**3GPP TSG RAN WG1 Meeting #103-e** [**R1-200**](file:///E:\1%20Meetings\RAN1\2020%2010_TSGR_103e\Docs\R1-200xxxx.doc)**9314**

**e-meeting, October 26th – November 13th, 2020**

**Source: Moderator (CATT)**

**Title: FL Summary for Potential Positioning Enhancements**

**Agenda item: 8.5.3**

**Document for: Discussion and Decision**

# Introduction

This document provides a summary of the following email discussion:

[103-e-NR-ePos-03] Email discussion/approval on potential positioning enhancements until 11/02; address any remaining aspects by 11/10 – Ren Da (CATT)

Potential Positioning Enhancements were discussed in RAN1#102-e [1]. The document further investigates the following aspects related to potential positioning enhancements based on proposals from [2-24]:

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| 1. Enhancements of DL positioning reference signals    1. DL PRS processing with aggregated DL PRS resources    2. DL PRS transmission patterns and additional DL PRS configuration    3. Simultaneous transmission and reception DL PRS with other signals/channels    4. DL PRS muting enhancements    5. New DL reference signals for positioning 2. Enhancements of UL positioning reference signals    1. UL SRS transmission patterns    2. UL SRS transmission with aggregated SRS resources    3. Simultaneous transmission of UL SRS for positioning with other signals/channels    4. Enhancement of SRS cyclic shift patterns    5. Power control for SRS for positioning    6. Mitigation of UL interference    7. Frequency hopping of UL SRS for positioning    8. New UL reference signals for positioning    9. Multi-port transmission of UL SRS for positioning 3. Enhancements of UE/gNB measurements    1. Multipath mitigation    2. Additional enhancements of UE/gNB measurements    3. Other issues related to the UE/gNB measurements 4. Enhancements of positioning methods and measurement procedure    1. UE positioning in idle/inactive states    2. On-demand DL PRS, A-PRS, SP-PRS    3. Enhancements of UL AoA and DL-AoD    4. Methods for reducing positioning latency    5. Methods for reducing timing measurement errors    6. Enhancements on E-CID positioning    7. Enhancements related to Measurement gap    8. UE-based positioning    9. SRS transmission time    10. UE positioning in DRX state    11. Beam-management of positioning    12. Additional proposals related to signalling enhancements    13. On-demand UL SRS for positioning    14. Additional positioning methods 5. Other proposals |

# Enhancements of DL positioning reference signals

## DL PRS processing with aggregated DL PRS resources

### Proposal 2-1

* Select one of the following options:
  + Option 1: Aggregating multiple DL positioning frequency layers in both intra-band and inter-band scenarios within the same FR is recommended for normative work;
    - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work
  + Option 2: Aggregating multiple DL positioning frequency layers in intra-band contiguous/non-contiguous scenarios are recommended for normative work;
    - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work
  + Option 3: Aggregating multiple DL positioning frequency layers in intra-band contiguous scenarios are recommended for normative work;
    - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work
  + Option 4: Not support aggregating multiple DL positioning frequency layers in Rel-17.

Comments

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| **Company** | **Comments** |
| Qualcomm | Support Option 1 |
| MTK | The phase continuity (due to time offset between carriers or other reasons) could be a crucial factor. If we agree on supporting CA for positioning, at least the requirement at the transmission should be defined. The intra-band contiguous CA could be the case to maintain better phase continuity than intra-band non-contiguous CA.  From UE receiver side, the general structure for receiving intra band contiguous CA is by 1 LNA, 1 mixer and 1 PGA (baseband gain amplifier). For receiving intra-band non-contiguous CA, it is by 1 LNA, 2 mixers and 2 PGAs. So we think intra-band non-contiguous CA would be more challenging to maintain phase continuity at both the transmission and receiving side.  Therefore, we prefer to consider intra-band contiguous CA case only🡪 option 3 |
| CATT | We support Option 3. In our point of view, no support of aggregating multiple intra-band non-contiguous and/or inter-band DL/UL frequency layers for positioning in Rel-17 due to the large TAE errors between the carriers. And Whether to support aggregating multiple intra-band contiguous DL/UL frequency layers for positioning in Rel-17 depends on whether it is feasible to reduce the TAE between the carriers within 1-2 ns. RAN4 may need to be consulted on the feasibility of reducing the TAE within 1-2 ns. |
| CMCC | From our perspective, introducing multiple PFLs aggregation (including both intra- and inter-band CA) can theoretically improve the measurement quality and positioning accuracy, which is a good thing, especially when we consider the case that more than one carriers would be deployed in IIoT scenarios. However, we also understand that it may be difficult to keep phase continuity in reality, and it may impose great complexity on the UE side. We prefer Option 1, and would like to hear views from more companies. |
| OPPO | Support Option 4 since the benefit of aggregation can only be achieved with ideal assumption, and cannot be achieved for practical gNB/UE.  1. From the perspective of gNB  According to the requirement of TS 38.104, the TAE requirement for intra-band contiguous CA cannot support the high accuracy of positioning   |  | | --- | | 6.5.3.2 Minimum requirement for *BS type 1-C* and *BS type* 1-H  For MIMO transmission, at each carrier frequency, TAE shall not exceed 65 ns.  For intra-band contiguous *carrier aggregation*, with or without MIMO, TAE shall not exceed 260ns.  For intra-band non-contiguous *carrier aggregation*, with or without MIMO, TAE shall not exceed 3µs.  For inter-band *carrier aggregation*, with or without MIMO, TAE shall not exceed 3µs. |   2. From the perspective of UE  Even for intra-band CA, because of the limited IF spectrum coverage with baseband circuits, for example amplifier, filter etc, we still need multiple different receive signal paths to support both contiguous and non-contiguous intra-band CA. The current implementation of 5G chipset is that each IF chain corresponds to one carrier. |
| vivo | Support option 4.  Firstly, the performance of PRS aggregation is greatly impacted by factors such as timing offset, phase offset and channel spacing, only when these values are very small, the accuracy gain can be obtained. However, it is unclear whether these values can be guaranteed to be small enough. Therefore, whether PRS aggregation can be applied in actual scenarios is still unknown.  Besides, these factors also make it difficult to define RAN4 requirements. For example, when the network configures PRS aggregation of 50MHz+50MHz, what accuracy should the network expected from the UE, 50MHz, or 100MHz, or between 50MHz and 100MHz? Furthermore, whether the accuracy expected by the network is different if the channel spacing of two FLs is different?  Also, too much normative work will be introduced; however our standardization time is limited. For example, complex requirements and UE capability should be defined, new measurement gap to process aggregated positioning frequency layers should be introduced.  Finally, from the perspective of the SID ‘Enhancements to Rel-16 positioning techniques, if they meet the requirements, will be prioritized, and new techniques will not be considered in this case’, judging from the baseline evaluation results of most companies, the accuracy requirements can be met without PRS aggregation, so we think PRS aggregation as a ‘new technology’ cannot be prioritized in Rel-17. |
| ZTE | 1st preference for option 1, we can live with option 2 and option 3, at least RS aggregation should be studied and supported . |
| Huawei/HiSilicon | We prefer Option 2. We suppose that the “intra-band contiguous” means that channel is contiguous, instead of PRS transmission.  In reply to OPPO   * RAN4 requirements only specify the worst case as it may impact UE Rx. As Rel-16 positioning cannot work under such large synchronization specified by TAE. The sync requirement is not specified by RAN4. * In case from UE side, each IF corresponds to one carrier, it is still possible to compensate the path delays between different IF chains. |
| Lenovo, Motorola Mobility | Support Option 3 from the spec effort point of view, FFS may be needed to further understand UE complexity implications of interband scenarios in Option 1 and intraband non-contiguous scenarios in option 2. The impact of the impairments mentioned (e.g. timing offset, channel spacing, phase offset, frequency error) can be further investigated in terms of UEs with advanced capabilities but the potential benefits of aggregating multiple FLs for accuracy enhancement are promising for timing-based positioning methods. |
| Intel | Option 2.  FFS: Option 1.  Our understanding, that simultaneous DL PRS transmission by gNB is possible starting from Rel.16, at least from RAN1 perspective.  We assume that the discussion is about UE reception of aggregated CCs. |

FL comments

It seems the companies have diverged views on whether and which CA scenarios should be supported. Among the responses from 10 companies, 3 companies are supportive to Option 1, 2 companies are supportive to Option 2, 3 companies are supportive to Option 3, and 2 companies are supportive to Option 4. Based on the feedbacks, it might be better to separate the discussions for each of the scenarios. To align the wording between the discussion of the DL CA and UL CA, suggest using either “Aggregating multiple positioning frequency layers” or “Simultaneous transmission and reception across multiple carriers” for both DL and UL.

### Proposal 2-1a

* Simultaneous transmission by the gNB and reception by the UE of the DL PRS across intra-band continuous carriers is recommended for normative work
  + - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work

Comments

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| **Company** | **Comments** |
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### Proposal 2-1b

* Simultaneous transmission by the gNB and reception by the UE of the DL PRS across multiple intra-band non-contiguous DL positioning frequency layers can be considered for normative work
  + - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work

Comments

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| **Company** | **Comments** |
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### Proposal 2-1c

* Simultaneous transmission by the gNB and reception by the UE of the DL PRS across multiple inter-band DL positioning frequency layers in the same FR can be considered for normative work
  + - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work

Comments

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| **Company** | **Comments** |
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# Enhancements of UL positioning reference signals

## UL SRS transmission patterns

### Proposal 3-1

* Partial staggering and non-staggering RE mapping of SRS for positioning with different combinations of comb-factors and symbol lengths is recommended for normative work.
* The details of the enhancements (e.g., which of the combinations of comb size and the number of symbols to be supported and the methods and signaling for addressing potential time-domain aliasing due to the partial/non-staggering RE mapping) are left for further discussion in normative work.

Comments

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| **Company** | **Comments** |
| Nokia/NSB | We do not support this proposal. The SRS for positioning configuration is already quite flexible in Rel-16 and we are unclear what gains (and even what metrics those gains apply to) would be achieved by this enhancement. |
| MTK | We don’t think that non-staggered pattern is needed. The reason is, the SNR gain at the receiver side is the same for non-staggered and staggered patterns. The non-staggered pattern has the SNR gain through averaging (simple linear interpolation) since the RS at different symbols occupy same subcarriers. The staggered pattern has the SNR gain though larger IDFT size to suppress noise.  Also, feMIMO is doing SRS enhancement. Basically they are still based on non-staggered pattern with certain enhancement, such as td-occ for improving multiplexing. So we don't think there is no need for positioning to enhancing SRS under non-staggered structure.  We feel that the whole spec direction can go for two ways:  1, positioning SRS to follow mimo SRS,  2, positioning SRS to build up a more comprehensive staggered structure. This existing staggered structure (zig-zag like, not ladder like) is more feasible to support partial stagger. We can utilize this nice property.  Actually, mimo SRS can also consider staggered structure, since the staggered structure support both larger UE multiplexing and larger observation range. The non-staggered structure can only support larger UE multiplexing through for example td-occ. But this is not what we can do to influence mimo people.  Rel-16 SRS for positioning has supported for partial staggering. Our preference is to further extend for more cases: comb-4 1 symbol, comb-8 1 symbol and comb-8 2 symbols |
| CATT | Support Proposal 3-1. |
| CMCC | Support |
| OPPO | Support |
| Xiaomi | Support the proposal |
| vivo | Don’t support. Partial staggering and non-staggering SRS patterns for positioning such as {comb-2, 1 symbol},{comb-4, 2 symbols} and {comb-8, 4 symbols} have already been supported in Rel-16. Additional enhancement is not needed. |
| LG | Similar view with Nokia |
| ZTE | Revise the second bullet as follow,   * The details of the enhancements (e.g., which of the combinations of comb size and the number of symbols to be supported and the methods and signaling for addressing potential time-domain aliasing/interference due to the full/partial/non-staggering RE mapping) are left for further discussion in normative work. |
| Huawei/HiSilicon | Support |
| Fraunhofer | Support.  Based on the InF evaluations at least one symbol comb-4/comb-8 for SRS for positioning should be supported. |
| Intel | We do not support current wording, since it opens the door for the long unnecessary debates. Prefer to define specific configurations constraints, for example, at least 1-symbol SRS with additional comb sizes. |

FL’s comments

It seems there are concerns on the scope, potential benefits, etc. to opens a general discussion for RE mapping of SRS for positioning. To make the progress, it might be better to narrow down the scope of the enhancements.

### Proposal 3-1 (Revision 1)

* RE mapping of SRS for positioning with the combinations of {comb-factors, symbol lengths} = {{4, 1}, {8, 1}, {8, 2}} can be considered for normative work.

## UL SRS transmission with aggregated SRS resources

Background

In RAN1#102-e, we have the following agreements on the investigation of aggregation of UL SRS resources in time and frequency domain [1]

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| --- |
| Agreement:  Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across multiple CCs and multiple slots can be investigated in Rel-17, which may consider   * The scenarios and performance benefits of the enhancement * The impact of channel spacing, TA and timing offset, phase offset, frequency error, and power imbalance across slots or CCs to the positioning performance for intra-band contiguous/ non-contiguous and inter-band scenarios |

Submitted Proposals

* (Huawei) Proposal 3:
  + Rel-17 should support at least intra-band contiguous and non-contiguous frequency aggregation with phase continuity
* (CATT)Proposal 5:
  + No support of aggregating multiple intra-band non-contiguous and/or inter-band DL/UL frequency layers for positioning in Rel-17 due to the large TAE errors between the carriers.
* (CATT)Proposal 6:
  + Whether to support aggregating multiple intra-band contiguous DL/UL frequency layers for positioning in Rel-17 depends on whether it is feasible to reduce the TAE between the carriers within 1-2 ns. RAN4 may need to be consulted on the feasibility of reducing the TAE within 1-2 ns.
* (Intel) Proposal 9:
  + Support reception by the gNB of the SRS for positioning across multiple CCs and multiple slots
* (OPPO) Proposal 6:
  + Do not to support the aggregation of multiple positioning frequency layers for positioning enhancement in Rel-17.
* (Qualcomm)Proposal 2:
  + Support enhancements to enable DL/**UL** PRS bundling in frequency domain in both intra-band and inter-band scenarios within the same FR, including at least the following aspects:
    - Signaling enhancements related to Timing, Phase, Power offsets, and QCL relations, amongst the PRS resources of different PFLs from the same TRP.
    - Enhancements related to Measurement period, accuracy requirements, and UE capabilities for scenarios of coherent and concurrent processing of multiple PFLs from the same TRP.

Feature lead’s view

Similar to the aggregation of multiple DL positioning frequency layers, the aggregation of multiple UL positioning frequency layers needs also to consider the impact of timing offset, channel spacing, phase offset, frequency error, and power imbalance among CCs on the positioning performance. The impact may be different for different carrier aggregation scenarios, especially related to whether the transmitter and/or the receiver use one or multiple Rx/Tx RF chains. For example, multiple Tx/Rx chains may be required for supporting inter-band carrier aggregation, while one single Tx/Rx chains may be used for supporting intra-band contiguous carrier aggregation, depending on UE’s capability. Thus, we need to discuss different carrier aggregation scenarios separately.

### Proposal 3-2

* Select one of the following options:
  + Option 1: Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across multiple intra-band and inter-band CCs within the same FR is recommended for normative work;
    - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work.
  + Option 2: Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across multiple intra-band CCs is recommended for normative work;
    - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work.
  + Option 3: Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across multiple intra-band contiguous CCs is recommended for normative work;
    - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work.
  + Option 4: No support of simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across multiple CCs in Rel-17.

Comments

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| **Company** | **Comments** |
| Qualcomm | Support of Option 1 |
| MTK | If DL PRS transmission under CA is not agreed, then there is no need to agree on SRS transmission under UL CA.  There are multiple PA structure for UL CA. we think single PA case maybe suitable for phase continuity.  We prefer to consider intra-band contiguous UL CA case, which is option 3 |
| CATT | We support Option 3. In our point of view, no support of aggregating multiple intra-band non-contiguous and/or inter-band DL/UL frequency layers for positioning in Rel-17 due to the large TAE errors between the carriers. And Whether to support aggregating multiple intra-band contiguous DL/UL frequency layers for positioning in Rel-17 depends on whether it is feasible to reduce the TAE between the carriers within 1-2 ns. RAN4 may need to be consulted on the feasibility of reducing the TAE within 1-2 ns. |
| CMCC | Option 1. See comments on proposal 2.1 |
| OPPO | Support Option 4. The same reason as 2-1. |
| vivo | Support Option 4. For uplink transmission, we keep similar views as proposal 2-1. |
| ZTE | 1st preference for option 1 , we can live with option 2 and option 3, at least RS aggregation should be studied and supported . |
| Huawei/HiSilicon | Option 2. See comments on proposal 2-1 |
| Intel | Our understanding, that in Rel.16 the simultaneous transmission of up to 2 CCs is already supported within a band and per band combination.  It is not clear what is discussed here: reception by the gNB or combination of multiple CCs, i.e. more than 2 (?).  Clarification is needed. |

FL’s comments

For Intel’s comment, the support of the simultaneous transmission by the UE and reception by the gNB of the SRS for positioning may have different signalling, measurement, accuracy requirements, UE capabilities, etc. from the simultaneous transmission by the UE and reception by the gNB of the other signals for data communications.

Similar with the discussion of DL CA for positioning, companies have diverged views on whether and which CA scenarios should be supported, it might be better to separate the discussions for each of the scenarios.

### Proposal 3-2a

* Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across intra-band continuous carriers is recommended for normative work
  + - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work

Comments

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| **Company** | **Comments** |
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### Proposal 3-2b

* Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across intra-band non-continuous carriers can be considered for normative work
  + - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work

Comments

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| **Company** | **Comments** |
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### Proposal 3-3c

* Simultaneous transmission by the UE and reception by the gNB of the SRS for positioning across inter-band carriers within the same FR can be considered for normative work
  + - the corresponding signaling, measurement, accuracy requirements, UE capabilities, etc. are left for further discussion in normative work

Comments

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| **Company** | **Comments** |
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# Enhancements of UE/gNB measurements

## Multipath mitigation

Background

Positioning accuracy can be significantly degraded due to the impact of the multipath caused by NLOS signals, which is especially true for IIoT scenarios. Rel-16 has introduced limited support of multipath mitigation by allows reporting multiple measurements from the same (pair of) TRPs. The following agreements were made for further investigation of multipath mitigation approaches:

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| --- |
| Agreement:   * Multipath mitigation techniques will be investigated in this SI for improving positioning accuracy, which may include, but not limited to the following:   + The applicable scenarios and performance benefits of multipath mitigation techniques   + The methods/measurement/signaling for the LOS/NLOS detection and identification   + The measurements for supporting the multipath mitigation/utilization   + The procedure and signaling for supporting the multipath mitigation/utilization   + Implementation-based solutions (e.g., outlier rejection) without the need of any additional specified method/measurements/procedures/signaling. * Note: The above study applies to DL only, UL only, DL+UL positioning solutions for UE-based and UE-assisted positioning. |

Submitted Proposals

* (Futurewei)Proposal 3:
  + Multipath mitigation methods support the feedback and mechanisms of a LOS/NLOS indicator, reuse of existing Rel-16 defined reference signals (DL PRS, UL SRS) and its configurability.
* (Futurewei) Proposal 4:
  + Additional measurements definition of the DL PRS including relative power to the first detected path should be supported to improve the positioning accuracy, specifically for DL-AoD positioning methods.
* (Huawei) Proposal 8:
  + Rel-17 should support angle information report associated with multi-paths.
* (Huawei) Proposal 9:
  + Rel-17 should support LOS/NLOS identification to improve the positioning accuracy.
* (vivo) Proposal 1:
  + The enhancements to improve positioning accuracy are needed for the NLOS scenario
* (vivo) Proposal 18:
  + LOS/NLOS detection/identification should not be considered in Rel-17.
* (vivo) Proposal 32:
  + The differential positioning technique and machine learning technique can be studied as the method for improving the accuracy in the presence of NLOS error
* (ZTE)Proposal 1:
  + Study mechanisms to assist determination of LOS & NLOS communication links. For example, coherence bandwidth can be attached in positioning measurement report.
* (Intel) Proposal 5:
  + Support signaling indicating the LOS/NLOS link propagation type for NR positioning
  + Support signaling of reliability metric (with probability meaning) for NLOS detection (variable u in the range from 0 to 1, with absolute value showing reliability of decision)
* (Intel) Proposal 6:
  + Support for additional first arrival path measurements, including:
    - Power of the first arrival path
  + Continue study of Doppler effect, velocity measurement, K-factor etc.
* (Intel) Proposal 7:
  + Study potential benefits of the multi-path measurements, clarify how these measurements can be potentially used in the positioning equations
* (Lenovo) Proposal 9:
  + A Measurement and signalling framework for LOS/NLOS identification can be deemed beneficial for the LMF/UE. Aspects of FFS include:
    - Triggering and reporting the TRP/link status in terms LOS/NLOS.
    - Associated procedures in the event of insufficient availability of suitable LOS TRPs/links.
    - Measurement period for LOS/NLOS TRP/link classification.
* (Xiaomi) Proposal 7:
  + To indicate the first arrival path by reporting the arrival time of each beam in beam measurement report.
* (Samsung)Proposal 4:
  + Angle based LOS/NLOS differentiation with joint measurement should be studied.
* (Samsung)Proposal 5:
  + In addition to the measurement reporting of RSRP, RSTD, RX-TX time difference, UE reports indication of LOS/NLOS.
* (OPPO) Proposal 13:
  + For multipath mitigation, only focus on the implementation-based solutions in Rel-17.
* (Nokia)Proposal 7
  + RAN1 to study NLOS identification and reporting from the UE to the LMF during at least UE-A DL positioning.
* (Nokia)Proposal 8:
  + RAN1 to study NLOS identification and reporting from the LMF to the UE during at least UE-B DL positioning.
* (Nokia)Proposal 9:
  + RAN1 to study both LOS/NLOS identification methods computed in PHY layer processing and LMF localization processing.
* (Sony) Proposal 5:
  + Support LOS & NLOS detection and measurement report mechanism, particularly to mitigate multipath issue in IIoT use-cases.
* (LGE) Proposal 3:
  + For the improvement of positioning accuracy, a method and signalling should be considered to identify the NLoS using the polarization characteristics.
* (LGE) Proposal 4:
  + For NLOS identification, RAN1 needs to consider signalling and benefits of the method introducing the propagation time difference threshold/window between a reference and a target TRP.
* (InterDigital) Proposal 13:
  + Study LOS and NLOS identification methods
* (InterDigital) Proposal 14:
  + Consider path identification mechanism
* (InterDigital) Proposal 15:
  + Study dynamic update of spatial information for SRS for positioning for multi-RTT positioning methods
* (Qualcomm) Proposal 5:
  + Support reporting from UE and the gNB to the LMF additional time-domain paths (beyond 2 paths which is already specified) and their corresponding relative powers.
* (Fraunhofer)Proposal 1:
  + Support enhanced CIR reporting for NR-Positioning in Rel-17.
* (Fraunhofer)Proposal 3:
  + The following candidates should be considered for LOS/NLOS detection and identification:
    - First-arriving-path tracking over multiple time instants
    - Phase tracking over multiple time instants
* (CEWiT)Proposal 1:
  + LOS confidence, power level and angle information of LOS path should be reported along with timing measurements in Release-17.
* (Ericsson) Proposal 1:
  + RAN1 should study what characteristics (such as e.g. power, angle of arrival, doppler frequency) of the detected paths that are useful to report for positioning purposes, and also how many paths that are useful to report.
* (Ericsson) Proposal 2:
  + The network should configure values P and Q for the measurements to be performed and reported by the UE, where P is the number of paths and Q is the number of beams.
* (Ericsson) Proposal 3:
  + Magnitude, SNR, Doppler frequency, angle of arrival of every path should be reported.
* (Ericsson) Proposal 4:
  + It shall be unambiguously defined what additional paths a UE shall report.
* (Ericsson) Proposal 5:
  + The UE shall always report both the first path and the strongest path
* (Ericsson) Proposal 6:
  + RAN1 should study how the UE should decide unambiguously what additional paths to report beyond the first path and the strongest path.
* (Ericsson) Proposal 7:
  + RAN1 should specify reporting of the strongest peak in rel. 17
* (Ericsson) Proposal 8:
  + We propose that RAN1 should study LOS detection techniques and reporting of LOS indicators for potential specification in Rel. 17.
* (Ericsson) Proposal 9:
  + Following measurements should be specified in Rel-17. These measurements can be part of rich reporting.
    - Location and magnitude of the first peak.
    - Location and magnitude of the highest peak.
    - Components of PDP/CIR around first/highest peak.

Feature lead’s view

Many companies have investigated the multipath mitigation techniques and provided their views on this issue according to the agreements made in RAN1#102e.

For multipath mitigation techniques, it seems the majority companies are supportive to the LOS/NLOS detection and identification method. However, there are some companies that are not convinced of the benefits of the method. Other methods are also proposed, e.g., differential positioning technique, machine learning technique, and implementation-based solutions, although these methds attract much less interests.

For the measurements for supporting the multipath mitigation/utilization, as discussed in previous meeting, there are significant interests for multipath mitigation based on the enhancements of the measurement reporting, e.g., angle, power, PDP, CIR, Doppler, SINR associated with multi-paths. In addition, there are proposal to mitigate the impact of multipaths through difference threshold/windows, Spatial information, etc.

In addition, there are proposals related to the signalling support and related positioning solutions.

### Proposal 4-1

* Multipath mitigation techniques are recommended for normative work for improving positioning accuracy;
* The details for supporting the multipath mitigation techniques are left for further discussion in normative work, which may include, but not limited to the following:
  + The methods/measurement/signaling for the LOS/NLOS detection and identification
  + The enhancement of measurement reporting (signal angle, power, and channel information etc.) for supporting the multipath mitigation/utilization
  + The procedure and signaling for supporting the multipath mitigation/utilization
  + Implementation-based solutions (e.g., outlier rejection) without the need of any additional specified method/measurements/procedures/signaling.

Comments

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| --- | --- |
| **Company** | **Comments** |
| Nokia/NSB | Support. |
| InterDigital | We are supportive of the proposal. However, for clarity, the note from the agreement should be kept in the proposal so that it is clear that the enhancements can be applied to all positioning methods, i.e., DL, UL and DL&UL positioning methods.   * Multipath mitigation techniques are recommended for normative work for improving positioning accuracy; * The details for supporting the multipath mitigation techniques are left for further discussion in normative work, which may include, but not limited to the following:   + The methods/measurement/signaling for the LOS/NLOS detection and identification   + The enhancement of measurement reporting (signal angle, power, and channel information etc.) for supporting the multipath mitigation/utilization   + The procedure and signaling for supporting the multipath mitigation/utilization   + Implementation-based solutions (e.g., outlier rejection) without the need of any additional specified method/measurements/procedures/signaling. * Note: The above study applies to DL only, UL only, DL+UL positioning solutions for UE-based and UE-assisted positioning. |
| Qualcomm | We have several aspects to point out regarding this proposal.   * First, we believe that the proposal above is too broad and general, and does not really reduce/constraint the scope of the normative work. We need to be able to conclude what type of enhancement we would do for the purpose of multipath mitigation/utilization. As an example, do we plan to specify “LOS/NLOS detection”, i.e. by specifying enhancements in DL PRS waveform that enable a UE to do LOS/NLOS detection, or do we plan to specify some generic “LOS/NLOS indication”, i.e., just a feedback from UE/gNB on whether a link is LOS/NLOS, in other words, a second, different “quality metric” on top of the quality metric that is already supported. * Also, if “implementation-based” solutions are still in scope, then how can we recommend them for normative work? * Furthermore, it is not clear what we mean by LOS/NLOS path. Is it the strict meaning of physical sense, or also a reflection that has TOA very close to the TOA of the true LOS is considered as an “almost-LOS”? In the latter case, it looks related to the already-supported, (but never evaluated), feature of “additional-path reporting”. If the UE is unsure whether a TOA is really LOS, because there are a few close-by paths which could be good candidates, a UE/gNB can already report up to 2 additional paths. Such a feature seems to have more useful information than a generic LOS/NLOS feedback reporting. Companies that support adding a “LOS/NLOS feedback bit” or a “soft quality metric of LOS/NLOS”, have they considered enhancing the feature of “additional path reporting” further, and let the LMF make the decision whether something is LOS or NLOS? Either way, adding a LOS/NLOS indicator will not be a formal “measurement”, no algorithm will be specified on how to compute it, and its definition, at best, will be another abstract quality metric.   Finally, I think there is a need for companies to digest at the simulation results, and discuss more on these, before recommending a specific normative work on this topic, (e.g., see whether indeed LOS/NLOS is really helpful, on top of an outlier rejection algorithm.) |
| MTK | We agree in general, and we prefer implementation based solutions. UE can actually reject to report the measurements which may not be suitable (outlier rejection) |
| CATT | Support Proposal 4-1. |
| CMCC | Support |
| OPPO | We prefer the implementation-based solutions without the need of any additional RAN1 specification. We are ok with the current proposal from FL. |
| NTT DOCOMO | Support |
| Xiaomi | Support the proposal |
| vivo | For recommending techniques for normative work, we share the similar understanding with QC. We believe that we can recommend multipath mitigation techniques which can be captured in WID after reaching the correct observation in the discussion of ‘achievable accuracy and latency’. For example, for LOS/NLOS identification, some companies think that LOS/NLOS identification is not needed since the outlier rejection method (implementation-based solutions) is enough, while other companies don’t think so. Without reached observation, it is too early to recommend multipath mitigation techniques in this email discussion. |
| LG | Support. |
| ZTE | Support. We think the last sub-bullet will not have spec efforts, may be we can remove it. |
| Huawei/HiSilicon | Support. |
| Lenovo, Motorola Mobility | Open to support FL’s proposal and further down scoping of solutions may be needed in ongoing discussions for solutions that have an actual impact for normative work. It is unclear how implementation-based solutions can be considered for further study. |
| Fraunhofer | Support. |
| Intel | Support. Our results have shown benefits of LOS/NLOS classification. |

# Enhancements of positioning methods and measurement procedure

## UE positioning in idle/inactive states

Background

UE positioning in idle/inactive states was discussed in Rel-16, but not supported. In RAN1#102-e, the following agreement was made

|  |
| --- |
| Agreement:   * NR positioning for UEs in RRC\_IDLE state and UEs in RRC\_INACTIVE state will be investigated in Rel-17, including the benefits on latency, network/UE efficiency and UE power consumption * FFS: which positioning methods to be supported, e.g., DL positioning, UL positioning, DL+UL positioning and/or Multi-RTT * FFS: the details of how to enable the UE positioning in RRC\_IDLE state and RRC\_INACTIVE state   + Reference signals (e.g., based on DL PRS signals, UL SRS signals, both of them, etc.)   + Signaling and procedures (e.g., based on PRACH procedure, paging triggered UL SRS transmission, etc.) |

### Proposal 5-1a

* NR positioning for UEs in RRC\_INACTIVE state is recommended for normative work, including
  + DL, UL, DL+UL, and Multi-RTT positioning methods
  + UE-based and UE-assisted positioning solutions
* The details of how to enable the UE positioning in RRC\_ INACTIVE state, are left for further discussion in normative work, while may include, but not limited to the following aspects:
  + DL reference signals (e.g., DL PRS) for DL measurements
  + UL reference signals (e.g., SRS for positioning, PRACH preambles) for UL measurements
  + Signalling and procedures for support the assistance data delivery, DL-PRS configuration, UL SRS for positioning resource configuration, measurement reporting), which may be developed based on the enhancements of existing signalling and procedures (e.g., existing 2-step and/or 4-step PRACH procedures, paging procedure, small data transmission).

Comments

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia/NSB | Support in principle. Two minor comments:   * The first sub-bullet says DL+UL and Multi-RTT. I guess we don’t need to say multi-RTT on top of DL+UL. * Under the 2nd bullet, 1st sub-bullet I don’t think any company has suggested a different RS for inactive in DL. We prefer to not mix this discussion with addition RS discussion. Suggest to change the first sub-bullet to “Extending DL positioning measurements to RRC\_inactive state” |
| InterDigital | We support the proposal from the feature lead. |
| Qualcomm | We are supportive but we should try to try to clarify further the scope for the normative work. For example, why cannot we try to conclude which DL/UL RS to be used? |
| MTK | 1, in NRPPa, we don't see multiple-RTT technique. Multiple-RTT can be realized by configuring UE RX-TX time difference measurement to the UE and configuring gNB RX-TX time different measurement to the gNB. So multiple-RTT techniques can be treated as the combining of DL measurement and UL measurement. Location server can also configure DL-RSTD measurement to the UE and configure UL-RTOA measurement to the gNB, which can be used to refine DL-RSTD measurement results (cancel sync error and in the mean time estimate the sync error. So probably it is okay to just say DL, UL and DL+UL  2, we don't expect any new DL PRS design for RRC inactive state. So we are okay for nokia’s view of “change the first sub-bullet to Extending DL positioning measurements to RRC\_inactive state” |
| CATT | Support Proposal 5-1a. |
| CMCC | Support. One thing to be clarified for both Proposal 5-1a and 5-1b, where only mentions RS configuration, measurement and reporting, are we excluding obtaining the location information (e.g., for UE-assisted positioning) in idle/inactive state? |
| OPPO | Support |
| NTT DOCOMO | Support |
| Xiaomi | Support the proposal |
| vivo | Support. And we propose to delete the description of ‘Multi-RTT’ in the first bullet, since DL+UL method includes Multi-RTT method. |
| LG | For the UEs in RRC inactive mode, SSB could also be used for DL RS. |
| ZTE | Support |
| Huawei/HiSilicon | Support. We suggest to modify the following subbullet to be more specific.   * + Measurement of DL reference signals (e.g., DL PRS) |
| Lenovo, Motorola Mobility | Support |
| Intel | Support. |

FL Comments

It seems all companies are supportive to the enhancements. For the comments on the 1st sub-bullet of the 2nd bullet, the consideration was whether we need to consider the measurements from other DL reference signals (e.g., SSB) in addition to the DL PRS. The proposal is revised with the consideration of the comments.

### Proposal 5-1a (Revision 1)

* NR positioning for UEs in RRC\_INACTIVE state is recommended for normative work, including
  + DL, UL, and DL+ULpositioning methods
  + UE-based and UE-assisted positioning solutions
* The details of how to enable the UE positioning in RRC\_ INACTIVE state, are left for further discussion in normative work, while may include, but not limited to the following aspects:
  + Extending DL positioning measurements to RRC\_INACTIVE with existing DL reference signals (e.g., DL PRS)
  + UL reference signals (e.g., SRS for positioning, PRACH preambles) for UL measurements
  + Signalling and procedures for support the assistance data delivery, DL-PRS configuration, UL SRS for positioning resource configuration, measurement reporting), which may be developed based on the enhancements of existing signalling and procedures (e.g., existing 2-step and/or 4-step PRACH procedures, paging procedure, small data transmission).

### Proposal 5-1b

* NR positioning for UEs in RRC\_ IDLE state is recommended for normative work, including
  + DL, UL, and Multi-RTT positioning methods
  + UE-based and UE-assisted positioning solutions
* The details of how to enable the UE positioning in RRC\_ IDLE state, are left for further discussion in normative work, while may include, but not limited to the following aspects:
  + DL reference signals (e.g., DL PRS) for DL measurements
  + UL reference signals (e.g., SRS for positioning, PRACH preambles) for UL measurements
  + Signalling and procedures for support the assistance data delivery, DL-PRS configuration, UL SRS for positioning resource configuration, measurement reporting), which may be developed based on the enhancements of existing signalling and procedures (e.g., existing 2-step and/or 4-step PRACH procedures, paging procedure, small data transmission).

Comments

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia/NSB | Okay. |
| InterDigital | Support. |
| MTK | For RRC idle state, we only consider DL only UE based, which should have been supported according to existing specification. |
| CATT | Support Proposal 5-1b. |
| CMCC | Support. See comments for Proposal 5-1a. |
| OPPO | Lower priority compared to RRC\_INACTIVE |
| NTT DOCOMO | Support |
| Xiaomi | Support the proposal |
| vivo | Support. And we propose to change the description of ‘Multi-RTT method’ to ‘DL+UL method’ in the first bullet to align with proposal 5-1a. |
| ZTE | Support |
| Huawei/HiSilicon | We think DL measurement in IDLE state should be prioritized over other enhancements.  In addition, we suggest to modify the following subbullets to be more specific.   * + Measurement of DL reference signals (e.g., DL PRS) |
| Lenovo, Motorola Mobility | Support |
| Intel | For L1 perspective we are supportive, but the final decision should be done taken into account RAN2 conclusions/comments.  It cannot be decided by RAN1 only. |

FL Comments

It seems most companies are supportive to the proposal. MTK is supportive only for DL only UE based. It is good comment from Intel that the final decision needs to take RAN2’s conclusions/comments into account. My understanding is that the agreement/conclusion made in RAN1’s discussion only presents RAN1’s decision. How to capture this as the final conclusion of the SI in the TR may need to take RAN2’s conclusions/comments into account.

### Proposal 5-1b(Revision 1)

* NR positioning for UEs in RRC\_ IDLE state is recommended for normative work, including
  + DL positioning methods
  + FFS: UL and DL+UL positioning methods
  + UE-based and UE-assisted positioning solutions
* The details of how to enable the UE positioning in RRC\_ IDLE state, are left for further discussion in normative work, while may include, but not limited to the following aspects:
  + Extending DL positioning measurements to RRC\_INACTIVE with existing DL reference signals (e.g., DL PRS)
  + FFS: UL reference signals (e.g., SRS for positioning, PRACH preambles) for UL measurements
  + Signalling and procedures for support the assistance data delivery, DL-PRS configuration, UL SRS for positioning resource configuration, measurement reporting), which may be developed based on the enhancements of existing signalling and procedures (e.g., existing 2-step and/or 4-step PRACH procedures, paging procedure, small data transmission).

## On-demand PRS, A-PRS, and SP-PRS

Background

In RAN1#102-e, the following agreement was made related to A-PRS, SP-PRS and On-demand PRS

|  |
| --- |
| Agreement:   * Semi-persistent and a-periodic transmission and reception of DL PRS will be investigated in Rel-17.   + FFS: the details on when and how to enable semi-persistent and a-periodic DL PRS   + FFS: to be supported for which positioning methods, e.g.,     - UE-assisted and/or UE-based positioning     - DL positioning and/or Multi-RTT * On-demand transmission and reception of DL PRS will be investigated in Rel-17.   + FFS: the details on when and how to enable on-demand DL PRS   + FFS: to be supported for which positioning methods, e.g.,     - UE-assisted and/or UE-based positioning     - DL positioning and/or Multi-RTT * Notes:   + Semi-persistent means MAC-CE triggered   + Aperiodic would correspond to DCI-triggered   + On-demand corresponds to the UE-initiated or network-initiated request of PRS and/or SRS. So, it is NOT the same as whether PRS is DCI-triggered or MAC-CE triggered. It is about UE or LMF request/suggesting/recommending specific PRS pattern, ON/OFF, periodicity, BW, etc. |

Submitted Proposals

* (Futurewei) Proposal 1:
  + On-demand DL PRS transmissions can be triggered by the UE through UL signaling e.g. uplink control signaling or dedicated pre-allocated UL SRS resources. On-demand PRS configurations should support at least the same configurability as in Rel-16 e.g. transmission period, multiple periods and muting.
* (Futurewei) Proposal 2:
  + On-demand DL PRS transmissions should be supported for both UE-assisted and UE-based positioning, including DL positioning and Multi-RTT
* (Huawei) Proposal 10:
  + Rel-17 should support the following 3 types of PRS requested by LMF
    - Type 1 5GC periodic PRS
    - Type 2 5GC semi-persistent PRS
    - Type 3 5GC aperiodic PRS
* (vivo)Proposal 4:
  + For on-demand PRS positioning, support at least one of the following behavior:
    - Option1:
      * Support the request/suggesting/recommending message from UE or LMF to gNB for suggesting a configuration of on-demand PRS
      * Support configuring a or multiple on-demand PRS for the response the requesting
    - Option 2:
      * Support pre-configuring multiple on-demand PRS for requesting
      * Support the request message or trigger message with an on-demand PRS from UE or LMF to gNB for the transmitting of on-demand PRS.
* (vivo)Proposal 5:
  + Configuring on-demand PRS within a flexible window as a specific PRS pattern can be considered in Rel-17.
* (vivo)Proposal 6:
  + Periodic, aperiodic, and semi-persistent on-demand PRS should be supported.
* (vivo)Proposal 7:
  + On-demand DL PRS supports semi-persistent configuration with MAC CE or DCI activation/deactivation.
  + On-demand DL PRS supports aperiodic configuration with triggered by DCI.
* (vivo)Proposal 8:
  + Choose one architecture of multi-TRP for semi-persistent/ aperiodic on-demand PRS:
    - Option 1: multi-TRP belongs to the serving cells (in this case, the procedure and message of CSI-RS can be used as a reference for semi-persistent/ aperiodic on-demand PRS)
    - Option 2: multi-TRP belongs to serving cells and neighbor cells (in this case, the procedure and message of SRS can be used as a reference for semi-persistent/ aperiodic on-demand PRS)
* (vivo)Proposal 9:
  + Both UE-initiated and network-initiated can be supported for on-demand PRS triggering if multi-TRP belongs to the serving cells.
  + Network-initiated trigger for on-demand PRS is preferred if multi-TRP belongs to serving cells and neighbor cells.
* (vivo)Proposal 10:
  + On-demand PRS should be supported for UE-assisted and UE-based positioning.
  + On-demand PRS should be supported for DL positioning and Multi-RTT positioning.
* (vivo)Proposal 11:
  + Semi-persistent DL PRS supports configuration with MAC CE or DCI activation/deactivation.
  + Aperiodic DL PRS supports aperiodic configuration with triggered by DCI.
* (vivo)Proposal 12:
  + Choose one architecture of multi-TRP for semi-persistent/ aperiodic DL PRS:
    - Option 1: multi-TRP belongs to the serving cells (in this case, the procedure and message of CSI-RS can be used as a reference for semi-persistent/ aperiodic DL PRS)
    - Option 2: multi-TRP belongs to serving cells and neighbor cells(in this case, the procedure and message of SRS can be used as a reference for semi-persistent/ aperiodic DL PRS)
* (vivo)Proposal 13:
  + Semi-persistent/ Aperiodic DL PRS should be supported for UE-assisted and UE-based positioning.
  + Semi-persistent/ Aperiodic DL PRS should be supported for DL positioning and Multi-RTT positioning.
* (vivo)Proposal 14:
  + Triggering a PRS window including all the triggered PRS can be considered in Rel-17.
  + Triggering an MG window and the PRS window together can be considered in Rel-17.
* (vivo)Proposal 34:
  + Aperiodic positioning measurement report can be considered in Rel-17.
* (CATT)Proposal 1:
  + Semi-persistent and a-periodic transmission and reception of DL PRS should be supported in Rel-17 for DL positioning and Multi-RTT methods of both UE-assisted and UE-based positioning.
* (CATT)Proposal 2:
  + On-demand transmission and reception of DL PRS should be supported in Rel-17 for DL positioning and Multi-RTT methods of both UE-assisted and UE-based positioning.
* (TCL) Proposal 2:
  + Study and support aperiodic and on-demand PRS transmission.
* (Intel) Proposal 3:
  + Support both semi-persistent and aperiodic DL PRS allocation for DL-TDOA, DL-AoD, Multi-RTT positioning methods
* (Lenovo) Proposal 1:
  + Support On-demand DL-PRS procedures based on UE-initiated and network-triggered requests.
* (Lenovo) Proposal 2:
  + Support On-demand DL-PRS procedures for DL-based and DL+UL-based positioning methods.
* (CMCC) Proposal 2:
  + The priority of DL PRS, at least that of the on-demand DL PRS, should be defined in Rel-17.
* (Xiaomi) Proposal 1:
  + To introduce positioning request between UE and serving gNB.
    - UE can indicate the positioning request to gNB by PRACH or SR.
    - gNB can indicate the positioning request to UE by paging or MAC CE/DCI.
* (Xiaomi) Proposal 2:
  + Support UE to recommend the PRS configuration parameter set ID by PUSCH during RA procedure or scheduled responding to SR.
* (Xiaomi) Proposal 3:
  + Support gNB to indicate the PRS configuration parameter set ID by MAC CE/DCI.
* (Xiaomi) Proposal 4:
  + The mapping between PRS configuration parameter set ID and related PRS configuration parameter set need to be transmitted to UE by LMF or serving gNB in advance.
* (OPPO) Proposal 3:
  + The framework of SP and AP CSI-RS can be used as the starting point for SP and AP DL PRS. Support a multi-instance transmission of AP DL PRS
* (OPPO) Proposal 4:
  + For on-demand DL PRS:
    - Support it for UE-based positioning, UE-assisted DL-based method, UE-assisted multi-RTT method
    - Support UE-specific configuration of the following parameters: QCL configuration, number of PRS resource repetition, BW, number of symbols, comb size, periodicity, number of transmission instances.
* (Nokia) Proposal 12:
  + On-demand and dynamic PRS should be supported for both UE-assisted and UE-based positioning.
* (Sony) Proposal 7:
  + On-demand PRS can be transmitted in relation with the legacy / periodic PRS transmission. Both on-demand and periodic PRS can be multiplexed in FDM and TDM.
* (Sony) Proposal 8:
  + Support semi-persistent and a-periodic transmission and reception of DL PRS that can be used for DL-TDOA and Multi-RTT.
* (InterDigital)Proposal 6:
  + Adopt on-demand PRS for flexibility in configuration of PRS, latency reduction and positioning with high accuracy
* (InterDigital)Proposal 7:
  + Timing of sending on-demand PRS in the multi-RTT positioning method should be studied
* (LGE)Proposal 14:
  + In Rel-17, RAN1 needs to consider the RS overhead reduction by introducing the SSB for timing measurement and the on-demand type PRS.
* (Qualcomm)Proposal 14:
  + Support on-demand DL PRS, including, but not limited to, the following aspects:
    - Required signaling & procedures to enable a target device or the network to request/recommend specific PRS configurations (e.g., ON/OFF, bandwidth, PRS resources/sets), and/or Positioning methods.
* (CEWiT) Proposal 12:
  + UE will dynamically indicate the DL or UL PRS resources to be configured based on favourable beam configuration from the set of configured resources by LMF.

Feature lead’s view

Based on the submitted proposals, it seems most companies are supportive of on-demand PRS, A-PRS, SP-PRS for both UE-assisted and UE-based positioning, including DL positioning and Multi-RTT positioning solutions.

### Proposal 5-2a

* Semi-persistent and a-periodic transmission and reception of DL PRS are recommended for normative work, including
  + DL and Multi-RTT positioning methods
  + UE-based and UE-assisted positioning solutions
* The signalling and procedures for enabling semi-persistent and a-periodic transmission and reception of DL PRS, including the configuration, transmission, reception and measurement reporting etc. are left for further discussion in normative work.

### Proposal 5-2b

* On-demand transmission and reception of DL PRS, including periodic, semi-persistent and a-periodic PRS, are recommended for normative work, including
  + DL and Multi-RTT positioning methods
  + UE-based and UE-assisted positioning solutions
  + UE-initiated and LMF(network)-initiated on-demand DL PRS
* The signalling and procedures for enabling on-demand DL PRS, including the configuration, transmission, reception and measurement reporting etc. are left for further discussion in normative work.

Comments

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia/NSB | Support in principle. If we agree to 5-2b is there a need to have 5-2a? Even if on-demand and AP/SP PRS have differences both seem to be covered by 5-2b. |
| InterDigital | Supportive of the proposal. We have a suggestion to change wording in Proposal 5-2b. The difference between Porposal 5-2a and 5-2b is what initiates PRS transmission. The modified proposal 5-2b is shown below.   * On-demand transmission and reception of DL PRS, ~~including periodic, semi-persistent and a-periodic PRS~~, are recommended for normative work, including   + DL and Multi-RTT positioning methods   + UE-based and UE-assisted positioning solutions   + UE-initiated and LMF(network)-initiated on-demand DL PRS including periodic, semi-persistent and a-periodic PRS * The signalling and procedures for enabling on-demand DL PRS, including the configuration, transmission, reception and measurement reporting etc. are left for further discussion in normative work. |
| Qualcomm | Support. It seems 5-2b has included SP/AP PRS, and it is also repeated in 5-2a. We are supportive of both features. |
| MTK | For both proposal 5-2a and proposal 5-2b, we suggest to change as DL and DL+UL positioning methods (we already mention the reason in above) |
| CATT | Support Proposal 5-2b. |
| CMCC | Support Proposal 5-2a/b |
| OPPO | Support Proposal 5-2b that is including 5-2a |
| Xiaomi | Support Proposal 5-2b |
| vivo | Support both 5-2a and 5-2b. |
| LG | Support |
| ZTE | Support Proposal 5-2b. |
| Huawei/HiSilicon | Proposal 5-2a   * For SP-PRS, we do not see the gain on latency aspects regarding MAC CE triggered SP PRS, as the PRS configuration by LMF is more like LMF triggered “SP-PRS”. In addition, we assume LMF would any request location measurement from the UE. In summary, we do not see the need of SP-PRS. * For AP-PRS, we think that PRS configuration should anyway be provided in advance, and given that the latency reduction is still in question. In addition, to allow PRS transmission/reception triggered by DCI, additional DCI codepoints overhead should be considered. Therefore, instead of recommending, we suggest to further study it in the WI. * In addition, for AP-PRS, we think a more feasible way is allow higher layer to configure the single-shot reception to the UE, rather than using DCI. * We suggest to change the description as * A-periodic transmission and reception of DL PRS can be considered for normative work, including   + DL and Multi-RTT positioning methods   + UE-based and UE-assisted positioning solutions * The signalling and procedures for enabling a-periodic transmission and reception of DL PRS, including the configuration, transmission, reception and measurement reporting etc. are left for further discussion in normative work.   Proposal 5-2b   * Support. |
| Lenovo, Motorola Mobility | Supportive of both 5-2a and 5-2b |
| Fraunhofer | Support both proposals |
| Intel | Support both. |

## Enhancements of UL AoA and DL-AoD

Background

For positioning methods based on the angular measurements, the positioning accuracy depends directly on the accuracy of the angular measurements. For example, the DL AoD and UL AoA measurement accuracy are related to the orientation uncertainties of the gNB Tx/Rx beams. The positioning accuracy can be improved if the LMF (network-based) and UE(UE-based) can calibrate the orientation uncertainties of the gNB Tx and Rx beams from the angular measurements. Also, the multipath signals may cause significant errors in the UL AoA measurements since the reflected signals may reach the receiver antenna at completely different angles than the LOS angle. In RAN1#102e, we have the following agreements:

|  |
| --- |
| Agreement:  The scenario, benefits, and methods for improving the accuracy of the UL AoA and DL-AoD methods for both UE-based and network-based (including UE-assisted) positioning can be investigated in Rel-17. |

Submitted Proposals

* (Futurewei) Proposal 4:
  + Additional measurements definition of the DL PRS including relative power to the first detected path should be supported to improve the positioning accuracy, specifically for DL-AoD positioning methods.
* (Huawei) Proposal 12:
  + Rel-17 should support enhanced AoA defined with respect to the ULA antenna direction.
* (Huawei) Proposal 13:
  + Rel-17 should support the following DL-AoD procedure enhancement
    - LMF requests AoD (AoA) measurement for the gNB based on RSRP report from the UE
    - gNB provides detailed beam information to facilitate LMF to calculate the angle based on RSRP
      * E.g. DFT beam coefficients, beam response
* (vivo) Proposal 29
  + The combination of Rel-16 technique as an implementation algorithm can improve the accuracy of angle-based positioning, and no specification change is needed.
* (CATT) Proposal 9:
  + LMF can provide the estimated UE position and the uncertainty associated with the estimated UE position to UE/gNB for aiding the UE/gNB in the reception of the DL/UL reference signals and proving reliable NR timing and angular positioning measurements.
* (Nokia) Proposal 14:
  + RAN1 to study beam orientation errors and potential correction mechanisms in order to improve the positioning accuracy achievable with DL-AoD.
* (LGE) Proposal 5:
  + As a potential enhancement of Rel-17 NR positioning, timing measurement based DL-AoD technique needs to be considered.
* (MTK) Proposal 5-1:
  + Define another type of RSRP measurement by measuring the power of the first-arrival path in work item phase. Moreover, the restriction of fixed measurement window across beams in time domain under CIR observation may also be specified.
* (MTK)Proposal 5-2:
  + The look up table for deriving the direction based on RSRP reports needs to consider entire angle range, because the beam responses with different steering direction may not be cyclically identical.
* (Qualcomm)Proposal 4:
  + Support the reporting from the gNB to the LMF, within a single report, multiple UL-AOAs from a single UE and multiple corresponding Timing measurements for each UL-AoA (e.g. RTOA and/or gNB Rx-Tx), together with their associated time-stamps.
* (Fraunhofer) Proposal 5:
  + Consider the following enhancements of the DL-AoD method during Rel. 17:
    - Reporting of radiation characteristics (i.e. main lobe power level, sidelobe level, etc.)
    - Association of timing difference measurements (e.g. using DL-PRS resources from the same resource set) with RSRP reports on beams.
    - FFS: reporting of additional UE antenna characteristics for the measured PRS resources.

Feature lead’s view

It seems we have quite diverged proposals for the methods for improving the accuracy of the UL AoA and DL-AoD methods. It may be difficult to have converged views on which of the proposed enhancements should be adopted in Rel-17. One possible solution is to have the agreement for the need of the enhancements in this meeting, and leave the discussion of the solutions to WI phase.

### Proposal 5-3

* The enhancements of the method, measurements, report, and signalling for improving the accuracy of the UL AoA and DL-AoD measurements are recommended for normative work, including
  + UE-based and network-based (including UE-assisted) positioning solutions
* The details of the solutions are left for further discussion in normative work, which may include, but not limited to the following aspects:
  + AoA definition with respect to ULA antenna direction
  + RSRP measurement of the first-arrival path with specified restriction of fixed measurement window across beams
  + Multiple UL-AOA reporting together with corresponding timing measurements for a UE
  + Timing measurement based DL-AoD technique
  + Association of timing difference measurements (e.g. using DL-PRS resources from the same resource set) with RSRP reports on the same set of beams.
  + LMF provides the estimated UE position and the uncertainty associated with the estimated UE position to UE.
  + gNB provides detailed Tx/Rx beam information to LMF (i.e. main lobe power level, sidelobe level, etc.)
  + Beam orientation errors correction mechanisms
  + LMF requests AoD (AoA) measurement for the gNB based on RSRP report from the UE

Comments

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| **Company** | **Comments** |
| Nokia/NSB | While we support some of the sub-bullets we are not sure how productive having a large list with very different proposals is for an agreement at this stage. Some of the proposals are related to timing measurements/enhancements, some are related to RSRP/ current AoA definition, and some are related to the beam information. Perhaps we could try to group these in different buckets and see if any progress could be made on a specific bucket. One attempt here (please feel free to suggest a different way):  Group 1:   * Multiple UL-AOA reporting together with corresponding timing measurements for a UE * Timing measurement based DL-AoD technique * Association of timing difference measurements (e.g. using DL-PRS resources from the same resource set) with RSRP reports on the same set of beams.   Group 2:   * RSRP measurement of the first-arrival path with specified restriction of fixed measurement window across beams * LMF requests AoD (AoA) measurement for the gNB based on RSRP report from the UE * AoA definition with respect to ULA antenna direction   Group 3:   * gNB provides detailed Tx/Rx beam information to LMF (i.e. main lobe power level, sidelobe level, etc.) * Beam orientation errors correction mechanisms * LMF provides the estimated UE position and the uncertainty associated with the estimated UE position to UE.   At least from Nokia side we would support group 3 and be open to discussing group 1 further. |
| Qualcomm | This is again a big list of items, and there needs to be an additional effort to understand what is needed and what can be recommended for normative work. Somehow the proposals needs to be further categorized. Maybe consider proposals for UL-AoA, UE-A/B DL-AoD separately?  I am not sure how the grouping of the proposals was done by Nokia. Can you provide more information on how these are being categorized?  A couple of first questions on a few bullets:   * “gNB provides detailed Tx/Rx beam information to LMF**/UE** (i.e. main lobe power level, sidelobe level, etc.)”. In UE-B DL-AoD, the UE needs this information.   How is the bullet: “LMF provides the estimated UE position and the uncertainty associated with the estimated UE position to UE. ” related to Angle methods? This is related to all methods. |
| MTK | 1, The “timing measurement based DL-AoD technique” by LGE would be quite similar to “RSRP measurement of the first-arrival path with specified restriction of fixed measurement window across beams” for improving accuracy under NLOS condition  2, for gNB provides detailed Tx/Rx beam information to LMF (i.e. main lobe power level, sidelobe level, etc.) 🡨 we suggest to either to remove i.e part or to additional add “full beam response”  3, For nokia’s proposal: “Beam orientation errors correction mechanisms”, we expect more explanations. Our question is, DL-AoD is to measure several beams, each with different beam direction. So the orientation error is random among beams? Or all the beams would be shifted uniquely?  4, We suggest the following grouping, and there is no need to MUTE/KILL a whole group   * For accuracy improvement, downlink * “Timing measurement based DL-AoD technique” and “RSRP measurement of the first-arrival path with specified restriction of fixed measurement window across beams” 🡨 maybe able to merge both * Beam orientation errors correction mechanism * For accuracy improvement, uplink   + Multiple UL-AOA reporting together with corresponding timing measurements for a UE * For signaling enhancement: * AoA definition with respect to ULA antenna direction * Association of timing difference measurements (e.g. using DL-PRS resources from the same resource set) with RSRP reports on the same set of beams * LMF provides the estimated UE position and the uncertainty associated with the estimated UE position to UE * gNB provides detailed Tx/Rx beam information to LMF * For procedure enhancement:   + LMF requests AoD (AoA) measurement for the gNB based on RSRP report from the UE |
| CATT | Support Proposal 5-3 |
| CMCC | Support |
| vivo | Thank FL for summarizing the big list, I think Nokia’s opinion is great. Ler try to group it and it is better if group naming is based on the classification method, For example,   * The details of the solutions are left for further discussion in normative work, which may include, but not limited to the following aspects:   + AoA definition with respect to ULA antenna direction   + The enhancement of reporting     - Multiple UL-AOA reporting together with corresponding timing measurements for a UE     - gNB provides detailed Rx beam information to LMF (i.e. main lobe power level, sidelobe level, etc.)   + The enhancement of the measurement     - RSRP measurement of the first-arrival path with specified restriction of fixed measurement window across beams     - Timing measurement based DL-AoD technique     - Association of timing difference measurements (e.g. using DL-PRS resources from the same resource set) with RSRP reports on the same set of beams.   + The enhancement of assistance data     - LMF provides the estimated UE position and the uncertainty associated with the estimated UE position to UE.     - Beam orientation errors correction mechanisms     - gNB provides detailed Tx beam information to LMF (i.e. main lobe power level, sidelobe level, etc.)   + The enhancement of procedure     - LMF requests AoD (AoA) measurement for the gNB based on RSRP report from the UE   In addition, we think the bottleneck of AoA and AoD needs be identified first. And details solutions are left for further discussion in normative work. For this, if I remember correctly, only angle error, and ULA performance is identified by Huawei. So, for us, the big list is not needed, and the wording as below:   * The enhancements of the method, measurements, report, and signalling for improving the accuracy of the UL AoA and DL-AoD measurements in the presence of the angle errors, and/or respect to ULA antenna direction are recommended for normative work, including   + UE-based and network-based (including UE-assisted) positioning solutions * The details of the solutions are left for further discussion in normative work |
| LG | To FL, our proposal related to this issue (Proposal #5) of our contribution was not captured, so please capture the following proposal in the submitted proposals above.  Proposal 6:   * In Rel-17, RAN1 needs to study how to use the UE’s RX beam index reporting for positioning.   In our view, for DL-AoD, even if the Rx beam index reporting was introduced in Rel-16, the LMF is difficult to meaningfully utilize the beam index information. In Rel-17, we need to discuss this to make this feature meaningful. We have a modified proposal as follows:   * The enhancements of the method, measurements, report, and signalling for improving the accuracy of the UL AoA and DL-AoD measurements are recommended for normative work, including   + UE-based and network-based (including UE-assisted) positioning solutions * The details of the solutions are left for further discussion in normative work, which may include, but not limited to the following aspects:   + AoA definition with respect to ULA antenna direction   + RSRP measurement of the first-arrival path with specified restriction of fixed measurement window across beams   + Multiple UL-AOA reporting together with corresponding timing measurements for a UE   + Timing measurement based DL-AoD technique   + Association of timing difference measurements (e.g. using DL-PRS resources from the same resource set) with RSRP reports on the same set of beams.   + LMF provides the estimated UE position and the uncertainty associated with the estimated UE position to UE.   + gNB provides detailed Tx/Rx beam information to LMF (i.e. main lobe power level, sidelobe level, etc.)   + Beam orientation errors correction mechanisms   + LMF requests AoD (AoA) measurement for the gNB based on RSRP report from the UE   + UE Rx beam index information for DL-AoD technique |
| ZTE | The lists are too big. The groups from MTK can be a starting point, at least we need to identify some enhancements with common interests. |
| Huawei/HiSilicon | Support. |
| Fraunhofer | Support the changes added by LG |
| Intel | The scope of the proposal is too broad. |

## Methods for reducing positioning latency

Background

In RAN1#102e, the following agreements were made on the signaling & procedures for reducing the latency and improving the efficiency:

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| Agreement:   * For reducing NR positioning latency, more efficient signaling & procedures will be investigated to enable a device to request and report positioning information, which may include, but not limited to, the following aspects:   + DL PRS/UL SRS configuration, activation or triggering.   + The request for positioning information (the assistance data, etc.).   + The report of positioning information (the measurement report, etc.). * Note: It is not within RAN1 scope to analyze positioning architecture enhancements to enable such more efficient signaling & procedures.   Note: RAN1 does not make any assumptions on whether the LCS architecture specified in TS 23.273 is enhanced or not. |

### Proposal 5-4

* The enhancement of signaling & procedures for reducing NR positioning latency are recommended for normative work, including
  + DL, UL DL+UL, and Multi-RTT positioning methods
  + UE-based and UE-assisted positioning solutions
* The details of the solutions are left for further discussion in normative work, which may include, but not limited to the following aspects:
  + Priority rules for positioning measurement and report
  + DL PRS configuration and activation via RRC signaling and/or physical layer procedure (MAC-CE and /or DCI)
  + UL SRS configuration and activation via RRC signaling and/or physical layer procedure (MAC-CE and /or DCI)
  + The request for positioning information (the assistance data, etc.) via RRC signaling and/or physical layer procedure (MAC-CE and /or DCI)
  + The report of positioning information (the measurement report, etc.) via RRC signaling
  + The request for DL measurement gap via lower layer procedure (MAC-CE and /or DCI)
  + Shorter reporting DL PRS/SRS transmission and reporting intervals
  + Measurement gaps (MG) configuration and activation via physical layer procedure (MAC-CE and /or DCI)

Comments

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| **Company** | **Comments** |
| Nokia/NSB | Support in principle but listing all the potential enhancements may lead to a long list which is not that usable when it comes to WI phase. Perhaps we could start by listing the potential enhancements and then see if we could trim the list before the end of RAN1#103-e. |
| InterDigital | Support |
| Qualcomm | We are generally supportive, but we need to try to agree on a few basic features that can be enhanced within the scope of the first bullet. Otherwise, it is too big of an item that RAN1 would recommend for normative work.  It may help to look at the latency analysis provided by the companies to identify which enhancements can reduce the PHY-layer latency the most.  A couple of quick first comments:   * there is already a separate proposal on AP/SP DL-PRS, why is it repeated again here? * UL SRS is already possible to be triggered/activated with MAC-CE/DCI, why it is repeated here?   The report of positioning information is an NAS container in RRC; why it would help with the latency if it is “RRC signaling”? Shouldn’t that be evaluated in RAN2? |
| MTK | 1, we suggest to add the item of “configured grant at least for periodic measurement reporting”. This has also been proposed by some companies in RAN2. So what RAN1 can do is agree in principle on the solution, and leave RAN2 for normative work |
| CATT | Support Proposal 5-4. |
| CMCC | Support in principle.  For the bullets regarding DL PRS configuration and activation, it seems to be covered by the 2nd bullet of Proposal 5-2a, which is reproduced here:   * The signalling and procedures for enabling semi-persistent and a-periodic transmission and reception of DL PRS, including the configuration, transmission, reception and measurement reporting etc. are left for further discussion in normative work. |
| OPPO | Support |
| Xiaomi | Support the proposal |
| vivo | Generally agree. In addition, we think some other enhancements should also be captured such as (DCI-based) BWP switching for PRS measurement. So we prefer the wording as below   * The enhancement of signaling & procedures for reducing NR positioning latency are recommended for normative work, including   + DL, UL DL+UL~~, and Multi-RTT positioning~~ methods   + UE-based and UE-assisted positioning solutions * The details of the solutions are left for further discussion in normative work, which may include, but not limited to the following aspects:   + Priority rules for positioning measurement and report   + ~~DL PRS configuration and activation via RRC signaling and/or physical layer procedure (MAC-CE and /or DCI)~~   + ~~UL SRS configuration and activation via RRC signaling and/or physical layer procedure (MAC-CE and /or DCI)~~   + The request for positioning information (the assistance data, etc.) via RRC signaling and/or physical layer procedure (MAC-CE and /or DCI)   + The report of positioning information (the measurement report, etc.) via RRC signaling and/or physical layer procedure   + The request for DL measurement gap via lower layer procedure (MAC-CE and /or DCI)   + Shorter reporting DL PRS/SRS transmission and reporting intervals   + Measurement gaps (MG) configuration and activation via physical layer procedure (MAC-CE and /or DCI)   + Positioning measurement without measurement gaps (MG) |
| LG | Support in principle |
| ZTE | We don’t think this proposal is necessary, some enhancements overlap the discussion of proposal 5-2 and 5-7. |
| Huawei/HiSilicon | We have questions on how this will impact UL methods, and why UE-based positioning is listed. |
| Lenovo, Motorola Mobility | Support FL’s proposal and share MTK’s view as well. |
| Intel | We prefer to have agreement on specific work directions to reduce latency.  It is not a good idea to leave whole discussion to the normative phase in terms of work item objectives and future discussions.  Also, some details on signalling may require input from or even driven by RAN2. |

## Methods for reducing timing measurement errors

### Proposal 5-5a

* The methods, measurements, signaling, and procedures for improving positioning accuracy in the presence of the UE Rx/Tx transmission delays, and/or and gNB Rx/Tx transmission delays are recommended for normative work, including
  + DL, UL DL+UL, and Multi-RTT positioning methods
  + UE-based and UE-assisted positioning solutions
* Note: The details of the solutions are left for further discussion in normative work.

Comments

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| **Company** | **Comments** |
| Nokia/NSB | Okay in principle. From our side we think it would be beneficial to have a better definition of what is/isn’t included in the timing delay. The model we agreed for simulations was clear on applying per panel, but we should be clear what problems we aim to solve with the normative work. |
| Qualcomm | Support |
| MTK | 1, to say DL, UL and DL+UL would be sufficient |
| CATT | Support Proposal 5-5a. |
| CMCC | Support |
| vivo | Okay |
| ZTE | Support |
| Huawei/HiSilicon | Support. |
| Intel | Support, if an impact on the specification is identified and justified, which needs to be discussed and decided first. |

### Proposal 5-5b

* The methods, measurements, signaling, and procedures for improving positioning accuracy in the presence of the network synchronization errors are recommended for normative work, including
  + DL, UL (DL+UL), and Multi-RTT positioning methods
  + UE-based and UE-assisted positioning solutions
* Note: The details of the solutions are left for further discussion in normative work.

Comments

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| **Company** | **Comments** |
| MTK | 1, We support the handling of network synchronization error. Even though IIOT scenario could have smaller sync error, the general scenario still suffers  2, we think all the potential solutions may not mandate the infra vendor to finetune sync error based on well synchronization to gps satellite. As we know, the operators also care about the sync error problem. We expect the infra vendors to be open-minded for considering this |
| CATT | Support Proposal 5-5b. |
| CMCC | Support |
| vivo | Support in principle, but we doubt whether the accuracy of Multi-RTT positioning methods is affected by synchronization. If not, do we need list multi-RTT here? |
| ZTE | Support |
| Huawei/HiSilicon | Support. |
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