|  |  |
| --- | --- |
| 3GPP TR 38.859 V0.2.0 (2022-08) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  Study on Expanded and Improved NR Positioning;  (Release 18) | |
|  | |
|  |  |
|  | |
| The present document has been developed within the 3rd Generation Partnership Project (3GPP TM) and may be further elaborated for the purposes of 3GPP. The present document has not been subject to any approval process by the 3GPPOrganizational Partners and shall not be implemented. This Specification is provided for future development work within 3GPPonly. The Organizational Partners accept no liability for any use of this Specification. Specifications and Reports for implementation of the 3GPP TM system should be obtained via the 3GPP Organizational Partners' Publications Offices. | |

|  |
| --- |
|  |
| ***3GPP***  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 |
| ***Copyright Notification***  No part may be reproduced except as authorized by written permission. The copyright and the foregoing restriction extend to reproduction in all media.  © 2022, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC).  All rights reserved.  UMTS™ is a Trade Mark of ETSI registered for the benefit of its members  3GPP™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners LTE™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners  GSM® and the GSM logo are registered and owned by the GSM Association |

Contents

Foreword 5

1 Scope 7

2 References 7

3 Definitions of terms, symbols and abbreviations 9

3.1 Terms 9

3.2 Symbols 10

3.3 Abbreviations 10

4 General Descriptions of Expanded NR Positioning Enhancements 10

5 Sidelink Positioning 11

5.1 Sidelink Positioning Scenarios and Requirements 12

5.2 Potential Solutions for Sidelink Positioning 13

5.2.1 Physical Layer aspects for SL Positioning Solutions 13

5.2.1.1 Positioning Methods for SL Positioning 13

5.2.1.2 Physical structure and reference signal design for SL Positioning 15

5.2.1.3 Physical layer procedures for SL Positioning 16

5.2.2 Potential Architecture and Signalling Procedures for Sidelink Positioning 18

5.3 Summary of Sidelink Positioning Evaluations 18

5.3.1 Evaluation of Bandwidth Requirements to meet Identified Accuracy Requirements 18

5.3.2 Evaluation of Absolute Positioning, Relative Positioning, and Ranging Methods 23

5.4 Potential specification impact for Sidelink Positioning 23

6 Positioning Enhancements for Improved Integrity, accuracy, and power efficiency 24

6.1 Integrity for RAT-Dependent Positioning Techniques 24

6.1.1 Identification of error sources 24

6.1.2 Methodologies, procedures and signalling for determination of positioning integrity 26

6.1.3 Summary of Evaluation Results for Integrity for RAT-Dependent Positioning Techniques 26

6.1.4 Potential Specification Impact for Integrity for RAT-Dependent Positioning Techniques 26

6.2 PRS / SRS Bandwidth Aggregation 26

6.2.1 Potential Solutions Based on PRS / SRS Bandwidth Aggregation 26

6.2.2 Summary of Evaluations for PRS/SRS Bandwidth Aggregation 26

6.2.3 Potential Specification Impact for PRS/SRS Bandwidth Aggregation 26

6.3 NR Carrier Phase Positioning 27

6.3.1 Potential Solutions for NR Carrier Phase Positioning 27

6.3.1.1 Reference signals for NR Carrier Phase Positioning 27

6.3.1.2 Physical layer measurements for NR carrier phase positioning 27

6.3.2 Summary of Evaluations for NR Carrier Phase Positioning 28

6.3.3 Potential Specification Impact for NR Carrier Phase Positioning 29

6.4 Low Power High Accuracy Positioning 29

6.4.1 Target use cases and requirements for Low Power High Accuracy Positioning 29

6.4.2 Potential Enhancements for Low Power High Accuracy Positioning 30

6.4.3 Summary of Evaluations for Low Power High Accuracy Positioning 30

6.4.4 Potential Specification Impact for Low Power High Accuracy Positioning 32

6.5 Positioning of UEs with Reduced Capabilities 32

6.5.1 Potential Solutions for Positioning for RedCap UEs 33

6.5.2 Summary of Evaluations for Positioning for RedCap UEs 33

6.5.3 Potential Specification Impact for Positioning for RedCap UEs 35

7 Conclusions 35

Annex A.1: Evaluation Methodology for Sidelink Positioning 35

Annex A.2: Evaluation Methodology for PRS/SRS Bandwidth Aggregation 38

Annex A.3: Evaluation Methodology for NR Carrier Phase Positioning 38

Annex A.4: Evaluation Methodology for Low Power High Accuracy Positioning 40

Annex A.5: Evaluation Methodology for Positioning for RedCap UEs 44

Annex B.1: Evaluation Results for Sidelink Positioning 46

B.1.X Results from source [X] 46

B.1.X.1 Description of evaluation scenarios 46

B.1.X.2 Positioning accuracy evaluation results for Sidelink Positioning 49

B.1.X.2.1 Positioning accuracy evaluation results for Sidelink Positioning for Highway Scenarios for V2X 49

B.1.X.2.2 Positioning accuracy evaluation results for Sidelink Positioning for Urban Grid Scenarios for V2X 51

B.1.X.2.3 Positioning accuracy evaluation results for Sidelink Positioning for IIoT 54

B.1.X.2.4 Positioning accuracy evaluation results for Sidelink Positioning for Public Safety 55

B.1.X.2.5 Positioning accuracy evaluation results for Sidelink Positioning for Commercial use cases 58

Annex B.2: Evaluation Results for Integrity for RAT-Dependent Positioning Techniques 60

Annex B.3: Evaluation Results for PRS/SRS Bandwidth Aggregation 60

Annex B.4: Evaluation Results for NR Carrier Phase Positioning 60

B.4.X Results from source [X] 60

B.4.X.1 Description of evaluation scenarios 60

B.4.X.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning 62

Annex B.5: Evaluation Results for Low Power High Accuracy Positioning 62

B.5.X Results from source [X] 62

B.5.X.1 Description of evaluation scenarios 62

B.5.X.2 Evaluation results for Low Power High Accuracy Positioning 63

Annex B.6: Evaluation Results for Positioning for RedCap UEs 64

B.6.X Results from source [X] 64

B.6.X.1 Description of evaluation scenarios 64

B.6.X.2 NR RedCap UE positioning accuracy evaluation results 66

Annex X: Change history 66

# 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 Expanded and Improved NR Positioning" [7]. 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 normative work on expanded 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] 3GPP TR 38.857: "Study on NR positioning enhancements".

[3] 3GPP TR 38.845: "Study on scenarios and requirements of in-coverage, partial coverage, and out-of-coverage NR positioning use cases".

[4] 3GPP TS 22.261: "Service requirements for the 5G system".

[5] 3GPP TR 22.855: "Study on ranging-based services".

[6] 3GPP TS 22.104: "Service requirements for cyber-physical control applications in vertical domains".

[7] RP-213588: "New SID on Study on expanded and improved NR positioning".

[8] 3GPP TR 37.885: "Study on evaluation methodology of new Vehicle-to-Everything (V2X) use cases for LTE and NR".

[9] 3GPP TR 36.885: "Study on LTE-based V2X Services".

[10] 3GPP TR 36.843: "Study on LTE Device to Device Proximity Services".

[11] 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz".

[12] 3GPP TR 38.855: "Study on NR positioning support".

[13] 3GPP TR 38.840: "Study on User Equipment (UE) power saving in NR".

[14] 3GPP TR 38.802: "Study on New Radio Access Technology - Physical Layer Aspects".

[15] 3GPP TR 38.830: "Study on NR coverage enhancements".

[16] 3GPP TS 37.355: "LTE Positioning Protocol (LPP)".

[17] 3GPP TS 38.455: "NR Positioning Protocol A (NRPPa)".

[18] R1-2208363 Evaluation of SL positioning Nokia, Nokia Shanghai Bell

[19] R1-2208452 SL positioning evaluations Huawei, HiSilicon

[20] R1-2208647 Evaluation of sidelink positioning performance vivo

[21] R1-2208820 Evaluation methodology and results of SL positioning OPPO

[22] R1-2208980 Evaluation methodology and performance evaluation for SL positioning CATT, GOHIGH

[23] R1-2209104 Discussion on evaluation of SL positioning Sony

[24] R1-2209212 Discussion on evaluation of SL positioning ZTE, CMCC

[25] R1-2209290 Discussion on evaluation of sidelink positioning xiaomi

[26] R1-2209392 SL Positioning Evaluation and Performance Lenovo

[27] R1-2209482 Discussion on evaluation of SL positioning LG Electronics

[28] R1-2209486 Evaluation results for SL positioning InterDigital, Inc.

[29] R1-2209735 Discussion on Evaluation for SL Positioning Samsung

[30] R1-2209989 Sidelink Positioning Evaluation Assumptions and Results Qualcomm Incorporated

[31] R1-2210038 Evaluation of SL positioning Intel Corporation

[32] R1-2210111 Evaluation results and observations on V2X and IIoT use case for sidelink positioning CEWiT

[33] R1-2210174 Evaluation of NR SL positioning and ranging Ericsson

[34] R1-2208456 Evaluation and solutions for LPHAP Huawei, HiSilicon

[35] R1-2208517 Discussion on Low Power High Accuracy Positioning Quectel

[36] R1-2208559 Discussion on evaluation on LPHAP Spreadtrum Communications

[37] R1-2208651 Discussion on Low Power High Accuracy Positioning vivo

[38] R1-2208737 Views on LPHAP Nokia, Nokia Shanghai Bell

[39] R1-2208802 Discussion on Low Power High Accuracy Positioning OPPO

[40] R1-2210242 Discussion on Low Power High Accuracy Positioning CATT

[41] R1-2209060 On Low Power High Accuracy Positioning Intel Corporation

[42] R1-2209107 Discussion on Low Power High Accuracy Positioning Sony

[43] R1-2210398 Discussion on low power high accuracy positioning ZTE

[44] R1-2209294 Discussion on Low Power High Accuracy Positioning xiaomi

[45] R1-2209344 Discussion on low power high accuracy positioning CMCC

[46] R1-2209396 LPHAP considerations Lenovo

[47] R1-2209490 Discussions on Low Power High Accuracy Positioning (LPHAP) techniques InterDigital, Inc.

[48] R1-2209739 Discussion on LPHAP Samsung

[49] R1-2209786 Views on low power high accuracy positioning Sharp

[50] R1-2209806 Discussion on LPHAP in idle/inactive state LG Electronics

[51] R1-2209910 Discussion on Low Power High Accuracy Positioning NTT DOCOMO, INC.

[52] R1-2209993 Requirements, Evaluations, Potential Enhancements for Low Power High Accuracy Positioning Qualcomm Incorporated

[53] R1-2210178 Evaluations for Low Power High Accuracy Positioning Ericsson

[54] R1-2208457, Discussion on RedCap positioning, Huawei, HiSilicon

[55] R1-2208652, Discussion on positioning for RedCap UEs, vivo

[56] R1-2208738, Views on Positioning for RedCap UEs, Nokia, Nokia Shanghai Bell

[57] R1-2208803, Discussion on Positioning for RedCap UEs, OPPO

[58] R1-2208985, Discussion on positioning for RedCap UEs, CATT

[59] R1-2209061, Enhancements for positioning for RedCap UEs, Intel Corporation

[60] R1-2209108, Considerations on positioning for RedCap UEs, Sony

[61] R1-2209153, Discussion on positioning support for RedCap UEs, NEC

[62] R1-2209217, Discussion on Positioning for RedCap UE, ZTE

[63] R1-2209346, Discussion on RedCap positioning, CMCC

[64] R1-2209397, Positioning for RedCap devices, Lenovo

[65] R1-2209491, Discussions on positioning for RedCap UEs, InterDigital, Inc.

[66] R1-2209590, Discussions on Positioning for RedCap UEs, Apple

[67] R1-2209740, Discussion on Positioning for RedCap UEs, Samsung

[68] R1-2209787, Views on positioning for RedCap UEs, Sharp

[69] R1-2209807, Discussion on positioning support for RedCap UEs, LG Electronics

[70] R1-2209911, Discussion on positioning for RedCap UEs, NTT DOCOMO, INC.

[71] R1-2209994, Positioning for Reduced Capability UEs, Qualcomm Incorporated

[72] R1-2210179, Positioning for RedCap UEs, Ericsson

[73] R1-2208455 Discussion on NR carrier phase positioning Huawei, HiSilicon

[74] R1-2208650 Discussion on carrier phase measurement enhancements vivo

[75] R1-2208983 Discussion on improved accuracy based on NR carrier phase measurement CATT

[76] R1-2209215 Discussion on carrier phase measurement based positioning ZTE

[77] R1-2210177 Improved accuracy based on NR carrier phase measurement Ericsson

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [6] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [6].

**Target UE**: UE to be positioned (in this context, using SL, i.e., PC5 interface).

**Anchor UE**: UE supporting positioning of target UE, e.g., by transmitting and/or receiving reference signals for positioning, providing positioning-related information, etc., over the SL interface.

**Sidelink positioning**: Positioning UE using reference signals transmitted over SL, i.e., PC5 interface, to obtain absolute position, relative position, or ranging information.

**Ranging**: Determination of the distance and/or the direction between a UE and another entity, e.g., anchor UE.

**Sidelink positioning reference signal (SL PRS)**: Reference signal transmitted over SL for positioning purposes.

**SL PRS (pre-)configuration**: (Pre-)configured parameters of SL PRS such as time-frequency resources (other parameters are not precluded) including its bandwidth and periodicity.

## 3.2 Symbols

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

Symbol format (EW)

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [6] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [6].

AGV Automated Guided Vehicle

BW Bandwidth

DL Downlink

GNSS Global Navigation Satellite System

IIoT Industrial Internet of Things

IoT Internet of Things

ITS Intelligent Transportation Systems

LPHAP Low Power High Accuracy Positioning

NR New Radio

PRS Positioning Reference Signal

RAN Radio Access Network

RAT Radio Access Technology

RedCap Reduced Capability

RTK Real Time Kinematic

SI Study Item

SID Study Item Description

SL Sidelink

SRS Sounding Reference Signals

TR Technical Report

TS Technical Specification

UE User Equipment

UL Uplink

V2X Vehicle to Everything

WI Work Item

# 4 General Descriptions of Expanded NR Positioning Enhancements

In Release 17, 3GPP RAN conducted studies on "NR positioning enhancements" TR 38.857 [2] and "Scenarios and requirements of in-coverage, partial coverage, and out-of-coverage NR positioning use cases" TR 38.845 [3].

The study on "Scenarios and requirements of in-coverage, partial coverage, and out-of-coverage NR positioning use cases" focussed on V2X and public safety use cases with the outcome being captured in TR 38.845 [3]. Additionally, SA1 has developed requirements in TS 22.261 [4] for "Ranging based services" TR 22.855 [5] and has developed positioning accuracy requirements in TS 22.104 [6] for IIoT use cases in out-of-coverage scenarios. There is a need for 3GPP to study and develop sidelink positioning solutions that can support the use cases, scenarios and requirements identified during these activities.

The study on "NR positioning enhancements" TR 38.857 [2] investigated higher accuracy, and lower latency location, high integrity and reliability requirements resulting from new applications and industry verticals for 5G. Some of the enhancements identified during that work have been specified during the Release 17 Work Item on "NR positioning enhancements", but there remain a number of opportunities for enhancement that have not yet been incorporated into the specifications.

Regarding higher accuracy, two promising techniques identified in earlier studies will be considered in Release 18: one is to take the advantage of the rich 5G spectrum to increase the bandwidth for the transmission and reception of the positioning reference signals based on PRS/SRS bandwidth aggregation for intra-band carriers, and the other is to use the NR carrier phase measurements. GNSS carrier phase positioning has been used very successfully for centimetre-level positioning but is limited to outdoor applications. NR carrier phase positioning has the potential for significant performance improvements for indoor and outdoor deployments in comparison with the existing NR positioning methods, as well as shorter latency and lower UE power consumption in comparison with RTK-GNSS outdoors.

Positioning integrity is a measure of the trust in the accuracy of the position-related data and the ability to provide timely warnings based on assistance data provided by the network. The focus in Release 17 work was on GNSS integrity, and for Release 18 it is natural to extend this to address other positioning techniques as well as there are relevant integrity aspects of mission critical use cases that rely on positioning estimates and the corresponding uncertainty estimate. Integrity enables applications to make the correct decisions based on the reported position, e.g., when monitoring a robotic arm to decide whether its arm movement are within allowed limits to ensure safety distances to humans and other objects.

SA1 has introduced requirements for LPHAP (Low Power High Accuracy Positioning) for industrial IoT scenarios including use cases such as massive asset tracking, AGV tracking in industrial factory and person localization in danger zones. The SA1 requirements are for high accuracy and extreme low power consumption with battery life sustainable up to one or more years. A typical scenario of interest is use case 6 as defined TS 22.104 [6], which corresponds to tracking of workpiece (in- and outdoor) in assembly area and warehouse with a target accuracy of <1m, a positioning interval of 15-30 seconds, and a battery life of 6-12 months. While Release 17 NR positioning has introduced support for positioning in RRC\_INACTIVE state, there is a need to evaluate whether the current system allows LPHAP requirements to be met.

Release 17 has specified support for RedCap UEs with reduced bandwidth support and reduced complexity including reduced number of receive chains. Such UEs could support NR positioning functionality but there is a gap in that the core and performance requirements have not been specified for the positioning related measurements performed by RedCap UEs, and no evaluation was performed to see how the reduced capabilities of RedCap UEs might impact eventual position accuracy. This gap is to be investigated by the present SI.

# 5 Sidelink Positioning

The scope of the study on solutions for SL positioning is defined in the SID [7] as:

* Scenario/requirements for SL positioning
* Identify specific target performance requirements to be considered for the evaluation based on existing 3GPP work and inputs from industry forums
* Define evaluation methodology with which to evaluate SL positioning for the use cases and coverage scenarios, reusing existing methodologies from sidelink communication and from positioning as much as possible
* Study and evaluate performance and feasibility of potential solutions for SL positioning, considering relative positioning, ranging and absolute positioning:
* Evaluate bandwidth requirement needed to meet the identified accuracy requirements
* Study of positioning methods (e.g., TDOA, RTT, AOA/D, etc) including combination of SL positioning measurements with other RAT dependent positioning measurements (e.g., Uu-based measurements)
* Study of sidelink reference signals for positioning purposes from physical layer perspective, including signal design, resource allocation, measurements, associated procedures, etc, reusing existing reference signals, procedures, etc from sidelink communication and from positioning as much as possible
* Study of positioning architecture and signalling procedures (e.g., configuration, measurement reporting, etc) to enable sidelink positioning covering both UE based and network-based positioning.

## 5.1 Sidelink Positioning Scenarios and Requirements

The following objectives are captured in SID [7] on scenarios and requirements for study of sidelink positioning solutions:

* Coverage scenarios to cover: In-coverage, partial-coverage and out-of-coverage.
* Requirements: Based on requirements identified in TR 38.845 [3] and TS 22.261 [4] and TS 22.104 [5].
* Use cases: V2X (TR 38.845) [3], public safety (TR 38.845) [3], commercial (TS 22.261) [4], IIOT (TS 22.104) [5].
* Spectrum: ITS, licensed

Both PC5-only-based positioning solutions and combination of Uu- and PC5-based positioning solutions are considered for study of sidelink positioning.

For evaluations, in-coverage and out-of-coverage scenarios are prioritized. Further, for evaluation of V2X and public safety use-cases, at least in-coverage and out-of-coverage scenarios are considered, while for evaluation of IIoT and commercial use-cases, at least in-coverage scenarios are considered.

For evaluations, operation in FR1 bands with channel bandwidths of up to 100 MHz is considered. Additionally, operation in FR2 bands with channel bandwidths of up to 400 MHz is optionally considered.

For evaluations of relative positioning, the horizontal plane is assumed to be parallel to the ground.

For this study, requirements on positioning accuracy are expressed as accuracy requirements in terms of percentiles of UEs for one or more of the following metrics:

- Ranging accuracy, expressed as the difference (error) between the calculated distance/direction and the actual distance/direction in relation to another node;

- Relative positioning accuracy, expressed as the difference (error) between the calculated horizontal/vertical position and the actual horizontal/vertical position relative to another node;

- Absolute positioning accuracy, expressed as the difference (error) between the calculated horizontal/vertical position and the actual horizontal/vertical position.

It should be noted that exact applicability of specific requirements can be expected to vary across use-cases.

For evaluation of V2X use-cases for SL positioning, the following accuracy requirements are considered:

- V2X-Set A (similar to "Set 2" defined in TR 38.845 [3])

- Horizontal accuracy of 1.5 m (absolute or relative); Vertical accuracy of 3 m (absolute or relative) for 90% of UEs

- V2X-Set B (similar to "Set 3" defined in TR 38.845 [3])

- Horizontal accuracy of 0.5 m (absolute or relative); Vertical accuracy of 2 m (absolute or relative) for 90% of UEs

For evaluation of public safety use-cases for SL positioning solutions, the following accuracy requirements are considered:

- 1 m (absolute or relative) horizontal accuracy and 2 m (absolute or relative between 2 UEs) or 0.3 m (relative positioning change for one UE) vertical accuracy for 90% of UEs

- Relative speed: up to 30 km/h.

For evaluation of commercial use-cases for SL positioning solutions, the following accuracy requirements are considered:

- 1 m (absolute or relative) horizontal accuracy and 2 m (absolute or relative) vertical accuracy for 90% of UEs

- Relative speed: up to 30 km/h.

For evaluation of IIoT use-cases for SL positioning solutions, the following accuracy requirements are considered:

- For horizontal accuracy,

- IIoT-hor-Set A: 1 m (absolute or relative) for 90% of UEs

- IIoT-hor-Set B: 0.2 m (absolute or relative) for 90% of UEs

- For vertical accuracy,

- IIoT-ver-Set A: 1 m (absolute or relative) for 90% of UEs

- IIoT-ver-Set B: 0.2 m (absolute or relative) for 90% of UEs

- Relative speed: up to 30 km/h.

For the above target requirements for evaluations, it should be noted that the target positioning requirements may not necessarily be achieved for all scenarios and deployments. Further, all positioning techniques may not achieve all positioning requirements in all scenarios.

For sidelink based ranging, for a given use-case, the value of the distance requirement for ranging distance accuracy is same as the value identified for horizontal positioning accuracy for relative positioning.

For ranging between two devices, ranging direction accuracy is defined as accuracy of angle of arrival (AoA) at a receiving node.

The following requirements on ranging direction accuracy are considered:

- RangingAngle-Set A: Y = ±15° for 90% of the UEs

- RangingAngle-Set B: Y = ±8° for 90% of the UEs

For the above target requirements for evaluations, it should be noted that the target positioning requirements may not necessarily be achieved for all scenarios and deployments. Further, all positioning techniques may not achieve all positioning requirements in all scenarios.

## 5.2 Potential Solutions for Sidelink Positioning

In the following subclauses the studies on potential solutions for sidelink positioning are summarized, focusing on physical layer aspects, architecture, and signalling procedures.

### 5.2.1 Physical Layer aspects for SL Positioning Solutions

#### 5.2.1.1 Positioning Methods for SL Positioning

As part of the study on potential solutions for sidelink positioning, at least the following positioning methods using SL measurements are identified for possible introduction:

* RTT-type solutions using SL
* FFS: This includes either single-sided (also known as one-way) RTT or both single-sided and double-sided (also known as two-way) RTT
* May include RTT with one or multiple devices.
* SL-AoA
* This includes both Azimuth of arrival (AoA) and zenith of arrival (ZoA) in the study
* SL-TDOA
* FFS: SL-AoD

Note that the above identification of methods does not necessarily imply their specification as separate methods nor specification of a unified positioning method for sidelink.

For the study of different positioning methods, the following aspects are considered:

* Definition(s) of the corresponding SL measurements for each method
* Applicability of different positioning methods to absolute or relative positioning or ranging, including whether such categorization is needed to be discussed
* For angle-based methods, antenna configuration consideration(s) using practical UE capabilities
* Per-panel location, if UE uses multiple panels
* UE’s mobility, especially for V2X scenarios
* Impact of synchronization error(s) between UEs
* Existing SL measurements (e.g., RSSI, RSRP), and UE ID information etc, may be used.

With regards to the sidelink positioning measurement report, the following aspects are included as part of the study:

* Contents of the measurement report, that may include:
* One or more sidelink positioning measurement(s)
* Timestamp(s) associated with a sidelink positioning measurement
* Quality metric(s) associated with a sidelink positioning measurement
* Identification Information for a sidelink positioning measurement
* FFS details for the above.
* Time domain behavior of the measurement report (e.g., one-shot, triggered, aperiodic, semi-persistent, periodic).

Whether sidelink positioning measurements can be higher-layer report and/or a lower-layer report is considered in the study.

With regards to the Positioning methods supported using SL-PRS measurements at least the following measurements are considered:

* SL Rx-Tx time difference measurement
* SL RSTD measurement
* SL RSRP measurement
* SL RSRPP measurement
* SL RTOA measurement
* SL Azimuth angle of Arrival (AoA) and SL Zenith angle of Arrival (ZoA) measurement.

#### 5.2.1.2 Physical structure and reference signal design for SL Positioning

, referred to as SL-PRS,

With regards to the numerologies of the SL-PRS, the study is limited to those supported for NR Sidelink.

As part of the study, at least the following aspects are considered: Sequence design, frequency domain pattern, time domain pattern (e.g., number of symbols, repetitions, etc), time domain behavior, configuration/triggering/activation/de-activation of the SL-PRS, AGC time, Rx-Tx turnaround times, supportable bandwidth(s), multiplexing options with other SL channels, and randomization/orthogonalization options.

On the physical structure of SL-PRS, a frequency domain pattern following a comb-N design is studied, at least including the following:

* N>=1 (where N=1 corresponds to full RE mapping pattern)
* Fully staggered SL-PRS pattern (e.g., M symbols of SL-PRS with comb-N with M=N and, at each symbol a different RE offset is used), Partially staggered SL-PRS pattern (e.g., M symbol(s) of SL-PRS with comb-N, with M<N, at each symbol a different RE offset is used), Unstaggered SL-PRS patterns (e.g., M symbol(s) of SL-PRS with comb- N, at each symbol a same RE offset is used, N > 1)
* Of the above, fully and partially staggered patterns are further prioritized.
* The number of symbols of SL-PRS within a slot
* Any relation to the comb-N option
* RE offset pattern repetitions within a slot

With regards to the frequency and time domain pattern of a SL-PRS resource within a slot, a SL-PRS resource has the following characteristics:

* On the value N (comb size) and the number M of SL-PRS symbols within a slot excluding the symbol(s) used for AGC training / Rx-Tx turnaround:
* At least the following values are considered as potential candidate values: N = {1,2,4,6,8,12}
* FFS: the values considered as potential candidate values for M
* FFS: Whether to consider N>12 as a potential candidate value(s)
* The symbols of a SL-PRS resource within a slot are consecutive symbols
* FFS: consecutive and/or non-consecutive symbols for shared resource pool
* FFS: RE-Offset sequence within a SL-PRS resource, including whether to have in the end of the SL-PRS pattern a symbol with the same RE-offset as the first symbol, for phase-tracking purpose.

For the new SL-PRS design, the following are further studied:

* Number of symbol(s) for AGC and/or Rx-Tx turnaround time.
* Conditions under which AGC training and/or Rx-Tx turnaround time are needed.

For sequence design for the new reference signal for SL-PRS, pseudo-random sequence, using existing DL-PRS sequence as a starting point, is identified as the preferred choice.

#### 5.2.1.3 Physical layer procedures for SL Positioning

On the configuration/ activation/ deactivation/ triggering/ reservation of SL-PRS, the study focused on the following options, with considerations on flexibility, overhead, latency, and reliability:

* Option 1: High-layer-only signalling involvement in the SL-PRS configuration.
* No Lower layer involvement, e.g., SL-MAC-CE or SCI or DCI, for the activation or the triggering of a SL-PRS.
* Based on the study, this option may correspond to:
  + A SL-PRS configuration that is a single-shot or multiple shots.
  + A high-layer configuration that may be received from an LMF, a gNB, or a UE.
* Option 2: High-layer and lower-layer signalling involvement in the SL-PRS configuration.
* Lower-layer may correspond to SL-MAC-CE, or SCI, or DCI.
* For example, high layer signalling can may be used for SL-PRS configuration and lower layer signalling can may be used for initiating SL positioning and/or configuration/triggering/activating/deactivating/indicating and potential resource indication/reservation transmission of SL-PRS.

Regarding resource allocation for SL-PRS, at least the following schemes are studied:

* **Scheme 1**: Network-centric operation SL-PRS resource allocation (e.g., similar to a legacy Mode 1 solution)
* The network (e.g., gNB, LMF, gNB & LMF) allocates resources for SL-PRS
* **Scheme 2**: UE autonomous SL-PRS resource allocation (e.g., similar to legacy Mode 2 solution)
* At least one of the UE(s) participating in the sidelink positioning operation allocates resources for SL-PRS
* Applicable regardless of the network coverage
* FFS: potential mechanisms, if needed, for SL-PRS resource coordination across a number of transmitting UEs (e.g., Inter-UE Coordination (IUC)-like solutions).

Regarding Scheme 1 SL-PRS resource allocation, a transmitting UE receives a SL-PRS resource allocation signaling from the network. One or both of the following options are considered further for the corresponding signalling:

* Opt. 1: Through higher layers from the LMF
* Opt. 2: Through dynamic grants, or via configurations of configured grant type 1 or type 2 from gNB.

Regarding Scheme 2 SL-PRS resource allocation, at least the following aspects are studied:

* Resource selection mechanism for SL-PRS
* Inter-UE coordination
* Aspects for congestion control mechanisms for SL-PRS.

Additionally, on SL positioning resource allocation, the following alternatives are studied:

* Alt. 1: Only dedicated resource pool(s) can be (pre-)configured for SL-PRS
* For dedicated resource pool(s) for SL positioning, at least the following details are agreed to be considered:
* which slots can be used, SL frame structure, SL positioning slot structure, multiplexing of SL-PRS with control information (if included in the same slot),
* positioning measurement report,
* whether a dedicated frequency allocation (e.g., layer/BWP) is needed for SL PRS,
* resource allocation procedure(s) of SL-PRS,
* Note: This option may or may not include control information (i.e., configuration/ activation/ deactivation/ triggering of SL-PRS) for the purpose of SL positioning operation.
* Alt. 2: Either dedicated resource pool(s) and/or a shared resource pool(s) with sidelink communication can be (pre-)configured for SL-PRS
* For shared resource pool(s) for SL positioning, at least the following details are considered:
* Co-existence between SL communication and SL positioning, backward compatibility
* Multiplexing considerations of SL-PRS with other PHY channels (PSCCH, PSSCH, PSFCH) and any modifications in the SL-slot structure.
* Note: whether other signals/channels can be present in the dedicated resource pool is to be studied further.

The following options are considered for multiplexing of other channels in a dedicated resource pool for SL positioning in addition to SL-PRS:

* Opt. 1: No other channel can be included beyond SL-PRS
* Opt. 2: PSCCH which carries SCI associated with SL-PRS transmission(s) is included
* Opt. 3: PSCCH which carries SCI associated with SL-PRS transmission(s) and PSSCH associated with SL-PRS transmission(s) are included
  + - FFS: Definition of “PSSCH associated with SL-PRS transmission(s)”.

At least for a dedicated resource pool for SL positioning, the following alternatives are studied for subsequent down-selection:

* Alt. 1: The bandwidth of SL-PRS can be same or smaller than that of the resource pool.
* Alt. 2: The bandwidth of SL-PRS shall be the same as that of the resource pool.
* FFS: Bandwidth of SL-PRS transmission for a shared resource pool.

For SL Positioning resource (pre-)configuration in a shared resource pool with Rel-16/17/18 sidelink communication, backward compatibility with legacy Rel-16/17 UEs should be ensured.

With regards to SL signaling of the reservation/indication of SL-PRS resource(s) for dedicated resource pool and shared resource pool for positioning:

* SCI can be used for reserving/indicating one or more SL-PRS resource(s)
  + - Note: This does not imply that only SCI is being used. Higher layer signaling may be used for the purpose of indicating a part of the SL-PRS configuration.
    - FFS: Whether SCI is single stage SCI or two stage SCI
* FFS: Use of SL-MAC-CE or other higher-layer signaling for SL-PRS resource reservation/indication.

The granularity of time-domain resource allocation for SL-PRS transmission is studied.

The following options for time-domain resource assignments and associated Tx UE behavior for SL-PRS transmissions are studied:

* Periodic SL-PRS
  + - SL-PRS is transmitted periodically with a transmission periodicity.
    - FFS: any additional details, including whether or not higher layers can start/stop transmission.
* Semi-persistent SL-PRS
  + - SL-PRS is transmitted periodically with a transmission periodicity after activation and until deactivation.
    - FFS: any additional details.
* Aperiodic SL-PRS
  + - SL-PRS is transmitted at least once after either triggering or request (FFS).
    - FFS: any additional details.
* FFS: Applicability of the above options to SL-PRS resource allocation schemes 1 and 2 respectively.
* FFS: Rx UE behavior is separately discussed.
* FFS: What mechanism(s) are used for activation/deactivation/triggering is part of the study.

Resource allocation for SL-Positioning measurement reports is also included in the study.

Power control mechanisms for SL-PRS transmission, including their necessity, are considered in the study.

### 5.2.2 Potential Architecture and Signalling Procedures for Sidelink Positioning

## 5.3 Summary of Sidelink Positioning Evaluations

The methodology for the evaluation of SL positioning can be found in Annex A.1.

### 5.3.1 Evaluation of Bandwidth Requirements to meet Identified Accuracy Requirements

The performance analysis for Rel-18 SL positioning shows that, with increasing of bandwidth of SL PRS, the positioning accuracy improves for both absolute positioning and relative positioning/ranging for all evaluated scenarios.

For V2X use case in highway scenario, 13 sources ([19], [20], [21], [22], [23], [24], [26], [27], [29], [30], [31], [32], [33]) provided simulation results for FR1, and 1 source ([32]) provided simulation results for FR2.

* For absolute horizontal accuracy, the results were provided by 13 sources. 11 out of 13 sources show that, the target requirement set A can be achieved, and 9 out of 13 sources show that the target requirement set B cannot be achievable even by 100MHz.
* The requirement 1.5m@90% (Set A)
* is achieved with 20MHz bandwidth in contributions from 3 sources ([24], [26], [32]),
  + where SL ToA+AoA technique and optional antenna configuration is used in contribution from ([26])
* and is achieved with at least 40MHz bandwidth in contributions from 4 sources ([19], [22], [27], [29]),
* and is achieved with at least 100MHz bandwidth in contributions from 5 sources ([20], [21], [23], [26], [33]),
  + where SL-TDOA technique is used in contribution from ([26])
* and is NOT achieved with 100MHz bandwidth in contributions from 2 sources ([30], [31])
* The requirement 0.5m@90% (Set B)
* is achieved with 40MHz in contribution from 1 source ([29]),
* and is achieved with at least100MHz in contributions from 3 sources ([19], [22], [24]),
  + where Joint Uu/SL positioning is used in contribution from ([24])
* and is NOT achieved with100MHz bandwidth in FR1 or 400MHz in FR2 in contributions from 9 sources ([20], [21], [23], [24], [26], [30], [31], [32], [33]),
  + where SL-only positioning is used in contribution from ([24])
* For absolute vertical accuracy, the results were provided by 1 source out of 13 sources.
* The requirement 3m@90% (Set A)
* is achieved with at least 100MHz bandwidth in contribution from 1 source ([24])
* The requirement 2m@90% (Set B)
* is achieved with 100MHz bandwidth in contribution from 1 source ([24])
* For relative horizontal accuracy, the results were provided by 5 sources out of 13 sources. The performance of relative horizontal accuracy is worse than that of distance accuracy of ranging mainly due to additional angle estimation error. All 5 sources show Set B cannot be met even by 100MHz in the case without RSU-UE positioning.
* The requirement 1.5m@90% (Set A)
* is achieved with at least 40MHz bandwidth in contributions from 2 sources ([19], [22])
  + X = 20m in contribution from ([22])
  + X = 50m in contribution from ([19]) where RSU deployment is additionally used for performing relative positioning
* and is achieved with at least 100MHz bandwidth in contributions from 3 source ([19], [22], [32])
  + X = 25m in contribution from ([22])
  + X = 150m in contributions from ([19], [32]), where BS or RSU deployment is additionally used for performing relative positioning
* and is NOT achieved with 100MHz bandwidth in contributions from 4 sources ([19], [20], [22], [23])
  + X = 50m and 150m in contribution from ([19])
  + X = 25m, 50m, and 100m in contribution from ([20])
  + X = 100m and 150m in contribution from ([22])
  + X = 50m in contribution from ([23]).
* The requirement 0.5m@90% (Set B)
* is achieved with at least 100MHz bandwidth in contributions from 1 source ([19])
  + X = 50m in contribution from ([19]) where RSU deployment is additionally used for performing relative positioning
* is NOT achieved with 100MHz bandwidth in FR1 or 400MHz in FR2 in contributions from 5 sources ([19], [20], [22], [23], [32]).
* For distance accuracy of ranging, the results were provided by 9 out of 13 sources. 5 of 9 sources show that the target requirement set A can be achievable by 20MHz, and 5 out of 9 sources show that the target requirement set B can be achievable by larger bandwidth, e.g., 40MHz or 100MHz, and 3 of 9 sources show that the target requirement set B cannot be achieved with 100MHz bandwidth.
* The requirement 1.5m@90% (Set A)
* is achieved with 20MHz bandwidth in contributions from 5 sources ([19], [20], [22], [24], [32])
  + X = 50m and 150 in contribution from ([19])
  + X = 25m, 50m, and 100m in contribution from ([20])
  + X = 20m, 25m, 100m and 150m in contribution from ([22])
  + X = 100m, 200m and 300m in contribution from ([24])
  + X = 150m in contribution from ([32]), where RSU deployment is additionally used for performing distance ranging
* and is achieved with at least 40MHz bandwidth in contribution from 1 source ([27])
  + X = 80m and 160m in contribution from ([27])
* and is achieved with at least 100MHz bandwidth in contributions from 4 sources ([23], [26], [30], [31])
  + X = 50m in contribution from ([23])
  + X = 50m and 100m in contribution from ([26], [31])
  + X = 100 m in contribution from ([30]).
* The requirement 0.5m@90% (Set B)
* is achieved with at least 40MHz in contributions from 3 sources ([19], [20], [32])
  + X = 50m in contribution from ([19])
  + X = 25m, 50m, and 100m in contribution from ([20])
  + X = 150m in contribution from ([32]), where RSU deployment is additionally used for performing distance ranging
* and is achieved with at least 100MHz in contributions from 4 sources ([19], [22], [23], [24])
  + X = 150m in contribution from ([19])
  + X = 25m, 100m and 150m in contribution from ([22])
  + X = 50m in contribution from ([23])
  + X = 100m in contribution from ([24])
* and is NOT achieved with 100MHz bandwidth in contributions from 3 sources ([26], [30], [31])
  + X = 50m and 100m in contribution from ([26], [31])
  + X = 100 m in contribution from ([30]).
* For angle accuracy of ranging, the results were provided by 6 sources out of 13 sources. All 6 sources show that both the target requirement set A and set B can be achieved by 20MHz or 40MHz.
* The requirement 15°@90% (Set A)
* is achieved with 20MHz bandwidth in contributions from 5 sources ([19], [20], [22], [23], [26]),
* and is achieved with 40MHz bandwidth in contribution from 1 source ([24]).
* The requirement 8°@90% (Set B)
* is achieved with 20MHz in contributions from 3 sources ([19], [23], [26])
* and is achieved with at least 40MHz in contributions from 3 sources ([20], [22], [24]).
* Note: For each SL PRS bandwidth, the above observations are based on the best performance from each source.
* Note: For the relative positioning accuracy or distance accuracy of ranging, X is the maximum distance between UEs for performing relative positioning or ranging.

For V2X use case in Urban grid scenario, 10 sources ([19], [20], [21], [22], [23], [24], [25], [26], [31], [32]) provided simulation results for FR1, and 1 source ([32]) provided simulation results for FR2.

* For absolute horizontal accuracy, the results were provided by 8 out of 13 sources. 5 out of 8 sources show that target requirements set A cannot be achieved, and 7 out of 8 sources show that target requirements set B cannot be achieved.
* The requirement 1.5m@90% (Set A)
* is achieved with 20MHz in contributions from 2 sources ([26], [32]),
  + where SL ToA + AoA technique and optional antenna configuration is used in contribution from ([26])
* and is achieved with at least100MHz in contribution from 1 source ([24]),
* and is NOT achieved with 100MHz bandwidth in contributions from 5 sources ([19], [20], [21], [22], [31]).
* The requirement 0.5m@90% (Set B)
* is achieved with at least 100MHz in contribution from 1 source ([24]),
* and is NOT achieved with 100MHz bandwidth in FR1 or 400MHz in FR2 in contributions from 7 sources ([19], [20], [21], [22], [26], [31], [32]).
* For Relative horizontal accuracy, the results were provided by 5 out of 13 sources. The performance of relative horizontal accuracy is worse than that of distance accuracy of ranging mainly due to additional angle estimation error. All 5 sources show that the target requirement set B is not achieved even by 100MHz. 3 sources show that the target requirement Set A can be achieved by 40MHz or 100MHz in case of X=10m.
* The requirement 1.5m@90% (Set A)
* is achieved with at least 40MHz bandwidth in contribution from 1 source ([20])
  + only for the case of X = 10m and the relative positioning is performed with LOS link only in contribution from ([20])
* and is achieved with at least100MHz bandwidth in contributions from 2 sources ([19], [22])
  + X = 10m in contributions from ([19], [22])
* and is NOT achieved with 100MHz bandwidth in contributions from 5 sources ([19], [20], [22], [23], [32])
  + X = 50m in contribution from ([19])
  + X = 10m, 25m, and 50m in contribution from ([20])
  + X = 25m in contribution from ([22])
  + X = 30m in contribution from ([23]).
* The requirement 0.5m@90% (Set B)
* is NOT achieved with 100MHz bandwidth in FR1 or 400MHz in FR2 in contributions from 5 sources ([19], [20], [22], [23], [32]).
* For distance accuracy of ranging, the results were provided by 9 out of 13 sources. Based on the results by a majority of sources, target requirements set A may be achievable by smaller bandwidth, e.g., 20MHz or 40MHz, and set B may be achieved by larger bandwidth, e.g., 100MHz or may even not be achievable.
* The requirement 1.5m@90% (Set A)
* is achieved with at least 20MHz in contributions from 3 sources ([20], [22], [32])
  + X = 25m in the case when the relative positioning is performed with all links, X = 25m, 50m, and 100m in the case when the relative positioning is performed with LOS link only in contribution from ([20])
  + X = 10m and 25m in contribution from ([22])
  + X = 150m in contribution from ([32]) where RSU deployment is additionally used for performing distance ranging
* and is achieved with at least 40MHz in contributions from 2 sources ([24], [25])
  + X = 20m and 30m in contribution from ([24])
  + X = 20m, 50m and 100m in contribution from ([25])
* and is achieved with at least 100MHz in contributions from 1 source ([19])
  + X = 10 and 50m in contribution from ([19])
* and is NOT achieved with 100MHz bandwidth in contributions from 4 sources ([20], [23], [26], [31])
  + X = 50m and 100m in contribution from ([20])
  + X = 30m in contribution from ([23])
  + X = 50m, 100m in contribution from ([26], [31]).
* The requirement 0.5m@90% (Set B)
* is achieved with at least 40MHz in contributions from 1 source ([20])
  + X = 25m, 50m, 100m in the case when the relative positioning is performed only with LOS links in contribution from ([20])
* and is achieved with at least 100MHz in contributions from 3 sources ([19], [22], [25])
  + X = 10m and 50m in contribution from ([19])
  + X = 10m and 25m in contribution from ([22])
  + X = 20m, 50m, 100m in contribution from ([25])
* and is NOT achieved with 100MHz bandwidth in FR1 or 400MHz in FR2 in contributions from 6 sources ([20], [23], [24], [26], [31], [32])
  + where the relative positioning is performed with all links in contribution from ([20]).
* For angle accuracy of ranging, the results were provided by 5 out of 13 sources.
* The requirement 15°@90% (Set A)
* is achieved with 20MHz in contribution from 2 sources ([19], [26])
* and is achieved with at least 100MHz in contribution from 1 source [22]
* and is NOT achieved with 100MHz bandwidth in contributions from 2 sources ([20], [23]).
* The requirement 8°@90% (Set B)
* is achieved with 20MHz in contribution from 1 source ([26])
* and is achieved with at least 40MHz in contribution from 1 source ([19])
* and is NOT achieved with 100MHz bandwidth in contributions from 3 sources ([20], [22], [23]).
* Note: For each SL PRS bandwidth, the above observations are based on the best performance from each source.
* Note: For the relative positioning accuracy or distance accuracy of ranging, X is the maximum distance between UEs for performing relative positioning or ranging.

### 5.3.2 Evaluation of Absolute Positioning, Relative Positioning, and Ranging Methods

The performance analysis for Rel-18 SL positioning shows that different SL positioning methods can be used to determine absolute position of a target UE:

* Simulation results for SL positioning based on SL-TDOA were reported in contributions from 10 sources ([18], [21], [22], [23], [24], [26], [27], [28], [31], [32])
* Simulation results for SL positioning based on SL-RTT (multi-RTT) were reported in contributions from 6 sources ([19], [20], [27], [28], [29], [30])
* Simulation results for SL positioning based on two anchors using SL-AOA and a single anchor using SL-TOA+AOA were reported in contribution from 1 source ([26]).

The performance analysis for Rel-18 SL positioning shows that, SL positioning methods can be used for relative positioning/ ranging between UEs. For relative positioning/ ranging positioning accuracy,

* Simulation results based on SL-RTT and/or AOA were provided in contributions from 10 sources ([19], [20], [22], [23], [24], [25], [26], [27], [30], [31])
* Results based SL-TDOA were provided in contribution from 1 source ([32]).

Simulation results in contributions from 7 sources ([19], [20], [22], [24], [25], [27], [31]) show that relative horizontal accuracy and/or distance accuracy of ranging performance improves with decreasing values of X, where X is the maximum distance between two UEs for performing relative positioning or ranging.

* In some simulation cases, for a certain SL PRS bandwidth, a target requirement may be achieved for a smaller value of X but may not be achieved for a larger value of X.
* In some simulation cases, a target requirement may be achieved using a smaller SL PRS bandwidth for a smaller value of X but may only be achieved using a larger SL PRS bandwidth for a larger value of X.

## 5.4 Potential specification impact for Sidelink Positioning

# 6 Positioning Enhancements for Improved Integrity, accuracy, and power efficiency

## 6.1 Integrity for RAT-Dependent Positioning Techniques

The following objectives of the study on solutions for integrity for RAT-dependent positioning techniques are listed in the SID [7]:

* Identification of the error sources.
* Study of methodologies, procedures, signalling, etc for determination of positioning integrity for both UE-based and UE-assisted positioning
* Reuse of concepts and principles developed for RAT-Independent GNSS positioning integrity are to be prioritized, when possible.

### 6.1.1 Identification of error sources

Sources of error for RAT-dependent positioning techniques are studied for timing-based and angle-based positioning methods focussing on the origin of the error source, the model of the error source, criteria for consideration as an error source, and mapping between an error source and a positioning method (e.g., DL, UL, DL&UL positioning method).

UE-based/assisted DL positioning methods, UL and DL&UL positioning methods are considered in the study.

For timing-based positioning methods, the following error sources are studied:

* TRP/UE measurements errors (e.g., ToA, Rx-Tx timing difference)
* FFS: Effect of multipath/NLoS channels on TRP/UE measurement errors
* Error in assistance data (e.g., TRP location, Inter-TRP synchronization errors (e.g., RTD))
* TRP/UE Timing error
* FFS: Further study identification of error sources resulting from the multipath/NLoS channel/radio propagation environment, including multipath/NLoS channel itself as an error source.

For angle-based positioning methods, the following error sources are studied:

* TRP/UE measurements errors (e.g., AoA, RSRP, RSRPP)
* FFS: Effect of multipath/NLoS channels on TRP/UE measurement errors
* Error in assistance data (e.g., TRP location, TRP beam antenna information)
* FFS: Further study identification of error sources resulting from the multipath/NLoS channel/radio propagation environment, including multipath/NLoS channel itself as an error source.

For UE-based positioning integrity mode, whether boresight direction of DL PRS (***NR-DL-PRS-BeamInfo***) and/or beam information (***NR-TRP-BeamAntennaInfo***) of DL PRS can be error sources is studied, focusing at least on the following aspects:

* Granularity of boresight direction of DL-PRS and its influence on positioning integrity
* Feasibility and complexity of modelling
* Feasibility of obtaining quality/statistical parameters of beam information from the gNB
* Influence on measurement errors at the UE.

For DL AoD, whether DL PRS RSRP/RSRPP measurement can be an error source is studied, focusing at least on the following aspect:

* Impact of RSRP/RSRPP measurement on positioning accuracy.

For LMF-based positioning integrity mode, whether System Frame Number (SFN) initialization time is an independent error source for UL-TDOA or UE-assisted DL-TDOA is studied.

Table 6.1.1-1 presents the identified error sources for LMF-based and UE-based positioning integrity modes for different positioning methods.

Table 6.1.1-1: Error sources for LMF-based and UE-based positioning integrity modes

| Positioning Integrity Mode | DL TDOA | UL TDOA | Multi-RTT | UL AoA | DL AoD |
| --- | --- | --- | --- | --- | --- |
| LMF-based (as defined in Table 9.4.1.1.1 in [2]) | * RSTD measurement * TRP location * FFS: Inter-TRP synchronization | * RTOA measurement * TRP location * Inter-TRP synchronization | * UE Rx-Tx time difference measurement * gNB Rx-Tx time difference measurement * TRP location | * Angle of arrival measurement * TRP location * ARP location (e.g., ***ARPLocationInformation*** in [17]) | * TRP location |
| UE-based (as defined in Table 9.4.1.1.1 in [2]) | * TRP location (e.g., ***NR-TRP-LocationInfo*** in [16]) * Inter-TRP synchronization (e.g., ***NR-RTD-Info*** in [16]) |  |  |  | * TRP location (e.g., ***NR-TRP-LocationInfo*** in [16]) * FFS: boresight direction of DL-PRS (e.g., NR-DL-PRS-BeamInfo in [16]) * FFS: beam information of DL-PRS (e.g., NR-TRP-BeamAntennaInfo in [16]) |

The distributions of RSTD, RTOA, and UE/gNB Rx-Tx time difference measurement errors are studied considering the following aspects:

* Whether TEG-related timing error is an independent error source from timing related measurement error (e.g., RTOA, RSTD, UE/gNB Rx-Tx time difference)
* Whether the measurement error is considered for each ToA or for the reported RSTD value
* Other Details (e.g., mean and standard deviation).

The distribution of angle of arrival measurement error is studied considering the following aspects:

* Whether the angle of arrival measurement error can be expressed as the error of the AoA/ZoA in LCS or GCS or the error of a defined function of AoA/ZoA in LCS
* Distribution of AoA measurement error for an NLOS/LOS link
* Other Details (e.g., mean, standard deviation).

The following alternatives for expression of angle of arrival measurement error for determination of positioning integrity for UL AoA are studied with the aim of eventual down-selection:

* Alt. 1: No conversion (e.g., the measurement error is expressed as error in AoA or ZoA in LCS/GCS)
* Alt. 2: conversion function (defined as function of AoA/ZoA in LCS).

Table 6.1.1-2 presents the choices of statistical distributions of the errors for the identified error sources.

Table 6.1.1-2: Identified candidates for distributions to model the errors due to different error sources

| Error source | Candidate(s) for distribution for error source |
| --- | --- |
| Timing measurement errors (Notes 1, 2, 3) | Gaussian distribution |
| Inter-TRP synchronization errors | * Uniform distribution (Note 4) * Gaussian distribution |
| TRP location error (e.g., ***NR-TRP-LocationInfo*** in [16]) | * Uniform distribution (Note 5) * Gaussian distribution |
| Note 1: Timing measurement errors are applicable to RSTD, RTOA and UE/gNB Rx-Tx time difference measurements.  Note 2: It is assumed that the timing measurement error is associated with the first path.  Note 3: It is assumed that the timing measurement error contains TEG related TX/RX timing error if the TEG related information is provided  Note 4: This may already be consistent with the uncertainty related to ***NR-RTD-Info*** in [16].  Note 5: This may already be consistent with the uncertainty related to ***NR-TRP-LocationInfo*** in [16]. | |

### 6.1.2 Methodologies, procedures and signalling for determination of positioning integrity

### 6.1.3 Summary of Evaluation Results for Integrity for RAT-Dependent Positioning Techniques

### 6.1.4 Potential Specification Impact for Integrity for RAT-Dependent Positioning Techniques

For UE-based positioning integrity mode, potential specification impacts related to errors in assistance data (e.g., related to inter-TRP synchronization error and TRP locations) include at least the enhancements to assistance data from the LMF to the UE (e.g., inclusion of parameters related to the error sources).

## 6.2 PRS / SRS Bandwidth Aggregation

### 6.2.1 Potential Solutions Based on PRS / SRS Bandwidth Aggregation

### 6.2.2 Summary of Evaluations for PRS/SRS Bandwidth Aggregation

### 6.2.3 Potential Specification Impact for PRS/SRS Bandwidth Aggregation

## 6.3 NR Carrier Phase Positioning

In the SID [7], the following objectives for the study on solutions for accuracy improvement based on NR carrier phase measurements have been identified:

* Study on reference signals, physical layer measurements, and physical layer procedures to enable positioning based on NR carrier phase measurements for both UE-based and UE-assisted positioning.

In this study, the reuse of existing PRS and SRS is prioritized, with consideration of new reference signals only if found necessary.

In the following three subclauses, potential solutions, achievable performance, and expected specification impact for support of positioning methods utilizing NR carrier phase measurements are presented.

For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, the carrier phase (CP) at a RF frequency at a receiver is a phase that is a function of the signal propagation time from a transmitter antenna reference point of a transmitter (e.g., a TRP or a UE) to a receiver antenna reference point of the receiver (e.g., a UE or a TRP). The propagation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP may be independent of the number of integer cycles.

### 6.3.1 Potential Solutions for NR Carrier Phase Positioning

#### 6.3.1.1 Reference signals for NR Carrier Phase Positioning

Existing DL PRS and UL SRS for positioning can be re-used as the reference signals to enable positioning based on NR carrier phase measurements for both UE-based and UE-assisted positioning. Whether to consider enhancements of the existing DL PRS and UL SRS for better positioning performance is to be studied further. Note that the use of MIMO SRS for positioning purpose is transparent to UE.

#### 6.3.1.2 Physical layer measurements for NR carrier phase positioning

The study of the accuracy improvement based on NR carrier phase measurements includes:

* UE-based and UE-assisted carrier phase positioning
* UL carrier phase positioning and DL carrier phase positioning
* NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies
* Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, Multi-RTT, etc.

For DL UE-assisted NR carrier phase positioning, at least the following options are considered:

* the difference between the carrier phase measured from the DL PRS signal(s) of the target TRP and the carrier phase measured from the DL PRS signal(s) of the reference TRP;
* the carrier phase measured from the DL PRS signal(s) of a TRP.

For UL UE-assisted NR carrier phase positioning, at least the carrier phase measured from the UL SRS for positioning purpose is considered.

6.3.1.3 Physical layer procedures for NR carrier phase positioning

Benefits of using the carrier phase measurements of multiple DL positioning frequency layers for NR carrier phase positioning, which may include the impact of the time gap between the carrier phase measurements of multiple DL Positioning Frequency Layers (PFLs) are studied.

* Note 1: The initial phase error and the frequency error for each PFL can be modelled independently.
* Note 2: For evaluations, the PRSs of all the PFLs of a TRP can be assumed to be transmitted from the same ARP or from different ARPs of the TRP.
* Note 3: The location error for ARPs can be modelled independently.
* Note 4: The timing errors of the PFLs may not be the same for PFLs in different bands or frequency ranges.
* Note 5: In Rel-17, simultaneous reception of DL PRS from multiple frequency layers is not supported.

The impact of multipath/NLOS on NR carrier phase positioning is evaluated during the study item. Based on the study, it is concluded that multipath/NLOS deteriorates the performance of carrier phase positioning, and it is necessary to consider multipath mitigation for NR carrier phase positioning.

The effectiveness of the following multipath mitigation methods for NR carrier phase positioning is studied:

* Identification and separation of the first path and other paths.
* Reporting of the carrier phase of the first path, and optionally, the additional paths.
* The use of LOS/NLOS indication for the carrier phase measurements.
  + Note: Rel-17 LOS/NLOS indicator can be considered as a starting point.
* The report of other channel information, such as RSRP/RSRPP.

The use of positioning reference unit (PRU) to facilitate NR carrier phase positioning is studied.

* For DL NR carrier phase positioning, a PRU works as a UE to receive the DL PRS reference signals and provide the DL carrier phase measurements to the LMF, where the double differential measurements can be obtained by the difference of the DL carrier phase measurements from the target UE and those from the PRU for eliminating the measurement errors.
* For UL NR carrier phase positioning, a PRU works as a UE to transmit the UL SRS signals for positioning purpose. The TRPs provide the UL carrier phase measurements obtained from the UL SRS signals of the target UE and of the PRU to the LMF, where the double differential measurements can be obtained by the difference of these UL carrier phase measurements for eliminating the measurement errors.

The following approaches for NR carrier phase positioning are studied:

* The reporting of the carrier phase measurements together with the existing positioning measurements.
* The reporting of the carrier phase-based measurements alone without reporting the existing positioning measurements.

Potential solutions for NR carrier phase positioning are evaluated with the consideration of various error sources, which include: phase noise (FR2), carrier frequency offset (CFO)/Doppler, oscillator-drift, transmitter/receiver antenna reference point (ARP) location errors, transmitter/receiver initial phase error, antenna phase center offset (PCO) etc. Detailed evaluation methodology and assumptions are presented in Annex A.3

A summary of the evaluation results for the impact of the multipath/NLOS on NR carrier phase positioning are presented in Section 6.3.2.

NR carrier phase positioning performance is evaluated at least with the carrier phase measurements of a single measurement instance.

### 6.3.2 Summary of Evaluations for NR Carrier Phase Positioning

The methodology for the evaluation of NR carrier phase positioning can be found in Annex A.3.

The impact of the initial phases of the transmitter and the receiver on NR carrier phase positioning is evaluated in the study item. The evaluation results from the sources (e.g., [73], [74], [75], [76]) show that if the initial phases of the transmitter and the receiver are not eliminated, it is impossible to support centimeter-level positioning accuracy.

The effectiveness of using double differential technique with PRU to eliminate the impact of the initial phases of the transmitter and the receiver on NR carrier phase positioning are evaluated in the study item. The evaluation results from the sources ([73], [75], [76], [77]) show that the initial phases of the transmitter and the receiver can be removed effectively by the double differential technique with the use of PRU:

* Source [73] shows the positioning accuracy of <1cm (80%) for Inf-SH and < 1cm (50%) for Inf-DH can be reached when the PRU is located within a distance of 5m from the target UE.
* Source [75] shows the positioning accuracy of <1cm (80%) for Inf-SH and <1cm (50%) for Inf-DH can be reached under the condition that the PRU is located at a fixed location in LOS of the TRP.
* Source [77] shows that the accuracy of <1cm (50%) when the PRU is located within 1m of the target UE. However, the effectiveness reduces when the PRU is located away from the target UE because the channel conditions of the PRU is different from the target UE.
* Note: in the above results, all other error sources (except initial phase error) were not modelled.

The impact of the residual CFO at the transmitter and the receiver for NR carrier phase positioning are evaluated during the study item.

* The evaluation results from the sources ([73], [76]) show that the impact of residual CFO on carrier phase positioning is negligible.
* The evaluation results from the source ([75]) show that the impact of the residual CFO on the performance of carrier phase positioning can be mitigated with the use of the double differential technique with a PRU that is located at a fixed location in LOS of the TRP.

### 6.3.3 Potential Specification Impact for NR Carrier Phase Positioning

## 6.4 Low Power High Accuracy Positioning

For the study on enhancing the power efficiency of RAT-dependent positioning methods for LPHAP use cases, the following objectives have been identified in the SID:

* Study of the requirements on LPHAP as developed by SA1 and evaluation of whether existing RAN functionality can support the power consumption and positioning requirements.
* Based on the evaluation, and, if found beneficial, study of potential enhancements to help address any limitations.

The study is limited to enhancements to RRC\_INACTIVE and/or RRC\_IDLE states.

### 6.4.1 Target use cases and requirements for Low Power High Accuracy Positioning

Use case 6 defined in TS 22.104 [6] is the single representative use case for the study of LPHAP.

For LPHAP, the main objective of the evaluations from the perspective of lower layers is on UE power consumption.

At least relative power unit is adopted as the performance metric to evaluate the power consumption of the Rel-17 RRC\_INACTIVE state positioning and potential enhancements.

A reference device (e.g., a mobile phone) with reference traffic type, reference battery capability, and reference battery life is defined for the purpose of identification of the performance gap that achieved by the Rel-17 RRC\_INACTIVE state positioning baseline and the target battery life of LPHAP use case 6.

For the evaluations of LPHAP use case 6, the following performance requirements are considered:

* Horizontal positioning accuracy < 1 m for 90% of UEs
* Positioning interval / duty cycle of 15-30 s
* UE battery life of 6 months – 1 year.

### 6.4.2 Potential Enhancements for Low Power High Accuracy Positioning

For UL and DL+UL positioning for UEs in RRC\_INACTIVE, the potential benefits and performance gains of enhancements on SRS for positioning to avoid frequent SRS (re)configurations are studied, including at least the following:

* The (pre-)configuration of SRS for positioning. FFS details, e.g., signaling and procedure, whether/how it is applicable to an area across multiple cells, consideration of UL overhead/capacity implied by (pre-)configuration and multiple cells, etc.
* SRS for positioning activation/request procedure(s), e.g., network activation of SRS via paging, UE request to obtain/update SRS via RACH-based procedure.
* FFS: Events of invalidity of SRS configuration to trigger the UE request procedure.
* FFS: Whether the enhancements may be applicable to UEs in RRC\_IDLE state.

### 6.4.3 Summary of Evaluations for Low Power High Accuracy Positioning

The methodology for the evaluation of low power high accuracy positioning (LPHAP) can be found in Annex A.4.

Evaluations of baseline Rel-17 RRC\_INACTIVE state positioning with the evaluation assumptions agreed for the study show that the power consumption on deep sleep state accounts for the highest proportion in the total power.

For the evaluation on the battery life of the baseline LPHAP Type A device with battery capacity C2 of 800mAh:

* Based on the results provided by all sources, the target requirement of 6~12 months is not achieved by the existing Rel-17 positioning for UEs in RRC\_INACTIVE state with baseline implementation factor K = 1 and baseline evaluation assumptions.
* Based on the results provided by all sources, the target requirement of 6~12 months is not achieved by the existing Rel-17 positioning for UEs in RRC\_INACTIVE state with optional implementation factor K or optional evaluation assumptions.
* For UE-assisted DL positioning, results are provided by 13 sources ([34], [36], [37], [38], [40], [42], [43], [44], [45], [48], [50], [52], [53]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 0 source, and is not achieved by 13 sources ([34],[36],[37],[38],[40],[42],[43],[44],[45],[48],[50],[52],[53]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, CG-SDT for measurement reporting, and implementation factor K = 4.
* The target requirement of 12 months is achieved by 0 source, and is not achieved by 13 sources ([34],[36],[37],[38],[40],[42],[43],[44],[45],[48],[50],[52],[53]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, CG-SDT for measurement reporting, and implementation factor K = 4.
* For UE-based DL positioning, results are provided by 10 sources ([34], [36], [37], [38], [40], [43], [44], [45], [50], [52]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 0 source, and is not achieved by 10 sources ([34],[36],[37],[38],[40],[43],[44],[45],[50],[52]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, and implementation factor K = 4.
* The target requirement of 12 months is achieved by 0 source, and is not achieved by 10 sources ([34],[36],[37],[38],[40],[43],[44],[45],[50],[52]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, and implementation factor K = 4.
* For UL positioning, results are provided by 12 sources ([34], [36], [37], [38], [40], [43], [44], [45], [48], [50], [52], [53]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 0 source, and is not achieved by 12 sources ([34], [36], [37], [38], [40], [43], [44], [45], [48], [50], [52], [53]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, no SRS (re)configuration, and implementation factor K = 4.
* The target requirement of 12 months is achieved by 0 source, and is not achieved by 12 sources ([34], [36], [37], [38], [40], [43], [44], [45], [48], [50], [52], [53]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, no SRS (re)configuration, and implementation factor K = 4.
* For DL+UL positioning, results are provided by 1 source ([52]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 0 source, and is not achieved by 1 source ([20]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, no SRS (re)configuration, CG-SDT for measurement reporting, and implementation factor K = 4.
* The target requirement of 12 months is achieved by 0 source, and is not achieved by 1 source ([20]) even with the most power efficient case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, no SRS (re)configuration, CG-SDT for measurement reporting, and implementation factor K = 4.

For the evaluation on the battery life of the optional LPHAP Type B device with battery capacity C2 of 4500mAh:

* Based on the results provided by all sources, the target requirement of 6~12 months is not achieved by the existing Rel-17 positioning for UEs in RRC\_INACTIVE state with the baseline implementation factor K=1 and baseline evaluation assumptions.
* For UE-assisted DL positioning, results are provided by 8 sources ([36], [37], [38], [42], [43], [45], [50], [52]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 4 sources ([36],[38],[45],[52]) with the implementation factor K = 4 and by 2 sources ([43],[50]) with the implementation factor K >= 2, and is not achieved by 6 sources with the implementation factor K < 4 ([36],[37],[38],[42],[45],[52]) and by 2 sources ([43],[50]) with the implementation factor K < 2.
* The target requirement of 12 months is achieved by 3 sources ([43],[50],[52]) with the case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, CG-SDT for reporting and implementation factor K = 4, and is not achieved by 8 sources ([36],[37],[38],[42],[43],[45],[50],[52]) with the implementation factor K < 4.
* For UE-based DL positioning, results are provided by 7 sources ([36], [37], [38], [43], [45], [50], [52]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 4 sources ([36],[38],[45],[52]) with the implementation factor K = 4 and by 2 sources ([43],[50]) with the implementation factor K >= 2 , and is not achieved by 5 sources with the implementation factor K < 4 ([36],[37],[38],[45],[52]) and by 2 sources ([43],[50]) with the implementation factor K < 2;
* The target requirement of 12 months is achieved by 3 sources ([43],[50],[52]) with the case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, and implementation factor K = 4, and is not achieved by 7 sources ([36], [37], [38], [43], [45], [50], [52]) with the implementation factor K < 4.
* For UL positioning, results are provided by 7 sources ([36], [37], [38], [43], [45], [50], [52]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 4 sources ([36],[38],[45],[52]) with the implementation factor K = 4 and by 2 sources ([11],[18]) with the implementation factor K >= 2, and is not achieved by 5 sources ([36],[37],[38],[45],[52]) with the implementation factor K < 4 and by 2 sources ([43],[50]) with the implementation factor K < 2;
* The target requirement of 12 months is achieved by 3 sources ([43],[50],[52]) with the case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, no SRS (re)configuration, and implementation factor K = 4, and is not achieved by 7 sources ([36], [37], [38], [43], [45], [50], [52]) with the implementation factor K < 4.
* For DL+UL positioning, results are provided by 1 source ([52]) out of 20 sources, and the following are observed:
* The target requirement of 6 months is achieved by 1 source ([52]) with implementation factor K = 4, and is not achieved by 1 source ([52]) with implementation factor K < 4;
* The target requirement of 12 months is achieved by 1 source ([52]) with the case that I-DRX cycle of 10.24s, 1 RS per 1 I-DRX cycle, high SINR, no SRS (re)configuration, CG-SDT for measurement reporting, and implementation factor K = 4, and is not achieved by 1 source ([52]) with implementation factor K < 4.
* Note: The implementation factor K is a factor related to the reference device in the model to convert the relative power unit to the battery life. Four values are introduced for K with K = 1 as the baseline and K = 0.5, 2, 4 as optional values. The model is captured in the Annex A.4.
* Note: Without otherwise noted, “high SINR” in the observation refers to the evaluation case that no intra-/inter-frequency RRM and single SSB for synchronization purpose is considered.

From evaluations for a LPHAP device, it is observed that the existing Rel-17 positioning procedures for UEs in RRC\_INACTIVE state cannot satisfy the target battery life required by LPHAP use case 6 for majority of the evaluation scenarios that are examined.

Based on the evaluations, it is concluded that enhancements to meet the target battery life in Rel-18 are necessary.

### 6.4.4 Potential Specification Impact for Low Power High Accuracy Positioning

## 6.5 Positioning of UEs with Reduced Capabilities

The scope of the study on positioning for RedCap UEs is defined in the SID [7] as:

* Evaluation of positioning performance of existing positioning procedures and measurements with RedCap UEs
* Based on the evaluations, assessment of the necessity of enhancements and, if needed, identification of enhancements to help address limitations associated with RedCap UEs.

For the purpose of the study of positioning performance for UEs with Reduced Capabilities (RedCap UEs), the following target performance requirements are considered:

For commercial use cases for both indoor and outdoor scenarios

- Horizontal positioning accuracy: (< 3 m) for 90% of UEs

- Vertical positioning accuracy: (< 3 m) for 90% of UEs

For IIoT use cases:

- Horizontal positioning accuracy: (< 1 m) for 90% of UEs

- Vertical positioning accuracy: (< 3 m) for 90% of UEs

For the above target requirements for evaluations, it should be noted that the target positioning requirements may not necessarily be achieved for all scenarios and use cases. Further, all positioning techniques may not achieve all positioning requirements in all scenarios.

### 6.5.1 Potential Solutions for Positioning for RedCap UEs

Potential enhancements to UL SRS for positioning to enable transmitter frequency hopping are studied, including but not limited to partial overlapping between hops, hopping bandwidth, and time gap between frequency hopping.

Potential enhancements to DL PRS to enable transmitter or receiver frequency hopping are studied, including but not limited to impact on processing capability, hopping bandwidth in the positioning frequency layer, time gap between frequency hopping, measurement period, and partial overlapping between hops.

### 6.5.2 Summary of Evaluations for Positioning for RedCap UEs

The methodology for the evaluation of positioning performance for RedCap UEs can be found in Annex A.5.

For the baseline performance of positioning for Redcap UEs in IIOT scenarios, based on the results provided by a majority of 19 sources, for InF-SH in FR1, the horizontal positioning requirement for IIOT use cases is not achieved by Rel.17 solutions using 5 MHz or 20 MHz of bandwidth.

* Sources in [54], [72] show that UL TDOA cannot meet the requirement.
* Sources in [71], [72] show that multi-RTT cannot meet the requirement.
* Sources in [57], [58], [59], [60], [61], [62], [65], [67], [72] show that DL-TDOA cannot meet the requirement.
* Source in [55] shows that the requirement can be met using 20 MHz of bandwidth.
* Source in [55] shows that the requirement cannot be met using 5 MHz of bandwidth.

Based on the results provided by 2 sources ([62], [71]) out of 19 sources, for InF-SH in FR2, the horizontal positioning requirement for IIOT use cases is achieved by Rel.17 solutions using 100 MHz of bandwidth.

* Source in [62] shows that DL-TDOA can meet the requirement.
* Source in [71] shows that multi-RTT can meet the requirement.

Based on the result provided by the following source, for InF-DH in FR1, the horizontal positioning requirement for IIOT use cases is not achieved by Rel.17 solutions using 20 MHz of bandwidth.

* Source in [60] shows that the requirements for IIOT use cases cannot be met for InF-DH.

For the baseline performance of positioning for Redcap UEs in commercial scenarios,

* based on the results provided by [54], for Umi in FR1, the horizontal positioning requirement for commercial use cases is not achieved by Rel.17 solutions using 20 MHz of bandwidth and UL TDOA.
* based on the results provided by [67], for Umi in FR1, the horizontal positioning requirement for commercial use cases is not achieved by Rel.17 solutions using 20 MHz of bandwidth and DL TDOA.
* based on the results provided by [71], for Umi in FR1, the horizontal positioning requirement for commercial use cases is not achieved by Rel.17 solutions using 20 MHz or 5 MHz of bandwidth and multi-RTT.

Regarding the performance for positioning of Redcap UEs using frequency hopping in IIoT scenarios, considering phase offset between hops:

* In FR1:
* If the phase offset between hops in frequency hopping is compensated, for InF-SH, the positioning requirement for IIOT use cases can be achieved using frequency hopping with partial overlap for the purpose of phase offset compensation,
* Results in [54] show that UL TDOA can meet the requirements.
* Results in [54], R1-2209217, show that DL TDOA can meet the requirements.
* Results in [55], show that the requirement cannot be met, even if the phase is compensated.
* If the phase offset between hops in Frequency hopping is not compensated,
* Results in [62] show that DL TDOA can meet the requirements if the random phase offset is set to be smaller than π.
* If the phase offset is ideally compensated,
* Results in [55], show that DL TDOA can meet the requirements.
* In FR2:
* Results in [71] show that the requirements can be met even if the phase is not compensated.
* Results in [62] show that PRS frequency hopping can improve positioning performance if the random phase between hops can be adjusted in FR2, InF-SH scenario.
* Note: Sources used different combinations of number of hops, gap size between hops and partial overlap sizes in their evaluations.

Regarding the performance for positioning of Redcap UEs using frequency hopping in commercial scenarios, considering phase offset between hops:

* In FR1, based on the results provided ([54], [71]), for the UMi positioning requirement for commercial use cases, positioning accuracy improvement is observed by two sources when the phase offset between hops in Frequency hopping is considered, if frequency hopping with partial overlap for the purpose of phase offset compensation is used, and if the phase offset is compensated.
* Results in [54] show that positioning accuracy improvement is observed with UL TDOA with phase offset compensation, but requirements are not met.
* Results in [54] show that positioning accuracy improvement is observed with DL TDOA with phase offset compensation, but requirements are not met.
* Results in [71] show that positioning accuracy improvement is observed with Multi RTT with phase offset compensation, but requirements are not met.
* Note: Sources used different combinations of number of hops, gap size between hops and partial overlap sizes in their evaluations

### 6.5.3 Potential Specification Impact for Positioning for RedCap UEs

# 7 Conclusions

# Annex A.1: Evaluation Methodology for Sidelink Positioning

In this clause, the evaluation methodology and assumptions for evaluation of sidelink positioning methods are described.

Table A.1-1 lists the performance metrics for evaluation of sidelink positioning.

Table A.1-1: Performance metrics for evaluations of sidelink positioning

| Evaluation case | Metrics |
| --- | --- |
| Relative or absolute positioning | * Horizontal accuracy * Vertical accuracy |
| Ranging | * Ranging distance * Ranging angle/direction |
| Metrics to be reported | * The percentiles of positioning/ranging accuracy error including 50%, 67%, 80%, 90% of UEs. * CDF of positioning/ranging accuracy error * For evaluated methods, sources are expected to report:   + whether the requirements are satisfied, and   + %-ile of UEs satisfying the target positioning accuracy for a requirement that may not be satisfied for 90% of the UEs. |
| Other metrics | Performance metrics other than positioning accuracy, such as PHY/end-to-end latency, are up to companies |

Tables A.1-2 through A.1-6 list the assumptions relevant to evaluation of all use-cases and those specific to each of the identified use-cases of V2X, public safety, commercial, and IIoT, respectively.

Table A.1-2: Evaluation assumptions common to all evaluations of sidelink positioning

| Assumptions | Value |
| --- | --- |
| Simulation bandwidth | * FR1: 10, 20, 40 and 100 MHz * FR2: 100, 200 and 400MHz |
| Reference signals for sidelink positioning | * Baseline: Existing pattern and sequence of DL-PRS or positioning SRS * Other choices of pattern and sequence not precluded – companies to provide details. * AGC settling time is considered. |
| 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 and anchor UE synchronization | * Baseline: Perfect synchronization between network and anchor UEs in the evaluation is assumed.   + Network synchronization error and timing errors defined in Table 6-1 in TR 38.857 [2] can also be optionally used for synchronization between BS and BS, between BS and anchor UEs, and between anchor UEs. |
| Sidelink anchor nodes | * For evaluation of SL only positioning, anchor UEs are used to locate target UEs. * For evaluation of Joint Uu/SL positioning, both BS and anchor UEs are used to locate target UEs. * Baseline for absolute positioning: sidelink anchors location coordinates are perfectly known.   + Uncertainty in the sidelink anchors location coordinates can be considered by companies |
| UE-pair selection for ranging | Relative positioning or ranging is performed between two UEs within X m. Value(s) of X to be reported by companies. |
| Positioning method | To be reported by companies. |
| Additional considerations | * Companies should report whether SL-PRS and other SL signals are FDM-ed or not FDM-ed, and whether other SL signals are present * System level simulations (rather than link level simulations) are used as the baseline tool. * For SL positioning evaluation in highway scenario or urban grid scenarios, performance metrics can include absolute horizontal accuracy, relative horizontal accuracy, ranging with distance accuracy, and ranging with direction accuracy (optionally). * In highway and urban grid scenarios, other UE types, e.g., pedestrian UE or VRU devices may be further considered. |

Table A.1-3: Evaluation assumptions for evaluations of sidelink positioning for V2X use-cases

| Assumptions | Value | |
| --- | --- | --- |
| Scenarios | V2X use-cases with highway and urban grid scenarios defined in TR 37.885 [8].   * Road configuration for urban grid and highway provided in Annex A in TR 37.885 [8] is reused. | |
|  | **Urban grid for V2X** | **Highway for V2X** |
| Carrier frequency | Uu : 4 GHz  SL: 6 GHz | Uu : 2 GHz or 4GHz SL: 6 GHz |
| Deployment layout for absolute positioning | * Alt 1 as optional: BS and UE-type RSU deployment follows TR 36.885, where wrap around method of 19\*3 hexagonal cells with 500m ISD in Figure A.1.3-3 of clause A.1.3 in TR 36.885 [9] is used. * Alt 2 as baseline: BSs are disabled, UE-type RSUs are uniformly located with 200m spacing on both sides of highway symmetrically.   + Optional: staggered/unsymmetrical UE-type RSU distribution like     Note: Alt 1 is assumed for evaluation of joint Uu/PC5 positioning, Alt 2 is assumed for evaluation of PC5-only positioning. | BS and UE-type RSU deployment follows the description in clause A.1.3 in TR 36.885 [9].   * Companies can provide results for additional BS/ UE-type RSU deployments, e.g., additional UE-type RSUs are added to UE-type RSU deployment in TR 36.885 [9] |
| Deployment layout for relative positioning/ranging | * BSs are disabled * UE type RSU may be disabled (as baseline) or enabled (as optional)   + If enabled, UE-type RSUs are uniformly located with 200m spacing on both sides of highway symmetrically.     - Optional: staggered/unsymmetrical UE-type RSU distribution like | * BSs are disabled (baseline), or enabled (optional)   + Companies to report their assumptions * UE type RSU may be disabled or enabled (companies should report their assumption)   + If enabled, UE type RSU deployment follows the description clause A.1.3 in TR 36.885 [9].   + If enabled, companies can provide additional RSU deployment, e.g. additional RSUs are added to RSU deployment in TR 36.885 [9]. |
| BS Tx power | Macro BS: 49dBm | |
| UE Tx power | Vehicle UE or UE type RSU: 23dBm | |
| BS receiver noise figure | 5dB | |
| UE receiver noise figure | 9 dB | |
| UE dropping | UE dropping option A defined in clause 6.1.2 of TR 37.885 [8]:   * UE dropping option A is used for the highway scenario:   + Vehicle type distribution: 100% vehicle type 2.   + Clustered dropping is not used.   + Vehicle speed is 140 km/h in all the lanes as baseline and 70 km/h in all the lanes optionally. * UE dropping option A is used for the urban grid scenario:   + Vehicle type distribution: 100% vehicle type 2.   + Clustered dropping is not used.   + Vehicle speed is 60 km/h in all the lanes.   In the intersection, a UE goes straight, turns left, turns right with the probability of 0.5, 0.25, 0.25, respectively. | |
| UE antenna model | Description in clause 6.1.4 in TR 37.885 [8] is reused:   * Vehicle UE option 1 is the baseline (Vehicle UE antenna is modelled in Table 6.1.4-8 and 6.1.4-9 in TR 37.885 [8]) * Vehicle UE option 2 (two panels) can be optionally selected by companies. | |
| Channel model | Description in clause 6.2 in TR 37.885 is reused. | |

Table A.1-4: Evaluation assumptions for evaluations of sidelink positioning for public safety use-cases

| Assumptions | Value |
| --- | --- |
| Overall assumptions | Companies to provide detailed simulation assumptions including selected scenarios, channel models, center frequency, UE drop models, etc. |
| Channel model | Channel model in TR 36.843 is reused:   * Reuse the parameters of "Channel models" specified in Clause A.2.1.2 of TR 36.843 with following modification: Each component of channel model reuses what is specified in TR 38.901. |
| Anchor UE height | To be reported by companies, e.g., same as TRP height. |
| Performance metrics | At least include absolute positioning accuracy and ranging with distance accuracy.   * Optional: Relative positioning accuracy or ranging with angle/direction accuracy |

Table A.1-5: Evaluation assumptions for evaluations of sidelink positioning for commercial use-cases

| Assumptions | Value |
| --- | --- |
| Overall assumptions | Companies to provide detailed simulation assumptions including selected scenarios, channel models, center frequency, UE drop models, etc. |
| Channel model | Channel model in TR 36.843 is reused:  Reuse the parameters of "Channel models" specified in Clause A.2.1.2 of TR 36.843 with following modification: Each component of channel model reuses what is specified in TR 38.901. |
| Anchor UE height | To be reported by companies, e.g., same as TRP height. |
| Performance metrics | At least include absolute positioning accuracy and ranging with distance accuracy.  Optional: Relative positioning accuracy or ranging with angle/direction accuracy |

Table A.1-6: Evaluation assumptions for evaluations of sidelink positioning for IIoT use-cases

| Assumptions | Value |
| --- | --- |
| Deployment scenario and BS-to-UE channel models | InF-SH and/or InF-DH defined in TR 38.857 [2]. |
| UE-to-UE channel model | * Option 1: BS-2-UE channel model defined in TR 38.901 [11] is revised:   + The UE parameters in the channel model defined in 38.901 [11], e.g. UE height, antenna model, transmit power are used to replace corresponding parameters for BS.   + Anchor UE height to be reported by companies, e.g., anchor UE height is the same as TRP. * Option 2: D2D channel mode from 36.843 A.2.1.2 is used. |
| Anchor UE dropping | Companies to report how to drop anchor UEs and how to select anchor UEs. |
| Performance metrics | At least include absolute and relative positioning accuracy |

# Annex A.2: Evaluation Methodology for PRS/SRS Bandwidth Aggregation

# Annex A.3: Evaluation Methodology for NR Carrier Phase Positioning

For evaluations of NR carrier phase positioning, the relevant evaluation assumptions as in TR 38.855 [12] and TR 38.857 [2] are reused, with optional modifications to the assumptions based on appropriate justification.

Evaluations for FR1 bands are considered as baseline while those for FR2 bands are optional.

For modelling of error sources, the following may be considered:

- Phase noise (FR2)

- CFO/Doppler

- Oscillator-drift

- Transmitter/receiver antenna reference point location errors

- Transmitter/receiver initial phase error

- Phase center offset

- Note: Other error sources are not precluded

- Note: UE mobility can be considered in the evaluations

- Note: one or more error sources can be evaluated jointly

- Note: companies should provide the error sources model with their evaluations

The impact of multipath will be considered as part of evaluations of NR carrier phase positioning, and the methods of mitigating the impact of multipath for the carrier phase positioning will be studied, if it is considered necessary after the evaluation.

The following multipath mitigation methods for the carrier phase positioning, which include, but are not limited to, the following are expected to be evaluated:

- The methods of estimating the carrier phase of the first path

- Note: Both time-domain and frequency-domain methods can be considered

- LOS/NLOS/ Multi-path indication for the carrier phase measurements for improving the accuracy of the position calculation

- Rel-17 LOS/NLOS indicator can be used as the starting point

- measurements of the first path and additional paths

- E.g., carrier phase measurements, timing measurements

- Other channel information, such as RSRP/RSRPP, CIR/CFR, etc.

Further, the use of PRUs to facilitate NR carrier phase positioning can be evaluated.

Table A.3-1 provides the assumptions for the evaluation of NR carrier phase positioning.

Table A.3-1: Assumptions for evaluation of NR carrier phase positioning

| Assumptions | Value | |
| --- | --- | --- |
| Scenarios | * Baseline: InF-SH, InF-DH * Optional: Indoor Open Office, Umi, Highway scenarios   + Other evaluation scenarios are not precluded   + Existing Rel-17 DL/UL reference signals for the Uu interface are to be used for the Highway scenario. | |
| Frequency errors – Note 1 | **Ideal** | **Practical** |
| Initial residual CFO  (is the same for one measurement instances [or multiple phase measurement instances]) | 0 (UE/TRP) | Uniform distribution within:   * [-30, +30] Hz (FR1, UE), [-100, +100] Hz (FR1, UE), * [-120, +120] Hz (FR2, UE), [-400, +400] Hz (FR2, UE), * [-10, +10] Hz (for each TRP, FR1), * [-40, +40] Hz (for each TRP, FR2). |
| Oscillator-drift  (is the same for one or multiple phase measurement instances for positioning fix) | 0 (UE/TRP) | Uniform distribution within:   * [-0.1, 0.1] ppm (UE) * [-0.02, +0.02] ppm (each TRP) within measurement duration |
| Antenna reference point (ARP) location error of a TRP | No ARP error | A zero-mean, truncated Gaussian distribution with zero mean and standard deviation of T=[1, 5] cm truncated to 2T in each of (x, y, z) direction |
| Initial phase of a transmitter | Modelled as a random variable uniformly distributed within [0, 2pi]   * The initial phase of a transmitter applies to all subcarriers of the same carrier frequency associated with the transmitter The initial phases of a transmitter for different carriers can be assumed to be independent of each other. | |
| Initial phase of a receiver | Modelled as a random variable uniformly distributed within [0, 2pi]   * The initial phase of a receiver applies to all subcarriers of the same carrier frequency associated with the receiver * The initial phases of a receiver for different carriers can be assumed to be independent of each other. | |
| UE/TRP antenna phase center offset (PCO) | *dPCO = a \* dPhi + w*  where   * *a* is the scale factor, *a*=[0, 1, 3]   + FFS: other values * *dPhi* is the direction difference (in degrees):   + Example 1, *dPhi* is the difference between the true and the calculated (or measured) directions between a transmitter (UE/TRP) and a receiver (TRP/UE).   + Example 2: *dPhi* is the direction difference between one UE to two TRPs, or between one TRP to two UEs. * *w* is 0 or a random variable uniformly distributed within [-2, +2], or [-5, +5], or [-X, +X] degrees   + FFS: value of X or left up to companies * Note: the above model is valid only when absolute value of *dPhi* < Y degrees   + FFS: value of Y or left up to companies | |
| Time instances for carrier phase measurements | UE position can be calculated by the use of the carrier phase measurements obtained at the *M* sequential time instances, where   * Baseline:   + M=1 * Optional :   + M=4 * Other values of M   + Companies should report their assumptions on UE mobility (e.g., speed) | |
| Note 1: The Doppler frequency can be determined based on the UE speed in the evaluation assumption. | | |

# Annex A.4: Evaluation Methodology for Low Power High Accuracy Positioning

Table A.4-1 lists the common assumptions for evaluation of LPHAP.

Table A.4-1: Evaluation assumptions common to all evaluations of LPHAP

| Assumptions | Value |
| --- | --- |
| Frequency range | FR1 baseline; FR2 optional |
| SCS | 30kHz for FR1 (baseline); 120kHz for FR2 (optional) |
| Bandwidth of the DL PRS and UL SRS for positioning | 100 MHz |
| Measurements per position fix | Single-sample measurement per position fix (baseline); 4-sample measurement per position fix (optional) |
| UE mobility | Up to 3 km/h |
| Power consumption modelling – basic considerations | * Power consumption of 5GC data traffic is not modelled and only the power consumption of the traffic type related to LPHAP positioning (e.g., obtaining/updating SRS configurations, DL PRS measurement reporting, etc.) is considered.   + Consideration of power consumption due to paging monitoring is not precluded for baseline evaluation. * Up to each company to provide detailed power model and evaluation results on power consumption in FR2. * Adopt the power consumption model, additional transition energy and total transition time of the three sleep types (deep sleep, light sleep, and micro sleep) in TR38.840 [13] as the evaluation baseline. |
| Periodicity of DL PRS / UL SRS for positioning | Baseline: 1 DL PRS / UL SRS for positioning occasion per N I-DRX cycle(s)   * Candidate values of N to evaluate is 1 and 8 for I-DRX cycle of 1.28s.   + Up to companies to select one or both of the above values. * Candidate value of N to evaluate is 1 for I-DRX cycle of 10.24s. |
| I-DRX configuration | Included in the baseline evaluations   * I-DRX cycles: 1.28s (baseline); 10.24s (optional) * Note: This does not preclude the case where no I-DRX cycle nor paging is considered in the evaluation of potential solutions to maximize the battery life. |
| e-DRX and/or paging reception | The following may be optionally considered:   * e-DRX cycles to evaluate: 20.48s; 30.72s. * For paging reception:   + 1 paging occasion is included in one eDRX cycle   + 10% paging rate * No paging reception can be optionally evaluated. * 1 DL PRS and/or UL SRS for positioning occasion per 1 eDRX cycle   + Minimizing the gap between PRS measurement, SRS transmission and/or measurement reporting with paging monitoring in time domain can be evaluated. |
| Positioning Reference Signal Bandwidth assumption | At least when the positioning accuracy is evaluated without jointly evaluating the associated power consumption, the target horizontal positioning accuracy requirement on LPHAP of <1m is assumed to be achieved by Rel-16/17 positioning techniques with a positioning bandwidth of at least 100 MHz. |

For conversion between relative power unit and device battery lifetime to identify any performance gaps, the following characterization is considered:

* Battery life is used as the metric to identify the gap

in which,

- C1 is the battery capacity of the reference device;

- T1 is the battery life of the reference device;

- P1 = 50 is the relative power unit obtained based on the reference traffic type;

- X is the percentage of the power consumed by the reference traffic type;

- C2 is the battery capacity of the LPHAP device;

- P2 is the evaluated relative power unit of the LPHAP device;

- T2\_req is the target battery life of the LPHAP device

- K is an implementation factor, K = 1 (baseline); K = 0.5, 2, 4 (optional)

Note: In the above model, the voltage is assumed to be the same for the reference device and the LPHAP device.

Note: As the reference device and LPHAP device characteristics, and therefore the parameter values of the model for determining battery life, is dependent on implementation factors, manufacturer, design options and cost options, it is up to individual company to evaluate the optional K values, and report the corresponding parameter values.

Examples of these parameters are provided as in Table A.4-2.

Table A.4-2: Example values of parameters for conversion between power consumption unit and device battery lifetime

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| C1 (mAh) | T1 (hours) | X | Reference traffic type | C2 (mAh) | T2req (months) |
| 4500 | 12 | 20 % | FTP (model 3) | 800 for Type A LPHAP device (baseline)  4500 for Type B LPHAP device (optional) | 6 to 12 |

The power consumption model used for baseline evaluation of Rel-17 positioning in RRC\_INACTIVE state is as in Table A.4-3.

Table A.4-3: Power consumption model for baseline evaluation of Rel-17 positioning in RRC\_INACTIVE state

|  |  |
| --- | --- |
| Power State | Relative power |
| PDCCH-only (PPDCCH) | 50Note |
| PDCCH + PDSCH (PPDCCH+PDSCH) | 120 |
| SSB proc. (PSSB) | 50 |
| UL | 250 (0 dBm)  700 (23 dBm) |
| (Optional) PRACH | [210] |
| (Optional) BWP switching | [50] |
| (Optional) Intra-frequency RRM measurement (Pintra) | [60] (synchronous case, N=8, measurement only; Pintra, meas-only)  [80] (combined search and measurement; Pintra, search+meas) |
| (Optional) Inter-frequency RRM measurement (Pinter) | [60] (measurement only per freq. layer; Pinter, meas-only)  [150] (neighbor cell search power per freq. layer; Pinter, search-only)  Micro sleep power assumed for switch in/out a freq. layer |
| Note: Power scaling to 20MHz reception bandwidth follows the rule in Clause 8.1.3 of TR 38.840, i.e., max{reference power \* 0.4, 50}. | |

For the purpose of LPHAP evaluation, an ultra-deep sleep state is considered with the two modelling options as in Table A.4-4.

Table A.4-4: Power consumption model for ultra-deep sleep state

|  |  |
| --- | --- |
| Parameters | Values |
| Model A (Note 1): | |
| Relative power unit | 0.015 |
| Additional transition energy | 10000 (Note 2) |
| Total transition time | 400 ms |
| Model B (Notes 1, 3): | |
| Relative power unit | 0.01 |
| Additional transition energy | 480 |
| Total transition time | 25 ms |
| FFS: Restrictions in processing associated with Model B after the UE comes out of ultra-deep sleep state | |
| Note 1: No new device type is expected based on ultra-deep sleep power modelling.  Note 2: Power consumption analysis from individual companies with additional transition energy of 5000 can be optionally evaluated.  Note 3: Power consumption analysis from individual companies with Model B can be optionally evaluated. | |

For DL PRS-based positioning, the following reference configuration is assumed:

- Number of Positioning Frequency Layers = 1;

- Number of DL PRS resources measured per slot = 8;

- DL PRS instance of smaller than or equal to 1 slot duration.

The power consumption model for DL PRS-based positioning and UL SRS-based positioning are as in Tables A.4-4 and A.4-5 respectively.

Table A.4-5: Power consumption model for DL PRS-based positioning

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **N: Number of** **TRPs for DL PRS measurement** | **Synchronous case (baseline)** | | **Asynchronous case (optional)** | |
| **FR1 (baseline)** | **FR2**  **(optional)** | **FR1** | **FR2** |
| N=4 (baseline) | 120 | 195 | 140 | 255 |
| N=8 (optional) | 150 | 225 | 170 | 285 |

Table A.4-6: Power consumption model for UL SRS-based positioning

|  |  |
| --- | --- |
| **Power State** | **Relative power** |
| SRS | 210 (baseline);  700 (optional) |

For DL positioning, at least the following power components and parameter values are considered for the baseline evaluation of Rel-17 RRC\_INACTIVE positioning:

- For UE-assisted DL positioning,

- SSB proc. with 2 ms duration and the periodicity of I-DRX cycle;

- Paging with 2 ms duration, the periodicity of I-DRX cycle, and group paging rate of 10%;

- DL PRS measurement with 0.5 ms duration;

- CG-SDT with 1ms duration and the periodicity of positioning interval;

- RRCRelsease after the CG-SDT can be optionally included with [1] ms duration;

- (Optional) BWP switching with [1] ms duration;

- (Optional) Intra-/inter-frequency RRM measurement in low SINR condition with [1] ms duration;

- (Optional) RA-SDT (e.g., including CORSET0 + SIB1, PRACH, RAR, Msg 3/4/5) in case of CG-SDT is unavailable.

- For UE-based DL positioning,

- SSB proc. with 2 ms duration and the periodicity of I-DRX cycle;

- Paging with 2 ms duration, the periodicity of I-DRX cycle, and group paging rate of 10%;

- DL PRS measurement with 0.5 ms duration;

- (Optional) BWP switching with [1] ms duration;

- (Optional) Intra-/inter-frequency RRM measurement in low SINR condition with [1] ms duration.

For UL positioning, at least the following power components and parameter values are considered for the baseline evaluation of Rel-17 RRC\_INACTIVE positioning:

- SSB proc. with 2 ms duration and the periodicity of I-DRX cycle;

- Paging with 2 ms duration, the periodicity of I-DRX cycle, and group paging rate of 10%;

- UL SRS for positioning transmission with 0.5 ms duration;

- (Optional) BWP switching with [1] ms duration;

- (Optional) Intra-/inter-frequency RRM measurement in low SINR condition with [1] ms duration.

In addition to the above, the following should be noted for DL and UL positioning in modelling the power components and timelines:

- The power component and parameter values for DL and UL positioning are respectively applicable to the DL and UL parts of UE-assisted DL+UL positioning method.

- Additional power components and different parameter values for those in brackets above can be considered in the evaluation.

- Companies are encouraged to provide the assumption on the timeline between different power consumption events in the evaluation of potential enhancements to reduce the transition times between different power states and to extend the sleeping time as much as possible.

# Annex A.5: Evaluation Methodology for Positioning for RedCap UEs

In this clause, the evaluation methodology and assumptions for evaluation of positioning performance for Reduced Capability (RedCap) NR UEs are described.

For evaluation of RedCap UE positioning performances, all RAT based positioning methods can be considered. Sources should detail the chosen method(s) when presenting performance evaluations.

Table A.5-1 lists the set of common parameters applicable for evaluation of positioning performance of RedCap UEs.

Table A.5-1: Common parameters applicable for all scenarios for Redcap UEs evaluations

| Assumptions | FR1 Specific Values | FR2 Specific Values |
| --- | --- | --- |
| Carrier frequency, GHz | 3.5GHz, 700MHz (optional) – Note 1 | 28GHz – Note 1 |
| Bandwidth, MHz | 20MHz baseline, 5MHz optional | 100MHz |
| Subcarrier spacing, kHz | 30KHz, 15KHz (for 700MHz carriers) | 120kHz |
| Positioning Reference Signals | DL PRS and/or UL SRS.  Sources to detail the chosen configuration of reference signal(s) | |
| Deployment scenarios | * Baseline: (Case 1): Umi street canyon, as described in Table 6.1-1-4 of TR 38.855 * Optional outdoor:   + (Case 2): UMa, as described in Table 6.1-1-6 of TR 38.855   + (Case 3): RMa, companies to report parameters assumed for evaluations. * Baseline: (Case 4): InF-SH as described in Table 6.1-1 of TR 38.857 * Optional indoor: (Case 5) Indoor Open Office, as described in Table 6.1-1-3 of TR 38.855 * Optional indoor: (Case 6) InF-DH as described in Table 6.1-1 of TR 38.857 | |
| **gNB model parameters** |  |  |
| gNB noise figure, dB | 5dB | 7dB |
| gNB antenna configuration | At 700MHz:  (M,N,P,Mg,Ng) = (4,2,2,1,1), (dH, dV) = (0.5, 0.8)λ – Note 3 | |
| **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 radiation pattern | Omni, 0dBi | Antenna model according to Table 6.1.1-2 in TR 38.855 |
| UE antenna configuration | Panel model 1 – Note 1  dH = 0.5λ, for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1)  for 2Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 2, 1, 1) | * (M, N, P, Mg, Ng) = (1, 2, 2, 1, 1) **as minimum antenna configuration (baseline)** * (M, N, P, Mg, Ng) = (2, 2, 2, 1, 1) **as optional configuration.** |
| UE antenna radiation pattern | Omni, 0dBi | Antenna model according to Table 6.1.1-2 in TR 38.855 |
| Number of UE branches | Baseline: 1Rx 1Tx  Optional: 2Rx 1 Tx | Baseline: 2Rx and 1Tx |
| 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 sources  - 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. | |
| Selection of RedCap UEs for indoor scenarios for reporting of results | * (Required): The UEs inside the convex hull of the horizontal BS deployment area. * (Optional): All the UEs. | |
| For the evaluation of TX/RX frequency hopping for positioning of RedCap UEs, value of time gap between two consecutive hops | Includes at least from 100us to 5ms   * Sources should indicate if other smaller values are used in their evaluations and justify the feasibility of smaller values. | |
| For the evaluation of TX/RX frequency hopping for positioning of RedCap UEs, value of UE speed | 3 km/h, 30 km/h, 60km/h.   * Other values are not precluded. | |
| Note 1: According to TR 38.802 [14]  Note 2: According to TR 38.901 [11]  Note 3: According to TR38.830 [15] | | |

# Annex B.1: Evaluation Results for Sidelink Positioning

## B.1.X Results from source [X]

### B.1.X.1 Description of evaluation scenarios

[Brief descriptions of the evaluated scenarios]

Common assumptions applicable to all evaluated scenarios that are different from or not provided in Tables A.1-1 through A.1-6 are provided in Table B.1.X.1-1.

Table B.1.X.1-1: Common assumptions for sidelink positioning evaluations that are different from or not provided in Annex A.1 from [X]

|  |  |
| --- | --- |
| Parameter |  |
| Carrier frequency |  |
| Subcarrier spacing |  |
| Reference Signal Transmission Bandwidth |  |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) |  |
| Reference signal including PRS, SRS and SL-PRS  (type of sequence, number of ports, …) |  |
| Number of symbols used per occasion |  |
| number of occasions used per positioning estimate |  |
| Power-boosting level |  |
| Uplink power control (applied/not applied) |  |
| interference modelling (ideal muting, or other) |  |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) |  |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) |  |
| Synchronization assumptions |  |
| UE/gNB RX and TX timing error assumption |  |
| Precoding assumptions (codebook, nrof antenna elements used, etc) |  |
| Additional notes, if any |  |

Evaluation cases and relevant additional assumptions for highway scenarios for V2X use cases are provided in Table B.1.X.1-2. [multiple tables are OK]

Table B.1.X.1-2: Assumptions for sidelink positioning in highway scenarios for V2X use cases that are different from or not provided in Annex A.1 from [X]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 1 | Case 2 | … | Case n |
| UE Antenna model |  |  |  |  |
| TRP antenna model |  |  |  |  |
| BS/RSU deployment for absolute positioning |  |  |  |  |
| BS/RSU deployment for relative positioning/ranging |  |  |  |  |
| Selected values of X (relative positioning or ranging is performed between two UEs within X m) |  |  |  |  |
| Positioning method |  |  |  |  |

Evaluation cases and relevant additional assumptions for urban grid scenarios for V2X use cases are provided in Table B.1.X.1-3. [multiple tables are OK]

Table B.1.X.1-3: Assumptions for sidelink positioning in urban grid scenarios for V2X use cases that are different from or not provided in Annex A.1 from [X]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 1 | Case 2 | … | Case n |
| UE Antenna model |  |  |  |  |
| TRP antenna model |  |  |  |  |
| BS/RSU deployment for absolute positioning |  |  |  |  |
| BS/RSU deployment for relative positioning/ranging |  |  |  |  |
| Selected values of X (relative positioning or ranging is performed between two UEs within X m) |  |  |  |  |
| Positioning method |  |  |  |  |

Evaluation cases and relevant additional assumptions for IIoT use cases are provided in Table B.1.X.1-4. [multiple tables are OK]

Table B.1.X.1-4: Assumptions for sidelink positioning for IIoT use cases that are different from or not provided in Annex A.1 from [X]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 1 | Case 2 | … | Case n |
| UE Antenna model |  |  |  |  |
| TRP antenna model |  |  |  |  |
| BS/RSU deployment for absolute positioning |  |  |  |  |
| BS/RSU deployment for relative positioning/ranging |  |  |  |  |
| Selected values of X (relative positioning or ranging is performed between two UEs within X m) |  |  |  |  |
| Positioning method |  |  |  |  |

Evaluation cases and relevant additional assumptions for public safety use cases are provided in Table B.1.X.1-5. [multiple tables are OK]

Table B.1.X.1-5: Assumptions for sidelink positioning for public safety use cases that are different from or not provided in Annex A.1 from [X]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 1 | Case 2 | … | Case n |
| Scenario |  |  |  |  |
| UE Antenna model |  |  |  |  |
| TRP antenna model |  |  |  |  |
| BS/RSU deployment for absolute positioning |  |  |  |  |
| BS/RSU deployment for relative positioning/ranging |  |  |  |  |
| Selected values of X (relative positioning or ranging is performed between two UEs within X m) |  |  |  |  |
| Positioning method |  |  |  |  |

Evaluation cases and relevant additional assumptions for public safety use cases are provided in Table B.1.X.1-5. [multiple tables are OK]

Table B.1.X.1-6: Assumptions for sidelink positioning for commercial use cases that are different from or not provided in Annex A.1 from [X]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 1 | Case 2 | … | Case n |
| Scenario |  |  |  |  |
| UE Antenna model |  |  |  |  |
| TRP antenna model |  |  |  |  |
| BS/RSU deployment for absolute positioning |  |  |  |  |
| BS/RSU deployment for relative positioning/ranging |  |  |  |  |
| Selected values of X (relative positioning or ranging is performed between two UEs within X m) |  |  |  |  |
| Positioning method |  |  |  |  |

### B.1.X.2 Positioning accuracy evaluation results for Sidelink Positioning

[Brief description of the content, without observations, e.g., which sidelink positioning scenarios are evaluated, etc.]

#### B.1.X.2.1 Positioning accuracy evaluation results for Sidelink Positioning for Highway Scenarios for V2X

Table B.1.X.2.1-1 provides horizontal absolute positioning accuracy results using sidelink positioning for highway scenarios for V2X use cases.

Table B.1.X.2.1-1: Sidelink positioning - horizontal absolute accuracy for highway scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #1, BW#100M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
| e.g., Case #2, BW#40M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |

Table B.1.X.2.1-2 provides vertical absolute positioning accuracy results using sidelink positioning for highway scenarios for V2X use cases.

Table B.1.X.2.1-2: Sidelink positioning - vertical absolute accuracy for highway scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.1-3 provides horizontal relative positioning accuracy results using sidelink positioning for highway scenarios for V2X use cases.

Table B.1.X.2.1-3: Sidelink positioning - horizontal relative accuracy for highway scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.1-4 provides vertical relative positioning accuracy results using sidelink positioning for highway scenarios for V2X use cases.

Table B.1.X.2.1-4: Sidelink positioning - vertical relative accuracy for highway scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.1-5 provides ranging distance accuracy results using sidelink positioning for highway scenarios for V2X use cases.

Table B.1.X.2.1-5: Sidelink positioning - ranging distance accuracy for highway scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.1-6 provides ranging distance accuracy results using sidelink positioning for highway scenarios for V2X use cases.

Table B.1.X.2.1-6: Sidelink positioning - ranging angle accuracy for highway scenarios for V2X use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging angle accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

#### B.1.X.2.2 Positioning accuracy evaluation results for Sidelink Positioning for Urban Grid Scenarios for V2X

Table B.1.X.2.2-1 provides horizontal absolute positioning accuracy results using sidelink positioning for urban grid scenarios for V2X use cases.

Table B.1.X.2.2-1: Sidelink positioning - horizontal absolute accuracy for urban grid scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #1, BW#100M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
| e.g., Case #2, BW#40M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |

Table B.1.X.2.2-2 provides vertical absolute positioning accuracy results using sidelink positioning for urban grid scenarios for V2X use cases.

Table B.1.X.2.2-2: Sidelink positioning - vertical absolute accuracy for urban grid scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.2-3 provides horizontal relative positioning accuracy results using sidelink positioning for urban grid scenarios for V2X use cases.

Table B.1.X.2.2-3: Sidelink positioning - horizontal relative accuracy for urban grid scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.2-4 provides vertical relative positioning accuracy results using sidelink positioning for urban grid scenarios for V2X use cases.

Table B.1.X.2.2-4: Sidelink positioning - vertical relative accuracy for urban grid scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.2-5 provides ranging distance accuracy results using sidelink positioning for urban grid scenarios for V2X use cases.

Table B.1.X.2.2-5: Sidelink positioning - ranging distance accuracy for urban grid scenarios for V2X use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.2-6 provides ranging distance accuracy results using sidelink positioning for urban grid scenarios for V2X use cases.

Table B.1.X.2.2-6: Sidelink positioning - ranging angle accuracy for urban grid scenarios for V2X use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging angle accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

#### B.1.X.2.3 Positioning accuracy evaluation results for Sidelink Positioning for IIoT

Table B.1.X.2.3-1 provides horizontal absolute positioning accuracy results using sidelink positioning for IIoT use cases.

Table B.1.X.2.3-1: Sidelink positioning - horizontal absolute accuracy for IIoT use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #1, BW#100M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
| e.g., Case #2, BW#40M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |

Table B.1.X.2.3-2 provides vertical absolute positioning accuracy results using sidelink positioning for IIoT use cases.

Table B.1.X.2.3-2: Sidelink positioning - vertical absolute accuracy for IIoT use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.3-3 provides horizontal relative positioning accuracy results using sidelink positioning for IIoT use cases.

Table B.1.X.2.3-3: Sidelink positioning - horizontal relative accuracy for IIoT use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.3-4 provides vertical relative positioning accuracy results using sidelink positioning for IIoT use cases.

Table B.1.X.2.3-4: Sidelink positioning - vertical relative accuracy for IIoT use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.3-5 provides ranging distance accuracy results using sidelink positioning for IIoT use cases.

Table B.1.X.2.3-5: Sidelink positioning - ranging distance accuracy for IIoT use cases from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the requirement of set A | Whether meet the requirement of set B |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table B.1.X.2.3-6 provides ranging distance accuracy results using sidelink positioning for IIoT use cases.

Table B.1.X.2.3-6: Sidelink positioning - ranging angle accuracy for IIoT use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging angle accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

#### B.1.X.2.4 Positioning accuracy evaluation results for Sidelink Positioning for Public Safety

Table B.1.X.2.4-1 provides horizontal absolute positioning accuracy results using sidelink positioning for public safety use cases.

Table B.1.X.2.4-1: Sidelink positioning - horizontal absolute accuracy for public safety use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #1, BW#100M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
| e.g., Case #2, BW#40M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |

Table B.1.X.2.4-2 provides vertical absolute positioning accuracy results using sidelink positioning for public safety use cases.

Table B.1.X.2.4-2: Sidelink positioning - vertical absolute accuracy for public safety use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.4-3 provides horizontal relative positioning accuracy results using sidelink positioning for public safety use cases.

Table B.1.X.2.4-3: Sidelink positioning - horizontal relative accuracy for public safety use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.4-4 provides vertical relative positioning accuracy results using sidelink positioning for public safety use cases.

Table B.1.X.2.4-4: Sidelink positioning - vertical relative accuracy for public safety use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.4-5 provides ranging distance accuracy results using sidelink positioning for public safety use cases.

Table B.1.X.2.4-5: Sidelink positioning - ranging distance accuracy for public safety use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.4-6 provides ranging distance accuracy results using sidelink positioning for public safety use cases.

Table B.1.X.2.4-6: Sidelink positioning - ranging angle accuracy for public safety use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging angle accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

#### B.1.X.2.5 Positioning accuracy evaluation results for Sidelink Positioning for Commercial use cases

Table B.1.X.2.5-1 provides horizontal absolute positioning accuracy results using sidelink positioning for commercial use cases.

Table B.1.X.2.5-1: Sidelink positioning - horizontal absolute accuracy for commercial use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #1, BW#100M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
| e.g., Case #2, BW#40M, FR#1, positioning method #TDOA, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |

Table B.1.X.2.5-2 provides vertical absolute positioning accuracy results using sidelink positioning for commercial use cases.

Table B.1.X.2.5-2: Sidelink positioning - vertical absolute accuracy for commercial use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.5-3 provides horizontal relative positioning accuracy results using sidelink positioning for commercial use cases.

Table B.1.X.2.5-3: Sidelink positioning - horizontal relative accuracy for commercial use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.5-4 provides vertical relative positioning accuracy results using sidelink positioning for commercial use cases.

Table B.1.X.2.5-4: Sidelink positioning - vertical relative accuracy for commercial use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target positioning accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.5-5 provides ranging distance accuracy results using sidelink positioning for commercial use cases.

Table B.1.X.2.5-5: Sidelink positioning - ranging distance accuracy for commercial use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging distance accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table B.1.X.2.5-6 provides ranging distance accuracy results using sidelink positioning for commercial use cases.

Table B.1.X.2.5-6: Sidelink positioning - ranging angle accuracy for commercial use cases from [X]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case ID and brief description | 50% | 67% | 80% | 90% | Whether meet the target requirement |
| e.g., Case #, BW#, FR#, positioning method#, |  |  |  |  | Yes?  If not, %-ile of UEs satisfying the target ranging angle accuracy requirement |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

# Annex B.2: Evaluation Results for Integrity for RAT-Dependent Positioning Techniques

# Annex B.3: Evaluation Results for PRS/SRS Bandwidth Aggregation

# Annex B.4: Evaluation Results for NR Carrier Phase Positioning

## B.4.X Results from source [X]

### B.4.X.1 Description of evaluation scenarios

[Brief descriptions of the evaluated scenarios]

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.X.1-1. [multiple tables are OK]

Table B.4.X.1-1: NR carrier phase positioning enhancements - evaluation scenarios and parameters from [X]

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **[Case ID], [Scenario]** | **[Case ID], [Scenario]** | **[Case ID], [Scenario]** |
| Scenario  [TS 38.855, TS 38.857] |  |  |  |
| Single carrier frequency, or multiple carrier frequencies, GHz |  |  |  |
| Bandwidth, MHz |  |  |  |
| Subcarrier spacing, kHz |  |  |  |
| RS signal descriptions  (PRS or posSRS, Number of OFDM simbles, Comb size) |  |  |  |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) |  |  |  |
| R16/R17 positioning method  (if it is used together with CPP) |  |  |  |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) |  |  |  |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) |  |  |  |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) |  |  |  |
| Multipath mitigation techniques  (e.g., first path detection, ...) |  |  |  |
| Single-measurement instance CPP, or multiple measurement instances CPP |  |  |  |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) |  |  |  |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) |  |  |  |
| UE/TRP Initial phase offset |  |  |  |
| CFO/Doppler |  |  |  |
| *Oscillator-drifts* |  |  |  |
| ARP errors |  |  |  |
| Phase Center Offsets |  |  |  |
| Phase noise (FR2) |  |  |  |
| Additional notes, if any |  |  |  |
| PRU assumptions (Note 1) |  |  |  |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | |

### B.4.X.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

[Brief description of the content, without observations]

Table B.4.X.2-1 provides horizontal positioning accuracy results using NR carrier phase positioning.

Table B.4.X.2-1: NR carrier phase positioning - horizontal accuracy from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario]**  **[additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met target requirements?**  **(Yes/No)** | **Additional comments** |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

[Note: It is up to the companies whether to include additional descriptions for each case, and which information are included. For example, it may include the error sources considered in the evaluation of the case, and/or the number of carrieries, and/or DL or UL CPP, etc.]

Table B.4.X.2-2 provides horizontal positioning accuracy results using NR carrier phase positioning.

Table B.4.X.2-2: NR carrier phase positioning - vertical accuracy from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met target requirements?**  **(Yes/No)** | **Additional comments** |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

[Note: It is up to the companies whether to include additional descriptions for each case, and which information are included. For example, it may include the error sources considered in the evaluation of the case, and/or the number of carrieries, and/or DL or UL CPP, etc.]

[Note: Companies are welcome to provide results in the form of CDF figure. It is recommended to limit figure scale X- axis [0 : 0.1 : 5]m or less and Y-axis [0 : 0.1 : 1]. Legends of lines recommended to be marked by tags: [Case ID], [Scenario].]

# Annex B.5: Evaluation Results for Low Power High Accuracy Positioning

## B.5.X Results from source [X]

### B.5.X.1 Description of evaluation scenarios

[Brief descriptions of the evaluated scenarios]

Evaluation cases and corresponding assumptions for UE power consumption analysis are provided in Table B.5.X.1-1. [multiple tables are OK]

Table B.5.X.1-1: Low Power High Accuracy Positioning - Evaluation cases and assumptions from [X]

|  |  |  |  |
| --- | --- | --- | --- |
| Evaluation assumption | [Case ID], [Frequency Band], [Positioning method], [LPHAP device type] | [Case ID], [Frequency Band], [Positioning method], [LPHAP device type] | [Case ID], [Frequency Band], [Positioning method], [LPHAP device type] |
| Sleep state |  |  |  |
| DRX cycle |  |  |  |
| paging reception |  |  |  |
| RS periodicity |  |  |  |
| M-sample |  |  |  |
| RRM measurement |  |  |  |
| BWP switching |  |  |  |
| Measurement reporting (e.g., RA/CG-SDT, reporting interval) |  |  |  |
| Implementation factor K |  |  |  |
| Note: Companies are recommended to provide the following information for each evaluation case:   * Case ID * Positioning method: e.g., UE-assisted DL positioning, UL positioning, UE-assisted DL+UL positioning, etc. * Frequency range: e.g., FR1 * LPHAP device type: e.g., Type A, Type B | | | |

### B.5.X.2 Evaluation results for Low Power High Accuracy Positioning

[Brief description of the content, without observations]

Table B.5.X.2-1 provides detailed UE power consumption results for each evaluated case.

Table B.5.X.2-1: UE power consumption results for each evaluation case from [X]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Evaluation case | Power states | Relative power unit | Duration (in slots) | Instances | Sum Durations (in slots) | Relative power | Power ratio |
| Case ID | e.g., Deep/light/micro sleep, SSB, paging, PRS measurement, UL, SRS, etc |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Total (every power cycle) | | | |  |  |  |
| Slot-averaged power unit | | | |  | | |
| Battery life (in month) | | | |  | | |

Table B.5.X.2-2 provides summary of UE power consumption results for each evaluated case.

Table B.5.X.2-2: Summary for UE power consumption results from [X]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Evaluation case description | Slot-averaged relative power unit (P2) | Battery life (in month) | Target requirements met? (Yes/No); If no, provide gaps | |
| 6 months | 12 months |
| [Case ID], [Rel-17, or potential enhancements] |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

# Annex B.6: Evaluation Results for Positioning for RedCap UEs

## B.6.X Results from source [X]

### B.6.X.1 Description of evaluation scenarios

[Brief descriptions of the evaluated scenarios]

Evaluation assumptions for system level analysis are provided in Table B.6.X.1-1 [multiple tables are OK]

Table B.6.X.1-1: NR RedCap UE positioning - evaluation scenarios and parameters from [X]

|  |  |
| --- | --- |
| Parameter | Case XYZ (channel model, FRx) |
| Scenario (baseline, otherwise state any modifications) |  |
| Carrier frequency |  |
| Subcarrier spacing |  |
| Reference Signal Transmission Bandwidth |  |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) |  |
| Reference signal  (type of sequence, number of ports, …) |  |
| Number of sites |  |
| Number of symbols used per occasion |  |
| number of occasions used per positioning estimate |  |
| Power-boosting level |  |
| Uplink power control (applied/not applied) |  |
| interference modelling (ideal muting, or other) |  |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) |  |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) |  |
| Network synchronization assumptions |  |
| UE/gNB RX and TX timing error |  |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) |  |
| Precoding assumptions (codebook, nrof antenna elements used, etc) |  |
| UE antenna configuration |  |
| Number of UE branches |  |
| Description of enhancement solutions, if any |  |
| gNB antenna configuration |  |
| UE noise figure |  |
| UE antenna height |  |
| gNB antenna height |  |
| Additional notes, if any |  |

### B.6.X.2 NR RedCap UE positioning accuracy evaluation results

[Brief description of the content, without observations]

Table B.6.X.2-1 provides summary of …

Table B.6.X.2-1: Rel.16 NR RedCap UE positioning (baseline) - horizontal location error results from [X]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case #, channel model, FRx, positioning method | (Optional) All UEs |  |  |  |  |  |
| Convex UEs |  |  |  |  |  |

Figure B.6.X.2-1 provides the results of …

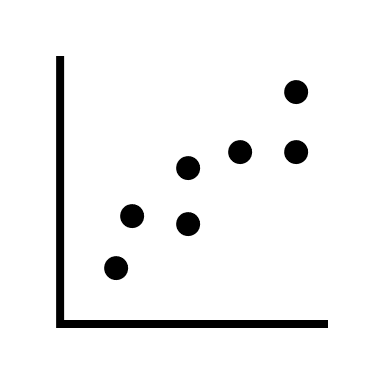


Figure B.6.X.2-1: results from [X]

Annex X: Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2022-05 | RAN1#109-e | R1-2205398 |  |  |  | Baseline TR skeleton. | 0.0.0 |
| 2022-08 | RAN1#110 | R1-2208275 |  |  |  | Incorporating decisions from RAN1 #109-e and RAN1 #110 | 0.1.0 |
| 2022-10 | RAN1#110bis-e | R1-2210715 |  |  |  | Incorporating decisions from RAN1 #109-e, RAN1 #110, and RAN1 #110bis-e | 0.2.0 |