3GPP TSG RAN WG1 #101 R1-20xxxxx

**e-Meeting, May 25th – June 5th, 2020**

**Agenda item: 8.4.1**

**Source: Moderator (China Telecom)**

**Title: [101-e-NR-Cov-Enh] Email discussion on evaluation methodology and simulation assumptions for NR coverage enhancements**

**Document for: Discussion and Decision**

# Introduction

In RAN #86 meeting, a new Rel-17 study item on NR coverage enhancements was approved [1]. The objective of this study item is to study potential coverage enhancement solutions for specific scenarios for both FR1 and FR2. The detailed objectives are as follows.

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

This contribution summarizes the email discussion on evaluation methodology and simulation assumptions for NR coverage enhancements.

# Discussion

## 2.1 FR1

2.1.1 Evaluation methodology

Based on the companies’ input for the evaluation methodology, there are three options summarized below.

* **Option 1: Based on link-level simulation**

Support: China Telecom, Huawei, HiSilicon, CATT, vivo, LG, Intel, Sierra Wireless, MTK, Samsung, Nokia, Nokia Shanghai Bell, Panasonic, Lenovo, xiaomi, Sony, OPPO, Sharp, CMCC, Softbank, Charter, Apple, InterDigital, NTT DOCOMO, Qualcomm (25 companies)

* **Option 2: Based on link- level and system-level simulation**
* Use link-level simulation to obtain the required SINRs for different channels.
* Use system-level simulation to obtain the target performance (i.e. the 5th percentile downlink or uplink SINR value in CDF curve)

Support: Ericsson, ZTE (2 companies)

* **Option 3: Based on system-level simulation for rural with long distance**

Support: Nomor

Based on the majority’s views, we have the following proposal:

**Proposal:**

* **Use the evaluation methodology based on link-level simulation for FR1.**

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| Nokia/NSB | Agree with the Moderator’s proposal. |
| Nomor Resarch GmbH | Nomor supports option 2.  In the link-level simulation, the users’ geometry distribution and network’s layout cannot be characterized, which would have impacts on issues such as beamforming gain and interference strength, as concerns are also raised on GTW1. System-level simulation is a tool that is useful for performance evaluation from a network perspective. In addition, for performance evaluation of specific solutions which are proposed by several companies to enhance coverage, system-level simulations are required. Link-level simulations are not solely enough to test the performance of those coverage enhancement methods. Therefore, we believe that eventually the need for system-level simulations will occur. System-level simulation considerations are already provided by Huawei, Ericsson, ZTE, IITH, CeWiT, IITM, Reliance Jio and Tejas Networks.  On the other hand, the approach that we have mostly used in our contribution [26] is not a full-scale system-level simulation for the baseline performance analysis, instead a similar one to the Option 2. We use system-level simulations to obtain SNR samples, and then convert those samples to throughput samples and look at the 5th percentile of CDF curve. That way, we can assess the performance of the system using the target throughput values defined in SID, i.e. 1Mbps DL and 100kbps UL throughput, for Rural scenario with long distance[1].  Nomor believes that system-level simulations should also be used to assess the coverage performance for FR1, along with link-level simulations, as the evaluation methodology to have better understanding of the system behaviour under different assumptions. |
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There are two main options on how to use the evaluation methodology based on link-level simulation.

* **Option 1-1 Based on link budget in IMT-2020 self-evaluation**
* Reuse the evaluation methodology employed in IMT-2020 self-evaluation [2] with the necessary revision.
* The calculated available path loss is considered as the baseline performance.

Support: China Telecom, Huawei, HiSilicon, CATT, vivo, LG, Intel, Sierra Wireless, MTK, Samsung, Nokia, Nokia Shanghai Bell, Panasonic, Lenovo, xiaomi, Sony, OPPO, Sharp, Qualcomm (19 companies)

* **Option 1-2 Based on MCL in TR 36.824**
* Reuse MCL in TR 36.824 for LTE coverage enhancement.
* The calculated MCL is considered as the baseline performance.

Support: Softbank, Charter, Apple, InterDigital, NTT DOCOMO (5 companies)

Based on the majority’s views, we have the following proposal:

**Proposal:**

* **Reuse the evaluation methodology employed in IMT-2020 self-evaluation for FR1.**
  + **Reuse the link budget template employed in IMT-2020 self-evaluation.**
  + **Some parameters can be revised based on the practical deployment.**
* **The calculated available path loss is considered as the baseline performance for FR1.**

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| Nokia/NSB | Agree with Moderator’s proposal. |
| Nomor Research GmbH | Nomor supports the proposal.  We support the reuse of the link-budget template employed in IMT-2020 self-evaluation, along with revisions based on the practical deployment. |
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2.1.2 Simulation assumptions for link-level simulation

(1) Target performance

* Option 1: Target ISD

Support: China Telecom, Huawei, HiSilicon, vivo, Lenovo, Samsung, OPPO, CMCC, CATT (9 companies)

urban:

* 400m (China Telecom, CMCC, Lenovo, OPPO, CATT, ZTE)
* 500m (China Telecom, Huawei, HiSilicon, Lenovo, Samsung, xiaomi, OPPO, vivo, CATT, ZTE)

rural:

* 1732m (China Telecom, Huawei, HiSilicon, CMCC, Lenovo, Samsung, OPPO, vivo, CATT, ZTE)
* 5000m (ZTE)
* 6000m (China Telecom, Lenovo, OPPO, CATT)

rural with long distance:

* 5000m (vivo)
* 12km (China Telecom, Huawei, HiSilicon, Lenovo, OPPO, ZTE)
* 30km (China Telecom, Nomor, Lenovo, Samsung, OPPO, CATT, ZTE)
* Option 2: Target MCL

Support: Qualcomm, LG, Softbank (3 companies)

Based on the majority’s views, we have the following proposal:

**Proposal:**

* **The target path loss derived from the target ISD is considered as the target performance for each scenario.**
  + **Urban: Target ISD = 400/500m**
  + **Rural: Target ISD = 1732/6000m**
  + **Rural with long distance: Target ISD = 12km/30km**

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| Nokia/NSB | In our view, defining ISD targets as first step is somehow counterintuitive. Indeed, it would seem more reasonable to first agree/align on the EVM and simulation assumptions and then discuss ISD targets. The proposed numbers are all reasonable figures, we have no objection to them quantitatively. However, we believe they are not acceptable in their current form qualitatively, since we should first agree on which propagation condition(s) will be studied for each scenario. Identifying a single ISD target per scenario for NLOS and LOS, and for O-to-O and O-to-I propagation does not seem very meaningful to us. |
| Nomor Research GmbH | Nomor supports the proposal.  The target path loss derived from target ISD is considered as the target performance for each scenario and we support the target ISD values of Urban and Rural scenarios.  For rural with long distance, most of the companies have reflected in their contributions that ISDs greater than 12km are required and 30km should be the baseline assumption for rural with long distance. Nomor also believes likewise that 30km is the appropriate value for rural with long distance scenario. We have shown with performance results in our contribution [26] that the system with ISD=30km is a good place to start, where DL system performance meets the 1Mbps criterion of SID and enhancement methods can lead the system to meet the target throughput 100kbps in UL.  Moreover, even larger ISDs, such as 100km are mentioned by several companies in the e-mail discussion during the discussions of SID. Therefore, at least 30km should be the baseline assumption to also meet this demand. |
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(2) Link budget template

For the link budget template employed in IMT-2020 self-evaluation, most parameters and values can be reused. While based on the companies’ inputs, some parameters identified with TBD (To Be Determined) in Table A need to be discussed and determined.

In order to facilitate discussion on simulation assumptions, we have the following proposal:

**Proposal:**

* **Adopt Table A for the baseline performance calculation for FR1.**

Table A Link budget template for FR1

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| **Parameter** | **Values** |
| Scenario | TBD |
| Frame structure | TBD |
| Carrier frequency (Hz) | TBD |
| BS antenna heights (m) | 25m for urban, 35m for rural |
| UT antenna heights (m) | 1.5 |
| Cell area reliability for control channel | 95% |
| Cell area reliability for data channel | 90% |
| Transmission bit rate for control channel (bit/s) | TBD |
| Transmission bit rate for data channel (bit/s) | TBD |
| Target packet error rate for the required SNR in item (19a) for control channel | 1% |
| Target packet error rate for the required SNR in item (19b) for data channel | TBD |
| Spectral efficiency (bit/s/Hz) | TBD |
| Pathloss model (select from LoS or NLoS) | TBD |
| UE speed (km/h) | TBD |
| Feeder loss (dB) | 3 |
| **Transmitter** | |
| (1) Number of transmit antennas. (The number shall be within the indicated range in § 8.4 of Report ITU-R M.2412-0) | TBD |
| (1bis) Number of transmit antenna ports | TBD |
| (2) Maximal transmit power per antenna (dBm) | TBD |
| (3) Total transmit power = function of (1) and (2) (dBm) (The value shall not exceed the indicated value in § 8.4 of Report ITU-R M.2412-0) | TBD |
| (4) Transmitter antenna gain (dBi) | 0 for UL, 8 for DL |
| (5) Transmitter array gain (depends on transmitter array configurations and technologies such as adaptive beam forming, CDD (cyclic delay diversity), etc.) (dB) | TBD |
| (6) Control channel power boosting gain (dB) | 0 |
| (7) Data channel power loss due to pilot/control boosting (dB) | 0 |
| (8) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for downlink) | 1 for UL, 3 for DL |
| (9a) Control channel EIRP = (3) + (4) + (5) + (6) – (8) dBm | - |
| (9b) Data channel EIRP = (3) + (4) + (5) – (7) – (8) dBm | - |
| **Receiver** | |
| (10) Number of receive antennas (The number shall be within the indicated range in § 8.4 of Report ITU-R M.2412-0) | TBD |
| (10bis) Number of receive antenna ports | TBD |
| (11) Receiver antenna gain (dBi) | 0 for DL, 8 for UL |
| (11bis) Receiver array gain (depends on transmitter array configurations and technologies such as adaptive beam forming, etc.) (dB) | TBD |
| (12) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for uplink) | 1 for DL, 3 for UL |
| (13) Receiver noise figure (dB) | 5 for UL, 7 for DL |
| (14) Thermal noise density (dBm/Hz) | -174 |
| (15a) Receiver interference density for control channel (dBm/Hz) | TBD |
| (15b) Receiver interference density for data channel (dBm/Hz) | TBD |
| (16a) Total noise plus interference density for control channel = 10 log (10^(((13) + (14))/10) + 10^((15a)/10)) dBm/Hz | - |
| (16b) Total noise plus interference density for data channel = 10 log (10^(((13) + (14))/10) + 10^((15b)/10)) dBm/Hz | - |
| (17a) Occupied channel bandwidth for control channel (for meeting the requirements of the traffic type) (Hz) | TBD |
| (17b) Occupied channel bandwidth for data channel (for meeting the requirements of the traffic type) (Hz) | TBD |
| (18a) Effective noise power for control channel = (16a) + 10 log((17a)) dBm | - |
| (18b) Effective noise power for data channel = (16b) + 10 log((17b)) dBm | - |
| (19a) Required SNR for the control channel (dB) | Obtained from link-level simulation |
| (19b) Required SNR for the data channel (dB) | Obtained from link-level simulation |
| (20) Receiver implementation margin (dB) | 2 |
| (21a) H-ARQ gain for control channel (dB) | 0 |
| (21b) H-ARQ gain for data channel (dB) | 0.5 |
| (22a) Receiver sensitivity for control channel = (18a) ++ (19a) + (20) – (21a) dBm | - |
| (22b) Receiver sensitivity for data channel = (18b) ++ (19b) + (20) – (21b) dBm | - |
| (23a) Hardware link budget for control channel = (9a) + (11) + (11bis) − (22a) dB | - |
| (23b) Hardware link budget for data channel = (9b) + (11) + (11bis) − (22b) dB | - |
| **Calculation of available pathloss** | |
| (24) Lognormal shadow fading std deviation (dB) | TBD |
| (25a) Shadow fading margin for control channel (function of the cell area reliability and (24)) (dB) | TBD |
| (25b) Shadow fading margin for data channel (function of the cell area reliability and (24)) (dB) | TBD |
| (26) BS selection/macro-diversity gain (dB) | 0 |
| (27) Penetration margin (dB) | TBD |
| (28) Other gains (dB) (if any please specify) | 0 |
| (29a) Available path loss for control channel = (23a) – (25a) + (26) – (27) + (28) – (12) dB | - |
| (29b) Available path loss for data channel = (23b) – (25b) + (26) – (27) + (28) – (12) dB | - |
| **Range/coverage efficiency calculation** | |
| (30a) Maximum range for control channel (based on (29a) and according to the system configuration section of the link budget) (m) | Note 1 |
| (30b) Maximum range for data channel (based on (29b) and according to the system configuration section of the link budget) (m) | Note 1 |

Note 1: The channel model for path loss calculation is defined in Report ITU-R M.2412 [3].

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| Nokia/NSB | From our perspective, the difference between control and data channels in terms of reliability targets and retransmission framework (data channels can have HARQ whereas control channels do not) is already accounted for when setting BLER requirements for SNR/SINR, i.e., 10% BLER for data and 1% BLER for control). Setting different cell area reliability between the two channels may not be necessary in this context. The latter parameter is related to shadow fading assumptions and represent the percentage of the cell for which coverage is guaranteed. We would like to discuss the reasons why such percentage should be different between the two channels. |
| Nomor Research GmbH | Nomor supports the proposal with slight concerns on particular issues mentioned below.  Note 1 indicates that the channel model for path loss calculation is defined in Report ITU-R M.2412. Firstly, there are two channel models, A and B in this report. Nomor would like to propose channel model B to be used in the evaluations. In addition, both of the channel models are not valid for distances greater than 21km. With ISDs such as 30km for rural long-range scenario, we need valid channel models. Therefore, Nomor proposes to have a discussion to define a channel model for such distances.  In addition, we have shown in [26] that larger antenna heights than 35m significantly enhances the performance. Nomor asks RAN1 to discuss whether a larger antenna height, such as 75m, should be defined as the baseline assumption or if this height is considered too high for real-world scenarios. |
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(3) Simulation assumptions for link-level simulation

Companies are encouraged to provide views on the simulation assumptions for PUSCH and PUCCH in the following table.

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| **Parameters and descriptions** | **Companies** | **Comments** |
| **Number of receive antenna elements for BS**   * Option 1: 192 antenna elements for urban,   (M,N,P,Mg,Ng) = (12,8,2,1,1)   * Option 2: 64 antenna elements for rural and rural with long distance,   (M,N,P,Mg,Ng) = (8,4,2,1,1) | Nokia/NSB | Option 1 preferred choice, however open to consider option 2. |
| Nomor Research GmbH | Nomor supports the number of antenna elements proposed on BS for rural and rural with long distance scenarios.  The proposal corresponds to our simulation assumption on the rural with long distance scenario, and also to the one we have used in IMT-2020 evaluation studies for rural scenario.  Nomor does not have objections for the proposal of urban scenario. |
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| **Number of receive TxRUs for BS**   * Option 1: 2 (The same value in IMT-2020) * Option 2: 4 * Option 3: 8 | Nokia/NSB | Option 1. |
| Nomor Research GmbH | Nomor supports option 3.  We have already used 4TxRUs per polarization in our IMT-2020 evaluation, where we have 4 columns of antenna elements per polarization in our system-level simulations. This is also the assumption we have used in [26]. Therefore, Nomor supports the idea that 8TxRUs (Mp,Np) = (1,4) should be used for the rural and rural with long distance scenarios. This is also mentioned as the baseline assumption in IMT-2020 evaluation process by some other companies in GTW1.  In the urban scenario with the BS antenna configuration proposed above, there should clearly be sub-array partitioning in vertical domain, i.e. Mp>1, due to the flatness of a beam generated by a column of 12 antenna elements and the wide variety of elevation angles under which the BS can see the UEs. Hence, here too, in our opinion there should be at least 8TxRUs, e.g. (Mp,Np)=(2,2) or even 16 TxRUs (Mp,Np)=(2,4). |
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| **Receiver array gain for BS**   * Option 1: Reuse the formula in IMT-2020 self-evaluation to calculate the array gain,   array gain = 10 \* 1og10 (number of receive antennas/number of receive TxRUs)   * Options 2: Other methods | Nokia/NSB | Option 1. |
| Nomor Research GmbH | Nomor supports the option 1. |
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| **Receiver interference density for control channel**   * Option 1: 161.70 dBm/Hz for UL, -169.30 dBm/Hz for DL.   (The same value in IMT-2020)   * Option 2: Other values | Nokia/NSB | Option 1. |
| Nomor Research GmbH | Nomor supports the option 1. |
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| **Receiver interference density for data channel**   * Option 1: -165.70 dBm/Hz for UL, -169.30 dBm/Hz for DL.   (The same value in IMT-2020)   * Option 2: Other values | Nokia/NSB | Option 1. |
| Nomor Research GmbH | Nomor supports the option 1. |
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| **Delay spread**   * + urban: TBD   + rural: TBD   + rural with long distance: TBD | Nokia/NSB | Rural FDD/TDD:   * NLOS: TDL-C 37ns * LOS: TDL-E 32 ns   Urban TDD:   * NLOS: TDL-C 363ns * LOS: TDL-E 93 ns |
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| **Shadow fading for control channel**   * Option 1:   + Urban: 7.56 dB for NLOS O-to-I   + Rural: 8.45 dB for NLOS O-to-I, 10.45 dB for NLOS O-to-O   + Rural with long distance: 8.06 dB for LOS O-to-O   (The same value in IMT-2020)   * Option 2: Other values | Nokia/NSB | Option 2. The slope of PL model and shadow fading standard deviation should be aligned first. The shadow fading margin can then be calculated based on the slope, standard deviation and cell area reliability requirement. |
| Nomor Research GmbH | Nomor supports the option 1. |
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| **Shadow fading for data channel**   * Option 1:   + Urban: 4.48 dB for NLOS O-to-I   + Rural: 5.13 dB for NLOS O-to-I, 6.61 dB for NLOS O-to-O   + Rural with long distance: 4.79 dB for LOS O-to-O   (The same value in IMT-2020)   * Option 2: Other values | Nokia/NSB | Option 2. The slope of PL model and shadow fading standard deviation should be aligned first. The shadow fading margin can then be calculated based on the slope, standard deviation and cell area reliability requirement. |
| Nomor Research GmbH | Nomor supports the option 1. |
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| **Penetration margin**   * Option 1:   + Urban: 26.25 dB for NLOS O-to-I   + Rural: 9.00 dB for NLOS O-to-O, 12.50 dB for NLOS O-to-I   + Rural with long distance: 9.00 dB for LOS O-to-O   (The same value in IMT-2020)   * Option 2: Other values | Nokia/NSB | Option 2 as follows: The values for O-to-I are the same as for Option 1, but the values for O-to-O apply only for high speed UEs, i.e., UEs inside vehicles (of any sort). Penetration margin for low speed O-to-O UE should be 0 dB. |
| Nomor Research GmbH | Nomor supports the option 1. |
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| **Other parameters** |  |  |
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* PUSCH

Companies’ views on simulation assumptions for PUSCH for link-level simulation for FR1 are summarized in Appendix 1. Based on the majority’s inputs, we have the following proposal:

**Proposal:**

* **Adopt Table B for PUSCH for FR1.**

Table B Simulation assumptions for PUSCH for FR1

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| Parameters | Values |
|  Scenario and frequency | * Urban: 4GHz(TDD), 2.6GHz(TDD) * Rural: 4GHz(TDD) , 2GHz(FDD), 700MHz(FDD) * Rural with long distance: 700MHz(FDD) |
|  Frame structure for TDD | DDDSU, DDDSUDDSUU, DDDDDDDSUU |
| BLER | 10% for eMBB, 2% rBLER for voice |
|  Codec for voice | 12.2 kbps |
|  Pathloss model (select from LoS or NLoS) | NLos for urban and rural, LoS for rural with long distance |
| Channel model for link-level simulation | TDL-C for urban and rural, TDL-D for rural with long distance |
| UE velocity | 120 km/h for outdoor, 3 km/h for indoor |
| Occupied channel bandwidth | 30PRBs for urban eMBB, 4 PRBs for urban VoIP,  4 PRBs for rural and rural with long distance. |
| Number of UE antennas | 2 for urban, 1 for rural and rural with long distance |
| Number of TRXU for UE | 2 for urban, 1 for rural and rural with long distance |
| DMRS configuration | DMRS:  - For 3km/h: Type I, one DMRS symbol, no multiplexing with data.  - For 120km/h: Type I, 2 DMRS symbol (one front- loaded and one additional), no multiplexing data |
| Repetition | eMBB: off, VoIP: on |
| Frequency hopping | on |

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| Nokia/NSB | Scenario and frequency: In principle we agree with the proposed values, however we would think that considering all of them as “mandatory” may lead to an excessive redundancy for the discussion and simulation. We would prefer to prioritize them as follows: Urban: 4 GHz (TDD) to be considered for the study and 2.6 GHz as optional; Rural: 4 GHz (TDD) and 700 MHz (FDD) to be considered for the study and 2 GHz (FDD) as optional.  Frame structure: In our view, setting a fixed frame structure for TDD deployments does not leverage the flexibility offered by NR frame structure in such scenarios. In particular, this choice is sub-optimal for coverage enhancement, as shown in R1-2004178. Therein we showed that an MPL enhancement of 2.7 to 3.8 dB, i.e., a coverage increase of around 20%, can be observed if the frame structure is set to account for the specific PUSCH throughput target while exceeding the throughput target for PDSCH. We prefer to replace either DDDSUDDSUU or DDDDDDDSUU with 4D1S5U (10D:2G:2U) in the list of considered frame structure for evaluation.  Codec for voice: According to GSMA VoLTE profile, The UE must support AMR wideband codec as described in TS 26.114. Therein, AMR-WB is defined as a mandatory codec, and even MTSI clients in constrained terminals shall support it. In our view, it seems reasonable to determine the reference value for the VoIP packet size to be used in this study according to the specification of the AMR-WB. We propose to focus on the AMR-WB 12.65 (kbit/s) codec, i.e., a reasonable ‘legacy’ choice which offers a better sound quality than the traditional narrowband codec.  Channel model: Similar to IMT-2020, our preference is to differentiate between NLOS and LOS propagation, and not between Urban and Rural. Hence, we prefer TDL-C for NLOS (rural, if applicable, and urban) and TDL-E for LOS (urban, if applicable, and rural)  UE speed: In our view, it is reasonable to differentiate between Urban and Rural when considering high speed UEs. Setting 30 Km/h for Urban scenarios and 120 Km/h for Rural seems more reasonable. Low speed UEs should move at 3 Km/s, both indoor and outdoor.  Occupied bandwidth: In our view, setting a fixed occupied bandwidth for eMBB service, without accounting for MCS selection, is highly sub-optimal for PUSCH coverage enhancement. This approach can lead to non-negligible underestimation of the MPL of PUSCH, as shown in R1-2004178 (more than 2 dBs), and thus it should be discouraged. In this context, MCS Table 5.1.3.1-3 in TS38.214 (‘qam64LowSE’) provides a set of MCS indices which enables the allocation of larger occupied PUSCH bandwidth and achieve coverage enhancement. Suitable MCS/number of PRBs couples can be found for each scenario. In our view, this approach is more appropriate to the scope of this study. Conversely, 4 PRBs for VoIP seem reasonable and we agree to that.  Number of UE antennas: Our preference is to consider the same UE configuration for both Urban and Rural. This seems more reasonable. We would prefer 2 antennas for UE in both cases.  Number of TXRUs for UE: Our preference is to consider the same UE configuration for both Urban and Rural. This seems more reasonable. We would prefer 1 TXRU for UE in both cases, which seems more suitable for coverage studies.  Repetition: Aggregation factor should consider the TDD frame structure.  Frequency hopping: our preference is for intra-slot frequency hopping ON.  HARQ: For VoIP, given the BLER requirement, we would like to highlight the need to agree on the number of retransmissions, which in turn should depend on the TDD frame structure. |
| Nomor Research GmbH | Nomor supports the assumptions on Table B, except items indicated below:  - LoS for rural with long distance: We believe that as for rural scenario, rural with long distance should also cover NLoS, since NLoS will be the bottleneck of the system, rather than LOS. Since we are looking at the coverage performance in this study, not considering NLoS can cause problems for the UEs that are actually NLoS in real world scenarios. In addition, we have shown in [26] that the system performance can be enhanced by various techniques, and the performance of the system including UEs that are NLoS, can meet performance criteria determined in [1]. Therefore, Nomor proposes to evaluate both LoS and NLoS separately for the rural long distance scenario.  - Nomor believes that 2 UE antennas and 2 TxRUs should be used, instead of 1, as up to 2 antennas were allowed in IMT-2020 evaluations for rural with long distance.  On the other hand, we have already showed in [26] that repetition does not bring significant benefit for eMBB, rather it enhances the performance of VoIP significantly in case of rural with long distance scenario. Therefore, Nomor fully supports this proposal. Moreover, our results have shown that frequency hopping significantly enhances the coverage performance. Thus, Nomor also fully supports this proposal and even would like to enhance the standardized frequency hopping procedure. |
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* PUCCH

Regarding the simulation assumptions for PUCCH for FR1, most parameters can be reused from PUSCH for FR1. Some channel-specific parameters for PUCCH are summarized based on companies’ inputs in Appendix 2.

Based on the majority companies’ views, we have the following proposal:

**Proposal:**

* **Adopt Table C for PUCCH for FR1.**

Table C Simulation assumptions for PUCCH for FR1

|  |  |
| --- | --- |
| Parameters | Values |
| Format type | Format 1, 2bits UCI  Format 3, 11/22 bits UCI |
|  Occupied channel bandwidth | 1 PRB |
| Number of UE antennas | 1 |
| Number of TRXU for UE | 1 |
| Repetition | on |
| Frequency hopping | on |

Note: Other general parameters for PUCCH can be reused from PUSCH.

Companies are invited to provide views on the above proposal.

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| --- | --- |
| **Companies** | **Comments** |
| Nokia/NSB | Occupied channel bandwidth: In our view the occupied channel bandwidth in case for format 3, especially for 22 bits UCI payload, could be increased to 2 PRBs.  Frequency hopping: our preference is for intra-slot frequency hopping ON. |
| Nomor Research GmbH | Nomor supports the proposal. |
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* Other channels for FR1

The channel-specific parameters for other channels, i.e. PDSCH, PDCCH, PRACH, Msg3, SSB/PBCH, are summarized based on companies’ input in Appendix 3.

Due to lack of sufficient inputs and detailed simulation assumptions for other channels, we would like to invite companies to provide further views and comments.

|  |  |  |
| --- | --- | --- |
| **Channel** | **Companies** | **Comments** |
| PDSCH | Nokia/NSB | In our view, full bandwidth allocation and lowest possible MCS index should be assumed for coverage study. The same observations we made on PUSCH on the TDD frame structure apply for PDSCH. |
| Nomor Research GmbH | We have observed in our simulation results [26] for rural long distance scenario that PDSCH performance meets the 1Mbps throughput criterion defined in SID. Therefore, Nomor believes that is not necessary to further investigate PDSCH on coverage enhancement. |
|  |  |
| PDCCH | Nokia/NSB | AL16, DCI payload size 40 bits, 2 OFDM symbols and CORESET bandwidth 48 PRBs is our preferred configuration. |
| Nomor Research GmbH | We have observed in our simulation results that PDCCH coverage performance is sufficient in the rural long distance scenario [26]. Therefore, Nomor believes that it is not necessary to further investigate PDCCH on coverage enhancement. |
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| PRACH |  |  |
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| Msg3 | Nokia/NSB | Size 56 bits (optional 72). |
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| SSB/PBCH |  |  |
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# Appendix

## Appendix 1

Appendix 1 Companies’ views on simulation assumptions for PUSCH for FR1

|  |  |
| --- | --- |
| Parameters | Companies’ views |
| Scenario and frequency | * Urban:   + 4GHz(TDD) (China Telecom, Huawei, HiSilicon, Sharp, Panasonic, MTK, Lenovo, Samsung, Sony, xiaomi, Qualcomm, Intel, OPPO, vivo, CATT, Nokia, Nokia Shanghai Bell, Ericsson, ZTE)   + 2.6GHz(TDD) (CMCC) * Rural:   + 4GHz(TDD) (China Telecom, Huawei, HiSilicon, MTK, Lenovo, Samsung, xiaomi, vivo, CATT, Nokia, Nokia Shanghai Bell, ZTE)   + 2GHz(FDD) (China Telecom, Huawei, HiSilicon, MTK, Lenovo, Samsung, OPPO, vivo, CATT, ZTE)   + 700MHz(FDD) (Panasonic, Qualcomm, Intel, Nokia, Nokia Shanghai Bell, Ericsson, ZTE) * Rural with long distance:   + 700MHz (FDD) (China Telecom, Huawei, HiSilicon, Panasonic, MTK, Lenovo, Samsung, Qualcomm, OPPO, vivo, CATT, ZTE) |
| Frame structure for TDD | Option 1: DDDSU (10D:2G:2U) (Nokia, Nokia Shanghai Bell, OPPO, xiaomi, Samsung)  Option 2: DDDSUDDSUU (10D:2G:2U) (China Telecom, Huawei, HiSilicon, vivo, CATT, MTK, Lenovo, OPPO, xiaomi, Samsung)  Option 3: DDDDDDDSUU (CMCC)  Option 4: 4D1S5U (periodicity 5ms for 30kHz SCS) (D:U=10:2 for S slot) (Nokia, Nokia Shanghai Bell)  Option 5: DDSU (S is 11DL:1G:2UL) 2ms periodicity (Qualcomm)  Option 6: DSUUD (Sony) |
| BLER | For PUSCH:   * + 10% iBLER for eMBB (China Telecom, Huawei, HiSilicon, Sharp, Panasonic, Samsung, Intel, Nokia, Nokia Shanghai Bell, ZTE)   + 2% rBLER for VoIP (Panasonic, Nokia, Nokia Shanghai Bell, InterDigital, Samsung, ZTE)   + eMBB scenarios = 10% BLER and optionally 40% BLER, Voice scenario = 1% BLER (Sierra Wireless)   + 10% BLER for eMBB service and 1% BLER for VoIP service (Lenovo) |
| Codec for voice | * Option 1: 7.2 kbps (Sierra Wireless) * Option 2: 12.2 kbps (China Telecom, Huawei, HiSilicon, ZTE, CATT, Lenovo, OPPO, Apple, Samsung, MTK, NTT DOCOMO) * Option 3: AMR-WB 12.65 kbps (Nokia, Nokia Shanghai Bell) * Option 4: EVS 13.2 kbps (Sierra Wireless, Softbank, Qualcomm) |
| Pathloss model (select from LoS or NLoS) | * Urban/rural:   + NLOS (China Telecom, Huawei, HiSilicon, ZTE, vivo, MTK, Lenovo, Samsung, OPPO, Sharp, xiaomi, CATT) * Rural with long distance:   + LOS (China Telecom, Huawei, HiSilicon, ZTE, vivo, MTK, Lenovo, Samsung)   + NLOS (OPPO) |
| Channel model for link-level simulation | Channel model for TDL:   * Urban:   + TDL-C (China Telecom, Huawei, HiSilicon, ZTE, vivo, CATT, MTK, Lenovo, Samsung, Panasonic, OPPO, Apple, Nokia, Nokia Shanghai Bell, InterDigital, Sierra Wireless, xiaomi, NTT DOCOMO)   + TDL-A (Intel, Panasonic, Ericsson, Apple) * Rural:   + TDL-C (China Telecom, Huawei, HiSilicon, ZTE, vivo, CATT, MTK, Lenovo, Samsung, Panasonic, OPPO, Nokia, Nokia Shanghai Bell, InterDigital, Sierra Wireless, xiaomi, NTT DOCOMO)   + TDL-A (Intel, Panasonic, Ericsson) * Rural with long distance:   + TDL-E (Huawei, HiSilicon)   + TDL-D (China Telecom, ZTE, vivo, CATT, MTK, Lenovo, Samsung)   + TDL-C (Panasonic, OPPO)   + TDL-A (Intel, Panasonic)   Channel model for CDL:   * + CDL-A (Sharp)   + CDL-C/E (Qualcomm) |
| Delay Spread | * Urban:   + 616ns (InterDigital)   + 363ns (Qualcomm, Nokia, Nokia Shanghai Bell)   + 300ns (China Telecom, Huawei, HiSilicon, vivo, ZTE, MTK, Lenovo, Samsung, OPPO, xiaomi, Ericsson, Apple)   + 240ns (CATT, Panasonic)   + 100ns (Ericsson)   + 30ns (Intel, Apple) * Rural:   + 363ns (Panasonic)   + 300ns (China Telecom, Huawei, HiSilicon, vivo, ZTE, MTK, Lenovo, Samsung, OPPO, xiaomi, Apple)   + 153ns (InterDigital)   + 100ns (Ericsson)   + 37ns for NLOS O2O, 34ns for NLOS O2I (CATT)   + NLOS 37ns, LOS 32ns (Qualcomm)   + 37ns (Nokia, Nokia Shanghai Bell)   + 30ns (Intel, Apple, Ericsson) * Rural with long distance:   + 363ns (Panasonic)   + 300ns (China Telecom, Huawei, HiSilicon, vivo, CATT, MTK, Lenovo, Samsung, OPPO, Apple)   + 37ns (Qualcomm, Nokia, Nokia Shanghai Bell)   + 30ns (ZTE, Intel, Apple) |
| UE velocity | * + 3km/h for indoor, 120km/h for outdoor (China Telecom, Huawei, HiSilicon, ZTE, vivo, CATT, MTK, Lenovo, Samsung, OPPO, Qualcomm)   + 3km/h for eMBB, 3km/h, 30km/h, 100km/h for VoIP (Sierra Wireless)   + 3km/h (Intel, Panasonic)   + 3km/h, [30km/h] for 4GHz, 3km/h, [30,120km/h] for 700MHz (Ericsson)   + 3km/h, 30km/h, for urban, 3km/h, 120km/h for rural. (Nokia, Nokia Shanghai Bell) |
| Occupied channel bandwidth | * Urban:   + eMBB:   + 40PRBs (xiaomi)   + 30PRBs (China Telecom, Huawei, HiSilicon, vivo, CATT, MTK, Lenovo, Samsung, OPPO, xiaomi)   + 20PRBs (xiaomi, Sierra Wireless)   + 15PRBs (NTT DOCOMO)   + 6PRBs (Intel)   + 4PRBs (Sharp)   + VoIP:   + 4PRBs (China Telecom, Huawei, HiSilicon, vivo, CATT, MTK, Lenovo, Samsung, OPPO, NTT DOCOMO)   + 1PRB (Sierra Wireless) * Rural/rural with long distance:   + eMBB:   + 4PRBs (China Telecom, Huawei, HiSilicon, vivo, CATT, MTK, Lenovo, Samsung, OPPO, xiaomi)   + 2PRBs (NTT DOCOMO, Intel, Sierra Wireless)   + VoIP:   + 4PRBs (China Telecom, Huawei, HiSilicon, vivo, CATT, MTK, Lenovo, Samsung, OPPO)   + 2PRBs (Intel)   + 1PRB (Sierra Wireless) |
| BS antennas configuration | * Urban:   + 192 elements and 2 TxRU (China Telecom, Huawei, HiSilicon, vivo, Lenovo, Samsung, OPPO)   + 192 elements and 4/8/64 TxRU (ZTE)   + 64 elements and 2 Rx (Nokia, Nokia Shanghai Bell)   + 32 elements and 4 Rx (Ericsson)   + 16 Rx (Sierra Wireless)   + 8 Rx (Apple)   + 4 Rx (Panasonic)   + 2 Rx (Intel, InterDigital, xiaomi) * Rural/rural with long distance:   + 64 elements and 2 TxRU (China Telecom, Huawei, HiSilicon, vivo, Lenovo, Samsung, OPPO)   + 64 elements and 2/4/8 TxRU (ZTE)   + 32 elements and 2 TxRU (Ericsson, Nokia, Nokia Shanghai Bell) |
| UE antennas configuration | * Urban:   + 1T (vivo, Intel, InterDigital, Sierra Wireless, Apple, Ericsson, Nokia, Nokia Shanghai Bell)   + 2T (China Telecom, ZTE, Lenovo, Samsung, OPPO, Huawei, HiSilicon, Panasonic, xiaomi) * Rural:   + 1T (China Telecom, ZTE, Lenovo, Samsung, OPPO, vivo, Intel, InterDigital, Sierra Wireless, Apple, Ericsson, Nokia, Nokia Shanghai Bell, xiaomi)   + 2T (Huawei, HiSilicon, Panasonic) * Rural with long distance:   + 1T (China Telecom, ZTE, Lenovo, Samsung, OPPO, Huawei, HiSilicon, vivo, Intel, InterDigital, Sierra Wireless, Apple)   + 2T (Panasonic) |
| DMRS configuration | * For 3km/h:   + 1 DMRS symbol (China Telecom, Huawei, HiSilicon, ZTE, vivo, Lenovo, Samsung, OPPO, MTK, CATT)   + 2 DMRS symbol (MTK, Sierra Wireless) * For 120km/h:   + 2 DMRS symbol (one front- loaded and one additional) (China Telecom, Huawei, HiSilicon, ZTE, vivo, Lenovo, Samsung, OPPO, Sierra Wireless, CATT)   + 3 DMRS symbol (MTK)   Type 1 with 3 symbols with no data on DMRS symbols (Qualcomm)  2 DMRS symbols (Intel, Nokia, Nokia Shanghai Bell) |
| Repetition | * For eMBB   + On (LG)   + Off (Sierra Wireless) * For VoIP   + On (InterDigital, Sierra Wireless, LG)   + Off |
| Frequency hopping | * + On (InterDigital, Sierra Wireless, Intel)   + Off (NTT DOCOMO) |
| Shadow fading margin | * Urban: 4.48 dB (China Telecom, Huawei, HiSilicon, OPPO) * Rural: 5.13 dB for O-to-I, 6.61 dB for O-to-O (China Telecom, Huawei, HiSilicon, OPPO) * Rural with long distance: 4.79 dB (China Telecom, Huawei, HiSilicon, OPPO); 8dB for 2.6GHz (CMCC) |
| Penetration margin | * Urban: 26.25 dB (Sharp, China Telecom, OPPO) * Rural: 9.00 dB for O-to-O, 12.50 dB for O-to-I (China Telecom, OPPO) * Rural with long distance: 9.00 dB (China Telecom, OPPO) * Rural at 4GHZ for NLoS O2I: 14.53 dB (Huawei, HiSilicon); 15dB for 2.6GHz (CMCC) |

## Appendix 2

Appendix 2 Companies’ views on simulation assumptions for PUCCH for FR1

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| --- | --- |
| Parameters | Companies’ views |
| Format type | * Format 1   + 2bits (China Telecom, Huawei, HiSilicon, Lenovo, Samsung, OPPO, Sharp)   + 1bit (CATT) * Format 1 and Format 3   + Format 1 or 3, 1bit, 2bits, 6bits, 11bits, 22bits. (ZTE)   + Format 1, 2bits; Format 3, 8bits. (vivo)   + Format 1 for VoIP with 1bit UCI, Format 3 for eMBB with 8bits UCI. (NTT DOCOMO)   + Format 1, UCI size = 1 bit; Format 3, UCI size = 50 bits (Intel)   + Format 1 with 2 bits UCI and Format 3 with 20 bits UCI (Nokia, Nokia Shanghai Bell)   + PUCCH format 1(1bit), PUCCH format 3 (19bits, + 9bits CRC) (Qualcomm) |
|  Occupied channel bandwidth | 1 PRB (China Telecom, Huawei, HiSilicon, ZTE, vivo, CATT, Intel, Lenovo, OPPO, Sharp, Samsung, Qualcomm)  1 PRB for VoIP, 8 PRBs for eMBB (NTT DOCOMO) |
| BS antennas configuration | * Urban:   + 192 elements and 2 TxRU (China Telecom, Huawei, HiSilicon, Lenovo, OPPO)   + 2/4/8/64 TxRU (ZTE) * Rural and rural with long distance:   + 64 elements and 2 TxRU (China Telecom, Huawei, HiSilicon, Lenovo, OPPO)   + 2/4 TxRU (ZTE) |
| UE antennas configuration | * + 1T (China Telecom, ZTE, CATT)   + 2T for urban and rural, 1T for rural with long distance (Huawei, HiSilicon)   + 2T for urban, 1T for rural and rural with long distance (Lenovo, OPPO) |
| Repetition | * + On (LG, CATT)   + Off |
| Frequency hopping | * + On (Intel, CATT)   + Off |
| Shadow fading margin | * Urban: 7.56 dB * Rural: 8.45 dB for O-to-I, 10.45 dB for O-to-O * Rural with long distance:   + 8.06 dB (China Telecom)   + 6 dB (Huawei, HiSilicon) |

## Appendix 3

Appendix 3 Companies’ views on simulation assumptions for other channels for FR1

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| --- | --- | --- | --- |
| Other channels | Company | Key parameters | |
| PDCCH | Huawei, HiSilicon | Aggregation level: 8, DCI payload size: 60 bits  CRC length: 24 bit, CORRESET PRB: 48, CORRESET symbols: 2  Channel model: TDL-C, Moving speed: 3km/h & 120km/h  DMRS overhead: 1 front-loaded DMRS, 1 front loaded DMRS + 1 additional DMRS | |
| Sharp | Aggregation level: 16, DCI payload size: 64 bits including CRC | |
| Panasonic | 1% BLER | |
| Samsung | DCI format 1-0/0-0, DCI size = 68 bit; QPSK, aggregation level = 16 CCE | |
| Qualcomm | Number of UE Rx antennas: 2, BW=48 RBs  PDCCH aggregation level: 8, DCI size=40 (+ 24 bits CRC)  PDCCH interleaving: Enabled, REG bundle size=6  Beam forming: Broadcast (precoder cycling), Unicast (SRS-based precoding)  Number of control symbols: 2 | |
| Intel | DCI size = 40 bits, Aggregation level = 4,  CORESET size in time = 2 symbols, CORESET size in frequency = 48 PRBs | |
| vivo | Format type: CCE0 AL=8 DCI size = 39bits  Occupied channel bandwidth: 48RB | |
| CATT | Payload size (include 24 bits CRC) 64bits, Length of PDCCH=2 OS | |
| Nokia | Aggregation level 16 with 40 bits DCI and 24 bits CRC.  A CORESET bandwidth of 48 PRBs and two OFDM symbols are used. | |
| ZTE | DCI payload (excluding 24bits CRC), 40 bits for fallback DCI, 30 bits for compact DCI  Transmission type: Interleaved (R=3 for 3OS,others,R=2)  REG bundling size=6  Antenna configuration: 4T4R for urban, 2T2R for rural. | |
| NTT DOCOMO | 1% BLER, 48 RBs | |
| PDSCH | Huawei, HiSilicon | MCS: 2 (2,251/1024), Scheduled PRB: Calculated  Channel model: TDL-C, Moving speed: 3km/h & 120km/h  DMRS overhead: 1 front-loaded DMRS, 1 front loaded DMRS + 1 additional DMRS | |
| Sharp | 12 OFDM symbols, MCS 7 | |
| Panasonic | 10 % iBLER for PDSCH | |
| NTT DOCOMO | 2% rBLER,  1 RB for VoIP, 40 RBs for eMBB (OtoI), 4 RBs for eMBB (rural) | |
| Qualcomm | Slot structure: 2 symbol PDCCH, 9 symbols PDSCH, 2 symbol guard/PUCCH/PUSCH, 1 symbol SRS  SRS configuration: Wideband SRS transmission from 2 physical antenna (out of the 4)  PDSCH DMRS : Type 1 with 3 symbols with Data and DM-RS TDMed on the DM-RS symbols  Precoding Closed Loop (CL): SVD-based precoding every 4 PRBs based on the SRS transmission | |
| Intel | For Rural scenario: TBS = 1032, MCS = 4, 14 PRBs, 12 symbols  For Urban scenario: TBS = 5120, MCS = 10, 32 PRBs, 12 symbols  2 DMRS symbols (4th and 10th symbol) | |
| vivo | Occupied channel bandwidth:  82RB for urban, 8RB for rural TDD, 11RB for rural FDD, 4RB for VoIP  DMRS configuration: Type I, two DMRS symbol, no multiplexing with data | |
| Nokia | For PDSCH, 2 OFDM symbols for DMRS are used in Rural and Suburban scenarios, where high-speed UEs (120 Km/h) are also considered.1 OFDM symbol is used for DMRS for PDSCH in the remaining scenarios. | |
| CATT | Length of DMRS = 1 OS,  Occupied channel bandwidth: 51PRBs for TDD, 106 PRBs for rural | |
| Samsung | eMBB: 10/1 (Urban/Rural) Mbps,  VoIP: 12.2kbps (304bits: 244 + 60 (header for RoHC compress)) | |
| Msg3 | Huawei, HiSilicon | MCS: 0 (2,120/1024), Scheduled PRB: 2, Payload size: 56 bits  Channel model: TDL-C, Moving speed: 3km/h & 120km/h  DMRS overhead: 1 front-loaded DMRS, 1 front loaded DMRS + 1 additional DMRS | |
| Qualcomm | Msg3 payload size: {56, 72} bits | |
| PRACH | Qualcomm | Urban:  Format B4, Sequence length=139,  30kHz SCS, 0.1% false alarm, 1% miss-detection | Rural:  Format 1, Sequence length=839  1.25 kHz SCS, 0.1% false alarm, 1% miss-detection |
| vivo | PRACH format B4, Occupied channel bandwidth: 12RB | |
| ZTE | Miss-detection target: 1%  Preamble:  NR PRACH preamble format 2 with Ncs = 167, Logical sequence index = 22, v=2 for O2I  NR PRACH preamble format 1 with Ncs = 202, Logical sequence index = 384, v=0 for O2O | |
| Intel | PRACH format 0, 0.1% false alarm target | |
| SSB/PBCH | Qualcomm | For SSS/PSS:  # of Rx: 2, Bandwidth=12 RBs  30kHz SCS, Frequency offset=5ppm  1% false alarm, 10% miss-detection | For PBCH:  # of Rx: 2, Bandwidth=20 RBs  30kHz SCS, 1% BLER  Frequency offset=0.05ppm |
| Intel | PBCH related parameters: 4 accumulations | |
| ZTE | PBCH payload (excluding 24bits CRC): 32 bits  Combined number: 4 SSBs  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 | |
| vivo | PBCH format: 4-shot combining, Occupied channel bandwidth: 20RB | |