**3GPP TSG RAN WG1 Meeting #102-e** [**R1- 200697**](file:///E%3A%5C1%20Meetings%5CRAN1%5C2020%2008_TSGR_102e%5CInbox%5Cdocs%5CR1-%20200697.doc)**2**

**e-meeting, 25th May – 5th June 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 the a summary of the issues and proposals for “AI 8.2.3 Potential positioning enhancements [1-26]) for the following discussion:

[102-e-NR-Pos-Enh-Pot-Pos-Enh] Email discussion/approval on potential positioning enhancements until 8/21; address any remaining aspects by 8/27 – Ren Da (CATT)

 It covers the following aspects:

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| --- |
| 1. Enhancements of DL positioning reference signals
	1. New DL PRS transmission patterns and additional DL PRS configuration
	2. Simultaneous transmission and reception DL PRS with other signals/channels
	3. DL PRS processing with aggregated DL PRS resources
	4. DL PRS muting enhancements
	5. New DL reference signals for positioning
	6. Multi-port DL PRS transmission
2. Enhancements of UL positioning reference signals
	1. New UL SRS transmission patterns
	2. Simultaneous transmission of UL SRS for positioning with other signals/channels
	3. UL SRS transmission with aggregated SRS resources
	4. Enhancement of SRS cyclic shift patterns
	5. Power control for SRS for positioning
	6. Mitigation of interference between UL SRSs
	7. New UL reference signals for positioning
	8. 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 for positioning
	3. On-demand UL SRS for positioning
	4. Methods for reducing timing measurement errors
	5. Methods for reducing angular measurement errors
	6. Enhancements on E-CID positioning
	7. Methods for reducing positioning latency
	8. Measurement gap
	9. UE-based positioning
	10. UE positioning in DRX state
	11. Beam-management of positioning
	12. Additional proposals for increasing the network and UE efficiency
	13. Additional positioning methods
	14. SRS transmission time
5. Architecture and signaling enhancements
	1. Additional proposals
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The following highlights will be used in this summary:

* The Pink highlights are proposals and issues for discussion with high priority in this email discussion
* The Yellow highlights are proposals and issues for discussion with medium priority in this email discussion
* The Dark Yellow highlights are proposals and issues for discussion with low priority in this email discussion
* The Turquoise highlights are offline consensus/conclusion based on offline discussion or comments
* The Grey sections are issues that have been discussed/revised/ resolved in this meeting email discussion

Note: The fact that a proposal is listed with a priority in this summary for this meeting should not be interpreted as a suggestion that the proposal will have the same priority in other meetings.

# Enhancements of DL positioning reference signals

## New DL PRS transmission patterns and additional DL PRS configuration

Background

In Rel-16, full staggering patterns are supported for DL PRS transmission, with at least 2 OFDM symbols per DL PRS resource. The minimum DL PRS transmission bandwidth is 24 PRBs. For reducing the positioning latency, minimizing the interference, and optimizing the resource usage, many companies propose supporting partial staggering and non-staggering DL PRS transmission pattern, e.g., 1-symbol PRS transmission, and smaller DL PRS transmission bandwidth in Rel-17.

Submitted Proposals

* (Huawei) Proposal 1:
	+ The enhancement of PRS should include studying
		- Partial staggering and non-staggering PRS RE mapping
* (Sony)Proposal 3:
	+ Support PRS configuration with 1 symbol PRS transmission.
* (Sony)Proposal 4:
	+ A mechanism to control or to mitigate interference of PRS transmission in a densified network shall be studied.
* (CATT)Proposal 1:
	+ In Rel-17 support DL PRS bandwidth smaller than 24 PRBs at least for one of the DL PRS resource sets in a TRP in a positioning frequency layer
* (Intel)Proposal 1:
	+ RAN1 to study new DL PRS transmission schedules aiming to randomize set of TRPs/gNBs transmitting in the same set of resources
* (OPPO) Proposal 2:
	+ Study to enhance the RE mapping of DL PRS resource to resolve the interference issue and increase the capacity of DL PRS resource.
* (CMCC) Proposal 1:
	+ The following DL PRS enhancements should be considered:
		- Non-full staggering DL PRS resource pattern
		- Comb-N size enhancements
* (Samsung)Proposal 1:
	+ New PRS pattern should be studied to avoid collision between multiple TRPs and two PRS patterns can be configured simultaneously and separated in time, frequency or space domain
* (Fraunhofer)Proposal 5:
	+ Consider interference for Rel-17 NR positioning including interference from positioning RSs or other interference sources.
* (LGE)Proposal 8:
	+ Support 1-symbol PRS resource for Rel-17 NR positioning.
* (Ericsson) Proposal 10:
	+ Allow configuration of DL-PRS with any combination of comb-factor and symbol length, including symbol length 1.

Feature lead’s view

Considering the potential benefits for positioning enhancements (e.g., reduction of the latency) and the relatively small impact on the speciation, suggest investigating this issue with high priority in this meeting.

### Proposal 2-1

* Partial staggering and non-staggering PRS RE mapping with different combinations of comb-factors and symbol lengths will be investigated in Rel-17.
	+ FFS: the additional PRS RE mapping patterns (e.g., 1-symbol DL PRS transmission)

Comments

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| **Company** | **Comments**  |
| Futurewei | Support |
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## Simultaneous transmission and reception of DL PRS with other signals/channels

Background

For Rel-16, it was agreed in RAN1#99 that UE is not expected to process DL PRS in the same OFDM symbol where other DL signals and channels are transmitted to the UE. For reducing the positioning latency and improving the network and UE efficiency, many companies propose to support simultaneous reception DL PRS and other signals/channels and to define the priority rules for the reception of the DL PRS and other DL signals/channels for supporting different postioning scenarios.

Submitted Proposals

* (Huawei) Proposal 1:
	+ The enhancement of PRS should include studying
		- Simultaneous reception of PRS along with other signals/channels
* (Huawei) Proposal 4:
	+ The enhancement of UE procedure of receiving PRS should include studying
		- Flexible PRS multiplexing with other signals/channels
* (vivo) Proposal 3:
	+ Introduce the priority indications of PRS for low latency positioning in Rel-17.
* (vivo) Proposal 4:
	+ PRS FDM multiplexing with other DL signals and channels at RB level outside of PRS time-frequency grid should be studied in Rel-17 .
* (vivo) Proposal 18:
	+ Priority rules for positioning measurement and report can be considered in Rel-17 positioning.
* (CATT) Proposal 9:
	+ Introduce the PRS measurement restriction. Those DL PRS resources within the measurement restriction may not be measured by UE.
* (Intel) Proposal 12:
	+ RAN1 to study mechanisms for prioritization of transmissions carrying reference signals and channels w/ control signaling for positioning vs other NR reference signals and channels
* (Lenovo) Proposal 2:
	+ Priority indications can be considered as potential enhancements in order to reduce the positioning latency for high priority scenarios.
* (CAICT)Proposal 1:
	+ The priority of PRS for low latency positioning could be considered in Rel-17, and implicitly or explicitly indicated to the positioning UEs based on the positioning service latency requirement.
* (InterDigital) Proposal 1:
	+ Study mechanisms supporting prioritized transmission of PRS and SRS for positioning
* (InterDigital) Proposal 2:
	+ Rel-16 URLLC prioritization mechanisms is used as a baseline for prioritized transmission of PRS and SRS for positioning.
* (Qualcomm) Proposal 15:
	+ For the purpose of enhanced efficiency, study further PRS processing without MG and DL/UL PRS prioritization over other channels and procedures.

Feature lead’s view

In Rel-17 we need to support very-low positioning latency in some scenarios, e.g., time-critical positioning service, while not to cause any significant performance degradation on data communication services in most scenarios. There is a need to support simultaneous transmission and reception of DL PRS with other signals/channels and define the corresponding priority rules, which allow the network to use different configurations to support different scenarios. Thus, suggest investigating this issue with high priority in this meeting.

### Proposal 2-2

* Simultaneous transmission of DL PRS and other signals/channels in the same OFDM symbol will be investigated in Rel-17
* Priority rules will be investigated for the processing of DL PRS and other signals/channels when DL PRS and other signals/channels are transmitted in the same OFDM symbol

Comments

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| **Company** | **Comments**  |
| Futurewei | Support the first bullet. Second bullet should be something to be considered as part of first bullet and hence there is no need to single out this as a separate agreement.  |
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## DL PRS processing with aggregated DL PRS resources

Background

The positioning measurement accuracy is tightly related to the available DL PRS resources in both the time and frequency domain. In NR Rel-16, the maximum bandwidth is 272 PRBs within a frequency layer and up to 4 frequency layers can be configured. However, Rel-16 does not provide the mechanism to support the coherent reception of the DL PRS from multiple frequency layers. Thus, the effective bandwidth of the received PRS is still limited to individual frequency layers. Many companies propose to investigate DL PRS processing with the aggregated DL PRS resources to increase the effective bandwidth of the received PRS for the enhancement of positioning accuracy.

Submitted Proposals

* (Huawei) Proposal 1:
	+ The enhancement of PRS should include studying
		- PRS aggregation
* (ZTE)Proposal 1:
	+ Rel-17 enhancements should consider joint measurement based on different frequency units, e.g. allow joint measurement based on DL PRS from different positioning frequency layers.
* (Intel)Proposal 5:
	+ RAN1 to study scenarios and performance benefits of aggregating multiple DL positioning frequency layers by UEs
* (BUPT)Proposal 2:
	+ NR positioning should support the Carrier Aggregation for PRS.
* (CEWiT)Proposal 5:
	+ Simultaneous reporting or processing of multiple frequency layers can improve the positioning accuracy.
* (MTK) Proposal 3-1
	+ Study the impact of channel spacing, timing offset and power imbalance among CCs to the positioning performance for intra-band contiguous CA
* (MTK) Proposal 3-2
	+ Study whether interband CA can be utilized for LOS detection due to different path loss and reflection properties over different bands
* (MTK)Proposal 3-3:
	+ Study whether intra-band non-contiguous CA can be utilized under conventional receiver and under advanced receiver providing super resolution, and the corresponding requirement on timing offset and power imbalance among CCs.
* (Qualcomm)Proposal 2:
	+ For the purpose of improved accuracy, study further DL PRS bundling in frequency domain, with considerations for both licensed and unlicensed operation and “PRS stitching” in both intra-band and inter-band scenarios.

Feature lead’s view

Considering the potential for the enhancement in positioning accuracy with the aggregating DL PRS resources, suggest investigating this issue with high priority in this meeting.

### Proposal 2-3

* The benefits and the issues associated with aggregating multiple DL positioning frequency layers of the same or different bands for improving positioning performance for both intra-band and inter-band scenarios will be investigated in Rel-17, which may include
	+ the scenarios and performance benefits of aggregating multiple DL positioning frequency layers by UEs
	+ the impact of channel spacing, timing offset and power imbalance among CCs to the positioning performance for intra-band contiguous/ non-contiguous and inter-band scenarios
		- FFS: unlicensed bands

Comments

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| **Company** | **Comments**  |
| Futurewei | Support |
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## New DL reference signals for positioning

Background

For improving the positioning performance (e.g., reducing the interference), several companies propose introducing new DL positioning reference in Rel-17.

Submitted Proposals

* (CATT)Proposal 13:
	+ Consider supporting NR carrier phase DL positioning in Rel-17. The reference signals for DL carrier phase measurements can be:
		- C-PRS (sinusoidal signals)
* (ZTE)Proposal 3:
	+ To better manage the interference, introduce orthogonal cover code (OCC) for positioning reference signals can be considered in Rel-17.
* (LGE)Proposal 7:
	+ NR should consider cyclic shift based SFN transmission of PRS.
		- Need to study on benefit of the simultaneous transmission of a common PRS sequence with different intentional cyclic time-domain delays.
* (Ericsson) Proposal 13:
	+ cyclic shifts for DL PRS is considered in rel17, with configurable cyclic shifts and configurable maximum number of cyclic shift.
* (Ericsson) Proposal 17:
	+ TRS is a candidate for positioning in release 17.

Feature lead’s view

The design of the DL positioning reference signals is of the key importance for all positioning methods that use the DL PRS measurements. Significant efforts were spent in Rel-16 for the development DL PRS reference signals. Suggest further investigating the benefits of introducing new DL positioning reference signals if we have the time to do so in this meeting.

### Proposal 2-4

* The benefits and the need of introducing new DL positioning reference signals for positioning enhancements can be investigated.

Comments

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| **Company** | **Comments**  |
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## DL PRS muting enhancements

Background

Flexible DL PRS muting pattern in time-domain is supported with the granularity of DL RS resource set. One company proposes to study the enhance the DL PRS muting with the granularity of DL RS resource, and one company proposes to study the enhance the DL PRS muting in the frequency domain.

Submitted Proposals

* (OPPO) Proposal 3:
	+ Study to support DL PRS resource-specific muting.
* (Samsung)Proposal 5:
	+ Frequency domain muting should be studied

Feature lead’s view

DL PRS muting is an effective approach to reduce DL PRS interference. DL PRS muting with the granularity of DL RS resource and/or the frequency domain may further reduce the DL PRS interference. Suggest further investigating the benefits of introducing new DL PRS muting enhancements if we have the time to do so in this meeting.

### Proposal 2-5

* The enhancements of DL PRS muting, e.g., DL PRS resource-specific muting and Frequency domain muting can be further investigated

Comments

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| **Company** | **Comments**  |
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## Multi-port DL PRS transmission

Background

In Rel-16, DL PRS is transmitted on one antenna port only. For Rel-17, there are proposals to support DL PRS transmission from more than 1-port with the potential to improve the measurement accuracy (e.g., multipath mitigation).

Submitted Proposals

* (Futurewei)Proposal 2:
	+ For the purpose of improving accuracy, methods to identify NLOS and the corresponding mitigation methods should be studied including the usage of polarization transmissions and measurements
* (Sony)Proposal 2:
	+ Support the study on enhanced beam operation for positioning, including PRS transmission with more than one antenna port (i.e. 2 antenna ports) and the usage of legacy reference signal for positioning (TRS, CSI-RS).
* (Spreadtrum)Proposal 2:
	+ For Rel-17 positioning enhancement, 2-port PRS should be further studied.

Feature lead’s view

The multi-port transmission of the positioning reference signals was discussed in Rel-16, but without a clear conclusion of the potential benefits. The main motivation for proposing multi-port DL PRS transmission again seems related to the support of the multipath mitigation. Thus, the multi-port DL PRS transmission may be investigated as part of the investigation of the multipath mitigation.

Comments

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

## New UL SRS transmission patterns

Background

In Rel-16, full staggering patterns are supported for UL SRS for positioning. For reducing the positioning latency, minimizing the interference, and optimizing the resource usage, several companies propose supporting partial staggering and non-staggering UL SRS transmission patterns as well as the frequency hopping in Rel-17.

Submitted Proposals

* (Huawei) Proposal 2:
	+ The enhancement of SRS should include studying
		- Partial staggering and non-staggering SRS RE mapping
* (CMCC) Proposal 4:
	+ The non-full staggering UL SRS for pos resource pattern should be considered.
* . (OPPO) Proposal 4:
	+ Study the enhancement of SRS resource for positioning to support larger transmission bandwdith, e.g., support frequency-hopping, larger Comb size
* (OPPO) Proposal 6:
	+ Study the enhancement of RE mapping of SRS resource for positioning to resolve the interference issue and increase the capacity of SRS resource for positioning.
* (CATT) Proposal 5:
	+ Frequency hopping of SRS-Pos for positioning should be supported in Rel-17 in order to obtain better positioning accuracy.

Feature lead’s view

Considering the potential benefits for positioning enhancements and the relatively small impact on the speciation, suggest investigating this issue with high priority in this meeting.

### Proposal 3-1

* Partial staggering and non-staggering RE mapping and frequency hopping of SRS for positioning will be investigated in Rel-17.

Comments

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| **Company** | **Comments**  |
| Futurewei | Support |
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## Transmission of UL SRS for positioning with other signals/channels

Background

The collision rule of PUSCH and periodic and semi-periodic SRS for positioning is already defined in Rel-16. The collision rule of PUSCH and a-periodic SRS for positioning is under discussion in Rel-16. To reduce the positioning latency for some scenarios, additional priority rules may need to be introduced in Rel-17 for a-periodic SRS/on-demand SRS.

Submitted Proposals

* (CMCC) Proposal 5:
	+ The collision rule of PUSCH and AP SRS for pos should be studied.
* (vivo) Proposal 8:
	+ Introduce the priority indications of SRS-PosResource for low latency positioning in Rel-17.
* (InterDigital) Proposal 1:
	+ Study mechanisms supporting prioritized transmission of PRS and **SRS** for positioning
* (InterDigital) Proposal 2:
	+ Rel-16 URLLC prioritization mechanisms is used as a baseline for prioritized transmission of PRS and SRS for positioning.

Feature lead’s view

In Rel-17 we need to support very-low positioning latency in some scenarios, e.g., time-critical positioning service, while not to cause any significant performance degradation on data communication services. There is a need to define the priority rules, allowing the network to use different configurations to support different scenarios. Thus, suggest investigating this issue with high priority in this meeting.

### Proposal 3-2

* Simultaneous transmission of UL SRS for positioning together with other UL signals/channels in the same OFDM symbol will be investigated in Rel-17
* Priority rules will be investigated for the transmission of UL SRS for positioning and other UL signals/channels in the same OFDM symbol

Comments

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| **Company** | **Comments**  |
| Futurewei | Support the first bullet. Second bullet should be something to be considered as part of first bullet and hence there is no need to single out this as a separate agreement. |
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## UL SRS transmission with aggregated SRS resources

Background

The positioning measurement accuracy is tightly related to the available RF resources in time and frequency. To further improving positioning accuracy, several companies propose to support the UL SRS transmission and reception with larger bandwidth and longer duration (inter-slot SRS repetition).

Submitted Proposals

* (Huawei) Proposal 2:
	+ The enhancement of PRS should include studying
		- Simultaneous SRS transmission across CCs
* . (OPPO) Proposal 4:
	+ Study the enhancement of SRS resource for positioning to support larger transmission bandwdith, e.g., support frequency-hopping, larger Comb size
* (Qualcomm)Proposal 3:
	+ For the purpose of improved accuracy, study further SRS for Positioning bunding in time domain & inter-slot SRS repetition.

Feature lead’s view

Considering the potential for providing a significant enhancement in positioning accuracy with the aggregating multiple UL positioning frequency layers, suggest investigating this issue with high priority in this meeting.

### Proposal 3-3

* The benefits and the issues associated with simultaneous transmission and reception of the SRS for positioning across multiple CCs and multiple slots can be investigated in Rel-17.

Comments

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| **Company** | **Comments**  |
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## Enhancement of SRS cyclic shift patterns

Background

Rel-16 SR for positioning reuses the formula of the legacy SRS cyclic shifts. The potential issues were identified in Rel-16 WI due to the staggered patterns are used in SRS for positioning. The solutions for these issues were also discussed during Rel-16 WI without reaching a consensus. Many companies propose to resolve the problem in Rel-17.

Submitted Proposals

* (Huawei) Proposal 2:
	+ The enhancement of SRS should include studying
		- Enhancement on cyclic shift pattern considering staggering
* (CATT) Proposal 4:
	+ Symbol-specific cyclic shifts for SRS-Pos should be supported in order to keep phase continuities when a staggered SRS-Pos pattern is de-staggered for the SRS-Pos detection at the receiver.
* (MTK) Proposal 9-1
	+ Increase the maximum cyclic shift number for each comb for the staggering SRS structure:
* (MTK) Proposal 9-2
	+ The amount of the phase rotation applied to the REs across symbols with SRS transmission may follow the order of occupied subcarriers
* (Fraunhofer) Proposal 6:
	+ For Rel-17 update the sequence generation by modifying the equations as

$$r\_{u,v}^{\left(α\_{i},δ,l^{'}\right)}\left(n\right)=r\_{u,v}^{\left(α,δ\right)}\left(n\right) e^{j\frac{f\left(l´\right)}{K\_{TC}}α^{'}}$$

$$α^{'}=α+2πa$$

$α^{'}$ configured via $n\_{SRS}^{eff}\in \{0,…,K\_{TC}n\_{max}-1\}$  and   $a=\left⌊\frac{n\_{SRS}^{eff}}{n\_{SRS}^{cs,max}}\right⌋$

$n\_{SRS}^{eff}$ is configurable (range for *cyclicshift* is extended)

Note: the maximum value of cyclic shift $n\_{SRS}^{cs,max}$ is not changed

* (Fraunhofer) Proposal 7:
	+ For Rel-17 SRS enhancement support:
		- a phase correction for the staggered SRS, and
		- maintain the cyclic shift step size of Rel-15.
		- Extend the range of the cyclic shift
* (Ericsson) Proposal 14:
	+ The cyclic shift of the UL SRS with staggered pattern can be configured to be 1) the same in each symbol, according to REL-15 behavior or 2) per SRS resource, across all symbols in the SRS resource, according to equation 1 above.
* (Ericsson) Proposal 15:
	+ The maximum number of available cyclic shifts $n\_{SRS}^{cs,max}$ for the SRS for positioning is configurable by the gNodeB as part of the RRC configuration.

Feature lead’s view

The issues of the cyclic shifts in Rel-16 SRS for positioning were identified and the potential solutions were also intensively discussed in Rel-16, but the issue is not resolved. Suggest resolving this issue in Rel-17.

### Proposal 3-4

* The cyclic shift patterns for SRS for positioning will be further investigated in Rel-17 to increase the maximum cyclic shift number for each comb for the staggering SRS structure as well as make the phase rotation applied to the REs across symbols with SRS transmission following the order of occupied subcarriers.
	+ FFS: the detailed formula for the cyclic shift pattern
	+ FFS: whether the maximum number of available cyclic shifts $n\_{SRS}^{cs,max}$ for the SRS for positioning is configurable

Comments

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| **Company** | **Comments**  |
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## Power control for SRS for positioning

Background

In Rel-16, open-loop power control is supported for SRS for positioning, i.e., the Tx power of SRS for positioning is based on the path loss estimation, but not subject to TPC command from the gNB. This could potentially result in interference with other UL signals/channels. Several companies propose to support close-loop for SRS for positioning in Rel-17.

Submitted Proposals

* (Huawei) Proposal 5:
	+ The enhancement of UE procedure of transmitting SRS should include studying
		- Closed-loop power control of SRS for positioning
* (vivo)Proposal 7:
	+ PHR based on SRS-PosResource should be introduced in Rel-17.
* (OPPO) Proposal 5:
	+ Study the enhancement of uplink power control of SRS for positioning
		- Support closed-loop power control on SRS for positioning.
		- Support configuring power control parameter per SRS resource for positioning
* (Spreadtrum) Proposal 3:
	+ For Rel-17 positioning enhancement, close loop power control can be further studied
* (Nokia)Proposal 4:
	+ RAN1 to study enhancements on transmit power control for UL and UL+DL positioning methods, e.g., study a new procedure for how serving gNB gets TPC parameters from neighbor gNBs/TRPs.
* (TCL) Proposal 3:
	+ Support Closed-loop power control for the transmission of SRS for positioning.

Feature lead’s view

Without the close-loop power control on SRS for positioning, the UE closes to a cell may create a significant interference for the reception of the UL signals/channel from other UEs by the same cell. The issue may get worse when the number of positioning UEs increases. Suggest investigating this issue with high priority in this meeting.

### Proposal 3-5

* Close-loop power control of SRS for positioning will be investigated in Rel-17.
	+ FFS: whether the TPC is generated from the serving gNB/TRP only, or also from the neighbor gNBs/TRPs

Comments

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| **Company** | **Comments**  |
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## Mitigation of interference between UL SRSs

Background

In Rel-16, each serving gNB decides the configuration of the transmission of SRS for positioning, and there is no support of the coordination among adjacent gNB/TRPs and LMF, which may result in the potential collision of the UL transmission of the UEs in adjacent gNB/TRPs. Thus, several companies propose to support the coordination schemes for the configurations of the SRS for positioning among adjacent gNB/TRPs and LMF to avoid a potential collision.

Submitted Proposals

* (CATT) Proposal 3:
	+ Support SRS-Pos resource coordination to achieve orthogonal SRS-Pos resource assignment and SRS-Pos interference cancellation to eliminate inter-cell SRS-Pos interference in Rel-17.
* (CMCC) Proposal 6:
	+ The SRS for POS coordination should be studied
* (CAICT)Proposal 3:
	+ Support positioning SRS resource muting or coordination to achieve interference cancellation among different cells in Rel-17.

Feature lead’s view

Support the coordination of the configurations the SRS for positioning among adjacent gNB/TRPs and LMF may avoid the potential collisions of the SRS for positioning and reduce the UL interference.

### Proposal 3-6

* Mechanisms coordinating the configuration of SRS for positioning to achieve orthogonal SRS-Pos resource assignment and avoid potential collision of the SRS for positioning from UEs can be investigated.

Comments

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| **Company** | **Comments**  |
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## New UL reference signals for positioning

Background

For improving the positioning performance, there are proposals for the enhancements of Rel-16 UL reference signals

Submitted Proposals

* (vivo) Proposal 10
	+ Support to reuse low PAPR RS agreed in Rel-16 MIMO for SRS sequence generation for positioning in Rel-17
* (CATT)Proposal 14:
	+ Consider supporting NR carrier phase UL positioning in Rel-17. The reference signals for UL carrier phase measurements can be:
		- C-PRS (sinusoidal signals)

Feature lead’s view

The design of the UL positioning reference signals is of the key importance for all positioning methods that use the UL SRS measurements. Significant efforts were spent in Rel-16 for the development UL SRS for positioning. In Rel-17, new UL positioning reference signals may be introduced if it can provide significant benefits for positioning enhancements.

### Proposal 3-7

* New UL positioning reference signals may be further investigated for positioning enhancements.

Comments

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| **Company** | **Comments**  |
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## Multi-port transmission of UL SRS for positioning

Background

In Rel-16, SRS for positioning is transmitted on a single antenna port. For Rel-17, there is a proposal to support the transmission of UL SRS for positioning from more than 1-port with the potential to improve the measurement accuracy (e.g., multipath mitigation)

Submitted Proposals

* (Fraunhofer)Proposal 2:
	+ Study multi-port SRS transmission for positioning in Rel. 17.

Feature lead’s view

The multi-port transmission of the positioning reference signals was discussed in Rel-16, but without a clear conclusion of the potential benefits. The main motivation for proposing multi-port positioning RS transmission again seems related to the support of the multipath mitigation. The multi-port positioning RS transmission may be investigated as a part of the investigation of the multipath mitigation.

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. To further address the problem, many companies propose different solutions for Rel-17 positioning enhancements.

Submitted Proposals

* (Huawei) Proposal 3:
	+ The enhancement of measurement should include studying
		- Multi-path measurements associated with angle/power measurements
		- NLOS/LOS identification
* (Futurewei)Proposal 2:
	+ For the purpose of improving accuracy, methods to identify NLOS and the corresponding mitigation methods should be studied including the usage of polarization transmissions and measurements.
* (Futurewei) Proposal 3:
	+ Additional measurement relative to the first detected path should be studied including its feasibility to improve AoD positioning accuracy.
* (vivo) Proposal 1:
	+ The enhancements to improve positioning accuracy are needed for the NLOS scenario.
* (Sony) Proposal 5:
	+ Support the study on LOS & NLOS detection mechanism at the UE and the associated signalling procedure.
* (CATT) Proposal 1:0
	+ Each measurement would be associated with a LOS/NLOS identifier
* (Intel) Proposal 6:
	+ RAN1 to support signaling indicating the LOS/NLOS propagation type or conditions for each link used for positioning
* (Intel) Proposal 7:
	+ RAN1 to study an impact of the NLOS offset on the positioning accuracy and make a conclusion whether the NLOS offset reporting is a valuable mechanism or not
* (Intel) Proposal 8:
	+ RAN1 to study benefits of the additional measurements for the first arrival path of the CIR component
		- First arrival path (FAP) power, K-factor, Doppler shift, etc
* (Samsung)Proposal 3:
	+ Angle based LOS/NLOS differentiation with joint measurement should be studied
* (MTK) Proposal 5-1:
	+ Study RSRP measurement for first-arriving path as accuracy improvement for DL-AoD technique
* (Spreadtrum) Proposal 3:
	+ Support UE to report the RSRP value corresponding to the PRS resource transmitted with the beam covering the first arrival path
* (Spreadtrum) Proposal 4:
	+ In Rel-17, study the LOS/NLOS condition measurement and reporting mechanism
* (Nokia) Proposal 5:
	+ RAN1 to study NLOS identification and reporting.
* (Fraunhofer)Proposal 1:
	+ Support enhanced CIR reporting for NR-Positioning in Rel-17.
* (Fraunhofer)Proposal 3:
	+ Study LOS/NLOS /OLOS channel state detection methods, their associated measurements and impacts on procedures.
* (CEWiT)Proposal 1:
	+ Reporting of LOS confidence and angle information of LOS path should be studied in Release-17.
* (CEWiT)Proposal 6:
	+ New KPIs such as priority, time-to-alarm, the false alarm rate and number of detectable false transmitters should be considered in Release-17 study.
* (Xiaomi)Proposal 5:
	+ We suggest to find the LOS path during beam management procedure.
* (Ericsson) Proposal 1:
	+ 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 2:
	+ Magnitude, SNR, Doppler frequency, angle of arrival of every path should be reported.
* (Ericsson) Proposal 3:
	+ It shall be unambiguously defined what additional paths a UE shall report.
* (Ericsson) Proposal 4:
	+ LOS detection mechanisms should be studied within the Rel. 17 positioning enhancement study item.
* (Ericsson) Proposal 5:
	+ 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.
* (Ericsson) Proposal 10:
	+ Introduce signaling of a threshold relative to the strongest peak for the UE search of the first peak and define the DL RSTD and UE RX-TX time difference measurements based on the first identified peak which is stronger than the strength of the strongest peak multiplied with the signaled relative threshold factor.
* (Ericsson) Proposal 11:
	+ RAN1 to study network control of thresholds for the UE search for the first peak including threshold relative to the estimated noise level (aimed at avoiding noise peaks), threshold relative to the strongest peak (aimed at avoiding channel peaks with delay longer than the measurement range) and delay dependent thresholds (aimed at avoiding side peaks).

Feature lead’s view

Effective multipath mitigation techniques are essentially important to achieve high-positioning accuracy, especially for IIoT scenarios. Thus, suggesting investigating this issue with high priority in this meeting.

### Proposal 4-1

* Multipath mitigation techniques will be investigated in this SI for improving positioning accuracy, which may include, but not limited to the following:
	+ The methods for the LOS/NLOS detection and identification, e.g.,
		- Based on the reference signals from multi-antenna ports
		- Based on beam associated information
		- Based on channel state detection
		- Based on the reference operation
	+ The measurements for supporting the multipath mitigation, e.g.,
		- Timing, angle, power K-factor, Doppler shift measurement of the first path
		- The timing, angle, power, SNR, Doppler shift, measurements of the additional paths
		- Location and magnitude of the first peak, the highest peak, components of PDP/CIR around first/highest peaks.
		- The LOS/NLOS indication and associated confidence level
	+ The procedure and signaling for supporting the multipath mitigation, e.g.,
		- The assistance from the network (e.g., the possible number of paths and the number of beams, detection thresholds, etc.)

Comments

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| **Company** | **Comments**  |
| Futurewei | Support |
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## Additional enhancements of UE/gNB measurements

Background

In addition to the measurements proposed for multipath mitigation discussed in the previous section, new types of the measurements are proposed, mainly for the enhancements of the DL/UL positioning accuracy and reliability.

Submitted Proposals

* (Huawei) Proposal 3:
	+ The enhancement of measurement should include studying
		- CSI measurements
		- Rx/Tx diversity based reporting
* (CATT) Proposal 13:
	+ Consider supporting NR carrier phase DL positioning in Rel-17. The reference signals for DL carrier phase measurements can be:
		- DL PRS
* (CATT) Proposal 14:
	+ Consider supporting NR carrier phase UL positioning in Rel-17. The reference signals for DL carrier phase measurements can be:
		- UL SRS for positioning
* (CATT) Proposal 15:
	+ Consider supporting the carrier phases measurements from two or more carrier frequencies for fast resolution of the integer ambiguity.
* (MTK) Proposal 6-1
	+ Study the feasibility of carrier phase measurement at least starting from Rel-17
* (BUPT)Proposal 1:
	+ NR should enhance PRS to support carrier phase measurement.
* (Intel) Proposal 9:
	+ RAN1 to support received waveform reporting to enable precise UE positioning
* (Intel) Proposal 10
	+ RAN1 to study whether additional physical layer measurements can benefit/support integrity of RAT-dependent positioning solutions
* (Fraunhofer) Proposal 4:
	+ Consider carrier phase measurements for positioning in both UL and DL timing-based methods at least in FR1.
* (Apple)Proposal 2:
	+ RAN1 to study any need of physical layer enhancements, e.g. additional measurements, in regard to enhancing positioning reliability.
* (Ericsson) Proposal 6:
	+ Consider absolute time reporting in release 17 measurement reports

Feature lead’s view

Introduce new positioning measurements may offer significant enhancements to the positioning performance. Suggest investigating this issue, especially the new measurements based on existing Rel-16 NR signals, with high priority in this meeting.

### Proposal 4-2

* New UE/gNB measurements will be investigated to improve positioning performance, especially positioning accuracy. The new UE/gNB measurements to be investigated may include the following:
	+ CSI measurements
	+ Carrier phase measurements
	+ received waveform reporting
	+ absolute time reporting

Comments

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| **Company** | **Comments**  |
| Futurewei | We are not in favour of listing the sub-bullets because other than generally proposed, there are no details that have been provided for companies to consider and evaluate the feasibility of each of the proposal. We don’t object to them either, keeping it a high level agreement (the first sentence) would resolve our concerns.  |
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## Other issues related to the UE/gNB measurements and reporting

Background

In this section, we discuss the proposed enhancements related to the UE/gNB measurements that are not covered in previous sections.

Submitted Proposals

* (vivo) Proposal 1:
	+ Introduce 10 ms level granularity for the response time and reporting intervals in *CommonIEsRequestLocationInformation*
* (Apple)Proposal 1:
	+ RAN1 to further study reusing/adopting other DL RS signals for DL positioning measurements.
* (Qualcomm) Proposal 17:
	+ For the purpose of enhanced efficiency, study further Positioning measurements derived on other reference signals and channels.
* (Ericsson) Proposal 7:
	+ Send LS to RAN4, requesting RAN4 to investigate the possibility to define two (or multiple) sets of requirements (based on UE-capabilities) for RSTD accuracy, UE RX-TX time difference accuracy and UE TX timing accuracy in order to accommodate for both general purpose eMBB UEs and for UEs requiring high (sub-meter) accuracy positioning in e.g. I-IoT scenarios.
* (Ericsson) Proposal 9:
	+ In order to maintain accuracy, the target latency must factor the need for tracking measurement, i.e. UE mobility

Feature lead’s view

Suggest further investigating the proposed measurement enhancements if we have the time to do so in this meeting.

### Proposal 4-3

* The following enhancements related to UE measurements can be investigated:
	+ the use of other DL RS signals for DL positioning measurements
	+ smaller granularity for the response time and reporting intervals measurement report
	+ the support of tracking measurements
	+ two (or multiple) sets of requirements for UE measurement accuracy

Comments

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| **Company** | **Comments**  |
| Futurewei | Do we have description of ‘tracking measurements’? Multiple sets of requirements sounded like RAN4 scope. In general. We think Proposal 4-2 and 4-3 should be combined into a single proposal and kept at a very general level e.g. “New measurements at the UE/gNB would be considered and studied..” |
|  |  |

# 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. For Rel-17 positioning enhancements, there are very strong interests in supporting UE positioning in idle/inactive states mainly due to the potential in improving device efficiency (e.g., UE power saving).

Submitted Proposals

* (Huawei) Proposal 6:
	+ Support measurement of DL PRS during RRC\_IDLE/INACTIVE state, and study the mechanism regarding transmission of UL signals/channels in INACTIVE state.
* (Futurewei)Proposal 4:
	+ Extend the support of Rel-16 positioning methods to Inactive and Idle UEs, at least for the DL positioning
* (vivo) Proposal 14:
	+ Positioning in idle/inactive states should be supported by RAN1 in Rel-17
* (ZTE)Proposal 5:
	+ Consider RS (including PRS and SRS) transmission and PRS measurement report in RRC inactive/idle state.
* (Sony)Proposal 7:
	+ Support the operation of NR positioning when the UE is in RRC idle/inactive mode.
* (CATT) Proposal 1:
	+ Positioning for UEs in RRC\_IDLE/INACTIVE states should be supported in Rel-17 with the enhancements as follows:
		- Using PRACH for UE in RRC\_IDLE/INACTIVE state for positioning purpose
		- Sending SRS-Pos for UE in RRC\_INACTIVE state.
* (CATT)Proposal 12:
	+ UEs in RRC\_IDLE/INACTIVE state have three SRS configuration methods:
		- Using RRC connected state SRS-Pos configurations information.
		- Using SRS-Pos configuration information carried in the paging message.
		- Using SRS-Pos configuration information obtained by UE in a new RACH procedure.
* (TCL) Proposal 1:
	+ Support positioning in RRC\_IDLE/INACTIVE states.
* (Intel) Proposal 4:
	+ RAN1 to study enhancements of a two-step RACH mechanism to facilitate accurate low-latency NR positioning
* (OPPO) Proposal 7:
	+ Study to support positioning in RRC\_INACTIVE state and RRC\_IDLE state.
		- Study measurement on DL PRS resource in RRC\_INACTIVE and RRC \_IDLE state.
		- Study transmission of uplink PRS in RRC\_INACTIVE state and RRC\_IDLE state.
		- Study the mechanism of positioning measurement reporting in RRC\_INACTIVE state and RRC\_IDLE state
* (Samsung)Proposal 2:
	+ IDLE/INACTIVE state positioning should be studied considering the challenges of measurement reporting, low mobility requirement, etc.
* (MTK) Proposal 8-1
	+ In RRC idle state, consider downlink only measurement with UE based mode for positioning
* (MTK) Proposal 8-2
	+ In RRC inactive state with UE assisted mode, the network may trigger the UE by paging the UE for a new cause of measurement for positioning, and the UE may respond with the RACH procedure
* (MTK) Proposal 8-3
	+ The preamble transmission in Msg1/MsgA can also serve the purpose of requesting uplink measurement results as assistance information
* (MTK) Proposal 8-4
	+ In RRC inactive state with UE based mode, the combined usage of DL-TDOA and UL-TDOA can be considered. Msg4 for 4-step RA and MsgB for 2-step RA with flexible payload size may carry the uplink measurement results to the UE for synchronization error cancellation
* (CMCC) Proposal 7:
	+ Positioning for UEs in idle/inactive state should be supported.
* (Lenovo)Proposal 5:
	+ Consider positioning measurement support for UEs in RRC\_IDLE/INACTIVE state
	+ Related enhancements may also require coordination with RAN2.
* (LGE) Proposal 10:
	+ RAN1 needs a study for positioning support of UEs in the RRC idle and inactive modes at least for RA-dependent positioning techniques from the perspective of latency and device efficiency.
* (Nokia)Proposal 1:
	+ Support RRC inactive and idle mode positioning for at least DL RAT-dependent positioning methods.
* (Nokia)Proposal 2:
	+ Support of DL RAT-dependent positioning methods for idle and inactive modes should include at least measurement of DL PRS and reporting of measurements without moving to RRC connected state.
* (Nokia)Proposal 3:
	+ RAN1 to study if/how UL or DL+UL RAT-dependent positioning methods could also be supported in RRC inactive and idle modes.
* (Xiaomi)Proposal 6:
	+ Random access procedure can be reused for UL and DL&UL positioning of Idle/Inactive UE.
* (Xiaomi)Proposal 7:
	+ Random access preamble can be reused as UL reference signal for Idle/Inactive UE.
* (Xiaomi)Proposal 8:
	+ To limit the number of SSBs refer to which preamble is sent to each TRP.
* (Xiaomi)Proposal 9:
	+ Consider to pre-configure the PRS for idle/inactive UE when UE is in connected mode.
* (CEWiT)Proposal 9:
	+ RRC Idle and inactive mode positioning should be supported considering power saving at UE and reducing the latency of the positioning.
* (Qualcomm) Proposal 16:
	+ For the purpose of enhanced efficiency, study further support and enhancements for NR Positioning in the RRC Idle/Inactive state, including but not limited to
		- Transmission of UL PRS signals & Reception of DL PRS signals
		- Enablement of Rel-16 DL-only UE-assisted methods, DL/UL methods, UL-only methods

Feature lead’s view

The benefits of supporting UE positioning in RRC\_IDLE/INACTIVE state seem obvious. The support was discussed in Rel-16 but not introduced due to the very tight working schedule of Rel-16. Suggest investigating UE positioning in RRC Idle/Inactive states with high priority in this meeting.

### Proposal 5-1

* + NR positioning for UEs in RRC Idle/Inactive states will be investigated in Rel-17.
		- FFS: which positioning methods to be supported, e.g.,
			* UE-assisted and/or UE-based positioning
			* DL positioning, UL positioning, and/or Multi-RTT
		- FFS: the details of how to enable the UE positioning in RRC Idle/Inactive states, e.g.,
			* 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.)

Comments

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| **Company** | **Comments**  |
| Futurewei | Support. As we discussed in our Tdoc, we think DL-based positioning would have the advantage to be completed sooner. We are ok with UL positioning support as well.  |
|  |  |

## On-demand DL PRS for positioning

Background

Rel-16 only supports periodic DL PRS transmission and reception. For Rel-17 positioning enhancements, many companies are interested in extending the support to semi-periodic and a-periodic DL PRS, as well as on-demand DL PRS, due to the potential in reducing the positioning latency and improving device efficiency (e.g., reducing the resource usage and power saving).

**Note:** In theproposals from the contribution, the terms “A-periodic PRS”, “on-demand”, and “dynamic PRS” are used. For clarification, here we assume these terms have different meanings:

* **Aperiodic PRS**: a non-period DL PRS transmission, i.e., the transmission of the PRS is neither periodic nor semi-periodic.
* **On-demand PRS**: The DL PRS is transmitted with a particular request, which may demand when, where, and how the DL PRS are transmitted. On-demand PRS may often be A-PRS. It may also be periodic PRS and semi-periodic PRS.
* **Dynamic PRS**: PRS resource allocation is allocated/deallocated dynamically. Here we assume the dynamic allocation of the PRS resource is more related to the implementation, e.g., the network may use dynamic PRS resource allocation or supporting on-demand and a-periodic PRS.

Submitted Proposals

* (Huawei) Proposal 4:
	+ The enhancement of UE procedure of receiving PRS should include studying
		- Aperiodic PRS only from the serving cells
* (vivo)Proposal 5:
	+ The on demand PRS should be introduced in Rel-17.
* (vivo)Proposal 6:
	+ The Aperiodic PRS should be studied in Rel-17.
* (vivo) Proposal 12:
	+ Aperiodic positioning measurement report can be considered in Rel-17
* (vivo) Proposal 17:
	+ Support to introduce on demand measurement gap for on demand PRS in Rel-17.
* (Futurewei) Proposal 1:
	+ Aperiodic DL PRS requests and transmission should be supported for its benefits in reducing PRS transmissions overhead and improving latency. Details on the specifications support and impact are for further study
* (OPPO) Proposal 1:
	+ Study to support UE-specific configuration and transmission of DL PRS resource
* (ZTE) Proposal 4:
	+ To further reduce positioning latency, at least following enhancements should be considered,
		- Support low-layer PRS triggering.
		- Support low-layer positioning measurement report.
* (Sony)Proposal 1:
	+ Support the study on dynamic PRS allocation / Aperiodic PRS transmission to improve positioning accuracy and/or reduce positioning latency.
* (CATT)Proposal 2:
	+ Aperiodic and semi-persistent DL PRS should be introduced in Rel-17 in order to reduce the latency and overhead of DL PRS
* (TCL) Proposal 2:
	+ Study and support aperiodic and on-demand PRS transmission.
* (Intel) Proposal 2:
	+ RAN1 to study benefits from support of dynamic UE centric DL PRS resource allocation
* (CMCC) Proposal 2:
	+ NW-triggered and UE-triggered on demand PRS configurations should be supported.
* (CMCC)Proposal 3:
	+ NR positioning should support the physical-layer procedures to trigger the on-demand DL PRS configurations.
* (InterDigital)Proposal 3:
	+ Study mechanism supporting on-demand **PRS** and SRS for positioning
* (Spreadtrum)Proposal 1:
	+ Support semi-persistent and aperiodic DL PRS transmission in Rel-17.
* (LGE)Proposal 1:
	+ In Rel-17, RAN1 needs a study on RS overhead reduction by introducing the SSB for timing measurement and the on-demand type PRS.
* (Nokia)Proposal 7:
	+ Study mechanisms to enable optimized PRS transmission by the network
* (Nokia)Proposal 8:
	+ Study mechanisms to support dynamic PRS configuration in UE dedicated manner to support UE specific positioning needs. Note: This may have RAN2 impact.
* (Lenovo) Proposal 3:
	+ Explore dynamic signalling mechanisms to enable the LMF and UE to better adapt to changes in the radio environment for reduced latency, e.g. beam failure, identification of NLOS beams
* (Xiaomi)Proposal 1:
	+ Consider to introduce On-demand DL PRS to reduce the latency and signaling overhead.
* (CEWiT)Proposal 8:
	+ Aperiodic reporting of position and/or positioning measurements based of pre-configured trigger should be studied for IIoT scenario.
* (CEWiT)Proposal 1:
	+ Dynamic and on demand PRS transmission should be studied in Release-17.
* (CAICT)Proposal 1:
	+ Considering Aperiodic and semi-persistent scheduling DL PRS in Rel-17 to satisfy the low latency requirement of positioning service.
* (Qualcomm)Proposal 13:
	+ At least for the purpose of efficiency, study further on-demand **PRS** and SRS transmissions, including, but not limited to, the following aspects:
		- Required signaling & procedures to enable a target device to request/recommend specific PRS configurations (e.g., on-demand ON/OFF switching, bandwidth, TRPs, beam directions), and/or Positioning methods.

Feature lead’s view

Suggest investigating the semi-periodic, a-periodic, and on-demand DL PRS for positioning with high priority in this meeting.

### Proposal 5-2

* Semi-periodic and a-periodic transmission and reception of DL PRS should be investigated in Rel-17.
	+ FFS: the details on when and how to enable semi-periodic 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 should 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

Comments

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| **Company** | **Comments**  |
| Futurewe | Support |
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## On-demand UL SRS for positioning

Background

Rel-16 has already supported semi-periodic and a-periodic SRS for positioning. For Rel-17 positioning enhancements, there are proposals to extend the support to on-demand UL SRS for positioning, due to the potential in reducing the positioning latency and improving device efficiency (e.g., reducing the resource usage and power saving).

Submitted Proposals

* (vivo) Proposal 9:
	+ Enhancements of aperiodic SRS for positioning should be studied in Rel-17.
* (Intel)Proposal 3:
	+ RAN1 to study opportunistic on-demand transmission of SRS for positioning (potentially associated with UL control signaling) to facilitate low latency ranging with gNBs/TRPs (e.g. low latency multi-RTT in combination w/ AoA or other measurements)
* (InterDigital)Proposal 3:
	+ Study mechanism supporting on-demand PRS and **SRS** for positioning
* (Qualcomm)Proposal 13:
	+ At least for the purpose of efficiency, study further on-demand PRS and **SRS** transmissions, including, but not limited to, the following aspects:
		- Required signaling & procedures to enable a target device to request/recommend specific PRS configurations (e.g., on-demand ON/OFF switching, bandwidth, TRPs, beam directions), and/or Positioning methods.

Feature lead’s view

Suggest On-demand UL SRS for positioning be investigated with high priority in this meeting.

### Proposal 5-3

* On-demand transmission and reception of UL SRS for positioning can be investigated in Rel-17.
	+ FFS: the details on when and how to enable on-demand UL SRS
	+ FFS: to be supported for which positioning methods, e.g.,
		- UE-assisted and/or UE-based positioning
		- UL positioning and/or Multi-RTT

Comments

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| **Company** | **Comments**  |
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## Methods for reducing timing measurement errors

Background

Network time synchronization errors have a direct impact on the positioning accuracy of DL-TDOA and UL-TDOA. For multi-RTT, although the precise network time synchronization is not a requirement, the group delays in the Tx and Rx RF trains of the UE and TRPs also impact directly on the positioning accuracy of multi-RTT. For supporting sub-meter positioning accuracy in Rel-17, it is a necessity to remove or compensate these timing errors.

Submitted Proposals

* (Huawei) Proposal 7:
	+ Study the mechanism of location based on network calibration, including
		- Time calibration (synchronization)
* (ZTE) Proposal 2:
	+ Network can deliver some prior channel information to UE, the information will assist UE to perform better positioning.
* (ZTE) Proposal 6:
	+ Enable network measurement to calibrate synchronization offset, e.g. support RSTD measurement between positioning nodes
* (CATT) Proposal 16:
	+ RAN1 should investigate the use of the RAT-dependent network synchronization techniques for NR positioning, where the precise network synchronization can be achieved by monitoring the reference signals transmitted from TRPs.
* (CATT) Proposal 18:
	+ A receiver should eliminate the impact of the Rx group delay when providing NR positioning measurements, e.g., UE should eliminate the Rx group delay in UE Rx-Tx time difference measurements.
* (CATT) Proposal 19:
	+ For network-based positioning, the information of the UE Tx group delay should be sent to LMF for eliminating the impact of the Tx group delay on NR positioning. For UE-based positioning, the information of the gNB Tx group delay should be sent to UE for eliminating the impact of the Tx group delay on NR positioning.
* (CATT) Proposal 20:
	+ 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.
* (MTK)Proposal 2-2
	+ For UE-based DL-TDOA, when combining with multiple-RTT or UL-TDOA, the measurement results at gNB side (gNB RX-TX time difference or UL-RTOA) can provide to the UE to reduce the impact of synchronization error between TRPs
* (CEWiT)Proposal 2:
	+ Deployment of reference UE in IIoT and indoor office scenario should be studied for determination of the network synchronization error.
* (CEWiT)Proposal 3:
	+ Achievable clock accuracy of network synchronization techniques like syncE and PTP should be studied.
* (Nokia) Proposal 9:
	+ RAN1 to study beam orientation errors and potential correction mechanisms in order to improve the positioning accuracy achievable with DL-AoD.
* (Qualcomm)Proposal 5:
	+ For the purpose of improved accuracy, study further UE and/or network assistance for UE and network calibration (group delay, NW synchronization) :
		- Methods/signaling to mitigate the group delay calibration errors in Multi-RTT (e.g., enabling differential Multi-RTT, enabling calibration gaps; other schemes are not precluded)
		- Enhancing TDOA and Multi-RTT reporting for assisting with network synchronization
		- More explicitly conveying any adjustment for group delay
* (Ericsson) Proposal 8:
	+ Study and specify methods to estimate UE RX and TX timing errors per UE antenna panel (due to filter group delays etc.) in order to enhance UL TDOA, DL TDOA and RTT positioning accuracy. Potential methods may include both reporting of what antenna panel has been used by the UE for a measurement or a SRS transmission and network control of what antenna panel the UE shall use for a measurement or a SRS transmission.

Feature lead’s view

To obtain the sub-meter positioning accuracy for Rel-17, it is clear that the measurement errors, including the errors caused by the network synchronization and the Tx/Rx group delays, need to be reduced to sub-meter level. Thus, suggest investigating the methods for reducing these measurement errors with high priority in this meeting.

### Proposal 5-4

* + The methods and signaling for the estimation and calibration of the network synchronization, which may be based on NR reference signals and measurements, will be investigated for both UE-based and network-based positioning in Rel-17
	+ The methods and signaling for the estimation and calibration of the UE and gNB Rx and Tx group delays, which may be based on NR reference signals and measurements, will be investigated for UE-based and network-based positioning in Rel-17.

Comments

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| **Company** | **Comments**  |
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## Methods for reducing angular measurement errors

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.

Submitted Proposals

* (Huawei) Proposal 3:
	+ The enhancement of measurement should include studying
		- AoA measurement enhancement targeting ULA
		- DL-AoD accuracy enhancement
* (MTK) Proposal 5-2
	+ RAN1 should take the lead for defining the mapping of a number of RSRP measurements to the angle for DL-AoD enhancement in Rel-17
* (CATT) Proposal 20:
	+ 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.
* (LGE) Proposal 4:
	+ As a potential enhancement of Rel-17 NR positioning, timing measurement based DL-AoD technique needs to be considered.
* (Nokia) Proposal 9:
	+ RAN1 to study beam orientation errors and potential correction mechanisms in order to improve the positioning accuracy achievable with DL-AoD.

Feature lead’s view

To obtaining the sub-meter positioning accuracy based on DL AoD and/or UL AOA, it is clear that the errors of the angular measurements need to be reduced such that the equivalent distance errors are in the same level. Thus, it is needed to investigate the methods for reducing angular measurement errors.

### Proposal 5-5

* The methods for improving the accuracy of the UL AoA and DL-AoD measurements can be investigated in Rel-17.

Comments

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| **Company** | **Comments**  |
| Futurewei | Support |
|  |  |

## Enhancements on E-CID positioning

Background

In Rel-16, E-CID is supported based on the Rel-15 RRM measurements. Several companies propose further enhancements of E-CID positioning based on Rel-15/Rel-16 NR reference signals for improving positioning accuracy and efficiency.

Submitted Proposals

* (Huawei) Proposal 3:
	+ The enhancement of measurement should include studying
		- E-CID enhancement to incorporate RTT measurement based on the serving gNB(s)
		- Use of SRS configured by SRS-Resource for multi-RTT
* (DCM) Proposal 1:
	+ TA based positioning scheme (e.g. reusing LTE Positioning scheme based on TA Type1 and TA Type2) should be consider for Rel-17 NR Positioning to reduce positioning latency.
* (CMCC) Proposal 8:
	+ Enhancement on E-CID positioning should be supported:
		- Supporting E-CID based on RTT + UL-AoA measurements
		- Supporting E-CID using Rel-16 DL/UL positioning reference signals
* (Ericsson) Proposal 19:
	+ Support reuse of Rel-15 SRS resource set for gNB Rx-Tx and UE Rx-Tx measurements for positioning in NR.
* (Ericsson) Proposal 20:
	+ Send an LS to RAN4 regarding UE Rx-Tx requirements
	+ Note: There is no impact to specifications managed by RAN1

Feature lead’s view

Suggest investigating the E-CID positioning enhancement based on Rel-15/16 NR reference signals with high priority in this meeting.

### Proposal 5-6

* Enhancements for E-CID positioning based on NR Rel-15 reference signals (e.g., Rel-15 CSI-RS and SRS) and Rel-16 reference signals (e.g., PRS and SRS for positioning) with timing related measurements (e.g., UE/gNB Rx-Tx measurements) and angular measurements (e.g., DL-AoD and UL AoA) will be investigated for the potential of improving positioning accuracy and device efficiency.

Comments

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| **Company** | **Comments**  |
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## Methods for reducing positioning latency

Background

One of the main objectives of the SI is to investigate the solutions for reducing the latency. Different solutions are proposed by many comapnies, and some of them are already discussed in previous sections (e.g., on-demand DL PRS). In this section, we discuss some additional proposals for reducing positioning latency, especially the triggering, processing, and reporting of the positioning measurements.

Submitted Proposals

* (vivo)Proposal 2:
	+ The enhancements are needed for **positioning latency**, network efficiency, and device efficiency
* (Sony) Proposal 6:
	+ Support the operation of fast positioning measurement report once the UE has obtained positioning measurement result (e.g. using uplink configured grant for positioning, UE to directly monitor control channel for uplink grant)
* (LGE)Proposal 9:
	+ In Rel-17, RAN1 needs a study on the reporting latency reduction considering the physical layer procedure for scheduling request and positioning performance impact if additional latency is required when the measurement reporting is not available at once.
* (Nokia)Proposal 1:0
	+ RAN1 should only focus on physical layer aspects when discussing enhancements on latency reduction for positioning.
* (Nokia)Proposal 1:
	+ Methods to reduce the delay in the positioning measurement report should be studied.
* (Qualcomm)Proposal 6:
	+ NR Rel-17 should target PHY-layer and High-layer enhancements to support a 10 msec End-To-End latency consider the following targets in the respective working groups:
	+ PHY-layer latency of $T\_{phy}=\left[4-7\right] ms$ which includes the time from location request/triggering to successful decoding of the positioning measurement report from the serving gNB
	+ High-layer latency of $T\_{high-layer}=10-T\_{phy}=[3-6]$ ms which includes the time to collect the measurements from the TRPs, perform the position estimation, and transmit the estimate to the external client.
* (Qualcomm) Proposal 8:
	+ For the purpose of reduced latency, study further Low-layer (e.g., DCI, MAC-CE) triggering of DL/UL PRS transmission and muting.
* (Qualcomm) Proposal 9:
	+ For the purpose of reduced latency, study further Enhanced PRS processing capabilities and PRS instances with reduced time-domain foot-print.
* (Qualcomm)Proposal 10:
	+ For the purpose of reduced latency, study further Low-layer (e.g., DCI, MAC-CE) triggering of DL/UL Location Information Reporting.
* (Qualcomm)Proposal 11:
	+ For the purpose of reduced latency, study further reporting of Positioning information directly to the serving gNB either by RRC, MAC-CE or UCI.
* (Ericsson) Proposal 16:
	+ Assume Rel-16 single-DCI based Multi-TRP architecture for IIoT scenario in order to reduce latency associated with positioning.
* (Ericsson) Proposal 17:
	+ In Rel-17 positioning, consider configuration of positioning measurement reports via RRC to reduce latency.

Feature lead’s view

The methods for reducing positioning latency, especially the triggering, processing, and reporting of the positioning measurements. should be investigated with high priority in this meeting.

### Proposal 5-7

* For reducing NR positioning, 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 via RRC, MAC-CE, or UCI.
	+ The request for positioning information (the assistance data, etc.) via RRC, MAC-CE, or UCI.
	+ The report of positioning information (the measurement report, etc.) via RRC, MAC-CE, or UCI.

Comments

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| **Company** | **Comments**  |
| Futurewei | Support |
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## Measurement gap

Background

In Rel-16, UE is not expected to process DL PRS if the measurement gap is not configured. UE measurement gap is configured through RRC signaling. For Rel-17 the following enhancements related to measurement gap for positioning are proposed (Note: In Rel-16, RAN4 decided not to provide the definitions of intra-/inter-frequency measurements for DL PRS due to the measurements from DL PRS are obtained under the assumption that the measurement gap is configured).

Submitted Proposals

* (vivo) Proposal 13:
	+ Measurement gap related indication should be included in positioning measurement report.
* (vivo) Proposal 15:

Positioning BWP switching can be considered in Rel-17 as an alternative to using measurement gap

* (vivo) Proposal 17:
	+ Support to introduce on demand measurement gap for on demand PRS in Rel-17.
* (Xiaomi)Proposal 2:
	+ It is necessary to study the method on PRS reception without measurement gap.
* (Qualcomm) Proposal 7:
	+ For the purpose of reduced latency, study further enhancements in MG configuration & triggering (e.g., DCI/MAC-CE triggered MG, Positioning-specific MG, band-specific/layer-specific MG)

Feature lead’s view

It is clearly undesirable that a measurement gap has to be configured whenever a UE needs to measure DL PRS. Thus, this issue needs to be resolved in Rel-17. Suggest investigating this issue with high priority in this meeting.

### Proposal 5-8

* The enhancements related to UE measurement gap will be investigated, which may include
	+ Measurement gap indication in positioning measurement report.
	+ BWP switching for positioning measurement
	+ on-demand measurement gap request
	+ DL PRS reception without measurement gap
	+ Enhancements in MG configuration & triggering (e.g., DCI/MAC-CE triggered MG, Positioning-specific MG, band-specific/layer-specific MG)

Comments

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| **Company** | **Comments**  |
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## UE-based positioning

Background

UE-based DL positioning is supported in Rel-16 with the broadcast of location assistance data. Enhancements for UE-based positioning are proposed to further reduce the positioning latency and accuracy.

Submitted Proposals

* (Lenovo)Proposal 1:
	+ UE-based positioning latency enhancements should be studied, which are especially applicable for IIoT scenarios
* (Qualcomm) Proposal 1:
	+ At least for the purpose of improved accuracy, additional support and enhancements for UE-based positioning should be supported, including, but not limited to:
		- Enhancements of the assistance data (e.g. RTD enhancements, beam-shape assistance data)
		- UE-based UL and DL & UL methods (e.g., UE-Based Multi-RTT)

Feature lead’s view

UE-based positioning may offer the advantage of reducing the positioning latency, especially when it only uses DL positioning measurements, which is supported in Rel-16. Suggest further investigating the benefits of other UE-based positioning methods, such as UE-based Multi-RTT, if we have the time to do so in this meeting.

### Proposal 5-9

* Enhancements for UE-based positioning may be investigated for the potential of improving positioning performance.

Comments

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| **Company** | **Comments**  |
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## UE positioning in DRX state

Background

In Rel-16, UE positioning is not supported for UE in DRX state. For reducing the UE power consumption, it is important to consider the support of positioning for a UE in DRX state.

Submitted Proposals

* (CATT) Proposal 8:
	+ For the purpose of device efficiency, it should be considered to send SRS-Pos signal at DRX active time for UL positioning.
* (Qualcomm)Proposal 14:
	+ For the purpose of enhanced efficiency, study further relation of DRX to DL/UL positioning reference signals, signaling, procedures and measurement accuracy including, but not limited to:
		- DL PRS reception and UL SRS for positioning transmission outside DRX active time
		- Measurement Accuracy requirements outside DRX active time
		- Any required signaling from the UE to LMF or serving gNB, or serving gNB to the LMF

Feature lead’s view

Supporting UE positioning in DRX state may potentially offer significant advantages for reducing UE power consumption , if we have the time to do so in this meeting.

### Proposal 5-10

* UE positioning in DRX state can be investigated.

Comments

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| **Company** | **Comments**  |
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## Beam-management of positioning

Background

The use of the beam related information for supporting NR positioning is carefully considered in Rel-16 NR positioning, Further enhancements of beam-management of the positioning reference signals may further reducing the overhead, latency, and power consumption.

Submitted Proposals

* (OPPO) Proposal 8:
	+ Study to enhance the multi-beam operation on DL PRS resource and support UE-specific beam configuration
* (LGE)Proposal 1:
	+ Rel-17 NR positioning needs a study on TX/RX beam optimization for the timing measurements for the improvement of positioning accuracy.
* (LGE)Proposal 5:
	+ Rel-17 NR positioning SI needs to study how to use the UE's RX beam index reporting for positioning.
* (Xiaomi)Proposal 3:
	+ Both UE based and gNB based beam managements of neighboring cell should be supported. Cell specific reference signal is preferred for UE based beam measurement of neighboring cell. Reuse beam management reference signal of serving cell for gNB based beam measurement of neighboring cell is preferred.
* (Xiaomi)Proposal 4:
	+ Multi-reference signal transmitted at the same time with different beam should be configured for UE with multi-panel to reduce beam management latency.
* (Xiaomi)Proposal 5:
	+ We suggest to find the LOS path during beam management procedure.

Feature lead’s view

Enhancements of the beam-management for the transmission and reception of the DL PRS and UL SRS may offer the benefits of improving UE positioning accuracy, reducing the measurement delay, and reducing UE power consumption.

### Proposal 5-11

* Enhancements of the beam managements for the transmission and reception of the DL PRS and UL SRS can be investigated for improving UE positioning accuracy, reducing the measurement delay, and reducing the UE power consumption.

Comments

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| **Company** | **Comments**  |
| Futurewei | Support. We consider enhancements that related to more complete multipath measurements and the beam aspects of it as the same category of enhancements. For example, knowing the beam index or direction would greatly provide a more accurate UE measurements of the channel sinve the UE would be able to align towards that direction when the channel profile measurements are made. |
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## Additional methods for increasing the network and UE efficiency

Background

Several proposals are presented related to the enhancements of network efficiency and device efficiency.

Submitted Proposals

* (vivo)Proposal 2:
	+ The enhancements are needed for positioning latency, network efficiency, and device efficiency
* (vivo) Proposal 16:
	+ Support to introduce positioning measurement window in Rel-17.
* (Lenovo) Proposal 4:
	+ Study DL-PRS overhead reduction techniques from the network and UE perspective.
* (Nokia)Proposal 6:
	+ RAN1 to study complexity reductions for RAT-dependent positioning techniques with a focus on FR2 operations.

Feature lead’s view

One of the main objectives of the SI is the improvement of the network and UE efficiency. Sggest further investigating the proposed enhancements in this meeting.

### Proposal 5-12

* The methods for the enhancement of the network and device efficiency and reduce the network and device complexity can be investigated, e.g.,
	+ positioning measurement window
	+ DL-PRS overhead reduction techniques

Comments

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| **Company** | **Comments**  |
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## Additional positioning methods

Background

Several companies proposed some additional methods. For example, the differential positioning technique, which is commonly used on GNSS positioning for improving the positioning accuracy by eliminating the measurement errors, is proposed for NR positioning.

Submitted Proposals

* (vivo) Proposal 19:
	+ The differential positioning can be studied as potential positioning techniques for the NLOS scenario.
		- Considering combining differential positioning with Rel-16 positioning techniques to improve the positioning accuracy
* (vivo) Proposal 20:
	+ Machine learning techniques can be studied as potential positioning techniques for the NLOS scenario in Rel-17.
* (CATT) Proposal 17:
	+ Consider supporting the differential operations for eliminating TRP synchronization errors for high-accuracy NR positioning in Rel-17.
* (Sony)Proposal 8:
	+ Support positioning procedure for the operation of two steps positioning (i.e. coarse and fine positioning)
* (Samsung)Proposal 4:
	+ Uplink transmission-based relative positioning should be studied
* (CEWiT)Proposal 10:
	+ Release 17 should support reporting of measurements by a UE performed on the SRS transmitted by other UEs. Release-16 CLI measurement mechanism can be baseline.

Feature lead’s view

The benefits of the proposed positioning methods may be investigated in this meeting.

### Proposal 5-13

* Additional positioning methods (differential positioning, two steps positioning, relative positioning, etc.) can be studied.

Comments

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| **Company** | **Comments**  |
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##  SRS transmission time

Background

In Rel-16 the timing advance of SRS transmission is based on the serving cell, which may cause an interference problem at a neighbor cell due to the different distances from UE to the serving and the neighbor cell. In addition, the timing measurement accuracy may be degraded if the UE changes the SRS transmission time between SRS transmission occasions.

Submitted Proposals

* (LGE)Proposal 2:
	+ Rel-17 NR positioning needs to study on cell/TRP-specific TA considering interference problem at a neighbour cell.
* (LGE)Proposal 6:
	+ Need a study to find solution(s) to minimize accuracy degradation according to the transmission timing change between SRS transmission occasions especially for UL-TDOA technique.

Feature lead’s view

The TA issue was discussed in Rel-16 without a conclusion. If UE changes the UL Tx time during a positioning measurement duration, it may result in a significant error to UL RTOA measurement.

### Proposal 5-14

* The UL interference at a non-serving cell, which is caused by the transmission of the SRS for positioning from the UEs of other cells, can be studied in this SI.
* The solution(s) to minimize accuracy degradation according to the transmission timing change between SRS transmission occasions can be studied in this SI.

Comments

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| **Company** | **Comments**  |
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# Architecture and signalling enhancements

## Architecture and signalling enhancements

Background

Rel-16 NR positioning adopts the LMF-centred architecture, including capability transfer, assistance data transfer, location information transfer, and measurement exchange. To improve the positioning enhancements, especially reducing the positioning delay and increase the network efficiency, the existing architecture and signally can be further enhanced. Also, hybrid positioning may significantly increase positioning accuracy and reliability. Hybrid positioning is supported in Rel-16 positioning architecture and signalling.

Submitted Proposals

* (Huawei) Proposal 8:
	+ Study the following architecture enhancement
		- NG-RAN assisted PRS scheduling
		- NG-RAN assisted NR-RAT dependent positioning measurement procedure
* (CEWiT)Proposal 7:
	+ Positioning architecture for NG-RAN should be optimised to reduce the latency incurred in TTFF of position of the UE.
* (Qualcomm)Proposal 4:
	+ For the purpose of improved accuracy, study further the reporting of additional motion state / kinematics constraints information for both UE-based and UE-assisted including but not limited to:
		- Signaling of side information / constraints on potential trajectory, path, velocity, direction of the target device.
* (Qualcomm)Proposal 12:
	+ To support ultra-low latency, study further enhancements to positioning architecture and signaling.
* (MTK)Proposal 2-1:
	+ The combined technique usage of DL-TDOA and multiple-RTT, or of DL-TDOA and UL-TDOA, can be considered as DL-TDOA enhancement to improve accuracy for both UE-assisted and UE-based mode
* (Lenovo)Proposal 6:
	+ Study efficient DL-PRS configuration, measurement and reporting mechanisms to support configurable Hybrid positioning techniques.

Feature lead’s view

Efficient architecture and higher-layer signalling are important for supporting very-low latency positioning. Although the architecture and higher-layer signalling are defined by other WGs, RAN1 may offer valuable inputs for the enhancements.

### Proposal 6-1

* Enhancements of the architecture, the signaling, and the assistance data can be investigated for reducing latency and increasing accuracy for both UE-based, UE-assisted and hybrid positioning, e.g.,
	+ NG-RAN assisted PRS scheduling
	+ NG-RAN assisted NR-RAT dependent positioning measurement procedure
	+ reporting of additional motion state/kinematics constraints information

Comments

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| **Company** | **Comments**  |
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# Additional proposals

## Performance evaluation

Background

There are proposals related to the evaluation of the proposed positioning enhancements.

Submitted Proposals

* (CATT) Proposal 6:
	+ For assessing the scalability of positioning solutions, the latency of a positioning procedure should be studied as a function of the number of devices to be positioned.
* (CATT) Proposal 7:
	+ The average power consumption of devices should be studied as a function of configured time and frequency resources for positioning.
* (Samsung) Proposal 6:
	+ Evaluation of IIoT OTDoA positioning performance should include a consideration of a sub-set of PRS and SRS possible parameter values for periodicity, slot offset and repetition rate, which conform to a dynamic TDD setting in the IIoT network.
* (Intel) Proposal 1:
	+ RAN1 to study performance benefits of super-resolution processing techniques for precise UE positioning
* (LGE)Proposal 3:
	+ For DL-TDOA and Multi-RTT, the performance impact according to the height difference between a UE and a TRP needs to be studied at least for InF scenarios.

Feature lead’s view

These proposals may be further discussed in AI 8.5.1/2 for performance evaluation.

Comments

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| **Company** | **Comments**  |
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## Positioning algorithms

Background

Using advanced signal processing and positioning algorithms is critical for a high-performance positioning system. There is a proposal related to the use of the positioning algorithms.

Submitted Proposals

* (CEWiT)Proposal 4:
	+ Support for enabling advanced positioning algorithms should be studied in Release-17.

Feature lead’s view

The proposal seems closely related to the UE/gNB implementation. 3GPP normally does not define which algorithms are used by UE/gNB.

Comments

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| **Company** | **Comments**  |
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# Summary (Part 1)

TBD

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