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| Technical Report |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  Study on NR Positioning Enhancements;  (Release 17) |
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For definitive guidance on drafting 3GPP TSs and TRs, see [3GPP TS 21.801](http://www.3gpp.org/DynaReport/21801.htm) supplemented by the 3GPP web page <http://www.3gpp.org/specifications-groups/delegates-corner/writing-a-new-spec>.

Ensure all blue guidance text is removed before submitting the TS/TR to the TSG for approval.

# Foreword

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

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

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

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

z the third digit is incremented when editorial only changes have been incorporated in the document.

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

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

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

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

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

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

**can** indicates that something is possible

**cannot** indicates that something is impossible

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

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

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

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

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

In addition:

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

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

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

# 1 Scope

The present document captures the findings of the study item "Study on NR positioning enhancements" [2]. The purpose of this technical report is to document the requirements, additional scenarios, evaluations and technical proposals treated during the study and provide a way forward toward enhancements to NR positioning in TSG RAN WGs.

# 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] RP-193237: "new SID on NR Positioning Enhancements".

[3] 3GPP TR 38.855: "Study on NR Positioning (Release 16)".

[4] R1-2007576 Evaluation results for Rel-16 positioning and Rel-17 enhancement Huawei, HiSilicon

[5] R1-2007665 Evaluation of NR positioning performance vivo

[6] R1-2007720 Evaluation of achievable positioning accuracy BUPT

[7] R1-2007754 Evaluation of achievable accuracy and latency ZTE

[8] R1-2007859 Discussion of evaluation of NR positioning performance CATT

[9] R1-2007908 NLOS Identification and Mitigation FUTUREWEI

[10] R1-2007945 NR positioning evaluation Intel Corporation

[11] R1-2007997 NR Positioning Latency Evaluations Lenovo, Motorola Mobility

[12] R1-2008225 Evaluation of NR positioning in IIOT scenario OPPO

[13] R1-2008300 Results on evaluation of achievable positioning accuracy and latency Nokia, Nokia Shanghai Bell

[14] R1-2008364 Discussion on Performance evaluation of Rel-17 positioning Sony

[15] R1-2008416 Discussions on evaluation of achievable positioning accuracy and latency for NR positioning LG Electronics

[16] R1-2008489 Evaluation of achievable positioning latency InterDigital, Inc.

[17] R1-2008618 Evaluation of achievable Positioning Accuracy & Latency Qualcomm Incorporated

[18] R1-2008709 Evaluation of positioning enhancements Fraunhofer IIS, Fraunhofer HHI

[19] R1-2008720 Positioning evaluation results on potential enhancements for additional use cases CEWiT

[20] R1-2008764 Evaluation of achievable positioning accuracy and latency Ericsson

…

[x] <doctype> <#>[ ([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

# 3 Definitions of terms, symbols and abbreviations

This clause and its three subclauses are mandatory. The contents shall be shown as "void" if the TS/TR does not define any terms, symbols, or abbreviations.

## 3.1 Terms

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

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

## 3.2 Symbols

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

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 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].

<ABBREVIATION> <Expansion>

# 4 General description of NR positioning

*(General description of NR positioning up to release 16 & NR positioning enhancements in rel17)*

# 5 Target requirements for NR positioning enhancements in Rel-17

## 5.1 Target requirements

## 5.2 Performance evaluation metrics

(Includes horizontal accuracy vertical accuracy and other metrics)

For evaluating performance of NR positioning technologies, the following metrics apply. The following percentiles of positioning error are analyzed: 50%, 67%, 80%, 90%.

### 5.2.1 Horizontal accuracy

### 5.2.2 Vertical accuracy

### 5.2.3 Other metrics

#### 5.2.3.1 Latency

Latency includes higher layer and physical layer latency.

The physical layer latency start- and end-time are defined for each positioning method in table 5.2.3.1-1

Table 5.2.3.1-1: Definition of physical layer latency start- and end-time

| Method | Start | End |
| --- | --- | --- |
| UE assisted DL-only & DL-ECID & Multi-RTT | Transmission of the PDSCH from the gNB carrying the LPP Request Location Information message | Successful decoding of the PUSCH carrying the LPP Provide Location Information message |
| UL-only method & UL ECID & Multi-RTT | Reception by the gNB of the NRPPa measurement request message | The transmission by the gNB of the NRPPa measurement response message |
| UE-based |  | Successful decoding of the PUSCH at gNB carrying the LPP Provide Location Information message if applicable, otherwise Calculation of Location Estimate at the UE |

#### 5.2.3.2 Network efficiency

PRS/SRS resource utilization is the metric used to evaluate network efficiency.

#### 5.2.3.3 Device efficiency

The UE power consumption models developed in TR38.840 can be considered as the starting point for defining the UE power consumption model for the evaluation for NR positioning. For evaluations, it is up to each company to detail their methodology (including the power model) for evaluation.

# 6 Additional scenarios and channel models for NR positioning enhancements

*From justification, for the evaluation of solutions, the Rel-16 scenarios and channel models in TR 38.855 are reused where applicable, and additional scenarios for IIoT use cases should be defined.*

*from objective 1a. Includes definition of additional scenarios (e.g. (I)IoT) based on TR 38.901 to evaluate the performance for the use cases e.g. (I)IoT)*

The scenario parameters common to all the scenarios in the study are detailed in table 6-1. Additionally, blockage model is not considered. For evaluations including UE mobility, the spatial consistency procedure defined in TR 38.901 is taken into consideration.

The evaluation methodology does not define any baseline reference signals. Configurations of DL PRS and UL SRS supported by Rel-16 specifications are used for evaluation of the achievable performance based on Rel-16 positioning technologies.

Table 6-1: Common scenario parameters applicable for all scenarios

|  |  |  |
| --- | --- | --- |
|  | FR1 Specific Values | FR2 Specific Values |
| Carrier frequency, GHz | 3.5GHz | 28GHz |
| Bandwidth, MHz | 100MHz | 400MHz |
| Subcarrier spacing, kHz | 30kHz for 100MHz | 120kHz |
| gNB model parameters |  |  |
| gNB noise figure, dB | 5dB | 7dB |
| UE model parameters |  |  |
| UE noise figure, dB | 9dB – Note 1 | 13dB – Note 1 |
| UE max. TX power, dBm | 23dBm – Note 1 | 23dBm – Note 1  EIRP should not exceed 43 dBm. |
| UE antenna configuration | Panel model 1 – Note 1  Mg = 1, Ng = 1, P = 2, dH = 0.5λ, (M, N, P, Mg, Ng) = (1, 2, 2, 1, 1) | Baseline:  Multi-panel Configuration 1 and Panel Configuration a – Note 1  - Multi-panel Configuration 1: (Mg, Ng) = (1, 2); Θmg,ng=90°; Ω0,1=Ω0,0+180°; (dg,H, dg,V)=(0,0)  - Panel Configuration a:  - Each antenna array has shape dH=dV=0.5λ  - Config a: (M, N, P) = (2, 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  Optional:  4-panels UE:  - The antenna elements of the same polarization of the same panel is virtualized into one TXRU |
| UE antenna radiation pattern | Omni, 0dBi | Antenna model according to Table 6.1.1-2 in TR 38.855 |
| PHY/link level abstraction | Explicit simulation of all links, individual parameters estimation is applied. Companies to provide description of applied algorithms for estimation of signal location parameters. | |
| Network synchronization | The network synchronization error, per UE dropping, is defined as a truncated Gaussian distribution of (T1 ns) rms values between an eNB and a timing reference source which is assumed to have perfect timing, subject to a largest timing difference of T2 ns, where T2 = 2\*T1  – That is, the range of timing errors is [-T2, T2]  – T1: 0ns (perfectly synchronized), 50ns (Optional) | |
| UE/gNB RX and TX timing error | (Optional) The UE/gNB RX and TX timing error, in FR1/FR2, can be modeled as a truncated Gaussian distribution with zero mean and standard deviation of T1 ns, with truncation of the distribution to the [-T2, T2] range, and with T2=2\*T1:   * T1: [X] ns for gNB and [Y] ns for UE * X and Y are up to companies * Note: RX and TX timing errors are generated per panel independently   Apply the timing errors as follows:   * For each UE drop,   + For each panel (in case of multiple panels)     - Draw a random sample for the Tx error according to [-2\*Y,2\*Y] and another random sample for the Rx error according to the same [-2\*Y,2\*Y] distribution. * For each gNB   + For each panel (in case of multiple panels)     - Draw a random sample for the Tx error according to [-2\*X,2\*X] and another random sample for the Rx error according to the same [-2\*X,2\*X] distribution. * Any additional Time varying aspects of the timing errors, if simulated, can be left up to each company to report. * For UE evaluation assumptions in FR2, it is assumed that the UE can receive or transmit at most from one panel at a time with a panel activation delay of 0ms. | |
| Note 1: According to 3GPP TR 38.802  Note 2: According to 3GPP TR 38.901 | | |

## 6.1 IIoT use cases

For evaluating baseline performance, the following scenarios (with various options/configurations) are defined for RAT-dependent positioning techniques for the NR positioning enhancements study

- Scenario 1. InF-SH for FR1 and FR2

- Scenario 2. InF-DH for FR1 and FR2

Parameters specific to scenario 1and 2 are detailed in table 6.1-1

Table 6.1-1: Parameters common to InF scenarios

|  | | FR1 Specific Values | | FR2 Specific Values |
| --- | --- | --- | --- | --- |
| Channel model | | InF-SH, InF-DH | | InF-SH, InF-DH |
| Layout | Hall size | InF-SH:  (baseline) 300x150 m  (optional) 120x60 m  InF-DH:  (baseline) 120x60 m  (optional) 300x150 m | | |
| BS locations | 18 BSs on a square lattice with spacing D, located D/2 from the walls.  - for the small hall (L=120m x W=60m): D=20m  - for the big hall (L=300m x W=150m): D=50m | | |
| Room height | 10m | | |
| Total gNB TX power, dBm | | 24dBm | 24dBm  EIRP should not exceed 58 dBm | |
| gNB antenna configuration | | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ – Note 1 | (M, N, P, Mg, Ng) = (4, 8, 2, 1, 1), dH=dV=0.5λ – Note 1  One TXRU per polarization per panel is assumed | |
| gNB antenna radiation pattern | | Single sector – Note 1 | 3-sector antenna configuration – Note 1 | |
| Peneteration loss | | 0dB | | |
| Number of floors | | 1 | | |
| UE horizontal drop procedure | | Uniformly distributed over the horizontal evaluation area for obtaining the CDF values for positioning accuracy, The evaluation area should be  - (baseline) at least the convex hull of the horizontal BS deployment.  - (optional) It can also be the whole hall area if the CDF values for positioning accuracy is obtained from whole hall area. | | |
| UE antenna height | | Baseline: 1.5m  (Optional): uniformly distributed within [0.5, X2]m, where X2 = 2m for scenario 1(Inf-SH) and X2= for scenario 2 (InF-DH) | | |
| UE mobility | | 3km/h | | |
| Min gNB-UE distance (2D), m | | 0m | | |
| gNB antenna height | | Baseline: 8m  (Optional): two fixed heights, either {4, 8} m, or {max(4,), 8}. | | |
| Clutter parameters: {density , height ,size } | | Low clutter density:  {20%, 2m, 10m}  High clutter density:  - Baseline): {40%, 2m, 2m} for fixed UE antenna height and gNB antenna height  - (Optional): {40%, 3m, 5m}  - (Optional): {60%, 6m, 2m} | | |
| Note 1: According to Table A.2.1-7 in 3GPP TR 38.802 | | | | |

## 6.2 General commercial use cases

For general commercial use cases, Rel-16 scenarios and channel models in TR 38.855 are reused. For the absolute time of arrival modelling in IOO, UMa, Umi, companies may provide the details of their model, if any.

# 7 Studied NR positioning enhancements

*(from objective 1c. Includes positioning techniques, DL/UL positioning reference signals, signalling and procedures for improved accuracy, reduced latency, network efficiency, and device efficiency for both RAN1 and RAN2.  
Enhancements to Rel-16 positioning techniques, if they meet the requirements, will be prioritized, and new techniques will not be considered in this case. )*

The following enhancements have been considered during this study:

* Partial staggering and non-staggering RE mapping of SRS for positioning with different combinations of comb-factors and symbol lengths, including the methods/signalling for addressing potential time-domain aliasing due to the partial/non-staggering RE mapping.
* Semi-persistent and a-periodic transmission and reception of DL PRS
  + Semi-persistent means MAC-CE triggered
  + Aperiodic would correspond to DCI-triggered
* On-demand transmission and reception of DL PRS
  + On-demand corresponds to the UE-initiated or network-initiated request of PRS and/or SRS, i.e. UE or LMF request/suggesting/recommending specific PRS pattern, ON/OFF, periodicity, BW, etc.
* Multipath mitigation techniques including but not limited to the following:
  + The applicable scenarios and performance benefits of multipath mitigation techniques
  + The methods/measurement/signaling for the LOS/NLOS detection and identification
  + The measurements for supporting the multipath mitigation/utilization
  + The procedure and signaling for supporting the multipath mitigation/utilization
  + Implementation-based solutions (e.g., outlier rejection) without the need of any additional specified method/measurements/procedures/signaling.
  + Note: The above study applies to DL only, UL only, DL+UL positioning solutions for UE-based and UE-assisted positioning.
* NR positioning for UEs in RRC\_IDLE state and UEs in RRC\_INACTIVE state, including the benefits on latency, network/UE efficiency and UE power consumption
* More efficient signaling & procedures enabling a device to request and report positioning information, which may include, but not limited to, the following aspects:
  + DL PRS/UL SRS configuration, activation or triggering.
  + The request for positioning information (the assistance data, etc.).
  + The report of positioning information (the measurement report, etc.).
  + Note: It is not within RAN1 scope to analyze positioning architecture enhancements to enable such more efficient signaling & procedures.
  + Note: RAN1 does not make any assumptions on whether the LCS architecture specified in TS 23.273 is enhanced or not.
* Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across multiple CCs and multiple slots can be investigated in Rel-17, which may consider
  + The scenarios and performance benefits of the enhancement
  + The impact of channel spacing, TA and timing offset, phase offset, frequency error, and power imbalance across slots or CCs to the positioning performance for intra-band contiguous/ non-contiguous and inter-band scenarios
* Scenario, benefits, and methods for improving the accuracy of the UL AoA and DL-AoD methods for both UE-based and network-based (including UE-assisted) positioning
* Scenario, benefits, methods and signaling for improving positioning accuracy in the presence of the UE Rx/Tx transmission delays, and/or and gNB Rx/Tx transmission delays

# 8 Performance evaluations for R17 performance targets

## 8.1 Performance analysis of Rel-16 positioning solutions

*Including accuracy and latency (objective 1b) performance, compared to rel17 performance targets*

### 8.1.1 Positioning accuracy analysis

### 8.1.2 Physical layer latency analysis for Rel-16

## 8.2 Performance of studied NR positioning enhancements

*Including performance of positioning techniques, DL/UL positioning reference signals, signalling and procedures for improved accuracy, reduced latency, network efficiency, and device efficiency ((objective 1c).*

## 8.3 Efficiency analysis for NR positioning enhancements

In this report, Network efficiency and UE efficiency is evaluated either via analytically or via simulations.

## 8.4 Summary of performance evaluations

Performance analysis of baseline I-IoT InF scenarios shows that InF-SH scenario (Scenario 1) is characterized by high probability of LOS links. In InF-DH (Scenario 2) the probability of LOS links is reduced substantially while probability of NLOS links is increased accordingly.

For the case without modeling synchronization and gNB/UE TX/RX timing errors in the InF-SH scenario (Scenario 2).

* + - Based on the results provided by a majority of sources, sub-meter level @ 90% of horizontal positioning accuracy is achieved by Rel.16 solutions.
    - Results were provided by [12] out of [17] sources for FR1 and by [9] sources out of [17] for FR2
* For NR positioning evaluations in FR1 band, the following is observed with respect to horizontal positioning accuracy:
  1. Accuracy of ≤ [0.2m @ 90%](mailto:0.2m@90%25) is achieved in contributions from [3] sources and is not achieved in contributions from [9] sources
  2. Accuracy of ≤ [0.5m @ 90%](mailto:0.2m@90%25) is achieved in contributions from [7] sources and is not achieved in contributions from [5] sources
* For NR positioning evaluations in FR2 band, the following is observed with respect to horizontal positioning accuracy:
  1. Accuracy of ≤ [0.2m @ 90%](mailto:0.2m@90%25) is achieved in contributions from [6] sources and is not achieved in contributions from [3] sources
  2. Accuracy of ≤ [0.5m @ 90%](mailto:0.2m@90%25) is achieved in contributions from [8] sources and is not achieved in contributions from [1] sources

# 9 Positioning integrity and reliability

*From objective 2: Includes solutions necessary to support integrity and reliability of assistance data and position information:*

# 10 Identified NR impacts in Rel-17

# 11 Conclusions

NR positioning for UEs in RRC\_INACTIVE state is recommended for normative work, including

* + DL, UL and DL+UL positioning methods
  + UE-based and UE-assisted positioning solutions
  + Support of UE positioning measurements for UEs in RRC\_inactive state
    - Options that can be considered include DL-PRS or DL-PRS and SSB
  + Support of gNB positioning measurements for UEs in RRC\_inactive state

The details of how to enable the UE positioning in RRC\_ INACTIVE state can be further discussed during normative work. These details may include, but are not limited to the following aspects:

* + UL reference signals (e.g., SRS for positioning, PRACH preambles) for UL measurements
  + Signalling and procedures for support the assistance data delivery, DL-PRS configuration, UL reference signals for positioning resource configuration, measurement reporting), which may be developed based on the enhancements of existing signalling and procedures (e.g., existing 2-step and/or 4-step PRACH procedures, paging procedure, small data transmission).

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2020-05 | RAN1#101-e | R1-2004948 |  |  |  | Baseline TR skeleton. | 0.0.1 |
| 2020-10 | RAN1#103-e | R1-2008762 |  |  |  | Update of TR based on RAN1#101-e and RAN1#102-e agreements. | 0.1 |