)	- N interfering TRP
UE speed	- 3 km/h, 30km/h, 120 km/h, 500km/h
Channel model	- Alternative 1: TDL-A/B/C/E models - All values of DS {10, 30, 100, 300, 1000} ns are evaluated with the selected TDL-DS combinations, i.e. - TDL-A for DS {10, 30}ns, - TDL-B for DS {100}ns, - TDL-C for DS {300, 1000}ns - TDL-E for DS {30}ns - Companies are allowed to choose additional combination(s) of other DS values and TDL–A and/or TDL-C in TR 38.901 [15]. - Antenna correlation - Tx={‘High’, ’Medium’}, Rx={‘Low’} - MIMO channel correlation matrices are followed in [Note 2]. - Alternative 2: CDL-A/B/C/E models - Possible DS values = {10, 30, 100, 300, 1000} ns. - ASA, ASD, ZSA, ZSD follow the values in sec 7.7.1 in TR 38.901 [15]

	- The angles of TRP, i.e., AoD, ZoD, are uniformly distributed within [-60, 60] degrees in azimuth domain and [90, 135] degrees in zenith domain, and those of UE, i.e., AoA, ZoA, are uniformly distributed within [-180, 180] degrees in azimuth domain and [45, 90] in zenith domain, via applying uniform-distribution desired mean angle in subclause 7.7.5.1 in TR 38.901 [15] accordingly. Note: Companies are encouraged to choose calibrated channel model for evaluation. Note: ITU Rural Macro CDL model (LOS scenario) can also be evaluated for high speed scenario (i.e. up to 500km/h).
TRP antenna configuration	- The number of antenna: Tx={2,4,8,16,32,64} Per antenna element pattern is in [Note 3] Note: Each company describes their own antenna configurations and TXRU to antenna elements mapping
UE antenna configuration	- The number of antenna: Rx={2,4,8} (M,N,P)={(1,1,2), (1,2,2), (1,4,2)} with 0.5λ spacing with omni-directional antenna element
NOTE 1: R1-1611012 NOTE 2: 3GPP TS36.101, subclause B.2.3A/B NOTE 3: 3GPP TR36.873_v210, Table 7.1.1 Antennal element vertical & horizontal radiation pattern	

Table A.1.6-2: Link-level evaluation assumptions for DMRS for data channel (30 GHz)

Assumptions	Value
Carrier frequency	30 GHz
Duplex	TDD
Subcarrier spacing	- 60kHz and 120kHz Other subcarrier spacing is not precluded.
Number of TXRUs	- TRP = {2, 4, 8} - UE = {2, 4}
Transmission layer for data channel	- SU-MIMO: up to 4 layers - MU-MIMO: up to N layers Note: Companies should provide the assumptions on N and the number of paired UEs and SNR distribution for MU-MIMO simulation.
Transmission Scheme	- Multi-antenna transmission schemes Note: Companies explain details of the using transmission scheme.
CSI feedback / Beam management scheme	- Each company describes their own assumptions on CSI feedback and/or beam management
CW to layer mapping	- LTE CW to layer mapping (baseline)
Data Allocation	- 1, 8, 32 RBs, and other option for maximum throughput - Co-scheduled “dummy” users allocated on neighboring RBs. (optional) - First 2 OFDM symbols for PDCCH, 10 OFDM symbols for data channel, last 2 OFDM symbols for guard and UL symbol. Note: Error free PDCCH decoding is assumed.
PRB bundling	- 1, N RBs as in LTE (baseline) - Other N (optional)
Modulation order, Coding rate	- QPSK (1/3, 1/2), 16QAM (1/2, 3/4), 64QAM (2/3, 5/6), 256QAM (3/4, 5/6) - QPSK (1/5) (optional) - Other MCS are not precluded Note: Companies are allowed to choose the more appropriate MCS(s) for DM-RS evaluation in the selected channel model.
Channel coding scheme	- LTE turbo coding (baseline) - Other channel coding schemes are not precluded.
Link adaptation / HARQ	- No link adaptation and no HARQ - Evaluation with HARQ and/or link adaptation
Channel estimation	- Real estimation Note: Companies provide the channel estimation method. Note: An ideal estimation based LLS performance result can be reported as a reference performance.
Performance Metric	- BLER - Spectral efficiency
Phase noise and frequency offset model (Optional)	- Evaluate with and without phase/frequency tracking with the model in table 1 in [Note 1]
Interference limited scenario (Optional)	- N interfering TRP
UE speed	- 3 km/h, 30km/h - 120km/h (optional) - 500km/h (optional for high speed train)
Channel model	- CDL-A /B/C for 30GHz - Possible DS values = {10, 30, 100, 300, 1000} ns. - ASA, ASD, ZSA, ZSD follow the values in sec 7.7.1 in TR 38.901 [15] - The angles of TRP, i.e., AoD, ZoD, are uniformly distributed within [-60, 60] degrees in azimuth domain and [90, 135] degrees in zenith domain, and those of UE, i.e., AoA, ZoA, are uniformly distributed within [-180, 180] degrees in azimuth domain and [45, 90] in zenith domain, via applying uniform-distribution desired mean angle in subclause 7.7.5.1 in TR 38.901 [15] accordingly. - CDL-D for 30 GHz (optional for high speed train [Note 2]) - 10ns DS and K-factor 13.3dB, - Parameter set # 1: 5(ASD), 5(ASA), 1(ZSA), 1(ZSD) - ZoD and ZoA for cluster #1 are fixed at 90 degrees
TRP antenna configuration	- In case of single panel: $(M, N, P, M_g, N_g) = (4, 8, 2, 1, 1)$; $(d_V, d_H) = (0.5, 0.5)\lambda$ with directional antenna element (HPBW=65°, directivity 8 dBi) - In case of multiple panels: $(M, N, P, M_g, N_g) = (4, 8, 2, 2, 2)$; $(d_V, d_H) = (0.5, 0.5)\lambda$. $(d_{g,V}, d_{g,H}) = (2.0, 4.0)\lambda$ for 30GHz A single TXRU is mapped per panel per polarization. Per antenna element pattern is in [Note 3]

	Each company describes their own antenna configurations and TXRU to antenna elements mapping. - For high speed train (optional): See Table A.2.1-5 [Note 2]
UE antenna configuration	- In case of single panel: (M, N, P, M_g, N_g) = (2, 4, 2, 1, 1) ; (d_V, d_H) = (0.5, 0.5)λ, with directional antenna element (HPBW=90°, directivity 5 dBi) - In case of multiple panels: (M, N, P, M_g, N_g) = (2, 4, 2, 1, 2); (d_V, d_H) = (0.5, 0.5)λ. ($d_{g,V}$, $d_{g,H}$) = (0, 0)λ. $\Theta_{mg,ng}$=90°; $\Omega_{0,1}$=$\Omega_{0,0}$+180°; Notes: the polarization angles are 0° and 90° Notes: introduce (Ωmg,ng, Θmg,ng) for orientation of the panel (mg, ng), 0≤mg<Mg, 0≤ng<Ng, where the orientation of the first panel ($\Omega_{0,0}$, $\Theta_{0,0}$) is the same as UE orientation, $\Omega_{mg,ng}$ is the array bearing angle and $\Theta_{mg,ng}$ is the array downtilt angle defined in [TR 36.873]. - For high speed train (optional): See Table A.2.1-5 [Note 2]
NOTE 1: R1-1611012 NOTE 2: 3GPP TR38.802, Table A.2.1-2: System level evaluation assumptions for High-speed train, Urban grid for eV2X, and Highway for eV2X NOTE 3: 3GPP TR36.873_v210, Table 7.1.1 Antennal element vertical & horizontal radiation pattern	

The link level evaluation assumptions for PT-RS are provided in Table A.1.6-3.

Table A.1.6-3: Simulation assumptions for PT-RS

Carrier Frequency	30GHz
Channel Model	AWGN CDL-C for 30 GHz (other CDL models are not precluded), with delay scaling values of 30 ns and 100ns with combination of ASA and ASD scaling values in sec. 7.7.5.1 in TR 38.901 [15], for above 6 GHz cases
Phase noise model	Recommendation: Examples in R1-165685 Each company decides phase noise model and should provide the details of phase noise model
Frequency Offset	Frequency offset in case of non-initial acquisition - TRP: uniform distribution +/- 0.05 ppm - UE: uniform distribution +/- 0.1 ppm
Evaluation cases	Case 1: Both phase noise and frequency offset Case 2: Phase noise only, and no frequency offset Case 3: No phase noise, and frequency offset only
Subcarrier Spacing(s)	60kHz, 120kHz, 240kHz
# of Physical RBs	4, 32 RBs
Antenna Configuration at the TRP	(4, 8, 2), with directional antenna element (HPBW=65°, directivity 8 dBi)
Antenna Configuration at the UE	(2, 4, 2), with directional antenna element (HPBW=90°, directivity 5 dBi)
Antenna Virtualization	Agreement in R1-1608661
Transmission Scheme	Single antenna transmission scheme (1 port) as a starting point Companies explain details of the using transmission scheme.
Doppler	3km/h as a starting point
Modulation order, Coding rate	QPSK (1/3, 1/2), 16QAM (1/2, 3/4), 64QAM (2/3, 5/6) 256QAM (3/4)
Channel coding scheme	LTE turbo coding (baseline) Other channel coding schemes are not precluded.
Link adaptation / HARQ	No link adaptation and no HARQ
Channel estimation	Ideal estimation (baseline) Real estimation (Proponent should report DMRS pattern with RS overhead)
Time/freq. tracking, Phase tracking	Real tracking (Proponent should report RS pattern* with RS overhead) * RS for time/freq. tracking, RS for phase tracking
Performance Metric	EVM, BLER, Spectral efficiency

The link level evaluation assumptions for beam management are provided in Table A.1.6-4.

Table A.1.6-4: Simulation assumptions for beam management.

Parameters	Values
Carrier Frequency	4 GHz, 30 GHz
Subcarrier Spacing for data	For 4 GHz: 15kHz For 30 GHz: 120kHz, 60kHz (Other subcarrier spacings can be considered)
Data allocation	8 RBs First 2 OFDM symbols for PDCCH, and following 12 OFDM symbols for data channel
PDCCH decoding	Ideal or Non-ideal (Companies explain how is modeled)
Channel Model	CDL-A /B/C model - delay spread =100ns - UE speed=3km/h. - The angles of BS, i.e., AoD, ZoD, are uniformly distributed within [-60, 60] degrees in azimuth domain and [90, 135] degrees in zenith domain, and those of UE, i.e., AoA, ZoA, are uniformly distributed within [-180, 180] degrees in azimuth domain and [45, 90] in zenith domain, via applying uniform-distribution desired mean angle in subclause 7.7.5.1 in TR 38.901 [15] accordingly.
TXRU mapping to antenna elements	Companies explain details of the using TXRU mapping to antenna elements. Notes: 30GHz: 2D DFT based beam per polarization as a baseline; 4GHz: 1D DFT per vertical dimension per polarization as baseline;
TXRU mapping weights	Companies explain details of the using TXRU mapping weights.
Procedure of beam sweeping	Companies explain details of procedure of beam sweeping.
Criteria for beam selection	Companies explain details of criteria for beam selection.
UE reporting	Companies explain details of criteria for UE reporting.
BS antenna configurations	For 4 GHz: $(M, N, P, M_g, N_g) = (8, 8, 2, 1, 1)$ as baseline. $(d_V, d_H) = (0.8, 0.5)\lambda$. For 30 GHz: $(M, N, P, M_g, N_g) = (4, 8, 2, 2, 2)$. $(d_V, d_H) = (0.5, 0.5)\lambda$. $(d_{g,V}, d_{g,H}) = (2.0, 4.0)\lambda$ Note: important to consider also other antenna configurations to maintain flexibility
BS antenna element radiation pattern	For 4GHz: According to TR36.873 For 30 GHz: According to TR38.802
UE antenna configurations	For 4 GHz: $M_g = 1$, $N_g = 1$, $P = 2$, $(d_V, d_H) = (0.5, 0.5)\lambda$, MxNxP<=8 (companies report M,N) For 30 GHz: $(M, N, P, M_g, N_g) = (2, 4, 2, 1, 2)$; $(d_V, d_H) = (0.5, 0.5)\lambda$. $(d_{g,V}, d_{g,H}) = (0, 0)\lambda$. * $\Theta_{mg,ng}=90°$; $\Omega_{0,1}=\Omega_{0,0}+180°$; Note: important to consider also other antenna configurations to maintain flexibility
BS array orientation	azimuth 0 degree; mechanic downtilt: 0 degree
UE array orientation	$\Omega_{UT,a}$ uniformly distributed on [0, 360] degree, $\Omega_{UT,b} = 0°$, $\Omega_{UT,g} = 0°$
UE antenna element radiation pattern	For 4 GHz: Omni-directional with 5dBi gain For 30 GHz: See Table A.2.1-8 in TR 38.802
Transmission scheme	Multi-antenna port transmission schemes Note: Companies explain details of the using transmission scheme.
MIMO mode	SU-MIMO
UE receiver type	MMSE-IRC as baseline; other advanced receiver is not precluded.
MCS	LTE MCS
Link adaptation	Based on CSI-RS
Metrics	BLER w/ beamforming Proponents are encouraged to provide additional observations on SINR and RSRP

A.2 System level simulation assumptions

A.2.1 General assumption

This subclause describes the reference deployment scenarios for the different system evaluations. The general system evaluation assumptions for Indoor hotspot, Dense urban, Rural, Urban macro, and High-speed train are provided in Tables A.2.1-1, A.2.1-2, and A2.1-3.

The BS and UE antenna configurations are also provided in Tables A.2.1-4 to A2.1-8.

For Indoor hotspot, ceiling mounted TRP deployment is adopted. The following three options can be considered.

- Option 1 (baseline at least for calibration): Boresight direction is perpendicular to the ceiling. Antenna model is taken from Wall-mount (90 degree HPBW in azimuth and zenith) in Table A.2.1.7.
  - The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.901 [15]. Placement of 3 sites is according to Figure A.2.1-1.
  - Antenna array baseline configuration:
    - $(M, N, P, M_g, N_g) = (4, 4, 2, 1, 1)$, $d_H = d_V = 0.5\ \lambda$ for 4GHz
    - $(M, N, P, M_g, N_g) = (4, 8, 2, 1, 1)$, $d_H = d_V = 0.5\ \lambda$ for 30GHz
    - $(M, N, P, M_g, N_g) = (8, 16, 2, 1, 1)$, $d_H = d_V = 0.5\ \lambda$ for 70 GHz
- Option 2: Three sectors (example below). Antenna model is taken from 3-sector in Table A.2.1.7. (65 degree HPBW in Azimuth and zenith).
  - Used antenna tilt should be reported by each company.
  - The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.901 [15]. Placement of 3 sites is according to Figure A.2.1-1.
  - Antenna array baseline configuration:
    - Same as Option 1
    - Boresight direction is according to TR 38.901 [15]
- Option 3: Boresight direction is perpendicular to the ceiling. Omni antenna model is applied for 4 GHz.
  - The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.901 [15]. Placement of 3 sites is according to Figure A.2.1-1.
  - Antenna array baseline configuration:
  - $(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1)$ for 4GHz.

For Dense urban, the following Option 1 and Option 2 are adopted with one sector deployment for micro cell TRP deployment in dense urban scenario, i.e.,

- Option 1 : Omni in horizontal, directional in vertical (5dBi gain, HPBW 40°, vertical tilt 90°, A_m =20dB, SLA_V=30dB)
  - Dropping in the center of the hotspot area
- Option 2: Directional in horizontal, directional in vertical (8dBi gain, HPBW = 65°, vertical tilt 90°, A_m =30dB, SLA_V=30dB)
  - One-sector deployment
  - Dropping of TRP and TRP antenna orientation according to the following three steps as described in TR 36.897 (non co-channel hetnet deployment)

    Step 1: Randomly drop TRP centers around the TRP cluster center within a radius of R; and consider the minimum distance between TRP centers ($D_{micro\text{-}TRP}$).

    Step 2: Randomly deploy TRP antennas on area circle with the radius of half of $D_{micro\text{-}TRP}$.

    Step 3: Determine the horizontal angle of the TRPs with the planer facing to the TRP center.
- Number of Tx antennas at micro cell TRP:
  - Baseline: $(M, N, P, M_g, N_g) = (8, 8, 2, 1, 1)$, $(0.5, 0.8)\lambda$ for 4GHz

The distance (d_{in}+d_{out}) from a UE to the closest TRP shall not exceed R (UE dropping radius). The minimum distance between Macro TRP and UE is 10m and that between Micro TRP and UE is 10m. The minimum distance between TRPs and UE cluster radius are also defined in Table A.2.1-9.

Table A.2.1-1: System level evaluation assumptions for Indoor hotspot, Dense urban, Rural, and Urban macro

Parameters	Indoor hotspot	Dense urban	Rural	Urban macro
Layout	Single layer Indoor floor: (12BSs per 120m x 50m) Candidate TRP numbers: 3, 6, 12	Single layer: Macro layer: Hex. Grid Two layer Macro layer: Hex. Grid Micro layer: Random drop (All micro BSs are all outdoor) - 3 micro BSs per macro BS - 6, or 9 micro BSs per macro BS (optional) See Figures A.2.1-3, A.2.1-4 and Table A.2.1-8	Single layer Macro layer: Hex. Grid	Single layer Macro layer: Hex. Grid
Inter-BS distance	20m	Macro layer: 200m	1732m for 4GHz and 1732m and 5km for 700 MHz	500m
Carrier frequency	4GHz, 30GHz, and 70GHz	Macro layer: 4GHz and 30GHz Micro layer: 30GHz and 4GHz; 70 GHz (optional)	4GHz and 700MHz	4 GHz and 30GHz
Aggregated system bandwidth	4GHz: Up to 200MHz (DL+UL) 30GHz or 70GHz: Up to 1GHz (DL+UL)	4GHz: Up to 200MHz (DL+UL) 30GHz and 70 GHz: Up to1GHz (DL+UL)	700MHz: Up to 20MHz(DL+UL) 4GHz: Up to 200MHz (DL+UL) (Consider larger aggregated system bandwidth if 20MHz cannot meet requirement)	4GHz: Up to 200 MHz (DL+UL) 30GHz: Up to 1GHz (DL+UL)
Simulation bandwidth	20MHz per CC below 6GHz and 80 MHz per CC above 6GHz Note: For FDD, simulation BW is split equally between UL and DL Note: UE TX power scaling will impact final results			
Channel model	Below 6GHz: ITU InH Above 6 GHz: 5GCM office Note: When 5GCM is found to be applicable to below 6GHz, 5GCM should be used	Below 6GHz: 3D UMa (Macro layer) and 3D UMi (Micro layer) Above 6GHz: 5GCM UMa (Macro layer) and UMi-Street canyon (Micro layer) Note: When 5GCM is found to be applicable to below 6GHz, 5GCM should be used	ITU Rural	Below 6GHz: 3D UMa 6 GHz: 5GCM UMa Note: When 5GCM is found to be applicable to below 6GHz, 5GCM should be used
BS Tx power	Below 6GHz: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm Above 6GHz: 23 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 23dBm EIRP should not exceed 58 dBm(*)	Macro layer: Below 6GHz: 44 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 44 dBm Above 6GHz: 40 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 40 dBm Micro layer: 4 GHz: 33dBm for 20MHz system bandwidth Above 6GHz: 33 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 33 dBm. EIRP should not exceed 73 dBm and 68 dBm for the macro and micro layers	49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm	Below 6GHz: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm Above 6GHz: 43dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 43dBm EIRP should not exceed 78 dBm (*)

		respectively(*)		

UE Tx power	Below 6GHz: 23dBm 30GHz: 23dBm 70GHz: 21dBm EIRP should not exceed 43 dBm (*)			
BS antenna configurations	See Table A.2.1-4.			
BS antenna height	3m	25m for macro cells and 10m for micro cells	35 m	25 m
BS antenna element gain + connector loss	See Table A.2.1-4			
BS receiver noise figure	Below 6GHz: 5dB Above 6GHz: 7dB			
UE antenna configuration	See Table A.2.1-4.			
UE antenna height	Follow TR36.873			
UE antenna gain	Follow the modeling of TR36.873			
UE receiver noise figure	Below 6GHz: 9dB Above 6GHz: 13dB (baseline performance), 10dB (high performance)			
Traffic model	Full buffer and FTP model 1/2/3 with packet size 0.1 and 0.5Mbytes (other value is not precluded). Other traffic models are not precluded.			
Traffic load (Resource utilization)	For baseline scheme: 25, 50 and 80% (other value is not precluded)			
UE distribution	100% Indoor, 3km/h, 10 users per BS for full buffer traffic	**Step1 (**):** Uniform/macro TRP (10 users per TRP for full buffer traffic) **Step2 (**):** Uniform/macro TRP + Clustered/micro TRP (10 users per TRP associated with macro cell geographical area for full buffer traffic. 2/3 users randomly and uniformly dropped within the clusters, 1/3 users randomly and uniformly dropped throughout the macro geographical area for FTP model 1/2/3, and 60 users for FTP model 2/3) (***) - 80% indoor (3km/h), 20% outdoor (30km/h) - In the case of full buffer, 10 users per TRP is the baseline. 20 users per TRP is not precluded. - In case of outdoor (30km/h), penetration loss in-car is 9 dB (LN, σ = 5 dB). Mix of O2I penetration loss models for higher carrier frequency - Option1 - Low loss model – 80% - High-loss model – 20% - Option2 - Low loss model – 50% - High-loss model – 50%	50% outdoor vehicles (120km/h) and 50% indoor (3km/h) 10 users per TRP for full buffer traffic User distribution: Uniform	20% Outdoor in cars: 30km/h, 80% Indoor in houses: 3km/h 10 users per TRP for full buffer traffic (10 users per TRP is the baseline with full buffer traffic. 20 users per TRP with full buffer traffic is not precluded.) Mix of O2I penetration loss models for higher carrier frequency - Option1 - Low loss model – 80% - High-loss model – 20% - Option2 - Low loss model – 50% - High-loss model – 50%

UE receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.
Feedback assumption	Realistic
Channel estimation	Realistic

(*): See Appendix in R1-164383 and R1-167533 for the derivation of maximum allowed EIRP. EIRP limit is only used for evaluation purpose in RAN1.
(**): Step 1 shall be used for the evaluation of spectral efficiency KPIs. Step2 shall be used for the evaluation of the other deployment scenario dependant KPIs.
(***): Companies are encouraged to investigate the ratio of UEs between the macro and micro cell geographical area depending on options for micro cell dropping (See Figures A.2.1-3 and A.2.1-4 and Table A.2.1-8)

Table A.2.1-2: System level evaluation assumptions for High-speed train, Urban grid for eV2X, and Highway for eV2X

Parameters	High Speed Train	Urban grid for eV2X	Highway for eV2X
Layout	Option 1: Macro only（Dedicated linear deployment along railway line） Option 2: Macro + relay nodes（Dedicated linear deployment along railway line） Option 1 is prioritized for evaluation. Parameter values related to train: Train length: 400m Num of users per train: 1000 UE distribution: Uniform in train For Option 1 and Option 2, both SFN scenario and non-SFN scenario are considered. For Option1 or Option 2 Alt.1, 4GHz Parameter Value for SFN scenario: RRH Railway track distance: 100m Num of RRHs connected to one BBU: 6 Parameter Value for non-SFN scenario: RRH Railway track distance: 100m Num of RRHs connected to one BBU: 2 For Option 2 Alt. 2, For BS to relay 30GHz, SFN/non-SFN RRH Railway track distance: 5m Num of RRHs connected to one BBU: 3 See Figure A.2.1-5 and A.2.1-6 Note: The key characteristics of high speed train scenario are consistent user experience with very high mobility.	Option 1: Macro only (with the road configuration in Figure 6.1.9-1 in TR38.913) Option 2: Macro + RSUs (with the road configuration in Figure 6.1.9-1 in TR38.913) Note: An RSU can be a BS type RSU or UE type RSU Out of coverage can be evaluated assuming eNB or RSU to be disabled.	Option 1: Macro only (straightline eNB placement with Road configuration in TR36.885) Option 2: Macro + RSUs (straightline eNB with Road configuration in TR36.885) Note: An RSU can be a BS type RSU or UE type RSU Out of coverage can be evaluated assuming eNB or RSU to be disabled.
Inter-BS distance	1732m NOTE: For Option1 or Option 2 Alt.1, 4GHz - 1732m between RRH For Option 2 Alt. 2, For BS to relay 30GHz, SFN/non-SFN - 1732m between BBU, (3RRHs in a cell connected to 1 BBU, inter RRH distance (580, 580, 572))	Inter Macro: 500m Inter RSU: RSU is dropped at each intersection	Inter Macro: 1732m, 500m (optional) Inter RSU: Uniform allocation with 100m spacing in the middle of the highway
Carrier frequency	4 GHz for macro only, 4GHz and 30GHz for BS to relay	Macro to/from vehicle/pedestrian UE : 4 GHz Between vehicle/pedestrian UE: 6 GHz BS-type-RSU to/from vehicle/pedestrian UE : 4 GHz UE-type-RSU to/from vehicle/pedestrian UE: 6 GHz Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink	Macro to/from vehicle/pedestrian UE : 2 GHz or 4GHz Between vehicle/pedestrian UE: 6 GHz BS-type-RSU to/from vehicle/pedestrian UE : 4 GHz UE-type-RSU to/from vehicle/pedestrian UE: 6 GHz Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink
Aggregated system bandwidth	4GHz: Up to 200 MHz (DL+UL) 30GHz or 70GHz: Up to 1GHz (DL+UL)	Up to 200 MHz (DL+UL) Up to 100 MHz (SL)	Up to 200 MHz (DL+UL) Up to 100 MHz (SL)

Simulation bandwidth	Option 2: 80 MHz Other values greater than 80MHz can be considered	20 or 40 MHz (DL+UL) 10 or 20 MHz (SL)	20 or 40 MHz (DL+UL) 10 or 20 MHz (SL)
Channel model	Option 1, Option 2 Alt 1: ITU Rural as the starting point. Note: When 5GCM is found to be applicable, 5GCM should be used. Option 2 Alt 2: - CDL-D, with DS=10 ns and K-factor = {7, 13.3}* dB with the following scaling angle spreads - Parameter set #1: 5(ASD), 5(ASA), 1(ZSA), 1(ZSD) - Parameter set #2: 5(ASD), 15(ASA), 5(ZSA), 1(ZSD) - ZoD and ZoA for cluster #1 are fixed at 90 degrees - TDL-D with DS=10ns and K-factor = {7, 13.3}* dB * Other values are not precluded. "K-factor" here refers to K_desired in subclause 7.7.6 in TR 38.901 [15], or "per-channel K factor" in R1-165440. For other candidate values for K-factor, the values in Table 7.5-6 in TR 38.901 [15] can also be used as a reference. Note: The values in the parameter set #1 and #2 are used for AS_desired in the scaling function in subclause 7.7.5.1 in TR 38.901 [15]. Calculation of AS_model in the scaling function is defined in Annex A of TR 25.996. Baseline values for per cluster spread c_{ASD}, c_{ASA}, c_{ZSD}, c_{ZSA} are defined in Table 7.7.1-4 in TR 38.901 [15]. If different values are selected for the per cluster spreads, companies should provide justification. Examples of CDL-D tables for all combinations are shown in R1-168174	Macro to/from vehicle/pedestrian UE : 3D UMa Between vehicle/pedestrian UE: V2X Channel model in TR36.885 RSU to/from vehicle/pedestrian UE : V2X Channel model in TR36.885	Macro to/from vehicle/pedestrian UE: 3D UMa for 500m ISD 3D RMa for 1732m ISD (2D RMa may be used until 3D RMa is complete) Between vehicle/pedestrian UE: V2X Channel model in TR36.885 RSU to/from vehicle/pedestrian UE : V2X Channel model in TR36.885
BS Tx power	BS: Below 6GHz: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm Above 6GHz: 30dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 30dBm EIRP should not exceed 69dBm (*). Relay: 27dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 27dBm EIRP should not exceed 43dBm (*)	Macro BS: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm BS-type-RSU: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm for RSU is not precluded	Macro BS: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm BS-type-RSU: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm for RSU is not precluded
UE Tx power	Below 6GHz: 23dBm Above 6GHz: 21dBm EIRP should not exceed 43dBm (*)	Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm is not precluded	Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm is not precluded
BS antenna	See Table A.2.1-5.		

configurations			
BS antenna height	For Option1 or Option 2 Alt.1, 4GHz, 35m For Option 2 Alt. 2, 30GHz, SFN/non-SFN, RRH 2.5m, relay 2.5m	Macro BS: 25m BS-type-RSU: 5m	Macro BS: 35m for ISD 1732m 25m for ISD 500m BS-type-RSU: 5m
BS antenna element gain + connector loss	See Table A.2.1-5	Macro BS: 8dBi BS-type-RSU: 8dBi	Macro BS: 8dBi BS-type-RSU: 8dBi
BS receiver noise figure	Below 6GHz: 5dB Above 6GHz: 7dB RRH and Relay for option 2 Alt.2: 7dB	Below 6GHz: 5dB Above 6GHz: 7dB	Below 6GHz: 5dB Above 6GHz: 7dB
UE antenna configurations	See Table A.2.1-5		
UE antenna height	Follow TR36.873	Vehicle/pedestrian UE: 1.5m UE-type-RSU: 5 m	Vehicle/pedestrian UE: 1.5m UE-type-RSU: 5 m
UE antenna gain	Follow the modeling of TR36.873	Vehicle UE: 3dBi Pedestrian UE: 0dBi UE-type RSU: 3dBi	Vehicle UE: 3dBi Pedestrian UE: 0dBi UE-type RSU: 3dBi
UE receiver noise figure	Below 6GHz: 9 dB Above 6GHz: 13dB (baseline performance), 10dB (high performance)		
Traffic model	Full buffer and FTP model 1/2/3 with packet size 0.1 and 0.5 Mbytes (other value is not precluded). Other traffic models are not precluded.	50 messages per 1 second with 60km/h, 10 messages per 1 second with 15km/h in TR38.913 Note: This value is tentative. After SA1 input, it can be modified.	50 messages per 1 second with absolute average speed of 100-250 km/h (relative speed: 200 – 500km/h) in TR38.913 Note: This value is tentative. After SA1 input, it can be modified.
Traffic load (Resource utilization)	For baseline scheme: 25, 50, and 80% (other value is not precluded)	-	-
UE distribution	100% of users in train 300 UEs per macro cell (assuming 1000 passengers per high-speed train and at least 30% activity ratio) Maximum mobility speed: 500km/h Note: Physical mobility of UE is to be modeled for option 1, and physical mobility of relay node is to be modelled for option 2 Path loss through external wall: $5 - 10\log_{10}(0.3) + L_{IRRglass}$ dB and $L_{IRRglass} = 23 + 0.3 f_c$ Indoor loss: $0.5 d_{\text{2D-in}}$ dB Standard deviation: [5.45]	Urban grid model (car lanes and pedestrian/bicycle sidewalks are placed around a road block. 2 lanes in each direction, 4 lanes in total, 1 sidewalk, one block size: 433m x 250m) in TR38.913 Average inter-vehicle distance (between two vehicles' center) in the same lane is 1sec * average vehicle speed (average speed 15 – 120km/h) in TR38.913 Vehicle UE location update in TR36.885 should be used for the evaluation of PRR in sidelink or communication interruption in uplink/downlink. Vehicle UE location update may not be assumed for the evaluation of PRR in uplink/downlink Note: Inter-vehicle distance is tentative. After SA1 input, it can be modified. Pedestrian UE distribution: Inter-pedestrian distance 20m, which is tentative. After SA1 input, it can be modified.	Average inter-vehicle distance (between two vehicles' center) in the same lane is 0.5 sec or 1sec * average vehicle speed (average speed: 100-300 km/h) in TR38.913 Vehicle UE location update in TR36.885 should be used for the evaluation of PRR in sidelink or communication interruption in uplink/downlink. Vehicle UE location update may not be assumed for the evaluation of PRR in uplink/downlink Note: Inter-vehicle distance is tentative. * After SA1 input, only one value will be selected.
UE receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.		

Feedback assumption	Realistic		
Channel estimation	Realistic		
Others	Option 2, alt. 2 Phase noise model: Follow the agreement in R1-165685		
(*): See Appendix in R1-164383 for the derivation of maximum allowed EIRP			

Table A.2.1-3: System level evaluation assumptions for urban coverage for massive connection and extreme long coverage

Parameters	Urban coverage for massive connection (Uplink)	Extreme Long Range
Layout	Single layer - Macro layer: Hex. Grid	Single layer: Isolated Macro cells
Inter-BS distance	1732m, 500m (optional)	N/A since single cell Cell radius 100km Feasibility of Higher Range shall be evaluated through Link level evaluation (for example in some scenarios ranges up to 150-300km may be required).
Carrier frequency	700MHz	700MHz
Aggregated system bandwidth	Companies report aggregated bandwidth used in evaluation	40MHz (DL+UL)
Simulation bandwidth	Companies report simulation bandwidth used in evaluation	40MHz (DL+UL)
Channel model	3D UMa Take 5GCM output into account if applicable	<u>LLS</u> For link level modelling and simple system-level modelling, use TDL-A and CDL-A with the following delay and angle scaling: - DS = [100 ns], ASD = [1°], ASA = [30°], ZSD = [0.1°], ZSA = [1°] - The absolute propagation delay is added to all tap delays <u>SLS</u> <u>PL Model</u> PL = 52.44 + 20*log10(d_km) + 20*log10(fc_MHz) d_km is distance in km fc_MHz is the carrier frequency in MHz <u>Shadowing model</u> Log normal with standard deviation: 4dB <u>Fast fading channel model</u> <u>Option 1</u> Use LLS but with the mean AOD,ZOD,AOA,ZOD for each link are determined from the geometry assuming LOS propagation <u>Option 2</u> 2D-RMa
BS Tx power	-	BS: 49dBm
UE Tx power	Max 23dBm or optional 10dBm	23dBm
BS antenna configurations	Rx: 2 and 4 ports (8 as optional)	Up to 256 Tx/Rx Following the modelling of TR36.873
BS antenna height	25m	N/A
BS antenna element gain + connector loss	8 dBi, including 3dB cable loss	8dBi
BS receiver noise figure	Below 6GHz: 5dB Above 6GHz: 7dB	5dB
UE antenna configuration	1Tx	Up to 8 Tx/Rx
UE antenna height	1.5m	1.5m
UE antenna gain	-4dBi	0dBi
UE receiver noise figure	-	Below 6GHz: 9 dB Above 6GHz: 13dB (baseline performance), 10dB (high performance)

Traffic model	Non-full buffer small packet. Consider future trend of mMTC traffic	FTP Model 3 with packet size 600kbit, Poisson packet arrival rate of 0.05 packets/second Target user experienced data rate: to be provided based on link budget analysis
Traffic load (Resource utilization)	-	-
UE distribution	20% of users are outdoor in cars (100km/h) or 20% of users are outdoors (3km/h) 80% of users are indoor (3km/h) Users dropped uniformly in entire cell	10% UE 160km/h and 90% UE 0km/h 95% of UEs uniformly distributed up to 50 km from the base station and 5% of UEs at an extreme range distance, 100km. Evaluate how many users can be served per cell site when the range edge users are serviced with the target user experience data rate Target user experienced data rate: up to 2 Mbps DL while stationary and 384 kbps DL while moving
BS receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.-	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.
UE receiver	-	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.
Feedback assumption	-	Realistic
Channel estimation	Realistic	

Table A.2.1-4: Antenna configurations for below and above 6GHz

	Below 6GHz (700MHz, 4GHz)	Above 6GHz (30GHz, 70GHz)
TXRU mapping	Per panel, reuse models in TR 36.897 Consider the following a TXRU to antenna elements mapping as examples 4GHz: the same as TR36.897	Per panel, reuse models in TR 36.897. Consider the following a TXRU to antenna elements mapping as examples 30GHz and 70GHz: Option 1: a single TXRU is mapped per panel per polarization. Option 2: a single TXRU is mapped per panel per subarray per polarization, - E.g., where a subarray consists of consecutive M/2 vertical antennas and N/2 horizontal antennas with the same polarization. - Other subarray configurations are not precluded. Option 3: Fully connected TXRU mapping within a panel per polarization. - Other Fully connected TXRU mapping is not precluded. For evaluating multi beam based approaches at 30GHz and 70GHz, consider the following: - TXRU to antenna mapping weights are adjustable and used to steer the panel beam direction in multi beam based approaches in time domain.
Number of BS antenna elements across all panels	700MHz: Up to 64 Tx /Rx antenna elements 4GHz: Up to 256 Tx /Rx antenna elements Note: Same as TR38.913	30GHz: Up to 256 Tx /Rx antenna elements Note: Same as TR38.913 70GHz: Up to 1024 Tx /Rx antenna elements
Number of UE antenna elements	**700MHz:** Up to 4 Tx /Rx antenna elements **4GHz:** Up to 8 Tx /Rx antenna elements Note: Same as TR38.913	**30GHz:** Up to 32 Tx /Rx antenna elements **70GHz:** Up to 32 Tx /Rx antenna elements Note: Same as TR38.913
BS (M, N, P, M_g, N_g)	**4GHz:** Dense urban and Urban macro: - Baseline: (M, N, P, M_g, N_g) = (8, 8, 2, 1, 1). - Note that for Urban macro, companies are also encouraged optionally to investigate larger panels, e.g. (8, 16, 2, 1, 1) Indoor hotspot: - Baseline: (M, N, P, M_g, N_g) = (4, 4, 2, 1, 1)	**30GHz:** Dense urban and Urban macro: - Baseline: (M, N, P, M_g, N_g) = (4, 8, 2, 2, 2). Indoor hotspot: - Baseline: (M, N, P, M_g, N_g) = (4, 8, 2, 1, 1) **70GHz:** Dense urban: - Baseline: (M, N, P, M_g, N_g) = (8, 16, 2, 2, 2) Indoor hotspot: - Baseline: (M, N, P, M_g, N_g) = (8, 16, 2, 1, 1)
BS $(d_H,d_V,d_{H,g},d_{V,g})$	**4GHz:** Dense urban and Urban macro: - Baseline: (d_H, d_V) = (0.5, 0.8)λ Indoor hotspot: - Baseline: (d_H, d_V) = (0.5, 0.5)λ	**30GHz:** Dense urban and Urban macro: - Baseline: (d_H, d_V) = (0.5, 0.5)λ. (dg,H,dg,V) = (4.0, 2.0)λ Indoor hotspot: - Baseline: (d_H, d_V) = (0.5, 0.5)λ **70GHz:** Dense urban: - Baseline: (d_H, d_V) = (0.5, 0.5)λ. $(d_{g,H}, d_{g,V})$ = (8.0, 4.0) λ. Indoor hotspot: - Baseline: (d_H, d_V) = (0.5, 0.5)λ
UE antenna model parameters	Panel model 1: $M_g = 1$, $N_g = 1$, $P = 2$, $d_H = 0.5$	For UE with (M_g, N_g) directional antenna panels. - Introduce $(\Omega_{mg,ng}, \Theta_{mg,ng})$ for orientation of the panel (mg, ng), $0 \le mg < M_g$, $0 \le ng < N_g$, where the orientation of the first panel $(\Omega_{0,0}, \Theta_{0,0})$ is the same as UE orientation, $\Omega_{mg,ng}$ is the array bearing angle and $\Theta_{mg,ng}$ is the array downtilt angle defined in [TR 36.873]. - For NR MIMO evaluation: - Config 1: $(M_g, N_g) = (1, 2)$; $\Theta_{mg,ng}=90°$; $\Omega_{0,1}=\Omega_{0,0}+180°$; $(d_{g,H}, d_{g,V})=(0,0)$

		- Config 2: $(M_g, N_g) = (1, 4)$; $\Theta_{mg,ng}$=90°; $\Omega_{0,1}=\Omega_{0,0}$+90°; $\Omega_{0,2}=\Omega_{0,0}$+180°; $\Omega_{0,3}=\Omega_{0,0}$+270°; $(d_{g,H}, d_{g,V})$=(0, 0) - Other configurations can have panel specific position offset (dgH, mg, ng, dgV, mg, ng). Note in this case the notation of (M_g, N_g) does not leads to rectangular shape. - UE orientation for mobile device $(\Omega_{0,0}, \Theta_{0,0})$=(U(0°,360°), 90°); UE orientation for customer premise equipment (CPE) can be optimized - Each antenna array has shape $d_H=d_V=0.5\lambda$ - Config 1 can be used with config a/b; Config 2 can be used with config c/d/e - Config a: (M, N, P) = (2, 4, 2), the polarization angles are 0 and 90 - Config b: (M, N, P) = (4, 4, 1) , the polarization angle for even panel is 0° and for odd panel is 90° - Config c: (M, N, P) = (2, 2, 2), the polarization angles are 0° and 90° - Config d: (M, N, P) = (2, 4, 1) , the polarization angle for even panel is 0° and for odd panel is 90° - Config e: (M, N, P) = (1, 4, 2), the polarization angles are 0° and 90° - The antenna elements of the same polarization of the same panel is virtualized into one TXRU - Note: The channel coefficients for each UE panel can be generated using spatial channel model
BS antenna element gain pattern	According to TR36.873	See Table A.2.1-6 and Table A.2.1-7
UE antenna element gain pattern	Omnidirectional	See Table A.2.1-8
Others	TXRUs within a panel can be assumed to be synchronized and phase-calibrated (at least to the same level as in LTE). It should be possible as one option to assume QCL between ports of two different panels of the same transmission points Distances $(d_{g,H}, d_{g,V})$ between panels should be limited. NR evaluations consider both cases of phase-calibration and no phase-calibration between panels: - Phase offset of non-calibrated panel (either TRP or UE side) is modeled as a uniform distributed random variable between $(-\pi,\pi)$. - Adopt the accumulated phase offset of non-calibrated panel pair in channel coefficients equation (7.21) and (7.26) in TR 38.901 [15].	

Table A.2.1-5: Antenna configurations for high speed train, urban grid for eV2X, and highway for eV2X

	High Speed Train	Urban grid for eV2X	Highway for eV2X
TXRU mapping	-	-	-
Number of BS antenna elements across all panels	For Option 2 Alt. 2 in Table A.2.1-2 Relay: Up to 256 Tx /Rx antenna elements Note: The antenna of the relay for RRH-to-Relay is located outside of a train RRH: Up to 256 Tx /Rx antenna elements Note: The above values are shown in TR 38.913	Macro BS: Up to 256 TX/RX antenna elements BS-type-RSU: Up to 8 TX/RX antenna elements	Macro BS: Up to 256 TX/RX antenna elements BS-type-RSU: Up to 8 TX/RX antenna elements
Number of UE antenna elements		Vehicle/pedestrian UE: Up to 8 TX/RX antenna elements UE-type RSU: Up to 8 TX/RX antenna elements	Vehicle/pedestrian UE: Up to 8 TX/RX antenna elements. UE-type RSU: Up to 8 TX/RX antenna elements
BS (M, N, P, M_g, N_g) BS (d_H,d_V,$d_{H,g}$,$d_{V,g}$)	The baseline BS antenna configuration at 4GHz in high speed train scenario is (M, N, P, M_g, N_g) =(8, 8, 2, 1, 1), where the radiation pattern of antenna elements follows TR 36.873 according to the current agreements. Other antenna configurations are not precluded. For Option 2 Alt. 2 in Table A.2.1-2 RRH: d_H = d_V = 0.5 - For unidirectional beam: (M, N, P, M_g, N_g) = (8, 16, 2, 1, 1), Other configurations such as (8, 8, 2, 1, 1) or (4, 8, 2, 2, 2) with $d_{g,H}$ =8.0, $d_{g,V}$ =4.0 are not precluded for unidirectional beam - For bidirectional beam: (M, N, P, M_g, N_g) = (4, 8, 2, 2, 2) with $d_{g,H}$ =8.0, $d_{g,V}$ =4.0 Relay: d_H = d_V = 0.5 - For unidirectional beam: (M, N, P, M_g, N_g) = (8, 16, 2, 1, 1), Other configurations such as (8, 8, 2, 1, 1) or (4, 8, 2, 2, 2) with $d_{g,H}$ =8.0, $d_{g,V}$ =4.0 are not precluded for unidirectional beam - For bidirectional beam: (M, N, P, M_g, N_g) = (4, 8, 2, 2, 2) with $d_{g,H}$ =8.0, $d_{g,V}$ =4.0		
UE antenna model parameters			
BS antenna element gain pattern	See Table A.2.1-10	Macro BS: Follow the modeling of TR 36.873 BS-type RSU: Follow the modeling of TR 36.873 Note: Further study if needed, e.g., vertical beamforming, vehicle-to-vehicle channel.	Macro BS: Follow the modeling of TR 36.873 BS-type RSU: Follow the modeling of TR 36.873 Note: Further study if needed, e.g., vertical beamforming effect, vehicle-to-vehicle channel.
UE antenna element gain pattern	See Table A.2.1-10	Vehicle/pedestrian UE: Half spherically uniform distribution with upper direction UE-type-RSU: Half	Vehicle/pedestrian UE: Half spherically uniform distribution with upper direction UE-type-RSU: Half

		spherically uniform distribution with bottom direction Note: directional antenna pattern is not precluded Note: uniform antenna models should be used for 2-D channel models	spherically uniform distribution with bottom direction Note: directional antenna pattern is not precluded Note: uniform antenna models should be used for 2-D channel models
Number of TXRUs			
Others	TXRUs within a panel can be assumed to be synchronized and phase-calibrated (at least to the same level as in LTE). It should be possible as one option to assume QCL between ports of two different panels of the same transmission points Distances ($d_{g,H}$, $d_{g,V}$) between panels should be limited. NR evaluations consider both cases of phase-calibration and no phase-calibration between panels Phase offset of non-calibrated panel (either TRP or UE side) is modeled as a uniform distributed random variable between (–π, π). Adopt the accumulated phase offset of non-calibrated panel pair in channel coefficients equation (7.21) and (7.26) in TR 38.901 [15].		

Table A.2.1-6: 3-Sector BS antenna radiation pattern for above 6GHz

Parameter	Values
Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right\}, \theta_{3dB} = 65^0, SLA_V = 30$
Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left\{12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right\}, \varphi_{3dB} = 65^0, A_m = 30$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	8dBi

Table A.2.1-7: Indoor BS antenna radiation pattern for above 6GHz

Parameter		Values
Single sector	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right\}, \theta_{3dB} = 65^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = 0$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = A_{E,V}(\theta'')$
	Maximum directional gain of an antenna element $G_{E,max}$	5dBi
3-sector	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right\}, \theta_{3dB} = 65^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left\{12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right\}, \varphi_{3dB} = 65^0, A_m = 25$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
	Maximum directional gain of an antenna element $G_{E,max}$	8dBi
	Electric tilting	110 degree
Wall-mount	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right\}, \theta_{3dB} = 90^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left\{12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right\}, \varphi_{3dB} = 90^0, A_m = 25$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
	Maximum directional gain of an antenna element $G_{E,max}$	5dBi
Ceiling-mount	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right\}, \theta_{3dB} = 130^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left\{12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right\}, \varphi_{3dB} = 130^0, A_m = 25$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
	Maximum directional gain of an antenna element $G_{E,max}$	5dBi
	Electric tilting	

Table A.2.1-8: UE antenna radiation pattern model 1

Parameter	Values
Antenna element radiation pattern in θ'' dim (dB)	$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta'' - 90^0}{\theta_{3dB}}\right)^2, SLA_V\right\}, \theta_{3dB} = 90^0, SLA_V = 25$
Antenna element radiation pattern in φ'' dim (dB)	$A_{E,H}(\varphi'') = -\min\left\{12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right\}, \varphi_{3dB} = 90^0, A_m = 25$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	5dBi

Note: (θ'',φ'') are in local coordinate system.

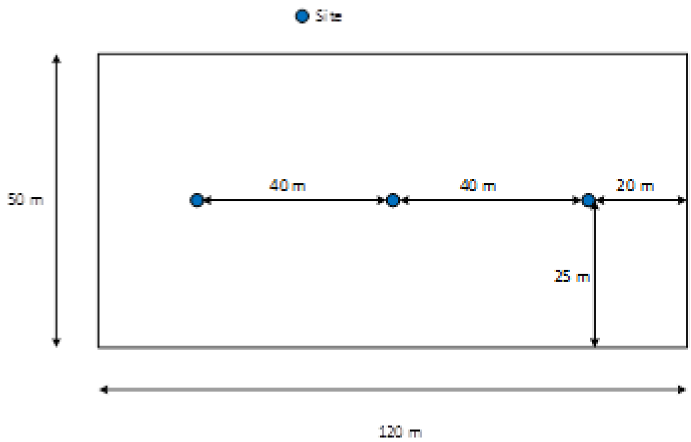


Figure A.2.1-1: Indoor hotspot 3-site deployment.

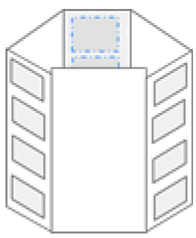
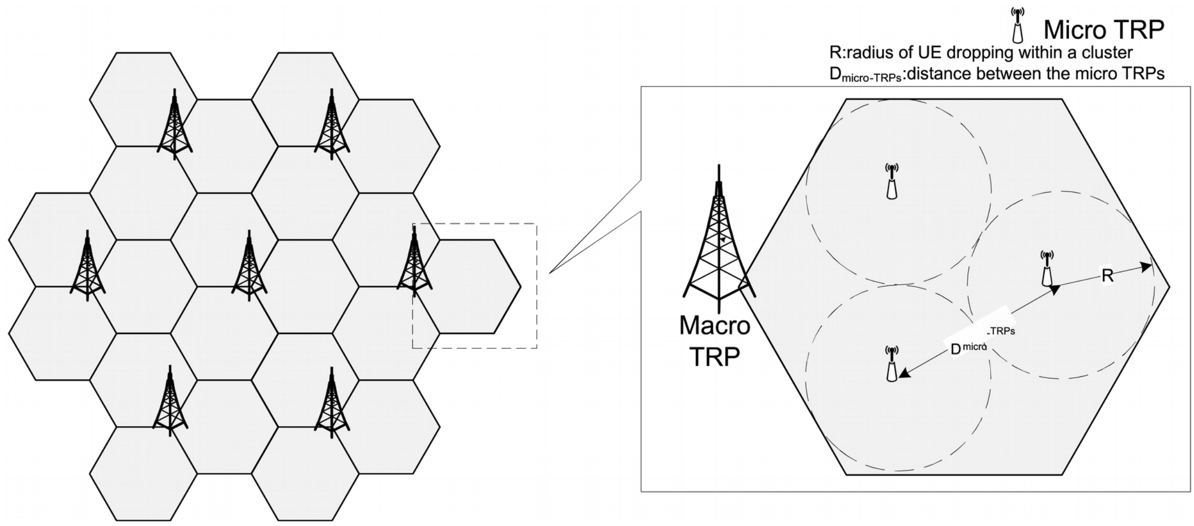
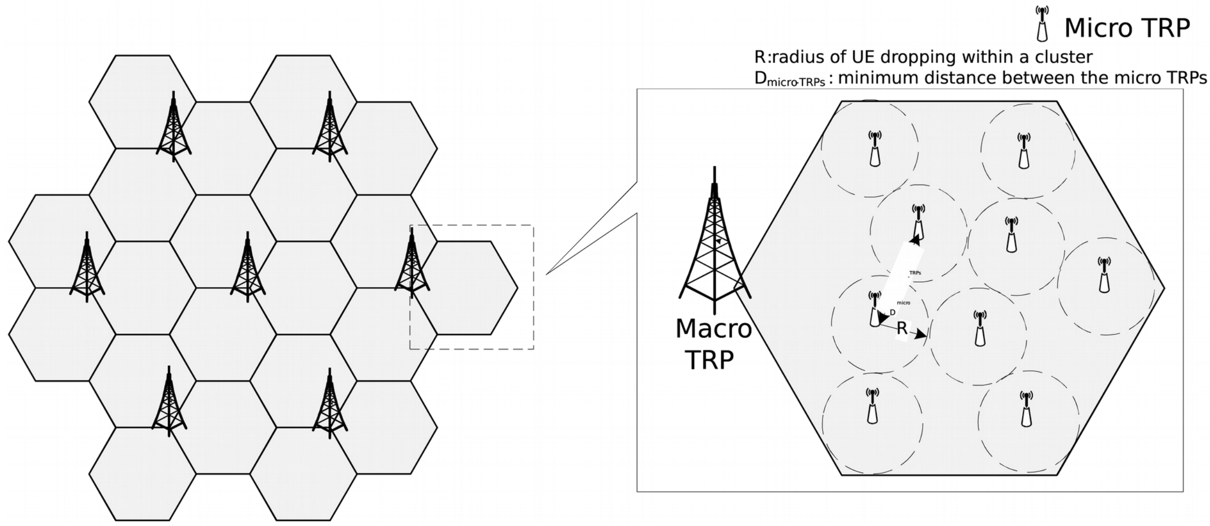


Figure A.2.1-2: Three sector antenna placement.



NOTE: Micro TRPs refers to micro TRP centers

Figure A.2.1-3: Cell layout for dense urban (3 Micro TRPs per Macro TRP)



NOTE: Micro TRPs refers to micro TRP centers

Figure A.2.1-4: Cell layout for dense urban (9 Micro TRPs per Macro TRP)

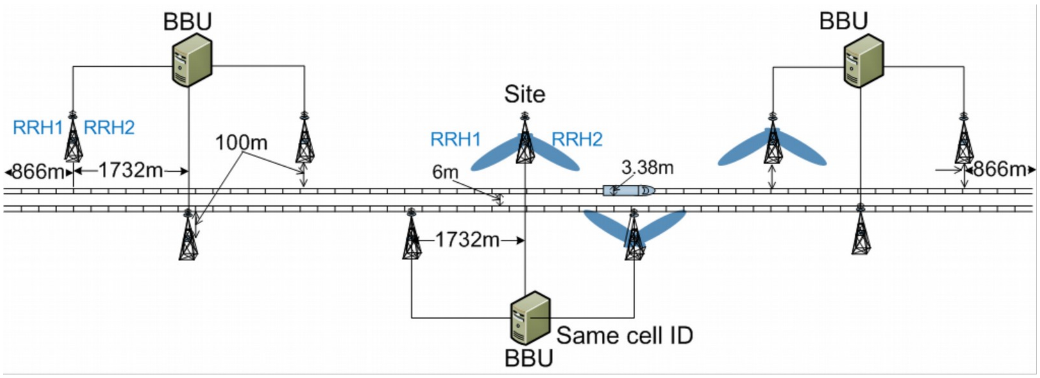
Table A.2.1-9: Minimum distance between TRPs and UE cluster radius

(a) Option 1

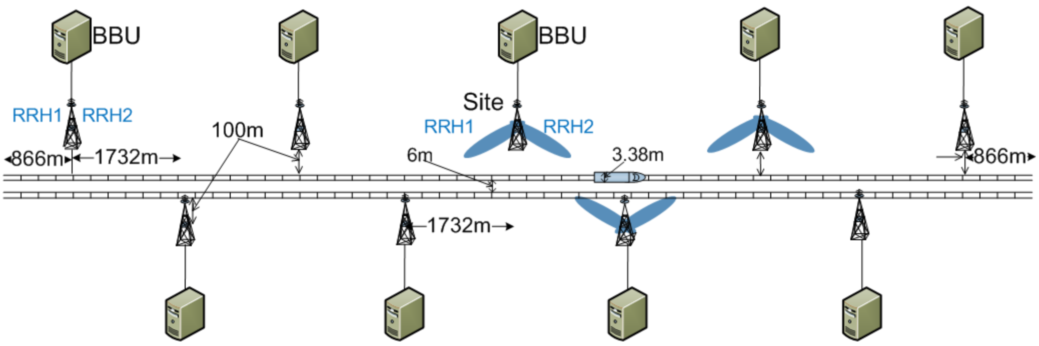
Number of the micro TRPs per macro TRP	Minimum distance between Micro TRP centers (m)	Radius of UE dropping within a cluster: R (m)
3	57.9	<28.9
6	42.4	<21.2
9	32	<16

(b) Option 2

Number of the micro TRPs per macro TRP	Minimum distance between Micro TRP centers (m)	Radius of UE dropping within a cluster: R (m)
3	40	50
6	32	50
9	25	50

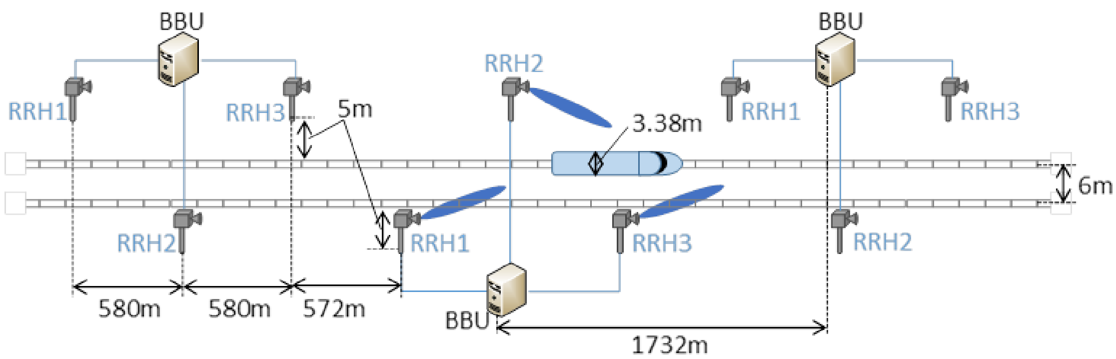


(a) SFN model

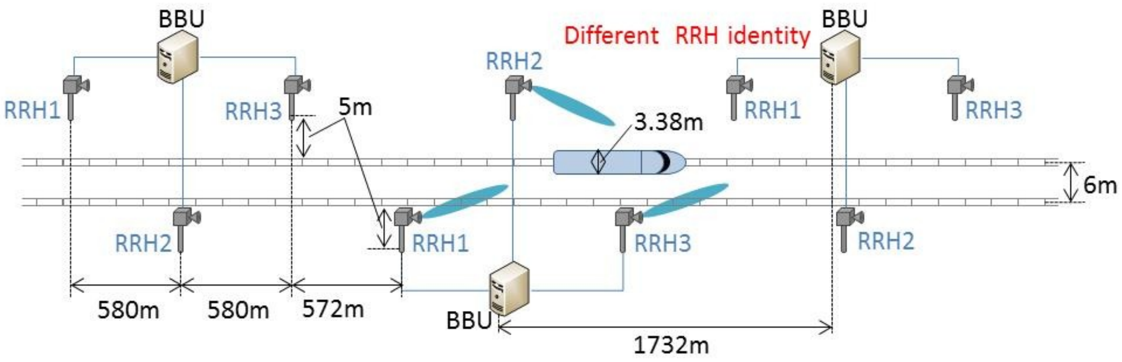


(b) Non-SFN model

Figure A.2.1-5: Cell layout for High Speed Train (4GHz)



(a) SFN model



(b) Non-SFN model

Figure A.2.1-6: Cell layout for High Speed Train (30 GHz)

Table A.2.1-10: RRH and Relay antenna radiation pattern for high speed train option 2, alt. 2

Parameter		Values
Antenna element vertical radiation pattern (dB)	RRH	$A_{E,V}(\theta'') = -min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 65^0, SLA_V = 30$
	Relay	$A_{E,V}(\theta'') = -min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 65^0, SLA_V = 30$
	Relay (Optional)	$A_{E,V}(\theta'') = -min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 90^0, SLA_V = 25$
Antenna element horizontal radiation pattern (dB)	RRH	$A_{E,H}(\varphi'') = -min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 65^0, A_m = 30$
	Relay	$A_{E,H}(\varphi'') = -min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 65^0, A_m = 30$
	Relay (Optional)	$A_{E,H}(\varphi'') = -min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 90^0, A_m = 25$
Combining method for 3D antenna element pattern (dB)	RRH	$A''(\theta'', \varphi'') = -min\{-[A_{E,V}(\theta'') + A_{E,H}(\varphi'')], A_m\}$
	Relay	$A''(\theta'', \varphi'') = -min\{-[A_{E,V}(\theta'') + A_{E,H}(\varphi'')], A_m\}$
	Relay (Optional)	$A''(\theta'', \varphi'') = -min\{-[A_{E,V}(\theta'') + A_{E,H}(\varphi'')], A_m\}$
Maximum directional gain of an antenna element $G_{E,max}$	RRH	8dBi
	Relay	8dBi
	Relay (Optional)	5dBi

The system level evaluation parameters specific to flexible duplex evaluation which are not covered by Table A.2.1-1are given in Table A.2.1-11.

Table A.2.1-11: Evaluation parameters specific to flexible duplex

Parameters	Dense urban	Urban macro	Indoor hotspot
Inter-BS distance	Macro-to-macro: 200m Macro-to-micro: 105m [TR36.897] Micro-to-micro: 57.9m	500m	20m
Minimum BS-UE (2D) distance	Macro-to-UE: 35m [TR36.897] Micro-to-UE: 10m [TR36.897]	35m [TR36.897]	0m [TR 38.901 [15]]
Minimum UE-UE (2D) distance	3m [TR36.843]		
Carrier frequency	Macro layer: 4 GHz, 30 GHz [TR38.913] Micro layer: 4 GHz, 30 GHz	2GHz [TR38.913], 4 GHz, 30 GHz	4 GHz, 30 GHz
	For 30GHz: Un-paired spectrum is preferred. For 2GHz: paired spectrum is preferred. For 4GHz: both paired and un-paired spectrum can be considered.		
Aggregated system bandwidth	4GHz: Up to 200MHz (DL+UL) 30GHz: Up to1GHz (DL+UL)	2GHz: Up to 40 MHz (DL+UL) 4GHz: Up to 200 MHz (DL+UL) 30GHz: Up to 1GHz (DL+UL)	4GHz: Up to 200MHz (DL+UL) 30GHz: Up to 1GHz (DL+UL)
Simulation bandwidth	20MHz per CC below 6GHz and 80 MHz per CC above 6GHz Note: For FDD, simulation BW is split equally between UL and DL Note: UE TX power scaling will impact final results		
Large-scale channel parameters(*)	Below 6GHz: - Macro-to-UE: 3D UMa - Micro-to-UE: 3D UMi - Macro-to-Macro: 3D UMa (h_{UE} =25m) - Macro-to-Micro: 3D UMa (h_{UE} =10m) - Micro-to-Micro: 3D UMi (h_{UE} =10m) - UE-to-UE: A.2.1.2 in TR36.843(***), penetration loss between UEs follows Table A.2.1-13 Above 6GHz: - Macro-to-UE: 5GCM UMa - Micro-to-UE: UMi-Street canyon - Macro-to-Macro: 5GCM UMa (h_{UE} =25m) - Macro-to-Micro: 5GCM UMa (h_{UE} =10m) - Micro-to-Micro: UMi-Street canyon (h_{UE} =10m) - UE-to-UE: UMi-Street canyon (h_{BS} =1.5m ~ 22.5m), penetration loss between UEs follows Table A.2.1-12		Below 6GHz: - TRP-to-UE: ITU InH - TRP-to-TRP: ITU InH (h_{UE} =3m) - UE-to-UE: A.2.1.2 in TR36.843 (***) Above 6GHz: - TRP-to-UE: 5GCM Indoor-office - TRP-to-TRP: 5GCM Indoor-office (h_{UE} =3m) - UE-to-UE: 5GCM Indoor-office (h_{BS} =1.5m)
Fast fading parameters(*)	Below 6GHz: - Macro-to-UE: 3D UMa - Micro-to-UE: 3D UMi - Macro to Macro: 3D UMa O-to-O (h_{UE} =25m); ASA and ZSA statistics(**) updated to be the same as ASD and ZSD; ZoD offset = 0 - Macro to Micro: 3D UMa O-to-O - Micro to Micro: 3D UMi O-to-O (h_{UE} =10m); ASA and ZSA statistics updated to be the same as ASD and ZSD; ZoD offset = 0 - UE to UE: InH for indoor to indoor, and 3D UMi for other cases. ASD and ZSD statistics updated to be the same as ASA and ZSA. Dual mobility support. Above 6GHz: - Macro-to-UE: 5GCM UMa - Micro-to-UE: UMi-Street canyon - Macro to macro: 5GCM UMa O-to-O (h_{UE} =25m); ASA and ZSA statistics updated to be the same as ASD and ZSD; ZoD offset = 0 - Macro to micro: 5GCM UMa O-to-O - Micro to Micro: UMi-Street canyon O-to-O (h_{UE} =10m); ASA and ZSA statistics updated to be the same as ASD and ZSD; ZoD offset = 0 - UE to UE: UMi-Street canyon; ASD and ZSD statistics updated to be the same as ASA and ZSA. Dual mobility support.		Below 6GHz: - TRP-to-UE: ITU InH - TRP-to-TRP: ITU InH (h_{UE} =3m), ASA statistics updated to be the same as ASD - UE-to-UE: A.2.1.2 in TR36.843 (ITU InH), ASD statistics updated to be the same as ASA. Above 6GHz: - TRP-to-UE: 5GCM Indoor-office - TRP-to-TRP: 5GCM Indoor-office (h_{UE} =3m), ASA and ZSA statistics(**) updated to be the same as ASD and ZSD - UE-to-UE: 5GCM Indoor-office (h_{BS} =1.5m), ASD and ZSD statistics updated to be the same as ASA and ZSA

Traffic model	Baseline: - FTP traffic model 3 with packet size 0.1, 0.5 and 2.0Mbytes - Ratio of DL/UL traffic = {2:1}, {4:1} and {1: 1} for optional [TR36.828]		
UE distribution	For FTP traffic model 3: 2/3 users randomly and uniformly dropped within the clusters, 1/3 users randomly and uniformly dropped throughout the macro geographical area, and 60 users per macro geographical area	For FTP traffic model 3: 10 users per macro TRP	For FTP traffic model 3: 10 users per TRP
Delay assumption	Companies to report the delay assumption used for coordination schemes if used in the simulations (delay assumption depends on RAN3 architecture discussion)		
(*): The assumption is used as starting point for flexible duplex evaluation, and further update might be made. (**): Statistics of ASA/ASD and ZSA/ZSD include its mean, standard variance, correlation distance in the horizontal plane, and in-cluster angular spread (e.g., cluster ASA/ASD). (***): For outdoor to indoor case, and indoor to indoor case, use "Remaining Layout Options" in A.2.1.2 of TR36.843 for pathloss calculation, and "ITU-R IMT UMi" for LOS Probability derivation. For outdoor to indoor case, the penetration loss term "20.0+0.5* d_{in}" is excluded in pathloss formula given in A.2.1.2 of TR36.843, and the penetration loss is derived according to Table A.2.1-13.			

Table A.2.1-12: Penetration loss for UE-to-UE link for 30GHz specific to flexible duplex

Location of UE_x	Location of UE_y	Sub-scenario	Penetration loss (for around 30GHz)
Indoor	Indoor	In different building (if inter-user 2D distance > 50m)	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = PL_{tw}^{(i)} + PL_{in}^{(i)} + N^{(i)}(0, \sigma_P{}^2)$ is the building penetration loss as given by subclause 7.4.3 in TR 38.901 [15]. *i*=*x*, *y*
		In the same building (if inter-user 2D distance ≤ 50m)	$PLoss = \left\|n_x - n_y\right\| \cdot L_{\mathrm{concrete}}$ where L_{concrete} is given by Table 7.4.3-1 in TR 38.901 [15], and n_i is the floor number for UE_i, *i*=*x*, *y*.
Indoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = PL_{tw}^{(x)} + PL_{in}^{(x)} + N^{(x)}(0, \sigma_P{}^2)$ is the building penetration loss as given by subclause 7.4.3 in TR 38.901 [15]. $PLoss_y = N^{(y)}(\mu, \sigma_P{}^2)$ is the car penetration loss as given by subclause 7.4.3 in TR 38.901 [15].
Outdoor	Indoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = N^{(x)}(\mu, \sigma_P{}^2)$ is the car penetration loss as given by subclause 7.4.3 in TR 38.901 [15]. $PLoss_y = PL_{tw}^{(y)} + PL_{in}^{(y)} + N^{(y)}(0, \sigma_P{}^2)$ is the building penetration loss as given by subclause 7.4.3 in TR 38.901 [15].
Outdoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = N^{(i)}(\mu, \sigma_P{}^2)$ is the car penetration loss as given by subclause 7.4.3 in TR 38.901 [15]. *i*=*x*, *y*

Note: The assumption is used as starting point for flexible duplex evaluation, and further update might be made.

Table A.2.1-13: Penetration loss for UE-to-UE link for 4GHz and 2GHz specific to flexible duplex

Location of UE_x	Location of UE_y	Sub-scenario	Penetration loss (for around 4GHz and 2GHz)
Indoor	Indoor	In different building (if inter-user 2D distance > 50m)	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = PL_{tw} + 0.5d_{in}^{(i)}$ where PL_{tw}=20dB, and $d_{in}^{(i)} \sim U(0,25)$ in meter TR 36.814 is the distance from user to internal wall, *i*=*x*, *y*, and *U(a,b)* indicates uniform distribution.
		In the same building (if inter-user 2D distance ≤ 50m)	$PLoss = 18.3dB$ for UEs on different floors TR 36.872; otherwise 0dB.
Indoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = PL_{tw} + 0.5d_{in}^{(x)}$ with PL_{tw}=20dB and $d_{in}^{(i)} \sim U(0,25)$ in meter is the building penetration loss as given by TR 36.814. $PLoss_y = N^{(y)}(\mu, \sigma_P{}^2)$ is the car penetration loss as given by subclause 7.4.3 in TR 38.901 [15].
Outdoor	Indoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = N^{(x)}(\mu, \sigma_P{}^2)$ is the car penetration loss as given by subclause 7.4.3 in TR 38.901 [15]. $PLoss_y = PL_{tw} + 0.5d_{in}^{(y)}$ with PL_{tw}=20dB and $d_{in}^{(i)} \sim U(0,25)$ in meter is the building penetration loss as given by TR 36.814.
Outdoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = N^{(i)}(\mu, \sigma_P{}^2)$ is the car penetration loss as given by subclause 7.4.3 in TR 38.901 [15]. *i*=*x*, *y*

Note: The assumption is used as starting point for flexible duplex evaluation, and further update might be made.

A.2.2 Simulation assumption for evaluation of multiple access scheme

This subclause describes the system level evaluation assumptions in order to assess multiple access schemes. The system level evaluation assumptions for multiple access schemes are provided in Table A.2.2-1. Table A.2.2-2 provides UL traffic model for mMTC which is only applied to multiple access evaluation.

Table A.2.2-1: Evaluation assumptions for multiple access schemes targeting eMBB

Parameters	Dense urban (eMBB)	Rural
Layout	Signal layer Two layers not precluded	Single layer Macro layer: Hex. Grid
Inter-BS distance	Macro layer: 200m	1732m
Carrier frequency	4 GHz for the single layer	700MHz
BS antenna configuration	4, 8, 16, 32 TXRUs	2, 4, 8 ports
BS scheduler	Both subband and wideband scheduler can be considered	
UE antenna configuration	2, 1 TXUs 2, 4 RXUs	2Tx, 1Tx port 2Rx, 4Rx ports
Traffic model	Full buffer model for spectral efficiency FTP model 1/3 for user experienced data rate NOTE: full buffer evaluation is not used for technical scheme down selection	
Traffic load (Resource utilization)	50%, 80% 25% (optional)	
UE density for full buffer model	10 UE per TRP 20 or other values are not precluded	10 UE per TRP other values are not precluded

Table A.2.2-2: UL traffic model for mMTC applied to multiple access evaluation

Parameters	Values/assumptions
Data packet arrival rate per UE	Poisson arrival with arrival rate λ
Number of UEs per cell	Companies report the number of UEs per cell and companies are encouraged to report λ to achieve the connection density target.
Packet size	Option 1: Follow TR45.820 Option 2: Fix 40 Bytes
Simulation Bandwidth	Companies report the simulation bandwidth
Target packet drop rate	0.01
Packet dropping timer	Baseline: 1s, 10s Other values are not precluded.

A.2.3 Simulation assumption related to initial access

This subclause describes the simulation assumptions for evaluating initial access. Table A.2.3-1 shows the evaluation assumption for synchronization signal related to initial access.

Table A.2.3-1: Simulation assumptions for synchronization signals/channels

	Below 6GHz	Above 6GHz
Scenario	Urban Macro (ISD = 500m), Macro only scenario in dense urban (ISD = 200m)	
Carrier Frequency	4 GHz	30, 70 GHz
Channel Model	TR 36.873	TR 38.901 [15]
UE dropping	According to TR 36.873 (one or two cellular tiers) Note: Company reports which value for the number (i.e., 1 or 2) of cellular tiers to choose for the evaluation	
Subcarrier Spacing(s)	15, 30, 60, 120, 240, or 480 kHz (to be clarified by each proponent; other values are not precluded)	
Network Synchronization	TRPs are synchronized, propagation delay difference between TRPs is modelled based on the free space assumption.	
Search window	The time window to search (correlate) NR-PSS. It depends on the periodicity of NR-SS transmission. The value needs to be provided by each proponent	
Antenna Configuration at the TRP	(8, 1, 2) with directional antenna element (HPBW=65 degrees, directivity 8 dBi)	(4, 8, 2), with directional antenna element (HPBW=65 degrees , directivity 8 dBi)
Antenna Configuration at the UE	(1, 1, 2) with omni-directional antenna element	(2, 4, 2), with directional antenna element (HPBW=90 degrees , directivity 5 dBi)
Antenna port virtualization	Clarified by each proponent in simulation assumptions (e.g. the beamforming method, beam directions, number of beams)	

Frequency Offset	- Initial acquisition
	  - TRP: uniform distribution +/- 0.05 ppm
	  - UE: uniform distribution +/- 5, 10, 20 ppm (each company to choose one)
	- Non-initial acquisition
	  - TRP: uniform distribution +/- 0.05 ppm
	  - UE: uniform distribution +/- 0.1 ppm	

PHY Abstraction	No PHY Abstraction. All the links shall be explicitly implemented in the system level platform. Note: Proponents are allowed to provide PHY abstraction details if used	

Tables A.2.3-2 to A.2.3.4 provide the evaluation assumption for evaluation of DL and UL mobility for dense urban, rural and high-speed train scenarios, respectively. Only the parameters which are different from Table A.2.1-1 and Table A.2.1-2 are provided. For dense urban, a UE speed of up to 60km/h is considered for macro-only evaluation while a UE speed of up to 30km/h is considered for dual layer evaluation.

Table A.2.3-2: Simulation assumptions for DL and UL mobility (Dense urban)

Parameters	Values or assumptions
Layout	Two layer Macro layer: Hex. Grid Micro layer: Random drop 9 micro BSs per macro BS
Carrier frequency	4 GHz
BS antenna configurations	(8, 1, 2) with directional antenna element (HPBW=65°, directivity 8 dBi) other values are not precluded
UE distribution	10 users per macro TRP, 10 users per micro TRP 100% outdoor,30km/h (baseline), 3, 60 km/h (optional) Simultaneous UEs within a slot UE location/movement direction randomly chosen

Table A.2.3-3: Simulation assumptions for DL and UL mobility (Rural)

Parameters	Values or assumptions
Carrier frequency	4GHz
Channel model	3D UMa
BS antenna configurations	(8, 1, 2) with directional antenna element (HPBW=65°, directivity 8 dBi) other values are not precluded

UE distribution	Outdoor vehicles 120km/h 10 UEs per TRPs UE location/movement direction randomly chosen

Table A.2.3-4: Simulation assumptions for DL and UL mobility (High-speed train)

Parameters	Values or assumptions
BS antenna configurations	(8, 1, 2) with directional antenna element (HPBW=65°, directivity 8 dBi) other values are not precluded
UE distribution	1000 UEs per train and 30% active UEs 100% of users in train at 480 km/h Each company should open how to model network configuration

A.2.4 Simulation assumption for URLLC

This subclause describes the simulation assumptions for evaluating the aspects related to URLLC. Indoor Hotspot and Urban Macro scenario are considered. Table A.2.4-1 shows the evaluation assumptions where URLLC as well as eMBB traffic models are taken into account.

Table A.2.4-1: Simulation assumptions for URLLC

Parameters	Urban Macro	Indoor Hotspot
Layout	Single layer Macro layer: Hexagonal Grid	Single-layer Indoor floor: (3, 6, 12) BSs per 120 m x 50 m
Inter-BS distance	500 m	Follow TRP placement from 38.802
Carrier frequency	4 GHz	4 GHz
Aggregated system bandwidth	4 GHz: Up to 200 MHz (DL+UL)	4 GHz: Up to 200 MHz (DL+UL)
Simulation bandwidth	20 MHz per CC below 6 GHz Note: For FDD, simulation BW is split equally between UL and DL Other bandwidths are not precluded	
Channel model	36.873 3D UMa	Below 6 GHz: ITU InH Note: When 5GCM is found to be applicable to below 6 GHz, 5GCM should be used
BS Tx power	46 dBm per 20 MHz	24 dBm per 20 MHz
UE Tx power	23 dBm	
BS antenna configurations	See 38.802, table A.2.1-4.	
BS antenna height	25 m	3 m
BS antenna element gain + connector loss	See 38.802, table A.2.1-4.	
BS receiver noise figure	Below 6 GHz: 5 dB	
UE antenna configurations	See 38.802, table A.2.1-4.	
UE antenna height	Follow the modelling of TR 36.873	
UE antenna gain	Follow the modelling of TR 36.873	
UE receiver noise figure	9 dB	
Traffic model	Unidirectional and bidirectional (DL or UL). URLLC: Both FTP Model 3 (with Poisson arrival) and periodic packet arrivals with packet size 32, 50, 200 bytes. eMBB: Option 1: Full buffer, Option 2: FTP model 3 with packet size, 0.1Mbytes and 0.5Mbytes	
Traffic load (Resource utilization)	URLLC: Packet arrival to achieve URLLC capacity eMBB: For FTP Model 3, arrival rate is selected to achieve RU of [20, 50] % for the case of no multiplexing with URLLC	
UE distribution	Follow Urban Macro user distribution for both URLLC and eMBB UEs 20% Outdoor in cars: 30 km/h, 80% Indoor: 3 km/h URLLC: 10 UE/sector eMBB: 0/10 UE/sector	Follow Indoor Hotspot user distribution for both URLLC and eMBB UEs 100% Indoor, 3 km/h URLLC: 10 UE/floor/TRP eMBB: 0/10 UE/floor/TRP

	Option 1 (DL only) Load only center 1 sector with 10 URLLCC and 0/10 eMBB Load other 56 sectors with 1 eMBB 1 eMBB UE in the other 56 sectors is of the same traffic model as the eMBB UEs in the center sector Option 2 Load all sectors with 10 URLLCC and 0/10 eMBB	
BS receiver	Reported by companies, Baseline is MMSE-IRC	
UE receiver	Reported by companies, Baseline is MMSE-IRC	
Feedback assumption & Link adaptation assumptions	Reported by companies	
Channel estimation	Reported by companies, Practical channel estimation	
Others	Companies report the assumption on admission control used	

A.2.5 Simulation assumption for Multi-antenna scheme

This subclause describes the simulation assumptions for evaluating multi-antenna scheme. For evaluating DR-RS, Table A.2.1-1 is used except that FTP traffic model is baseline and full-buffer traffic model is optional.

Table A.2.5-1 provides the evaluation assumptions for advanced receivers based on network coordination. The other parameters not covered by Table A.2.5-1 follow Table A.2.1-1.

Table A.2.5-1: Evaluation assumptions for advanced receivers based on network coordination

Parameters	Urban Macro	Dense urban (Single or Dual layer)	Indoor hotspot
Carrier frequency	4GHz	Macro layer: 4GHz Small cell layer: 4GHz (co-channel)	4GHz, 30GHz
TP antenna configuration (Optional parameters)	$(M, N, P, M_g, N_g) = (8,8,2,1,1)$ $(M, N, P, M_g, N_g) = (8,4,2,1,1)$ $(M, N, P, M_g, N_g) = (8,2,2,1,1)$ $(M, N, P, M_g, N_g) = (8,1,2,1,1)$ $(M, N, P, M_g, N_g) = (1,1,2,1,1)$ $(d_H, d_V) = (0.5, 0.8)\lambda$	$(M, N, P, M_g, N_g) = (8,8,2,1,1)$ $(M, N, P, M_g, N_g) = (8,4,2,1,1)$ $(M, N, P, M_g, N_g) = (8,2,2,1,1)$ $(M, N, P, M_g, N_g) = (8,1,2,1,1)$ $(M, N, P, M_g, N_g) = (1,1,2,1,1)$ $(d_H, d_V) = (0.5, 0.8)\lambda$	$(M, N, P, M_g, N_g) = (4,4,2,1,1)$ $(M, N, P, M_g, N_g) = (1,1,2,1,1)$ for 4GHz (4,8,2,1,1) for 30GHz
UE receiver	Baseline for calibration purpose : MMSE-IRC Advanced receiver : advanced receivers can be provided by each company		
Transmission scheme	closed-loop rank 1 and 2 SU-MIMO with rank adaptation, open-loop rank 1 and 2 SU-MIMO with rank adaptation (optional), other ranks are not precluded. MU-MIMO are not precluded		
Coordination cluster size for ideal backhaul	Provided by each company		
Coordinated TP measurement set size	Provided by each company		
Feedback assumption (Optional parameters)	Non-ideal CSI-RS/IMR channel/interference estimation (Number of CSI-RS ports = 16, 32 for $(M, N, P, M_g, N_g) = (8, 8, 2, 1, 1), (4, 4, 2, 1, 1), (4, 8, 2, 1, 1)$ Number of CSI-RS ports = 8 for $(M, N, P, M_g, N_g) = (8, 4, 2, 1, 1)$, Number of CSI-RS ports = 4 for $(M, N, P, M_g, N_g) = (8, 2, 2, 1, 1)$, Number of CSI-RS ports = 2 for $(M, N, P, M_g, N_g) = (8, 1, 2, 1, 1)$, Number of CSI-RS ports = 2 for $(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1)$)		
Feedback assumption	Non-ideal CSI-RS/IMR channel/interference estimation (# of CSI ports = 32)		
Traffic model	Non full buffer FTP traffic model 1/3, S = 0.1Mbytes (optional) or 0.5Mbytes		
Traffic load (Resource utilization)	20%, 40%, 60%, Optional 80%		
Backhaul link delay	0ms, 2ms (optional), 5ms, 50ms (optional). Other values are not precluded. Report by each company		
Coordination assumptions	Complexity of coordination / information exchange shall be taken into account		

Table A.2.5-2 provides the simulation assumptions for evaluating beam management.

Table A.2.5-2: Evaluation assumptions for beam management

Parameters	Values
Scenarios (Carrier Frequency)	Indoor hotspot :4 GHz, 30GHz; Urban macro: 4 GHz, 30GHz; Dense Urban: For 4 GHz: Evaluate macro layer For 30 GHz: Evaluate micro layer Note: other antenna configurations should be considered as well.
Mode	DL SU-MIMO/ MU-MIMO
Simulation bandwidth	4GHz: 20MHz (DL+UL) 30GHz: 80MHz.(DL+UL) or 40MHz.(DL+UL)
Subcarrier Spacing for data	For 4 GHz: 15kHz For 30 GHz: 120kHz, 60kHz (Other subcarrier spacings can be considered)
Channel Model	Following related assumption in TR 38.802
TXRU mapping to antenna elements	Companies explain the details of TXRU mapping to antenna elements. Notes: 30GHz: 2D DFT based beam per polarization as a baseline; 4GHz: 1D DFT per vertical dimension per polarization as baseline;
TXRU mapping weights	Companies explain the details of TXRU mapping weights.
Criteria for selection for serving TRP	Companies explain the details of criteria for selection for serving TRP.
Criteria for beam selection for serving TRP	Companies explain the details of criteria for beam selection for serving TRP.
Constraints for the range of selective beams per TRP sector	Companies explain what scheme is used
Scheduling algorithm	PF scheduler
Link adaptation	Based on CSI-RS.
Traffic Model	FTP model 1/3 with packet size 0.1 and 0.5Mbytes (other value is not precluded). Other traffic models including the full buffer are not precluded.
BS antenna configurations	For 4GHz: $(M, N, P, M_g, N_g) = (8, 8, 2, 1, 1)$ as baseline. $(d_V, d_H) = (0.8, 0.5)\ \lambda$. For 30GHz: $(M, N, P, M_g, N_g) = (4, 8, 2, 2, 2)$. $(d_V, d_H) = (0.5, 0.5)\ \lambda$. $(d_{g,V}, d_{g,H}) = (2.0, 4.0)\ \lambda$ Note: important to consider also other antenna configurations to maintain flexibility
BS antenna element radiation pattern	For 4GHz: According to TR36.873 For 30 GHz: According to TR38.802
UE antenna configurations	For 4GHz: $M_g = 1$, $N_g = 1$, $P = 2$, $(d_V, d_H) = (0.5, 0.5)\ \lambda$, MxNxP<=8 (companies report M,N) For 30GHz: $(M, N, P, M_g,N_g) = (2, 4, 2, 1, 2)$; $(d_V, d_H) = (0.5, 0.5)\ \lambda$. $(d_{g,V}, d_{g,H}) = (0, 0)\ \lambda$. $*\Theta_{mg,ng}=90°$; $\Omega_{0,1}=\Omega_{0,0}+180°$; Note: important to consider also other antenna configurations to maintain flexibility
UE antenna element radiation pattern	For 4GHz: Omni-directional with 5dBi gain For 30GHz: See Table A.2.1-8 in TR 38.802
Inter-panel calibration	Ideal, non-ideal following 38.802 (optional)
Beam correspondence	Companies report details of the assumptions
Control and RS overhead	Companies report details of the assumptions
Control channel decoding	Ideal or Non-ideal (Companies explain how is modeled)
UE receiver type	MMSE-IRC as the baseline, other advanced receiver is not precluded
BF scheme	Companies explain what scheme is used
Transmission scheme	Multi-antenna port transmission schemes Note: Companies explain details of the using transmission scheme.
UE mobility feature	Follow Phase 3 calibration i.e. Add-on features including UE mobility, rotation, blockage, etc. can be considered. Note: Companies explain whether or which model is used in simulation evaluation. If used, the configuration details should be explained
MCS	Use LTE MCS
Metric	Spectral efficiency (evaluated under full buffer) 5%,50% UPT(evaluated under FTP model)

	Outage Beam management latency Proponents are encouraged to provide additional observations on beam failure rate, SINR and RSRP.

A.3 Evaluation results

A.3.1 Evaluation results for flexible duplexing

A.3.1.1 Indoor hotspot

Tables A.3.1.1-1 to A.3.1.1-9 provide the system level evaluation results for indoor hotspot scenario. In those tables, each source corresponds to the following references.

- Source 1: R1-1702837
- Source 2: R1-1702247
- Source 4: R1-1703509
- Source 5: R1-1701672
- Source 7: R1-1703770, R1-1704056
- Source 8: R1-1703301, R1-1703300

Table A.3.1.1-1: Evaluation results for indoor hotspot (source 1)

Source 1 (R1-1702837), Indoor hotspot													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
4:1 Low load	Static TDD	132	275	453	294	1	15.8	33.5	77	117	79.3	0.998	14.5
	Case 1-1	145 9.85%	292 6.18%	493 8.83%	317 7.82%	0.999	19.5	120 258.21%	297 285.71%	486 315.38%	308 288.40%	1	20.5
	Case 1-2	157 18.94%	326 18.55%	493 8.83%	335 13.95%	0.998	17.4	163 386.57%	311 303.90%	486 315.38%	328 313.62%	1	19
	Case 1-3	155 17.42%	289 5.09%	493 8.83%	314 6.80%	1	19.1	157 368.66%	317 311.69%	466 298.29%	321 304.79%	1	20.4
	Case 2-1	161 21.97%	342 24.36%	524 15.67%	358 21.77%	0.999	16.1	161 380.60%	342 344.16%	524 347.86%	349 340.10%	0.996	16
	Case 3-1	172 30.30%	365 32.73%	559 23.40%	376 27.89%	0.997	16.7	212 532.84%	342 344.16%	508 334.19%	358 351.45%	0.996	14.3
	Case 3-2	185 40.15%	377 37.09%	579 27.81%	388 31.97%	0.998	15.7	218 550.75%	342 344.16%	533 355.56%	366 361.54%	0.995	13.9
4:1 Medium load	Static TDD	88.1	215	425	225	0.998	28.9	28.1	71.1	125	74.6	0.983	26.5
	Case 1-1	90.2 2.38%	243 13.02%	486 14.35%	251 11.56%	0.996	34	70.5 150.89%	256 260.06%	453 262.40%	258 245.84%	0.995	31.9
	Case 1-2	86.9 -1.36%	236 9.77%	486 14.35%	249 10.67%	0.998	34.4	83.5 197.15%	271 281.15%	466 272.80%	271 263.27%	1	28.1
	Case 1-3	96.4 9.42%	240 11.63%	493 16.00%	253 12.44%	0.997	34.7	83.3 196.44%	258 262.87%	453 262.40%	264 253.89%	0.999	32.6
	Case 2-1	106 20.32%	264 22.79%	524 23.29%	274 21.78%	0.998	32.2	72.5 158.01%	284 299.44%	486 288.80%	287 284.72%	1	30.2
	Case 3-1	126 43.02%	292 35.81%	550 29.41%	308 36.89%	0.997	28	153 444.48%	326 358.51%	541 332.80%	341 357.10%	0.996	25.6
	Case 3-2	113 28.26%	280 30.23%	533 25.41%	292 29.78%	0.999	29.6	104 270.11%	311 337.41%	508 306.40%	313 319.57%	1	25.6
Note (interference mitigation/cancellation schemes, evaluation assumption, etc): - Interference mitigation schemes - At the transmitter, fixed analog beamforming and SVD precoding is applied. - At the receiver, MMSE-IRC receiver is applied. - Ideal channel estimation - FTP model 1 with 0.5Mbytes													

Table A.3.1.1-2: Evaluation results for indoor hotspot (source 2)

Source 2 (R1-1702247) Indoor Hotspot Scenario

Ratio of DL/UL traffic	Feature	DL UPT (Mbps)					UL UPT (Mbps)					served packet including late arrival packets (%)**	served packet without late arrival packets (%)**
		5%-tile	50%-tile	95%-tile	Average	RU (%)	5%-tile	50%-tile	95%-tile	Average	RU (%)		
2:1 (DL λ=0.25)	Scheme 1	37.76	45.22	49.42	44.33	3.49	29.41	41.58	46.32	40.36	1.68	88	100
	Scheme 1a*	45.31	54.26	59.30	53.20		35.29	49.90	55.58	48.43			
	Scheme 2	7.21	41.84	48.01	38.28	4.23	0.43	35.07	44.25	29.50	2.01	85	100
	Gain$_{1over2}$(%)	423.7	8.08	2.94	15.80		6740	18.56	4.68	36.81			
	Gain$_{1aover2}$(%)	528.4	29.68	23.52	38.98		8107	42.29	25.60	64.17			
1:1 (DL λ=0.5)	Scheme 1	26.32	39.26	46.18	38.44	7.25	24.19	35.65	42.64	34.92	7.27	90	100
	Scheme 1a*	31.59	47.11	55.41	46.13		29.03	42.78	51.17	41.90			
	Scheme 2	5.79	32.63	42.65	28.94	9.13	1.08	17.35	37.50	17.71	8.84	84	100
	Gain$_{1over2}$(%)	354.6	20.32	8.28	32.83		123.98	105.5	13.71	97.18			
	Gain$_{1aover2}$(%)	445.6	44.38	29.92	59.40		168.80	146.6	36.45	136.6			
2:1 (DL λ=0.5)	Scheme 1	26.58	41.85	47.92	40.46	7.15	25.75	38.37	46.31	37.85	3.48	87	100
	Scheme 1a*	31.89	50.23	57.51	48.56		30.89	46.05	55.57	45.42			
	Scheme 2	6.43	38.19	45.69	34.62	8.85	0.40	24.00	43.24	22.60	4.19	83	100
	Scheme 3	17.61	36.65	40.84	34.87	7.13	12.56	16.26	18.95	16.16	3.46	87	100
	Gain$_{1over2}$(%)	313.4	9.58	4.88	16.87		6338	59.87	7.10	67.48			
	Gain$_{1aover2}$(%)	356.0	31.53	25.87	40.27		7623	91.88	28.46	101.0			
	Gain$_{1aover3}$(%)	50.94	14.19	17.34	16.03		105.0	136.0	144.4	134.2			
1:1 (DL λ=1)	Scheme 1	14.12	29.84	39.60	29.15	15.66	11.98	26.10	36.38	25.32	16.19	89	100
	Scheme 1a*	16.94	35.81	47.52	34.98		14.38	31.31	43.66	30.38			
	Scheme 2	1.94	14.70	32.97	15.91	21.06	1.07	6.05	25.13	9.16	20.47	80	100
	Gain$_{1over2}$(%)	627.8	103.0	20.11	83.22		1020	331.4	44.77	176.4			
	Gain$_{1aover2}$(%)	773.2	143.6	44.13	119.9		1244	617.5	73.74	231.7			
2:1 (DL λ=1)	Scheme 1	14.76	34.41	43.53	33.13	15.11	14.18	31.98	44.39	30.67	7.52	86	100
	Scheme 1a*	17.71	41.29	52.24	39.75		17.01	38.38	53.26	36.81			
	Scheme 2	3.87	25.54	40.05	23.42	19.52	0.39	11.88	37.68	15.43	9.25	79	100
	Scheme 3	10.34	30.42	38.60	28.72	15.04	8.76	13.70	17.84	13.62	7.29	86	100
	Gain$_{1over2}$(%)	281.4	34.73	8.69	41.46		3536	169.2	17.81	98.77			
	Gain$_{1aover2}$(%)	357.6	61.67	30.44	69.73		4262	223.1	41.35	138.6			
	Gain$_{1aover3}$(%)	42.75	13.12	12.77	15.36		61.87	133.4	148.8	125.2			

* UPT results in scheme 1a is a prorated version of scheme 1, assuming 2 symbols less signaling overhead.
** Since the simulation assumes unlimited amount of ARQ attempts, unfinished packet are only due to their late arrival time. The transmission of these late-arrival packets did not finish before the end of simulation.
FTP packet size = 0.1 MB
Interference management schemes:
scheme 1: Link adaptation based on time-aligned DL and UL interference measurement in the scheduled resource
scheme 1a: Link adaption based on time-aligned DL and UL interference measurement in the scheduled resource and cross-slot scheduling
scheme 2: Dynamic TDD without CIM
scheme 3: static TDD with configuration DDUDDUDDUD for DL/UL ratio 2:1

Table A.3.1.1-3: Evaluation results for indoor hotspot (source 4)

Source 4 (R1-1703509), Indoor Hotspot Scenario													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)	5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)
2:1 Low load	Static TDD	4.586	63.217	101.282	62.258	99.481	4.941	17.919	59.576	78.431	48.949	100.000	1.849
	Dynamic TDD	3.221 -29.76%	112.833 +78.49%	166.667 +64.56%	108.641 +74.50%	99.481	3.890	1.007 -94.38%	81.165 +36.24%	136.302 +73.79%	70.146 +43.30%	98.514	2.971
	Dynamic TDD with sensing (-82dBm)	8.408 +83.34%	115.055 +82.00%	166.667 +64.56%	110.899 +78.13%	100.000	3.371	23.334 +30.22%	112.837 +89.40%	190.476 +142.86%	101.786 +107.94%	99.719	1.756
2:1 Medium load	Static TDD	3.015	12.512	38.309	16.194	97.729	27.954	5.142	44.087	76.933	42.145	99.497	4.551
	Dynamic TDD	0.959 -68.19%	15.228 +21.71%	61.738 +61.16%	21.636 +33.61%	89.607	35.584	0.148 -97.12%	3.858 -91.25%	67.643 -12.08%	14.832 -64.81%	72.187	29.808
	Dynamic TDD with sensing (-82dBm)	9.589 +218.04%	38.376 +206.71%	81.761 +113.43%	41.415 +115.75%	98.603	18.386	5.598 +8.87%	44.853 +1.74%	105.75 +37.46%	48.244 +14.47%	99.267	8.071
2:1 High load	Static TDD	1.600	8.945	32.201	12.274	93.387	35.275	2.809	21.462	52.422	22.536	97.627	12.805
	Dynamic TDD	0.818 -48.88%	4.388 -50.94%	34.272 +6.43%	9.486 -22.71%	85.414	42.485	0.150 -94.66%	2.118 -90.13%	21.088 -59.77%	6.280 -72.13%	55.427	33.121
	Dynamic TDD with sensing (-82dBm)	2.633 +64.56%	18.797 +110.14%	64.608 +100.64%	25.659 +109.05%	94.927	29.331	1.966 -30.01%	21.917 +2.12%	73.779 +40.75%	27.811 +23.41%	93.909	18.353

NOTE 1:	- schemes - Static TDD：The DL: UL ratio for the allocated slot is fixed and the same DL: UL ratio is used by all nodes in the network The scheme is the baseline. - Dynamic TDD：The change of transmission direction/transmission direction is dependent on the incoming traffic and the scheduler decisions and any slot can transmit DL or UL traffic. - Dynamic TDD with sensing：The method of dynamic TDD is used along with a sensing operation at the gNB or UE before DL transmission (e.g. the UE performs sensing on the DL slot, if successful the UE can transmit its UL traffic on the DL slot) or UL transmission (e.g. the gNB performs sensing on the UL slot, if successful the gNB can transmit its DL traffic on the UL slot). - FTP model 3 with 0.5Mbytes - Carrier frequency：4.0GHz - BS antenna configurations：Omni antenna model, $(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1)$ - λ(files/s): 0.12, 0.2, 0.24.
NOTE 2:	- RU for a link direction (DL or UL) is defined as the amount of occupied resources for the given link direction divided by the total number of resources (irrespective of link directions). - DL and UL Performance for different TDD cases

Table A.3.1.1-4: Evaluation results for indoor hotspot (source 4)

Source 4 (R1-1703509) Indoor Hotspot Scenario													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)	5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)
1:1	Static TDD	10.998	49.592	91.719	50.797	98.959	8.652	0.676	5.891	26.780	9.089	85.150	24.836
	Dynamic TDD with sensing (-82dBm)	10.947 -0.47%	45.525 -8.20%	99.5845 +8.58%	49.364 -2.82%	99.700	9.697	2.2485 +232.69%	32.481 +451.37%	112.5575 +320.31%	40.453 +345.08%	98.123	24.770
1:2	Static TDD	9.282	73.007	102.339	68.119	99.591	3.203	0.321	3.919	22.025	6.895	65.737	31.960
	Dynamic TDD with sensing (-62dBm)	2.296 -75.26%	39.966 -45.26%	112.835 +10.26%	46.271 -32.04%	98.652	5.133	7.361 +2193.15%	33.769 +761.67%	75.961 +244.89%	37.919 +449.95%	93.583	38.152
2:1	Static TDD	3.015	12.512	38.309	16.194	97.729	27.954	5.142	44.087	76.933	42.145	99.497	4.551
	Dynamic TDD with sensing (-82dBm)	9.589 +218.04%	38.376 +206.71%	81.761 +113.43%	41.415 +115.75%	98.603	18.386	5.598 +8.87%	44.853 +1.74%	105.75 +37.46%	48.244 +14.47%	99.267	8.071
4:1	Static TDD	1.356	7.325	29.525	10.762	90.683	37.356	11.317	61.446	78.431	49.926	99.813	1.398
	Dynamic TDD with sensing (-82dBm)	4.268 +214.75%	17.770 +142.59%	50.235 +70.14%	21.713 +101.76%	94.911	34.864	5.579 -50.70%	42.787 -30.37%	88.156 +12.40%	41.917 -16.04%	99.278	2.727

NOTE 1: - schemes
- Static TDD：the DL: UL ratio for the allocated slot is fixed and the same DL: UL ratio is used by all nodes in the network. The scheme is the baseline.
- Dynamic TDD with sensing：The method of dynamic TDD is used along with a sensing operation at the gNB or UE before DL transmission (e.g. the UE performs sensing on the DL slot, if successful the UE can transmit its UL traffic on the DL slot) or UL transmission (e.g. the gNB performs sensing on the UL slot, if successful the gNB can transmit its DL traffic on the UL slot).
- FTP model 3 with 0.5Mbytes
- Carrier frequency：4.0GHz
- BS antenna configurations：Omni antenna model , (M, N, P, M_g, N_g) = (1, 1, 2, 1, 1)
- λ(files/s): 0.2

NOTE2: - RU for a link direction (DL or UL) is defined as the amount of occupied resources for the given link direction divided by the total number of resources (irrespective of link directions)
- DL and UL Performance for different TDD cases with different DL and UL traffic ratio

Table A.3.1.1-5: Evaluation results for indoor hotspot (source 5)

Source 5(R1-1701672), Indoor hotspot @4GHz													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
1:1	Scheme 0	24.1	50.63	75.47	50.58	98.33	8.79	23.81	44.94	48.78	41.92	99.17	6.98
	Scheme 1	27.21	64.52	114.29	67.13	99.16	8.6	30.77	68.97	86.96	64.61	99.44	10.41
	Scheme 2	27.97 (+16.1%)	64.52 (+27.4%)	114.29 (+51.4%)	68.35 (+35.1%)	99.89	8.37	31.25 (+31.2%)	68.97 (+53.5%)	86.96 (+78.3%)	65.01 (+55.1%)	99.44	10.16
2:1	Scheme 0	16.6	45.98	74.07	45.28	99.38	13.05	30.08	46.51	48.78	44.33	100	4.82
	Scheme 1	22.47	57.97	100	57.35	99.18	12.95	30.53	76.92	90.91	70.37	99.61	7.13
	Scheme 2	22.6 (+36.1%)	57.97 (+26.1%)	100 (+35%)	58.25 (+28.6%)	99.18	12.73	31.01 (+3.1%)	76.92 (+65.4%)	90.91 (+86.4%)	70.56 (+59.2%)	99.61	7.17
4:1	Scheme 0	17.24	55.56	100	56.11	99.17	19.36	14.23	25	27.21	23.52	99.4	3.33
	Scheme 1	20.51	62.5	111.11	61.3	99.34	18.08	14.98	57.14	83.33	55.31	100	6.86
	Scheme 2	21.05 (+22.1%)	62.5 (+12.5%)	111.11 (+11.1%)	62.14 (+10.7%)	99.5	17.83	15.56 (+9.3%)	57.97 (+131.9%)	85.11 (+212.8%)	55.37 (+135.4%)	100	6.87

Note:

- Scheme 0: Static UL/DL resource allocation. The UL/DL resources can’t be changeable. The scheme is the baseline.
- Scheme 1: Flexible UL/DL resource allocation without cross-link interference mitigation scheme. The UL/DL resources can be changeable in accordance with instantaneous UL/DL traffic demand.
- Scheme 2: On top of the scheme1, the advanced IRC receiver is used for TRP-to-TRP interference mitigation. Coordinated scheduling and UL power control is used for UE-to-UE interference mitigation. Coordinated scheduling based on long-term UE-UE measurement/reporting and scheduling information exchange between TRPs with about 4 TTI latency. UL power control is based on short-term UE-UE measurement or overhearing of the control signaling.

- Evaluation assumptions refer to the agreed in [2][3][4][6], except the following parameters:
- Ratio of DL/UL traffic ={1:1}with {λDL, λUL} ={0.21, 0.21},
- Ratio of DL/UL traffic ={2:1}with {λDL, λUL} ={0.28, 0.14},
- Ratio of DL/UL traffic ={4:1}with {λDL, λUL} ={0.35,0.0875}

Table A.3.1.1-6: Evaluation results for indoor hotspot (source 7)

Source 7 (R1-1703770) Indoor hotspot													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/ offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/ offered packets	RU (%)
DL:UL= 4:1 Light load	Static TDD	22.27	38.46	60.57	39.51	0.99	15.7	8.15	13.6	17.07	13.31	0.99	4.2
	Dynamic TDD	37.28	60.55	88.13	61.93	0.99	13.3	12.69	29.02	47.68	29.73	0.99	6.9
	Dynamic TDD with DL LBT	33.75	54.77	82.16	55.21	0.99	13.4	16.23	33.29	49.28	33.08	0.99	4.7
DL:UL= 4:1 Medium load	Static TDD	13.25	25.3	43.25	26.72	0.99	25	6.04	11.88	16.55	11.63	0.99	5.8
	Dynamic TDD	17.82	42.01	66.32	42.46	0.99	21.3	4.65	17.7	38.02	19.19	0.99	13.6
	Dynamic TDD with DL LBT	17.35	35.24	61.04	36.55	0.99	21.4	7.24	23.53	41.53	23.74	0.99	6.9
Note (interference mitigation/cancellation schemes, evaluation assumption, etc): • DL:UL=7:3 for static TDD • At a TRP (UL TRP) which expects an uplink transmission, a busy tone signal is sent out before the scheduled uplink transmission from a UE. The busy tone signal's power is adjusted according to the target SIR for the scheduled UL transmission. In the same slot, at another TRP (DL TRP) which can potentially conduct a downlink transmission, channel sensing is performed over the time interval where the busy tone signal is transmitted. The sensing result determines whether the DL TRP can proceed with a DL transmission.													

Table A.3.1.1-7: Evaluation results for indoor hotspot (source 7)

Source 7 (R1-1704056) Indoor hotspot													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/ offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/ offered packets	RU (%)
DL:UL= 4:1	Static TDD	12.73	25.29	43.35	26.59	0.99	25.1	6.17	11.88	16.58	11.63	0.99	6.1
	Dynamic TDD with OTA for all cells	18.17	38.18	63.79	39.56	0.99	17.9	2.53	6	13.84	6.78	0.99	28
	Dynamic TDD with backhaul among cells under one operator	4.28	22.37	47.75	23.84	0.99	23.5	0.77	2.59	7.02	3.11	0.99	37.5

NOTE 1: - schemes
- Static TDD：The DL: UL ratio for the allocated slot is fixed and the same DL: UL ratio is used by all nodes in the network The scheme is the baseline.
- Dynamic TDD with coordination among cells from one operator (backhaul coordination)：
The coordination transmission method is that all TRPs in the coordination group will decide a common DL:UL configuration. Each TRP follows the configuration to schedule the transmission direction of its traffic when it has bi-directional traffic (i.e. DL traffic buffer is not empty and UL traffic buffer(s) is not empty). When it has only uni-directional traffic, it does not need to follow the common configuration. For example, a TRP would transmit DL traffic in an UL slot if the TRP does not have any UL traffic. We assume that the common DL:UL configuration updates every 80ms among coordination cells.

Transmission for cells under he same operator is coordinated through backhaul signaling.
- Dynamic TDD with coordination among all cells (coordination through OTA signaling)：
The coordination transmission method is that all TRPs in the coordination group will decide a common DL:UL configuration. Each TRP follows the configuration to schedule the transmission direction of its traffic when it has bi-directional traffic (i.e. DL traffic buffer is not empty and UL traffic buffer(s) is not empty). When it has only uni-directional traffic, it does not need to follow the common configuration. For example, a TRP would transmit DL traffic in an UL slot if the TRP does not have any UL traffic. We assume that the common DL:UL configuration updates every 80ms among coordination cells.

Transmission for all cells is coordinated through OTA signaling.

For UE transmit power control parameters, P0=-75dBm and α=0.8 are assumed for the simulation results.
- BS antenna configurations：Omni antenna model, $(M, N, P, M_g, N_g) = (1, 1, 2, 1, 1)$
- λ(files/s): 0.12, 0.2, 0.24.

Table A.3.1.1-8: Evaluation results for indoor hotspot (source 8)

Source 8 (R1-1703301) Indoor Hotspot at 30GHz																						
Ratio of DL:UL traffic	**Feature**	**DL + UL RU (%)**	**DL Performance**										**UL Performance**									
			DL RU(%)	**DL User Throughput (Mbps)**				**Served/Offered traffic (%)**	**Gain in DL User Throughput (%)**				**UL RU(%)**	**UL User Throughput (Mbps)**				**Served/Offered traffic (%)**	**Gain in UL User Throughput (%)**			
				5%-ile	**50%-ile**	**95%-ile**	**Mean**		**5%-ile**	**50%-ile**	**95%-ile**	**Mean**		**5%-ile**	**50%-ile**	**95%-ile**	**Mean**		**5%-ile**	**50%-ile**	**95%-ile**	**Mean**
1 : 1 Low loads	Scheme 1	25.00	13.00	104.15	184.72	247.82	181.69	99.8	-21.68	-33.89	-46.27	-36.79	12	102.05	194.47	255.02	189.21	99.8	-50.34	-49.35	-48.92	-49.51
	Scheme 2	30.00	18.00	132.98	279.41	461.24	287.43	99.9	0.00	0.00	0.00	0.00	12	205.50	383.97	499.30	374.74	99.9	0.00	0.00	0.00	0.00
	Scheme 3	30.00	18.00	142.32	278.96	460.29	289.37	99.9	7.02	-0.16	-0.20	0.68	12	208.99	386.13	500.95	377.32	99.9	1.70	0.56	0.33	0.69
	Scheme 4	29.00	17.00	88.51	192.50	332.60	199.76	99.7	-33.44	-31.10	-27.89	-30.50	12	170.40	356.05	472.48	347.71	99.9	-17.08	-7.27	-5.37	-7.21
	Scheme 5	32.00	19.00	112.90	238.17	420.05	250.90	99.7	-15.10	-14.76	-8.93	-12.71	13	116.27	221.40	340.75	225.08	99.4	-43.42	-42.34	-31.75	-39.94
1 : 1	Scheme 1	50.00	25.00	54.97	116.66	208.97	122.89	99.4	93.38	17.55	-28.16	-0.26	25	47.64	126.76	210.37	128.38	99.4	-29.97	-37.10	-44.01	-38.62

Medium loads	Scheme 2	71.00	46.00	28.43	99.24	290.87	123.21	97.5	0.00	0.00	0.00	0.00	25	68.03	201.52	375.71	209.15	99.5	0.00	0.00	0.00	0.00
	Scheme 3	64.00	40.00	44.47	129.83	332.94	151.52	99.2	56.42	30.82	14.46	22.97	24	83.21	229.07	388.29	230.86	99.7	22.30	13.67	3.35	10.38
	Scheme 4	58.00	33.00	1.16	15.65	82.06	24.33	76.5	-95.91	-84.23	-71.79	-80.25	25	8.01	64.18	183.98	77.41	93.7	-88.23	-68.15	-51.03	-62.99
	Scheme 5	63.00	46.00	4.10	29.58	135.35	43.34	88.2	-85.58	-70.19	-53.47	-64.82	17	0.75	7.80	62.27	16.56	62.1	-98.90	-96.13	-83.43	-92.08
1 : 1 High loads	Scheme 1	80.00	41.00	14.69	48.50	144.29	60.31	96.4	1441.84	147.73	19.87	69.06	39	10.76	62.29	157.98	70.88	95.7	-27.67	-21.32	-24.06	-23.26
	Scheme 2	95.00	57.00	0.95	19.58	120.37	35.67	79.7	0.00	0.00	0.00	0.00	38	14.88	79.16	208.04	92.37	96.5	0.00	0.00	0.00	0.00
	Scheme 3	92.00	52.00	7.62	45.10	184.76	62.81	93.6	699.63	130.37	53.49	76.06	40	12.90	80.67	236.43	98.23	96.0	-13.32	1.90	13.65	6.35
	Scheme 4	58.00	30.00	0.64	8.25	49.98	14.16	62.6	-32.43	-57.86	-58.47	-60.31	28	3.91	36.37	121.68	47.01	89.0	-73.73	-54.06	-41.51	-49.11
	Scheme 5	63.00	46.00	2.97	24.80	120.78	36.89	86.5	211.65	26.69	0.34	3.41	17	0.57	5.42	50.13	12.77	57.6	-96.17	-93.15	-75.91	-86.17
4 : 1 Low loads	Scheme 1	25.00	20.00	180.38	305.22	397.95	300.62	99.9	-7.60	-10.69	-18.89	-12.54	5	29.05	68.12	97.48	66.51	99.6	-78.63	-79.14	-79.11	-79.22
	Scheme 2	28.00	24.00	195.20	341.73	490.65	343.70	99.9	0.00	0.00	0.00	0.00	4	135.92	326.49	466.68	320.01	99.9	0.00	0.00	0.00	0.00
	Scheme 3	27.00	23.00	200.01	347.71	496.04	348.67	99.9	2.46	1.75	1.10	1.44	4	143.71	325.67	467.36	321.47	99.9	5.73	-0.25	0.15	0.46
	Scheme 4	28.00	24.00	153.77	278.26	409.17	280.34	99.8	-21.22	-18.57	-16.61	-18.44	4	111.20	310.92	457.16	304.87	99.6	-18.18	-4.77	-2.04	-4.73
	Scheme 5	28.00	24.00	187.75	331.72	487.95	336.52	99.9	-3.82	-2.93	-0.55	-2.09	4	71.30	207.18	349.06	210.51	99.6	-47.54	-36.54	-25.20	-34.22
4 : 1 Medium loads	Scheme 1	50.00	41.00	88.79	191.58	330.16	199.23	99.7	25.96	5.14	-12.12	0.71	9	15.30	48.05	84.63	48.42	98.3	-67.55	-72.96	-76.74	-74.26
	Scheme 2	61.00	53.00	70.49	182.21	375.70	197.83	99.2	0.00	0.00	0.00	0.00	8	47.14	177.69	363.81	188.09	99.2	0.00	0.00	0.00	0.00
	Scheme 3	57.00	49.00	90.09	198.32	383.65	215.27	99.5	27.79	8.84	2.11	8.82	8	52.53	191.09	376.28	199.71	99.6	11.42	7.54	3.43	6.18
	Scheme 4	62.00	53.00	24.47	82.18	240.44	99.63	97.7	-65.29	-54.90	-36.00	-49.64	9	22.41	86.71	277.49	113.60	98.6	-52.47	-51.20	-23.73	-39.60
	Scheme 5	63.00	56.00	39.04	116.58	312.83	140.29	98.8	-44.61	-36.02	-16.74	-29.09	7	1.57	12.16	100.62	28.15	76.2	-96.67	-93.16	-72.34	-85.03
4 : 1 High loads	Scheme 1	80.00	65.00	23.99	81.37	231.00	97.99	97.1	300.30	90.52	13.57	48.35	15	5.51	26.12	64.78	29.88	93.9	-28.70	-41.36	-70.08	-54.73
	Scheme 2	93.00	80.00	5.99	42.71	203.39	66.05	90.4	0.00	0.00	0.00	0.00	13	7.73	44.54	216.51	66.01	97.7	0.00	0.00	0.00	0.00
	Scheme 3	86.00	72.00	21.03	80.84	259.48	102.07	96.8	251.03	89.29	27.57	54.53	14	12.22	64.70	243.30	88.39	97.4	58.19	45.25	12.37	33.90
	Scheme 4	71.00	59.00	1.86	18.68	109.08	29.53	79.2	-68.90	-56.27	-46.37	-55.29	12	5.85	28.27	109.00	38.74	95.5	-24.28	-36.52	-49.66	-41.31
	Scheme 5	74.00	70.00	12.97	60.37	238.37	80.46	96.0	116.38	41.35	17.20	21.81	4	0.45	2.19	52.26	10.98	36.6	-94.17	-95.09	-75.87	-83.37

NOTE:	**Scheme 1: Static TDD** A coordinated TDD scheme where the DL:UL ratio for the allocated slots is fixed for some period of time and the same DL:UL ratio is used by all nodes in the network. This scheme is equivalent to the traditional legacy TDD. In other words, the number of DL slots followed by UL slots are the same and synchronous across all the nodes in the network. Operation based on static TDD is immune to so-called cross-link interference while the DL to UL ratio for the allocated slots follows a static or semi-static structure that is matched to the long term statistics of the incoming DL to UL traffic ratio. **Scheme 2: Dynamic TDD** A TDD scheme where the direction of transmission is not fixed on any resource in a static or semi-static manner and can be changed dynamically between DL and UL. In the evaluation, depending on the incoming traffic and the scheduler decision, any slot can carry DL or UL traffic. Operation based on dynamic TDD is expected to cause so-called cross-link interference where the dominant interference for a transmission in one direction (e.g., downlink) is caused by another transmission in the other direction (e.g., uplink). **Scheme 3: Distributed Hybrid TDD** A hybrid scheme where dynamic TDD is used unless there is traffic in opposite directions to be scheduled in the cell, in which case, the cell switches to a fixed TDD scheme with a fixed DL:UL ratio. The DL:UL ratio used is the same for all cells in the network. **Scheme 4: Dynamic TDD with DL LBT** Dynamic TDD is used along with a listen-before-talk operation performed at the TRPs before DL transmissions. **Scheme 5: Dynamic TDD with UL TDD** Dynamic TDD is used along with a listen-before-talk operation performed at the UEs before UL transmissions.

Table A.3.1.1-9: Evaluation results for indoor hotspot (source 8)

Source 8 (R1-1703300) Indoor Hotspot at 4 GHz																						
			DL Performance										**UL Performance**									
				DL User Throughput (Mbps)					**Gain in DL User Throughput (%)**					**UL User Throughput (Mbps)**					**Gain in UL User Throughput (%)**			
Ratio of DL:UL traffic	**Feature**	**DL + UL RU (%)**	**DL RU(%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**	**Served/Offered traffic (%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**	**UL RU(%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**	**Served/Offered traffic (%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**
1 : 1 Low loads	Scheme 1	25.00	12.00	33.70	47.83	59.88	47.85	99.8	-43.08	-45.15	-46.72	-45.02	13	34.35	49.24	60.98	48.79	99.7	-53.26	-51.99	-51.13	-51.97
	Scheme 2	26.00	14.00	59.21	87.20	112.38	87.02	99.8	0.00	0.00	0.00	0.00	12	73.49	102.55	124.77	101.60	99.9	0.00	0.00	0.00	0.00
	Scheme 3	26.00	14.00	60.03	87.51	114.35	87.75	99.9	1.38	0.35	1.75	0.84	12	75.85	102.10	126.44	102.45	99.9	3.21	-0.44	1.34	0.84
	Scheme 4	23.00	13.00	56.90	82.99	107.02	82.98	99.8	-3.90	-4.83	-4.77	-4.65	10	79.52	107.28	126.64	106.20	99.9	8.21	4.61	1.50	4.53
	Scheme 5	24.00	12.00	69.74	97.53	120.37	96.84	99.9	17.79	11.85	7.11	11.28	12	59.31	83.34	107.07	83.92	99.9	-19.29	-18.73	-14.19	-17.40
1 : 1 Medium loads	Scheme 1	50.00	24.00	20.66	32.85	48.42	33.78	99.2	-25.07	-33.16	-38.29	-33.92	26	18.82	31.78	47.48	32.45	99.0	-52.72	-52.61	-50.90	-52.33
	Scheme 2	56.00	34.00	27.58	49.15	78.46	51.12	98.8	0.00	0.00	0.00	0.00	22	39.81	67.06	96.70	68.07	99.7	0.00	0.00	0.00	0.00
	Scheme 3	53.00	30.00	29.80	53.58	80.09	54.10	99.5	8.07	9.01	2.08	5.82	23	41.85	69.00	97.42	69.62	99.6	5.13	2.90	0.75	2.28
	Scheme 4	44.00	26.00	22.54	40.81	65.83	42.48	98.5	-18.25	-16.97	-16.10	-16.90	18	45.56	71.38	98.39	72.22	99.6	14.45	6.44	1.75	6.09
	Scheme 5	50.00	25.00	32.11	53.44	79.71	54.73	99.2	16.43	8.72	1.60	7.06	25	17.34	33.46	57.45	35.02	93.8	-56.44	-50.10	-40.59	-48.55
1 : 1 High loads	Scheme 1	80.00	39.00	7.47	16.07	30.47	17.45	94.5	910.95	305.90	101.74	216.34	41	5.97	13.89	28.08	15.07	93.9	11.60	-9.56	-26.15	-16.13
	Scheme 2	97.00	55.00	0.74	3.96	15.11	5.52	76.3	0.00	0.00	0.00	0.00	42	5.35	15.35	38.02	17.96	95.7	0.00	0.00	0.00	0.00

	Scheme 3	87.00	48.00	7.68	17.13	35.64	19.18	93.1	939.68	332.57	135.91	247.70	39	12.20	26.58	52.19	28.88	95.3	127.92	73.13	37.27	60.79
	Scheme 4	64.00	34.00	0.47	2.33	10.03	3.57	71.2	-36.07	-41.04	-33.61	-35.36	30	3.97	12.02	32.67	14.35	92.6	-25.77	-21.73	-14.07	-20.12
	Scheme 5	66.00	43.00	5.48	13.06	27.72	14.76	94.8	641.50	229.80	83.53	167.60	23	0.30	1.81	10.48	3.05	54.5	-94.42	-88.22	-72.43	-83.01
4 : 1 Low loads	Scheme 1	25.00	20.00	61.08	79.66	96.20	79.63	99.9	-18.51	-18.67	-21.14	-19.00	5	8.42	17.21	23.89	17.09	99.7	-77.68	-80.91	-80.02	-80.47
	Scheme 2	26.00	22.00	74.95	97.95	121.99	98.30	99.9	0.00	0.00	0.00	0.00	4	37.71	90.13	119.56	87.51	99.9	0.00	0.00	0.00	0.00
	Scheme 3	26.00	22.00	74.85	96.90	120.42	97.57	99.9	-0.13	-1.07	-1.28	-0.74	4	39.84	88.95	117.49	87.02	100.0	5.67	-1.30	-1.72	-0.56
	Scheme 4	24.00	20.00	71.95	94.36	117.76	95.16	99.9	-4.00	-3.66	-3.47	-3.20	4	35.23	91.97	123.00	89.94	100.0	-6.56	2.04	2.88	2.78
	Scheme 5	24.00	20.00	80.14	103.39	124.46	103.25	99.9	6.94	5.56	2.02	5.03	4	24.99	68.87	104.37	68.16	99.8	-33.73	-23.59	-12.70	-22.11
4 : 1 Medium loads	Scheme 1	50.00	41.00	34.33	51.92	73.72	53.42	99.4	-13.80	-17.44	-18.88	-17.16	9	4.26	12.25	20.43	12.68	98.1	-77.90	-78.95	-78.71	-78.45
	Scheme 2	52.00	44.00	39.82	62.88	90.88	64.49	99.4	0.00	0.00	0.00	0.00	8	19.29	58.18	95.93	58.84	99.5	0.00	0.00	0.00	0.00
	Scheme 3	52.00	44.00	40.06	62.99	90.20	64.43	99.5	0.59	0.17	-0.75	-0.09	8	19.72	57.96	97.01	59.15	99.7	2.21	-0.37	1.13	0.53
	Scheme 4	48.00	42.00	37.16	56.53	83.08	58.12	99.3	-6.69	-10.10	-8.59	-9.87	6	19.86	62.80	100.30	62.75	99.4	2.95	7.95	4.55	6.64
	Scheme 5	50.00	42.00	41.30	61.97	87.94	63.10	99.5	3.70	-1.45	-3.24	-2.15	8	5.74	25.83	60.31	28.88	89.4	-70.26	-55.61	-37.13	-50.92
4 : 1 High loads	Scheme 1	80.00	65.00	11.35	23.00	42.13	24.72	95.2	34.58	27.80	9.86	21.30	15	1.74	6.21	15.06	7.20	91.8	-63.34	-65.44	-67.61	-65.45
	Scheme 2	88.00	75.00	8.44	18.00	38.35	20.38	90.5	0.00	0.00	0.00	0.00	13	4.75	17.98	46.50	20.85	97.5	0.00	0.00	0.00	0.00
	Scheme 3	83.00	69.00	12.14	25.72	50.31	28.10	95.0	43.92	42.92	31.18	37.89	14	5.24	21.88	58.11	25.95	95.9	10.35	21.67	24.95	24.43
	Scheme 4	75.00	65.00	6.12	14.14	31.74	16.13	89.7	-27.50	-21.45	-17.23	-20.85	10	5.91	19.49	49.88	22.57	98.2	24.39	8.38	7.26	8.25
	Scheme 5	76.00	72.00	6.23	15.60	34.52	17.67	93.0	-26.17	-13.34	-10.00	-13.31	4	0.13	0.68	12.53	2.74	25.2	-97.35	-96.23	-73.05	-86.85

NOTE: **Scheme 1: Static TDD**
A coordinated TDD scheme where the DL:UL ratio for the allocated slots is fixed for some period of time and the same DL:UL ratio is used by all nodes in the network. This scheme is equivalent to the traditional legacy TDD. In other words, the number of DL slots followed by UL slots are the same and synchronous across all the nodes in the network.
Operation based on static TDD is immune to so-called cross-link interference while the DL to UL ratio for the allocated slots follows a static or semi-static structure that is matched to the long term statistics of the incoming DL to UL traffic ratio.
Scheme 2: Dynamic TDD
A TDD scheme where the direction of transmission is not fixed on any resource in a static or semi-static manner and can be changed dynamically between DL and UL. In the evaluation, depending on the incoming traffic and the scheduler decision, any slot can carry DL or UL traffic.
Operation based on dynamic TDD is expected to cause so-called cross-link interference where the dominant interference for a transmission in one direction (e.g., downlink) is caused by another transmission in the other direction (e.g., uplink).
Scheme 3: Distributed Hybrid TDD
A hybrid scheme where dynamic TDD is used unless there is traffic in opposite directions to be scheduled in the cell, in which case, the cell switches to a fixed TDD scheme with a fixed DL:UL ratio. The DL:UL ratio used is the same for all cells in the network.
Scheme 4: Dynamic TDD with DL LBT
Dynamic TDD is used along with a listen-before-talk operation performed at the TRPs before DL transmissions.
Scheme 5: Dynamic TDD with UL TDD
Dynamic TDD is used along with a listen-before-talk operation performed at the UEs before UL transmissions.

A.3.1.2 Dense urban

Tables A.3.1.2-1 to A.3.1.2-9 provide the system-level evaluation results for dense urban scenario. In those tables, each source corresponds to the following references.

- Source 1: R1-1702836
- Source 2: R1-1703446
- Source 3: R1-1702499
- Source 5: R1-1701674
- Source 6: R1-1703462
- Source 8: R1-1703299

Table A.3.1.2-1: Evaluation results for dense urban (source 1)

Source 1 (R1-1702836), Dense urban													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
4:1 Low load	Static TDD	125	280	453	290	0.99	16.5	31	72.6	111	72.7	0.965	15.5
	Case 1-1	119 -4.80%	314 12.14%	493 8.83%	322 11.03%	0.992	18.3	77.1 148.71%	221 204.41%	390 251.35%	222 205.36%	0.993	15.8
	Case 1-2	106 -15.20%	292 4.29%	493 8.83%	308 6.21%	0.983	19.6	77 148.39%	221 204.41%	399 259.46%	225 209.49%	0.997	16.6
	Case 1-3	94.8 -24.16%	294 5.00%	493 8.83%	306 5.52%	0.987	19.5	79.9 157.74%	218 200.28%	399 259.46%	223 206.74%	0.992	16
	Case 2-1	119 -4.80%	326 16.43%	524 15.67%	336 15.86%	0.993	18.2	97 212.90%	247 240.22%	430 287.39%	254 249.38%	0.992	14.7
	Case 3-1	141 12.80%	350 25.00%	559 23.40%	363 25.17%	0.99	16.3	97.5 214.52%	260 258.13%	460 314.41%	262 260.39%	0.995	13.7
	Case 3-2	141 12.80%	365 30.36%	569 25.61%	370 27.59%	0.994	15.4	103 232.26%	262 260.88%	436 292.79%	261 259.01%	0.996	12.2
4:1 Medium load	Static TDD	70.1	197	442	217	0.969	36	23.6	64	108	63.4	0.903	27.9
	Case 1-1	38.3 -45.36%	178 -9.64%	479 8.37%	207 -4.61%	0.939	48.1	44.8 89.83%	147 129.69%	339 213.89%	163 157.10%	0.977	41.4
	Case 1-2	38.3 -45.36%	173 -12.18%	479 8.37%	202 -6.91%	0.927	48.8	30.2 27.97%	132 106.25%	300 177.78%	144 127.13%	0.975	47.6
	Case 1-3	40.3 -42.51%	179 -9.14%	486 9.95%	211 -2.76%	0.943	45.4	33.9 43.64%	129 101.56%	311 187.96%	145 128.71%	0.969	46
	Case 2-1	47.1 -32.81%	214 8.63%	524 18.55%	238 9.68%	0.981	43.2	46.4 96.61%	150 134.38%	339 213.89%	168 164.98%	0.981	39.6
	Case 3-1	49.8 -28.96%	243 23.35%	550 24.43%	263 21.20%	0.958	38	55 133.05%	181 182.81%	386 257.41%	195 207.57%	0.979	36.1
	Case 3-2	54.1 -22.82%	245 24.37%	550 24.43%	266 22.58%	0.971	36.8	52.3 121.61%	170 165.63%	365 237.96%	187 194.95%	0.982	34.8
Note (interference mitigation/cancellation schemes, evaluation assumption, etc): - Interference mitigation schemes - At the transmitter, fixed analog beamforming and SVD precoding is applied. - At the receiver, MMSE-IRC receiver is applied. - Ideal channel estimation - FTP model 1 with 0.5Mbytes													

Table A.3.1.2-2: Evaluation results for dense urban (source 2)

Source 2 (R1-1703446) Dense Urban Scenario micro layer													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)					UL UPT (Mbps)					served packet including late arrival packets (%)**	served packet without late arrival packets (%)**
		5%-tile	50%-tile	95%-tile	Average	RU (%)	5%-tile	50%-tile	95%-tile	Average	RU (%)		
1:1 (DL λ=0.5)	Scheme 1	1.26	23.75	45.32	22.71	6.48	1.03	22.93	40.62	20.58	6.78	89	100
	Scheme 1a*	1.51	28.50	54.39	27.25		1.23	27.51	48.74	24.70			
	Scheme 2	0.86	21.85	53.29	23.05	6.75	0.54	4.92	40.35	10.54	6.47	82	100
	Gain$_{1over2}$(%)	46.51	8.70	-14.96	-1.48		90.74	366.1	0.67	95.26			
	Gain$_{1aover2}$(%)	75.58	30.43	2.06	18.22		127.8	459.2	20.79	134.4			
2:1 (DL λ=0.5)	Scheme 1	1.56	32.82	49.18	27.45	6.50	1.15	25.21	45.92	22.92	3.44	86	100
	Scheme 1a*	1.87	39.38	59.02	32.49		1.38	30.25	55.11	27.50			
	Scheme 2	1.23	32.21	58.66	29.54	6.65	0.18	5.69	50.29	13.58	3.25	80	100
	Gain$_{1over2}$(%)	26.83	1.89	-16.16	-7.08		538.9	343.1	-8.69	68.78			
	Gain$_{1aover2}$(%)	52.03	22.26	0.61	9.99		666.7	431.6	9.58	102.5			
1:1 (DL λ=1)	Scheme 1	0.51	10.61	37.27	14.30	12.61	0.51	8.75	31.53	12.15	13.70	82	100
	Scheme 1a*	0.61	12.73	44.72	17.16		0.61	10.50	37.84	14.58			
	Scheme 2	0.36	5.44	35.73	10.38	13.55	0.30	2.14	9.43	3.24	12.55	80	100
	Gain$_{1over2}$(%)	41.67	95.04	4.31	37.76		70.00	308.9	234.4	275.0			
	Gain$_{1aover2}$(%)	69.44	134.0	25.16	65.32		103.3	390.7	301.3	350.0			
2:1 (DL λ=1)	Scheme 1	0.85	15.27	39.85	17.74	13.19	0.49	8.71	32.18	12.11	7.08	90	100
	Scheme 1a*	1.02	18.23	47.49	21.29		0.59	10.45	38.61	14.53			
	Scheme 2	0.81	11.98	47.60	16.96	13.74	0.27	1.19	16.15	3.38	6.11	82	100
	Gain$_{1over2}$(%)	4.94	27.46	-16.28	4.60		81.48	631.9	99.26	258.3			
	Gain$_{1aover2}$(%)	25.93	52.17	-0.23	25.53		118.5	778.2	139.1	329.9			

*: UPT results in scheme 1a is a prorated version of scheme 1, assuming 2 symbols less signaling overhead.
**: Since the simulation assumes unlimited amount of ARQ attempts, unfinished packet are only due to their late arrival time. The transmission of these late-arrival packets did not finish before the end of simulation.
FTP packet size = 0.1 MB
Interference management schemes:
scheme 1: Link adaptation based on time-aligned DL and UL interference measurement in the scheduled resource
scheme 1a: Link adaption based on time-aligned DL and UL interference measurement in the scheduled resource and cross-slot scheduling
scheme 2: Dynamic TDD without CIM

Table A.3.1.2-3: Evaluation results for dense urban (source 3)

Source 3 (R1-1702499), Dense urban													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
2:1	Static (6:4)	65.02	136.53	178.09	127.99	0.97	14.9	33.03	65.02	95.26	65.39	0.93	9.37
	Duplexing flexibility w/o CLI mitigation scheme	77.28 18.87%	170.67 25.00%	240.94 35.29%	163.16 27.47%	0.97	15	17.21 - 47.90%	39.77 - 38.83%	89.04 -6.52%	44.19 -32.42%	0.88	15.53
	Duplexing flexibility w/ CLI mitigation scheme	68.27 5.00%	141.24 3.45%	215.58 21.05%	139.98 9.36%	0.97	17.62	34.71 5.08%	73.14 12.50%	117.03 22.86%	73.65 12.64%	0.94	10.02
Note (interference mitigation/cancellation schemes, evaluation assumption, etc): • DL power control: TRP with having “DL” direction reduces DL power in (flexible) subframe where the transmission direction of reference configuration is UL, which is based on target IoT level in the UL reception of the closest TRP. • UL power control: UL power boosting of 3 dB is assumed only at the flexible subframe where TRP changes its transmission direction from UL indicated by reference UL/DL configuration to DL													

Table A.3.1.2-4: Evaluation results for dense urban (source 5)

Source 5(R1-1701674), Dense urban@4GHz													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
1:1	Baseline	18.43	53.33	78.43	51.98	1	8.31	5.5	18.52	34.48	19.17	0.98	14.05
	Duplexing flexibility -w/o CIM	13.65 (-25.94%)	42.11 (-21.05%)	102.56 (+30.77%)	48.7 (-6.30%)	1	10.43	2.15 (-60.91%)	11.83 (-36.09%)	45.45 (+31.82%)	16.34 (-14.74%)	0.97	29.79
	Duplexing flexibility -w CIM	22.99 (+24.71%)	64.52 (+20.97%)	108.11 (+37.84%)	65.88 (+26.75%)	1	8.48	5.7 (+3.56%)	23.81 (+28.57%)	67.8 (+96.61%)	28.53 (+48.83%)	0.97	15.89
2:1	Baseline	20.41	54.79	78.43	53.53	1	7.43	7.07	19.8	34.48	20.1	0.97	6.43
	Duplexing flexibility -w/o CIM	15.21 (-25.48%)	51.28 (-6.41%)	108.11 (+37.84%)	55.48 (+3.65%)	1	9.28	3.59 (-49.15%)	15.5 (-21.71%)	50.63 (+46.84%)	19.73 (-1.87%)	0.98	13.24
	Duplexing flexibility -w CIM	22.1 (+8.29%)	66.67 (+21.67%)	111.11 (+41.67%)	67.62 (+26.32%)	1	8.11	7.12 (+0.71%)	25.16 (+27.04%)	67.8 (+96.61%)	30.18 (+50.11%)	0.94	8.17
4:1	Baseline	19.7	65.57	102.56	64.6	1	11.16	3.27	9.85	18.52	10.2	0.98	4.28
	Duplexing flexibility -w/o CIM	15.87 (-19.44%)	61.54 (-6.15%)	108.11 (+5.41%)	61.9 (-4.17%)	1	15.19	1.75 (-46.27%)	8.2 (-16.80%)	36.7 (+98.17%)	12.37 (+21.30%)	0.97	13.34

	Duplexing flexibility -w CIM	19.7 (+0.00%)	66.67 (+1.67%)	111.11 (+8.33%)	67.44 (+4.40%)	1	12.75	4.55 (+39.21%)	18.35 (+86.24%)	57.14 (+208.57%)	23.32 (+128.66%)	0.98	6.54
Note Ø CIM (cross-link interference mitigation) scheme is MMSE-IRC receiver and dynamic beam coordination. Dynamic beam coordination is based on long-term TRP-TRP measurement and inter-TRP information exchange (include subframe type and DL/UL traffic information), the delay for the information exchange is 4ms and period for the information exchange is 10ms. Dynamic beam coordination includes analog beam coordination and digital beamforming. Ø Evaluation assumptions refer to the agreed in [2], except the following parameters: • Traffic - {1:1}-the DL User arrival rate λ is 0.15 - {2:1}-the DL User arrival rate λ is 0.15 - {4:1}-the DL User arrival rate λ is 0.2 • BS antenna tilt is 105 degree for baseline.													

Table A.3.1.2-5: Evaluation results for dense urban (source 5)

Source 5(R1-1701674), Dense urban@30GHz													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
1:1	Baseline	29.23	173.59	309.29	169.67	0.98	13.67	3.88	70.89	177.78	77.62	0.89	20.03
	Duplexing flexibility -w/o CIM	10.21 (-65.09%)	88.96 (-48.75%)	333.91 (+7.96%)	119.35 (-29.66%)	0.92	20.29	1.71 (-55.79%)	12.99 (-81.67%)	136.34 (-23.31%)	31.88 (-58.93%)	0.39	48.02
	Duplexing flexibility -w CIM	34.13 (+16.75%)	190.69 (+9.85%)	376.87 (+21.85%)	194.32 (+14.53%)	0.97	13.03	6.86 (+76.84%)	79.64 (+12.35%)	266.67 (+50.00%)	101 (+30.12%)	0.89	19.31
2:1	Baseline	20.18	148.47	299.09	150.98	0.99	22.49	4.41	71.46	179.78	79.27	0.91	16.23
	Duplexing flexibility -w/o CIM	21.05 (+4.34%)	149.86 (+0.94%)	400.25 (+33.82%)	174.13 (+15.33%)	0.99	31.06	2.07 (-53.19%)	12.57 (-82.41%)	86.06 (-52.13%)	23.91 (-69.84%)	0.26	37.53
	Duplexing flexibility -w CIM	40.22 (+99.33%)	225.53 (+51.91%)	444.44 (+48.60%)	231.69 (+53.45%)	0.99	20.64	7.1 (+60.88%)	74.18 (+3.79%)	351.69 (+95.63%)	115.96 (+46.29%)	0.88	15.02
4:1	Baseline	32.32	206.87	405.13	206.89	0.98	22.82	3.56	42.25	100.31	45.62	0.85	7.4
	Duplexing flexibility -w/o CIM	25.22 (-21.99%)	206.53 (-0.17%)	426.74 (+5.34%)	210.28 (+1.64%)	0.99	28.66	2.12 (-40.46%)	15.4 (-63.55%)	101.96 (+1.64%)	29.54 (-35.26%)	0.33	24.82
	Duplexing flexibility -w CIM	35.73 (+10.53%)	225.76 (+9.13%)	444.44 (+9.70%)	230.77 (+11.54%)	0.99	22.93	7.95 (+123.12)	73.94 (+74.98%)	355.56 (+254.44%)	117.86 (+158.32%)	0.89	8.25

Note
Ø CIM (cross-link interference mitigation) scheme is MMSE-IRC receiver and dynamic beam coordination. Dynamic beam coordination is based on long-term TRP-TRP measurement and inter-TRP information exchange (include subframe type and DL/UL traffic information), the delay for the information exchange is 4ms and period for the information exchange is 10ms. Dynamic beam coordination includes analog beam coordination and digital beamforming. Ø Evaluation assumptions refer to the agreed in [2], except the following parameters: • Traffic - {1:1}-the DL User arrival rate λ is 1.6 - {2:1}-the DL User arrival rate λ is 1.6 - {4:1}-the DL User arrival rate λ is 2.4 • BS antenna tilt is 90 degree for baseline.

Table A.3.1.2-6: Evaluation results for dense urban (source 6)

Source 6 (R1-1703462), Dense urban													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)	5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)
2:1 Light Load	Static	38.11	46.84	51.43	46.13	99.96	4.3	5.05	20.83	27.5	19.04	99.81	3.94
	Greedy	59.22	72.54	80	71.47	99.97	4.11	10.85	47.8	74.34	45.58	99.95	5.47
	IA	63.7	74.93	80	73.87	99.98	4.12	10.84	47.11	72.72	45	99.95	5.42
	Greedy + IC	60.15	73.01	80	71.92	99.98	4.11	12.09	51.88	77.45	49.08	99.97	4.77
	IA + IC	55.66	73.59	80	71.66	99.98	4.26	12.46	52.42	76.8	49.22	99.97	4.59
2:1 Low Load	Static	23.34	37.25	49.26	37.08	99.83	10.88	1.59	13.15	25.78	13.36	98.75	11.93
	Greedy	8.03	42.24	68.48	40.8	98.85	9.2	1.04	12.9	43.7	16.45	98.12	39.32
	IA	26.5	52.24	72.95	51.21	99.94	10.35	2.4	17.1	44.91	19.52	99.09	27.31
	Greedy + IC	19.93	50.16	71.73	48.73	99.67	9.22	2.32	19.97	53.57	22.64	99.22	28.09
	IA + IC	34.89	58.41	75.03	57.18	99.95	9.65	3.3	21.89	54.26	24.43	99.46	22.27
2:1 Medium Load	Static	5.8	18.79	43.47	21.01	99.62	27.26	0.22	3.48	18.53	5.53	85.84	26.66
	Greedy	0.37	2.48	23.24	6.13	79.18	12.68	0.12	1.22	12.21	2.92	64.96	81.27
	IA	5.88	18.96	44.29	21.21	99.63	29.2	0.21	3.28	17.96	5.28	85.47	27.05
	Greedy + IC	0.43	3.43	32.74	8.12	83.61	13.58	0.15	1.87	18.83	4.37	74.4	77.53
	IA + IC	5.9	19.07	44.18	21.23	99.64	29.29	0.22	3.45	18.69	5.51	85.94	26.66
2:1 High Load	Static	0.52	3.52	36.88	9.26	88.22	47.6	0.18	1.51	12.14	3.13	68.08	31.02
	Greedy	0.33	1.57	14.83	3.81	70.54	16.45	0.14	0.66	6.08	1.6	35.98	81.12
	IA	0.52	3.56	36.89	9.31	88.22	48.98	0.18	1.42	11.68	3.01	67.89	31.13
	Greedy + IC	0.38	1.84	17.42	4.52	73.02	17.3	0.13	0.9	8.54	2.19	46.51	79.22
	IA + IC	0.52	3.56	36.88	9.33	88.21	49.02	0.17	1.48	11.99	3.08	68	31.02

Schemes
- "Static": A static uplink-downlink configuration – the ratio of the number of uplink to downlink slots is chosen by sweeping over several choices and selecting the one where the ratio of user perceived throughput for downlink and uplink is closest to the ratio of the offered traffic load for downlink and uplink. For the offered load ratio of 2:1, the best DU slot ratio was found to be 65% DL, 35% UL.
- "Greedy": A greedy scheme where each gNB dynamically selects downlink or uplink based on queue size information (select a direction if the queues are longer for that direction)
- "IA (Interference-aware)": Dynamic switching with transmission power adjustment based on knowledge of the long term interference profile
- IC: gNB can cancel two strongest interfering gNB DL transmission with 20dB efficiency (1% residual)

Traffic Model
- FTP traffic model 3, packet size 0.1 Mbytes

Table A.3.1.2-7: Evaluation results for dense urban (source 6)

Source 6 (R1-1703462), Dense urban													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)	5%-tile	50%-tile	95%-tile	Mean	Served / Offered (%)	RU (%)
4:1 Light Load	Static	47.04	55	59.06	54.28	99.99	4.25	4.62	16.28	19.65	14.67	99.92	1.71
	Greedy	65.37	74.17	79.46	73.44	99.99	4.14	12.82	51.59	76.64	48.72	99.95	2.44
	IA	67.25	75.21	79.61	74.56	99.99	4.14	12.77	51.31	76.31	48.42	99.95	2.42
	Greedy + IC	65.99	74.35	79.55	73.65	99.99	4.14	14.36	55.95	78.73	51.95	99.95	2.14
	IA + IC	67.4	75.37	79.65	74.66	99.99	4.14	14.17	55.41	78.49	51.63	99.95	2.13
4:1 Low Load	Static	32.85	46.21	57.06	45.84	99.97	10.11	2.73	12.64	19.06	11.92	99.53	4.64
	Greedy	43.11	59.57	73.99	59.14	99.94	9.2	3.97	24.67	54.15	26.16	99.84	12.88
	IA	41.77	60.46	75.34	59.57	99.97	9.96	4.27	25.53	53.27	26.68	99.86	11.33
	Greedy + IC	45.8	61.29	74.57	60.79	99.94	9.19	4.83	29.6	61	30.6	99.88	10.52
	IA + IC	48.52	64.66	76.59	63.7	99.97	9.38	5.11	29.51	59.8	30.72	99.88	9.77
4:1 Medium Load	Static	15.29	31.52	53.05	32.76	99.92	21.72	0.96	8.03	17.62	8.6	98.34	9.92
	Greedy	0.99	6.67	40.17	11.91	92.84	15.76	0.09	1.53	16.62	3.89	81.54	69.25
	IA	15.44	31.59	53.09	32.87	99.92	25.53	0.9	7.87	17.53	8.47	98.26	10.1
	Greedy + IC	1.72	13.41	49.2	18.61	95.71	16.41	0.17	3.1	25.78	6.61	89.5	59.28
	IA + IC	13.59	36.24	65.3	37.45	99.89	20.87	0.9	9.47	30.8	11.45	98.64	31.3
4:1 High Load	Static	0.94	7.85	44.84	13.78	96.62	48.58	0.16	2.77	13.64	4.25	90.08	18.23
	Greedy	0.56	2.55	11.08	3.77	86.89	23.57	0.06	0.33	3.53	0.96	39.58	73.68
	IA	0.93	7.9	44.83	13.81	96.64	51.42	0.15	2.69	13.57	4.17	89.79	18.28
	Greedy + IC	0.65	2.96	15.34	4.87	88.36	24.48	0.07	0.55	6.33	1.61	53.86	71.04
	IA + IC	0.95	7.97	45.13	13.91	96.69	51.34	0.16	2.7	13.67	4.2	89.87	18.2

Schemes

- "Static": A static uplink-downlink configuration – the ratio of the number of uplink to downlink slots is chosen by sweeping over several choices and selecting the one where the ratio of user perceived throughput for downlink and uplink is closest to the ratio of the offered traffic load for downlink and uplink. For the offered load ratio of 4:1, the best DU slot ratio was found to be 3:1 (i.e., 75% DL, 25% UL).
- "Greedy": A greedy scheme where each gNB dynamically selects downlink or uplink based on queue size information (select a direction if the queues are longer for that direction)
- "IA (Interference-aware)": Dynamic switching with transmission power adjustment based on knowledge of the long term interference profile
- IC: gNB can cancel two strongest interfering gNB DL transmission with 20dB efficiency (1% residual)

Traffic Model

- FTP traffic model 3, packet size 0.1 Mbytes

Table A.3.1.2-8: Evaluation results for dense urban (source 8)

Source 8 (R1-1703299) Outdoor Dense Urban, Macro layer at 4 GHz																							
Ratio of DL:UL traffic	Feature	DL + UL RU (%)	DL Performance										UL Performance										
			DL RU(%)	DL User Throughput (Mbps)				Served/Offered traffic (%)	Gain in DL User Throughput (%)				UL RU(%)	UL User Throughput (Mbps)				Served/Offered traffic (%)	Gain in UL User Throughput (%)			
				5%-ile	50%-ile	95%-ile	Mean		5%-ile	50%-ile	95%-ile	Mean		5%-ile	50%-ile	95%-ile	Mean		5%-ile	50%-ile	95%-ile	Mean
1 : 1 Low loads	Scheme 1	25.00	9.45	27.71	50.74	64.12	49.12	99.9	-31.84	-37.95	-45.75	-39.63	15.55	8.96	36.55	60.33	35.43	100.0	82.27	0.15	-35.27	-14.08
	Scheme 2	44.00	10.10	40.66	81.77	118.19	81.36	100.0	0.00	0.00	0.00	0.00	33.9	4.92	36.49	93.20	41.24	99.8	0.00	0.00	0.00	0.00
	Scheme 3	30.00	9.08	36.05	71.58	102.58	70.55	100.0	-11.34	-12.46	-13.21	-13.29	20.92	9.80	48.51	102.56	51.08	99.8	99.30	32.94	10.05	23.87
	Scheme 4	28.00	9.47	39.22	76.08	106.25	75.36	100.0	-3.52	-6.96	-10.10	-7.38	18.53	11.74	55.91	105.94	57.31	99.9	138.84	53.22	13.67	38.97
1 : 1 Medium loads	Scheme 1	50.00	18.79	16.42	37.63	57.30	37.30	99.8	724.02	188.04	33.16	124.04	31.21	2.09	19.92	50.04	21.74	99.3	4859.75	4863.99	143.56	541.35
	Scheme 2	99.00	37.94	1.99	13.06	43.03	16.65	95.2	0.00	0.00	0.00	0.00	61.06	0.04	0.40	20.54	3.39	12.4	0.00	0.00	0.00	0.00
	Scheme 3	57.00	18.05	16.91	40.12	63.95	40.35	100.0	142.39	207.11	48.60	142.39	38.95	1.85	22.31	62.73	25.72	98.9	4301.09	5460.91	205.32	658.82
	Scheme 4	54.00	18.48	17.78	40.56	69.85	41.71	99.9	150.56	210.48	62.32	150.56	35.52	3.17	25.25	72.06	29.79	99.4	7423.84	6192.93	250.76	778.78
1 : 1 High loads	Scheme 1	80.00	36.09	1.10	14.38	43.27	17.45	96.8	58.30	55.63	8.29	28.78	43.91	0.20	4.82	34.42	9.10	88.1	319.33	1104.65	42.48	132.02
	Scheme 2	99.00	40.51	0.70	9.24	39.96	13.55	93.6	0.00	0.00	0.00	0.00	58.49	0.05	0.40	24.16	3.92	8.5	0.00	0.00	0.00	0.00
	Scheme 3	81.00	35.78	1.46	14.32	45.87	17.53	96.7	110.18	55.05	14.79	29.42	45.22	0.23	4.90	32.53	8.94	88.7	391.98	1123.25	34.67	127.86
	Scheme 4	81.00	36.03	1.44	14.73	45.25	17.86	96.9	107.09	59.47	13.26	31.83	44.97	0.22	5.03	35.62	9.32	88.2	372.65	1157.22	47.46	137.64
4 : 1 Low loads	Scheme 1	25.00	17.68	47.72	81.16	102.40	78.88	99.9	-2.79	-10.79	-18.72	-11.91	7.32	2.22	10.47	21.15	10.90	99.7	95.49	-24.96	-66.53	-46.81
	Scheme 2	50.00	19.78	49.09	90.98	125.98	89.54	100.0	0.00	0.00	0.00	0.00	30.22	1.13	13.95	63.17	20.49	97.4	0.00	0.00	0.00	0.00
	Scheme 3	31.00	17.61	55.04	92.55	119.85	90.44	100.0	12.13	1.73	-4.86	1.00	13.39	3.01	22.17	74.41	28.86	99.9	165.69	58.88	17.79	40.87

	Scheme 4	27.00	17.10	56.23	96.80	121.96	94.09	100.0	14.54	6.39	-3.19	5.08	9.9	5.69	30.66	81.58	35.71	99.9	402.49	119.70	29.14	74.28
4 : 1 Medium loads	Scheme 1	50.00	36.37	24.18	55.66	90.13	56.09	99.9	184.59	57.51	6.84	41.42	13.63	0.45	4.77	17.29	6.32	96.7	1181.95	571.78	-6.92	60.29
	Scheme 2	97.00	49.19	8.50	35.34	84.36	39.66	99.0	0.00	0.00	0.00	0.00	47.81	0.03	0.71	18.58	3.94	23.0	0.00	0.00	0.00	0.00
	Scheme 3	57.00	37.24	20.62	54.66	92.92	55.24	99.8	142.75	54.67	10.15	39.28	19.76	0.44	6.86	35.80	10.72	96.6	1167.51	866.12	92.73	171.84
	Scheme 4	54.00	35.90	24.45	56.75	95.02	58.06	99.8	187.85	60.60	12.63	46.37	18.1	0.78	9.30	43.46	13.58	97.7	2140.10	1210.02	133.95	244.27
4 : 1 High loads	Scheme 1	80.00	62.23	1.20	16.34	66.25	23.37	94.5	179.03	200.68	7.89	46.65	17.77	0.18	1.95	11.20	3.24	81.7	598.03	76.64	-34.12	-16.81
	Scheme 2	99.00	68.46	0.43	5.44	61.41	15.94	89.9	0.00	0.00	0.00	0.00	30.54	0.03	1.10	17.01	3.90	1.8	0.00	0.00	0.00	0.00
	Scheme 3	81.00	62.39	1.35	15.61	65.15	23.35	93.5	215.20	187.17	6.09	46.53	18.61	0.16	2.14	12.33	3.70	81.6	528.36	94.07	-27.52	-5.03
	Scheme 4	80.00	61.02	1.24	17.30	69.02	23.96	93.9	187.92	218.30	12.40	50.32	18.98	0.20	2.09	12.54	3.64	83.1	666.85	89.21	-26.24	-6.78

NOTE: **Scheme 1: Static TDD**
A coordinated TDD scheme where the DL:UL ratio for the allocated slots is fixed for some period of time and the same DL:UL ratio is used by all nodes in the network. This scheme is equivalent to the traditional legacy TDD. In other words, the number of DL slots followed by UL slots are the same and synchronous across all the nodes in the network.
Operation based on static TDD is immune to so-called cross-link interference while the DL to UL ratio for the allocated slots follows a static or semi-static structure that is matched to the long term statistics of the incoming DL to UL traffic ratio.
Scheme 2: Dynamic TDD
A TDD scheme where the direction of transmission is not fixed on any resource in a static or semi-static manner and can be changed dynamically between DL and UL. In the evaluation, depending on the incoming traffic and the scheduler decision, any slot can carry DL or UL traffic.
Operation based on dynamic TDD is expected to cause so-called cross-link interference where the dominant interference for a transmission in one direction (e.g., downlink) is caused by another transmission in the other direction (e.g., uplink).
Scheme 3: Distributed Hybrid TDD with Intra-site coordination at Macro cells
A hybrid scheme where dynamic TDD is used at the macro cells unless there is traffic in opposite directions to be scheduled in the macro cells at the same site, in which case, the macro cell is switched to a fixed TDD scheme with a fixed DL:UL ratio. The DL:UL ratio used is the same for all macro cells in the network.
Scheme 4: Distributed Hybrid TDD with Intra-site coordination at Macro cells and with ideal interference cancellation of two closest interfering macro-cells from other sites
In addition to the intra-site coordination described in the scheme 3, ideal cancellation of the interference from the two closest macro cells from neighboring sites that are pointed towards this cell is assumed.

Table A.3.1.2-9: Evaluation results for dense urban (source 8)

Source 8 (R1-1703299) Indoor Hotspot at 4 GHz																						
			DL Performance										**UL Performance**									
				DL User Throughput (Mbps)					**Gain in DL User Throughput (%)**					**UL User Throughput (Mbps)**					**Gain in UL User Throughput (%)**			
Ratio of DL:UL traffic	**Feature**	**DL + UL RU (%)**	**DL RU(%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**	**Served/Offered traffic (%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**	**UL RU(%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**	**Served/Offered traffic (%)**	**5%-ile**	**50%-ile**	**95%-ile**	**Mean**
1 : 1 Low loads	Scheme 1	25.00	9.63	39.46	154.00	258.50	152.50	99.7	-29.88	-40.78	-48.82	-43.13	15.37	11.23	92.99	246.57	106.99	97.6	-4.22	-27.09	-44.07	-35.46
	Scheme 2	34.00	10.31	56.27	260.04	505.11	268.16	99.6	0.00	0.00	0.00	0.00	23.69	11.72	127.55	440.81	165.77	96.4	0.00	0.00	0.00	0.00

	Scheme 3	32.00	9.74	59.88	262.32	507.68	274.90	99.7	6.42	0.87	0.51	2.51	22.26	12.30	137.32	444.31	173.81	97.3	4.96	7.66	0.79	4.85
	Scheme 4	34.00	9.45	47.47	224.34	454.29	235.48	99.4	-15.63	-13.73	-10.06	-12.19	24.55	11.05	120.38	434.22	158.30	95.0	-5.68	-5.62	-1.49	-4.50
	Scheme 5	33.00	10.19	57.11	248.51	503.30	263.76	99.5	1.50	-4.44	-0.36	-1.64	22.81	8.37	110.98	382.31	144.95	95.1	-28.59	-12.99	-13.27	-12.56
1 : 1 Medium loads	Scheme 1	50.00	21.84	10.42	94.72	227.25	103.53	95.7	8.78	-8.96	-39.32	-22.85	28.16	2.69	47.92	203.60	69.11	89.9	259.69	102.77	-16.49	14.80
	Scheme 2	70.00	23.99	9.58	104.04	374.50	134.20	94.1	0.00	0.00	0.00	0.00	46.01	0.75	23.63	243.82	60.20	68.4	0.00	0.00	0.00	0.00
	Scheme 3	63.00	22.44	12.25	122.56	399.74	153.67	96.1	27.80	17.80	6.74	14.51	40.56	2.19	46.87	303.22	83.13	86.6	192.50	98.32	24.36	38.08
	Scheme 4	70.00	23.54	7.17	80.79	315.41	110.46	91.5	-25.15	-22.35	-15.78	-17.69	46.46	0.77	20.01	247.69	54.81	65.7	3.01	-15.35	1.59	-8.95
	Scheme 5	67.00	24.86	8.43	95.58	352.76	125.06	93.8	-12.04	-8.14	-5.80	-6.81	42.14	0.72	17.10	203.95	45.44	65.0	-4.35	-27.66	-16.35	-24.53
1 : 1 High loads	Scheme 1	80.00	38.81	2.09	22.53	134.44	38.23	60.5	-7.82	7.73	-4.50	-4.49	41.19	1.40	14.98	109.69	29.15	52.8	12.61	89.83	25.76	37.47
	Scheme 2	90.00	41.88	2.26	20.92	140.79	40.03	56.8	0.00	0.00	0.00	0.00	48.12	1.24	7.89	87.22	21.20	26.4	0.00	0.00	0.00	0.00
	Scheme 3	86.00	39.16	2.33	24.23	181.61	49.81	60.7	2.83	15.82	29.00	24.43	46.84	1.50	14.75	127.84	32.03	50.0	20.14	86.90	46.56	51.07
	Scheme 4	86.00	38.40	2.02	15.76	119.51	31.81	52.7	-10.91	-24.64	-15.11	-20.54	47.6	1.34	8.21	69.33	18.96	26.4	7.72	4.03	-20.51	-10.59
	Scheme 5	82.00	40.88	2.00	21.05	137.65	39.78	57.4	-11.76	0.63	-2.23	-0.64	41.12	1.19	6.91	63.78	16.71	23.8	-4.76	-12.43	-26.88	-21.21
4 : 1 Low loads	Scheme 1	25.00	18.33	59.91	243.15	417.45	242.30	99.5	-18.22	-15.46	-20.74	-17.84	6.67	3.93	30.06	85.36	35.81	96.1	-26.52	-64.91	-75.40	-70.40
	Scheme 2	33.00	18.29	73.27	287.63	526.68	294.92	99.6	0.00	0.00	0.00	0.00	14.71	5.35	85.68	347.03	120.98	94.8	0.00	0.00	0.00	0.00
	Scheme 3	33.00	18.57	67.28	294.27	526.32	297.74	99.8	-8.17	2.31	-0.07	0.96	14.43	6.75	89.65	357.25	123.58	96.0	26.20	4.63	2.94	2.15
	Scheme 4	35.00	18.77	50.74	248.63	472.43	256.76	99.3	-30.75	-13.56	-10.30	-12.94	16.23	5.10	74.13	357.07	110.29	94.3	-4.68	-13.48	2.89	-8.83
	Scheme 5	33.00	18.65	64.74	284.89	526.51	292.99	99.6	-11.64	-0.95	-0.03	-0.66	14.35	4.60	69.88	304.71	99.81	94.2	-13.96	-18.44	-12.20	-17.50
4 : 1 Medium loads	Scheme 1	50.00	38.72	8.73	131.43	356.86	151.29	93.7	-19.73	-3.47	-17.34	-9.63	11.28	1.95	18.08	71.21	25.00	81.8	83.49	22.78	-64.32	-44.40
	Scheme 2	67.00	40.58	10.87	136.15	431.71	167.42	93.3	0.00	0.00	0.00	0.00	26.42	1.06	14.73	199.58	44.97	64.3	0.00	0.00	0.00	0.00
	Scheme 3	63.00	39.17	10.89	140.39	448.28	174.35	94.6	0.12	3.12	3.84	4.14	23.83	1.85	21.88	218.69	52.08	80.9	73.82	48.56	9.58	15.82
	Scheme 4	65.00	40.34	7.96	102.86	375.96	134.93	90.4	-26.79	-24.45	-12.91	-19.40	24.66	0.92	10.92	171.44	38.89	59.3	-14.04	-25.86	-14.10	-13.51
	Scheme 5	64.00	40.86	9.21	133.72	422.95	163.80	92.8	-15.29	-1.78	-2.03	-2.16	23.14	0.88	10.60	149.41	35.41	59.6	-17.58	-28.02	-25.14	-21.26
4 : 1 High loads	Scheme 1	80.00	64.35	2.03	26.77	195.13	50.56	60.3	10.87	24.05	-1.89	4.45	15.65	1.89	10.00	51.59	15.68	48.1	138.47	101.91	8.48	21.93
	Scheme 2	88.00	67.36	1.83	21.58	198.89	48.40	56.2	0.00	0.00	0.00	0.00	20.64	0.79	4.95	47.56	12.86	20.7	0.00	0.00	0.00	0.00
	Scheme 3	86.00	65.93	2.14	25.91	212.78	54.65	58.9	16.82	20.03	6.98	12.92	20.07	1.69	9.15	71.25	19.03	41.3	113.08	84.65	49.80	47.99

	Scheme 4	82.00	61.40	1.65	17.81	169.91	39.60	52.8	-10.08	-17.50	-14.57	-18.18	20.6	0.88	4.76	44.41	12.08	20.4	11.50	-3.94	-6.64	-6.01
	Scheme 5	84.00	66.90	1.48	22.09	177.36	47.23	55.5	-19.05	2.36	-10.82	-2.43	17.1	0.55	3.80	42.22	10.38	17.1	-30.82	-23.24	-11.23	-19.28

NOTE: **Scheme 1: Static TDD**

A coordinated TDD scheme where the DL:UL ratio for the allocated slots is fixed for some period of time and the same DL:UL ratio is used by all nodes in the network. This scheme is equivalent to the traditional legacy TDD. In other words, the number of DL slots followed by UL slots are the same and synchronous across all the nodes in the network.

Operation based on static TDD is immune to so-called cross-link interference while the DL to UL ratio for the allocated slots follows a static or semi-static structure that is matched to the long term statistics of the incoming DL to UL traffic ratio.

Scheme 2: Dynamic TDD

A TDD scheme where the direction of transmission is not fixed on any resource in a static or semi-static manner and can be changed dynamically between DL and UL. In the evaluation, depending on the incoming traffic and the scheduler decision, any slot can carry DL or UL traffic.

Operation based on dynamic TDD is expected to cause so-called cross-link interference where the dominant interference for a transmission in one direction (e.g., downlink) is caused by another transmission in the other direction (e.g., uplink).

Scheme 3: Distributed Hybrid TDD

A hybrid scheme where dynamic TDD is used unless there is traffic in opposite directions to be scheduled in the cell, in which case, the cell switches to a fixed TDD scheme with a fixed DL:UL ratio. The DL:UL ratio used is the same for all cells in the network.

Scheme 4: Dynamic TDD with DL LBT

Dynamic TDD is used along with a listen-before-talk operation performed at the TRPs before DL transmissions.

Scheme 5: Dynamic TDD with UL TDD

Dynamic TDD is used along with a listen-before-talk operation performed at the UEs before UL transmissions.

A.3.1.3 Urban macro

Tables A.3.1.3-1 to A.3.1.3-6 provide the system-level evaluation results for urban macro scenario. In those tables, each source corresponds to the following references.

- Source 1: R1-1702838
- Source 5: R1-1701673
- Source 9: R1-1703109

Table A.3.1.3-1: Evaluation results for urban macro (source 1)

Source 1 (R1-1702838), Urban macro													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
4:1 Low load	Static TDD	35.4	79.9	113	79.2	0.997	19.1	1.62	15	30.7	15.4	0.963	17.7
	Case 1-1	13.3 - 62.43%	93.2 16.65%	123 8.85%	84 6.06%	0.996	13.9	1.9 17.28%	22.2 48.00%	89.2 190.55%	30.7 99.35%	0.94	18.1
	Case 1-2	8.53 - 75.90%	85.6 7.13%	123.4 9.20%	79.4 0.25%	0.997	14.5	2.1443 32.36%	24.385 62.57%	93.207 203.61%	31.54 104.81%	0.944	17.6
	Case 1-3	11.7 - 66.95%	85.6 7.13%	123 8.85%	80.6 1.77%	0.995	14.1	1.87 15.43%	21.6 44.00%	98.7 221.50%	31.9 107.14%	0.951	17
	Case 2-1	11.6 - 67.23%	101 26.41%	131 15.93%	88.6 11.87%	0.996	14.1	1.77 9.26%	24.9 66.00%	99.9 225.41%	32.8 112.99%	0.949	14.8
	Case 3-1	15.8 - 55.37%	115 43.93%	140 23.89%	98.6 24.49%	0.997	10.9	2.22 37.04%	23.2 54.67%	96.4 214.01%	32.6 111.69%	0.936	18.1
	Case 3-2	13.4 - 62.15%	112 40.18%	147 30.09%	97.3 22.85%	0.998	10.4	2.12 30.86%	35.2 134.67%	123 300.65%	44.6 189.61%	0.959	14.7
Note (interference mitigation/cancellation schemes, evaluation assumption, etc): - Interference mitigation schemes - At the transmitter, fixed analog beamforming and SVD precoding is applied. - At the receiver, MMSE-IRC receiver is applied. - Ideal channel estimation - FTP model 1 with 0.5Mbytes													

Table A.3.1.3-2: Evaluation results for urban macro (source 5)

Source 5(R1-1701673), Urban macro on unpaired spectrum@4GHz													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
1:1	Baseline	13.89	48.19	78.43	46.62	1	7.51	0.55	9.09	30.08	11.41	0.83	13.98
	Duplexing flexibility -w/o CIM	10.5 (-24.41%)	42.55 (-11.70%)	83.33 (+6.25%)	43.7 (-6.26%)	1	11.77	0.41 (-25.91%)	6.7 (-26.30%)	33.9 (+12.71%)	10.59 (-7.14%)	0.75	17.92
	Duplexing flexibility -w/ CIM	15.56 (+12.06%)	50 (+3.75%)	95.24 (+21.43%)	51.99 (+11.52%)	1	8.79	0.61 (+10.93%)	10.26 (+12.82%)	44.44 (+47.78%)	14.78 (+29.53%)	0.81	14.26

2:1	Baseline	13.79	48.19	78.43	46.83	1	7.57	0.6	10.2	30.53	11.86	0.85	7.69
	Duplexing flexibility -w/o CIM	10.96 (-20.55%)	47.06 (-2.35%)	97.56 (+24.39%)	49.02 (+4.66%)	1	11.09	0.41 (-30.85%)	6.39 (-37.38%)	35.09 (+14.91%)	10.65 (-10.15%)	0.77	9.65
	Duplexing flexibility -w/ CIM	17.09 (+23.93%)	54.8 (+13.70%)	102.56 (+30.77%)	57.2 (+22.13%)	1	8.44	0.7 (+18.15%)	10.72 (+5.09%)	44.94 (+47.19%)	15.14 (+27.73%)	0.84	7.72
4:1	Baseline	13.42	54.8	102.56	55.7	1	14.7	0.42	5.04	16.06	6.27	0.82	6.73
	Duplexing flexibility -w/o CIM	10.61 (-20.94%)	44.44 (-18.91%)	102.56 0	49.18 (-11.71%)	1	19.79	0.41 (-2.38%)	3.86 (-23.41%)	29.2 (+81.82%)	7.87 (+25.52%)	0.74	9.86
	Duplexing flexibility -w/ CIM	15.04 (+12.07%)	56.34 (+2.81%)	108.11 (+5.41%)	57.58 (+3.38%)	1	15.81	0.53 (+26.19%)	7.71 (+52.98%)	40.4 (+151.56%)	12.24 (+95.22%)	0.85	7.77

NOTE:

- CIM (cross-link interference mitigation) scheme is MMSE-IRC receiver and dynamic beam coordination. Dynamic beam coordination is based on long term TRP-TRP measurement and inter-TRP information exchange (include subframe type and DL/UL traffic information), the delay for the information exchange is 4ms and period for the information exchange is 10ms. Dynamic beam coordination includes analog beam coordination and digital beamforming.
- Evaluation assumptions refer to the agreed [2], except the following parameters:
- Traffic
  - {1:1}-the DL User arrival rate λ is 0.12
  - {2:1}-the DL User arrival rate λ is 0.12
  - {4:1}-the DL User arrival rate λ is 0.2
- BS antenna tilt is 100 degree for baseline

Table A.3.1.3-3: Evaluation results for urban macro (source 5)

Source 5(R1-1701673), Urban macro on paired spectrum@2GHz													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
4:1	baseline	4.64	22.6	57.97	26.17	0.98	24.87	1.51	22.47	58.82	24.87	0.97	5.55
	Duplexing flexibility(TX power 46dBm@UL carrier)	7.75 (+67.03%)	31.01 (+37.21%)	74.07 (+27.77%)	35.94 (+37.33)	1	22.83	1.36 (-9.93%)	21.28 (-5.30%)	53.33 (-9.33%)	23.71 (-4.66%)	0.93	5.4
	Duplexing flexibility(TX power 23dBm@UL carrier)	6.66 (+43.53%)	26.32 (+16.46%)	68.96 (+18.96%)	31.14 (+18.99)	0.99	25.17	1.47 (-2.65%)	22.27 (-0.89%)	53.33 (-9.33)	24.47 (-1.61%)	0.94	5.5

Note
- CIM (cross-link interference mitigation) scheme is MMSE-IRC receiver and semi-static beam coordination. Semi-static beam coordination is based on long term TRP-TRP measurement. Semi-static tilt coordination is used as semi-static beam coordination.
- Evaluation assumptions refer to the agreed in [2] except the following parameters:
- Traffic, the DL User arrival rate λ is 0.36
- BS antenna tilt is 100 degree for baseline
- The DL transmission power on UL carrier is 46dBm or 23dBm

Table A.3.1.3-4: Evaluation results for urban macro (source 5)

Source 5(R1-1701673), Urban macro DL performance evaluation with SRS@ DL dominant spectrum							
Antenna configure	Feature	DL Throughput Gain					
		5%-tile	50%-tile	95%-tile	Cell Average	Served/offered packets	RU (%)
4TXRU	SRS@ DL part carrier w/o. adjacent-channel interference	17.78%	22.55%	41.74%	31.95%	NA	NA
	SRS@ DL part carrier w. adjacent-channel interference	6.89%	14.00%	36.35%	27.17%	NA	NA
8TXRU	SRS@ DL part carrier w/o. adjacent-channel interference	26.52%	31.55%	42.33%	35.71%	NA	NA
	SRS@ DL part carrier w. adjacent-channel interference	12.58%	21.46%	35.48%	32.36%	NA	NA
16TXRU	SRS@ DL part carrier w/o. adjacent-channel interference	35.65%	62.69%	92.64%	73.46%	NA	NA
	SRS@ DL part carrier w. adjacent-channel interference	19.35%	47.11%	78.92%	69.64%	NA	NA

Note
• CIM (cross-link interference mitigation) scheme is MMSE-IRC receiver and semi-static beam coordination. Semi-static beam coordination is based on long term TRP-TRP measurement. Semi-static tilt coordination is used as semi-static beam Note • Periodic SRS configuration, one SRS symbol per 5ms • The overhead of both the SRS symbols and GP symbols are modelled • Alignment SRS symbols of all the cells that within one operator's network • Evaluation assumptions refer to the agreed in [2] except the following parameters: - The traffic model is full buffer - BS antenna tilt is 100 degree for baseline

Table A.3.1.3-5: Evaluation results for urban macro (source 9)

Source 9 (R1-1703109) Urban macro													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
1:1	Static TDD	1.49	5.07	11.54	5.77	0.93	24.2	0.18	0.36	1.67	0.52	0.43	41.8
	Dynamic TDD	0.26	1.37	21.29	4.24	0.56	11	0.11	0.37	2.06	0.63	0.42	73.9
2:1	Static TDD	3.23	9.47	16.18	9.96	0.98	22.7	0.16	0.32	1.33	0.44	0.46	22
	Dynamic TDD	0.62	2.56	22.6	6.36	0.82	16.7	0.09	0.44	2.27	0.69	0.42	57.1
4:1	Static TDD	4.1	12.03	18.04	12	0.98	22.2	0.16	0.34	0.91	0.41	0.45	9.7
	Dynamic TDD	1.18	6.28	22.8	9.73	0.93	19.4	0.07	0.55	2.78	0.86	0.5	37.8
Note (interference mitigation/cancellation schemes, evaluation assumption, etc):													

Table A.3.1.3-6: Evaluation results for urban macro (source 9)

Source 9 (R1-1703109) Urban macro													
Ratio of DL/UL traffic	Feature	DL UPT (Mbps)						UL UPT (Mbps)					
		5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)	5%-tile	50%-tile	95%-tile	Average	Served/offered packets	RU (%)
1:1	Without DIC	0.26	1.37	21.29	4.24	0.56	11	0.11	0.37	2.06	0.63	0.42	73.9
	With DIC	0.38	1.81	21.17	4.97	0.72	14.5	0.35	0.89	3.78	1.3	0.66	64.5
2:1	Without DIC	0.62	2.56	22.6	6.36	0.81	16.7	0.09	0.44	2.27	0.69	0.42	57.1
	With DIC	1.26	5.46	22.78	8.9	0.94	19.7	0.59	1.85	4.58	2.16	0.85	39.2
4:1	Without DIC	1.18	6.28	22.8	9.73	0.93	19.4	0.07	0.55	2.78	0.86	0.5	37.8
	With DIC	2.41	12.02	22.84	12.7	0.98	19.9	1.25	2.86	4.58	2.96	0.94	19
Note (interference mitigation/cancellation schemes, evaluation assumption, etc):													

Annex <B>: Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2016-04	RAN1#84b	R1-163376				Draft Skeleton TR	0.0.1
2016-05	RAN1#85	R1-165216				Updated version	0.0.2
2016-05	RAN1#85	R1-165889				Inclusion of agreements made at RAN1#84b on introduction, evaluation assumptions and methodologies	0.0.3
2016-08	RAN1#86	R1-168526				Inclusion of agreements made at RAN1#85 on forward compatibility, UL multiple access scheme, and updated evaluation assumptions	0.1.0
2016-10	RAN1#86b	R1-1610053					0.2.0
2016-10	RAN1#86b	R1-1610848				Inclusion of agreements made at RAN1#86 on duplexing, numerologies, frame structure, DL/UL concepts, multi-antenna scheme, and updated evaluation assumptions	0.3.0
2016-11	RAN1#87	R1-1613687				Inclusion of agreements made at RAN1#86b including numerologies, frame structure, DL/UL concepts, aspects related to initial access/mobility, multi-antenna scheme	1.0.0
2017-01	RAN1#AH1_NR	R1-1701422				Inclusion of agreements made at RAN1#87 including, DL/UL concepts, aspects related to initial access/mobility, multi-antenna scheme, channel coding and modulation, LTE-NR coexistence	1.1.0
2017-02	RAN1#88	R1-1703622				Inclusion of agreements made at RAN1 NR Ad-hoc including, DL/UL concepts, initial access/mobility, multi-antenna scheme, channel coding and modulation, LTE-NR coexistence	1.2.0
2017-03	RAN#75	RP-170377				Inclusion of agreements made at RAN1#88 Version presented to RAN#75 for approval	2.0.0
2017-03	RAN#75					Version approved as Rel-14 – Under change control process	14.0.0
2017-06	RAN#76	RP-171208	0001	1	F	Correction for channel model references	14.1.0
2017-06	RAN#76	RP-171208	0002	-	F	TR38.802_CR_Section_7.1.6_MIMO calibration	14.1.0
2017-06	RAN#76	RP-171208	0003	-	F	CR on LDPC code [38.802]	14.1.0
2017-09	RAN#77	RP-171648	0004	-	F	CR for definitions, symbols and abbreviations in TR38.802	14.2.0
2017-09	RAN#77	RP-171648	0005	-	F	TR38.802_CR_Section_7.1.6_MIMO calibration	14.2.0