3GPP TSG RAN Meeting #91-e **RP-210674**
Electronic Meeting, 16 –26 March 2021

Agenda item: **9.6.2**
Source: **Lenovo, Motorola Mobility**
Title: **Initial views on V2X and Public Safety Positioning Use Cases**
Document for: **Discussion and Decision**

1 Introduction

During the RAN#88-e meeting [1], a RAN-level study item was approved to investigate the positioning use cases, requirements, and scenarios for UEs in-coverage, partial coverage, and out-of-coverage scenarios. The objectives are laid out as follows:

1. Identify the positioning use cases and requirements for V2X and public safety, based on the existing 3GPP work and input from industry fora.
2. Identify potential deployment and operation scenarios

Note: Studying the feasibility of the identified requirements is not in the scope of this SI.

Note: The work in this SI shall take into account the outcomes and progresses of NR positioning study in both Rel-16 and Rel-17.

Note: Work plan

- RAN#91: TR skeleton, initial input on Objective 1
- RAN#92: Finalize Objective 1, initial input on Objective 2
- RAN#93: Finalize Objective 2, approve the TR (SI target completion)

This contribution provides initial views on the identified V2X and Public Safety Positioning Use Cases and requirements (Objective 1) with respect to 3GPP work performed thus far as well as industry inputs [2].

2 Rel-16 & Rel-17 Positioning Requirements

The positioning framework based on NR and corresponding 5GC standalone architecture (SA) was first specified in Rel-16. Rel-16 mainly catered towards fulfilling the target use cases including commercial and regulatory (emergency services) service requirements and shown in Table 1.

Table 1: Rel-16 Positioning Requirements [2]

Positioning KPIs	Indoor	Outdoor
Horizontal Positioning Accuracy	**< 3m** for **80%** of UEs	**< 10m** for **80%** of UEs
Vertical Positioning Accuracy	**< 3m** for **80%** of UEs	**< 3m** for **80%** of UEs

However, Rel-17 NR positioning takes into consideration the IIoT (indoor factory) positioning use cases, where the overall positioning requirements are more stringent with respect to Rel-16. The Rel-17 performance requirements have been agreed upon and documented in the latest version of TR.38.857 [3] and is shown in Table 2. An additional positioning KPI related to end-to-end latency has also been considered for Rel-17, which is especially relevant in defining potential requirements for V2X and Public Safety use cases.

Table 2: Rel-17 Target Positioning Requirements [3]

Positioning KPIs	Commercial Use Cases	IIoT Use Cases
Horizontal Positioning Accuracy	< **1 m** for **90%** of UEs	< **0.2 m** for **90% of UEs;**
Vertical Positioning Accuracy	< **3 m** for **90%** of UEs	< **1 m for 90% of UEs**
Physical layer latency for position estimation of UE	< **10 ms**	< **10 ms**
End-to-End Latency for position estimation of UE	<**100 ms**	< **100 ms**, in the order of **10 ms** is desired

Observation 1: The Rel-17 KPI of end-to-end positioning latency can be seen as a critical requirement for V2X and Public Safety positioning use cases and can be extended accordingly.

It is evident that the current 3GPP positioning use cases have catered mainly towards the fulfilling the absolute positioning use cases over the Uu interface:

- Regulatory
- Commercial
- IIoT

Observation 2: 3GPP has thus far supported Regulatory, Commercial and IIoT absolute positioning use cases.

V2X and Public Safety is seen as a safety critical location service, where both precise and timely absolute and relative UE positioning is required. In addition, SL positioning is a key enabler of positioning in different coverage areas, especially for partial and out-of-coverage scenarios such as tunnels, underground parking and other remote areas without network/GNSS coverage.

3 Discussion on Use Cases and Requirements

3.1 V2X Positioning

Sidelink (SL) positioning can be seen as a necessary positioning technology, which can complement the already existing array of onboard vehicular localization sensors and radar/lidar technologies, where neither GNSS nor the network is able to meet the positioning requirements.

Stage 1 specifications, TS 22.186 related to the enhanced 3GPP support for V2X scenarios have already defined the following relative positioning requirements [4]:

- **General Requirements [R.5.1-007]**: The 3GPP system shall support relative lateral position accuracy of 0.1 m between UEs supporting V2X application.

- **Requirements to support vehicle platooning [R.5.2-003]**: The 3GPP system shall support relative longitudinal position accuracy of less than 0.5 m for UEs supporting V2X application for platooning in proximity.

Relative positioning among UEs is a key enabler to support the lateral and longitudinal localization requirements of V2X use cases. It can also be noted that according to [R.5.1-007], the relative lateral positioning requirement is much tighter than today's absolute Rel-16/Rel-17 positioning requirements. Automated driving requires especially stringent positioning requirements.

Table 3: Requirements for positioning on L4/L5 Automated Driving [6]

Requirement	Indicators	Value
Location Accuracy	95th Percentile (2-sigma)	< 30cm
Location Integrity	Location Integrity Alert limit	< 1.5m
Attitude Accuracy	Attitude Accuracy Error mean	< 0.5 degree
Attitude Robust	Attitude Robust Maximum error	< 2.0 degree
Scenarios	Covered scenarios	All-weather, open highway

Table 3 shows the required positioning KPIs for SAE L4/L5 automated driving, which is especially stringent in terms of accuracy (<0.3m) and attitude (orientation) (<0.5) requirements. Although not included, it can be assumed that low end-to-end latency and high availability of the positioning estimate are also key requirements for L4 and L5 automated driving.

Observation 3: High-precision location and orientation accuracy are required for higher automated driving levels, L4 and L5.

The following select use cases and SLRs (Service Level Requirements) were identified by 5GAA and are tabulated (see Table 4) in relation to the target positioning accuracies<1.5 m, corresponding V2X use cases [5, 6] and assumed minimum driving automation level:

Table 4: Adapted High Precision Performance requirements for V2X Use Cases [6]

Positioning Use Case Group	Assumed minimum Driving Automation Level	V2X Positioning Use Cases	Required Positioning Accuracy (m)
Safety			
Lane Level	L3	Cross Traffic Left-Turn Assist§	1.5*
Lane Level	L3	Intersection Movement Assist§	1.5*
Lane Level	L2	Emergency Break Warning§	1.5*
Lane Level	L2	Lane Change Warning – Lagging Vehicle, Leading Vehicle, Highway	1.5**
Lane Level	L2	Lane Change Warning – Lagging Vehicle, Leading Vehicle, Urban	1.5**
Lane Level	L2	Lane Change Warning – Not Permitted Case, Rural	1.5**
Lane Level	L3	See-Through for Pass Manoeuvre	1.5*

Autonomous Driving			
Submeter	L4	High-Definition Sensor Sharing	0.1*
Submeter	L4	Real-Time Situational Awareness and High-Definition Maps	0.5
Lane Level	L2	Hazard Collection – Vehicle Collects Hazard and Road Event Information for AV	1.5*
Lane Level	L3	Autonomous Vehicle Disengagement Report	1.5*
Submeter	L5	Infrastructure Assisted Environment Perception – Data Distribution about Objects on the Road	0.1*
Lane Level	L3	Awareness Confirmation	1.5*
Traffic Efficiency and Environmental Friendliness			
Lane Level	L3	Speed Harmonisation	1.5*
Platooning			
Lane Level	L3	Vehicles Platooning in Steady State	1.5*
Lane Level	L3	Cooperative Lane Merge	1.5*
Society and Community			
Submeter	L3	Vulnerable Road User – Awareness Near Potentially Dangerous Situations	1*
Submeter	L3	Vulnerable Road User – Collision Risk Warning	0.5*
Lane Level	-	Accident Report	1.5*
Additional Driven and Autonomous Use Cases			
Lane Level	L2/L3	Vehicle Health Monitoring	1.5*
Submeter	L4	Group Start	0.2*
Submeter	L4/L5	Tele-Operated Driving (TOD)	0.1*
Submeter	L4/L5	TOD Support	0.1*
Submeter	L4/L5	TOD for Automated Parking	0.1*
Lane Level	L3	Obstructed View Assist via Remote Vehicles	1.5*
Submeter	L4/L5	Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations	0.2*
Lane Level	L3	Continuous Traffic Flow via Green Lights Coordination	1.5*
Submeter	L4/L5	High-Definition Map Collecting and Sharing	(0.1-0.5) *
Submeter	L4/L5	Automated Intersection Crossing	0.15*
Lane Level	L3	Vehicle Decision Assist – RV Waiting for a Short Period of Time, RV Broken Down, Bus Having to Wait	1.5*
Lane Level	L3	Vehicle Decision Assist – Slow Vehicle en Route	1.5*
Lane Level	L3	Bus Lane Sharing Request	1.5*
Lane Level	L3	Bus Lane Sharing Revocation	1.5*
Cooperative Driving			
Lane Level	L3	Coordinated, Cooperative Driving Manoeuvre – Cooperative Lane Change	1.5*
Lane Level	L3	Coordinated, Cooperative Driving Manoeuvre – Road	1.5*

		Blockage	
Submeter	L4	Coordinated, Cooperative Driving Manoeuvre – Pedestrian Crossing	1*
Submeter	L3	Cooperative Traffic Gap	Longitudinal (absolute): 1.5* Lateral (Relative): 1*
Submeter	L4/L5	Cooperative Lateral Parking	0.2*
Submeter	L3	Cooperative Curbside Management	1*
NOTE: * - 99.7th Percentile (Availability) ** - 95th Percentile (Availability) §- Applicable to both Safety and Autonomous Use cases			

The key V2X positioning use cases, which have been shown in Table 4, should at least cover the following two groups of positioning requirements as noted by the LS sent by 5GAA [7] :

- Group 2) Lane level positioning requirements
- Group 3) Below meter (Submeter) positioning requirements

It should also be established whether the above use cases can either be satisfied by the existing 3GPP positioning framework or a new SL positioning framework or a combination of both. Furthermore, it can be highlighted that for the use cases mentioned in Table 4, the absolute positioning estimate via GNSS/network-based positioning is especially challenging in deep indoor areas such as a long tunnel or an underground parking lot. In general, the KPIs should be further differentiated based on the absolute and relative location accuracy and in the context of V2X services, lateral and longitudinal accuracy should also be taken into account. Due to safety critical nature of the services, the targeted availability for such positioning accuracies should be 99% of all serviced UEs, which differs from the existing Rel-16/Rel-17 positioning requirements as noted in Tables Table 1 and Table 2.

Observation 4: Accurate absolute positioning is especially challenging in partial coverage or out-of-coverage scenarios, e.g. long tunnels, underground parking lots.

Observation 5: The positioning availability requirements are especially stringent, i.e. 99% with respect to Rel-16 and Rel-17 requirements, which are 80% and 90%, respectively.

Proposal 1: At least adopt the lane level and submeter V2X positioning requirements shown in Table 4 for Rel-18 Positioning.

A unified framework should be the design goal, where network-based RAT-dependent, RAT-independent methods (GNSS, etc.) and potential SL-based positioning should be harmonised to fulfil different requirements based on the type of positioning scenario. Absolute and relative location awareness can be utilised in tandem for the benefit of V2X and other SL applications.

Observation 6: Relative positioning can complement the existing absolute RAT-dependent and RAT-independent positioning techniques to further improve the absolute location estimation accuracy.

VRUs are an important component of the V2X ecosystem and as such the positioning requirements would also be slightly different in terms of energy requirements for absolute and relative positioning. Energy efficient absolute and relative positioning would also be a key requirement in the case of VRUs.

Observation 7: Energy efficient absolute and relative positioning are an important consideration for fulfilling the VRU use cases.

The current NR PRS framework relies on beam-based transmissions to achieve the Rel-16/Rel-17 absolute positioning requirements. In the case of SL, further discussions would be needed on how to enable the different positioning techniques given the current lack of beamforming support in SL. In the context of V2X, various positioning techniques can be used in a hybrid fashion to achieve the desired lateral and longitudinal accuracy.

In the existing positioning framework, timing-based positioning techniques such as TDOA methods rely on fixed anchors such as gNBs. Similarly, RSUs in V2X scenario can be leveraged to act as fixed anchors to enable such methods. In addition, although more challenging, further consideration should also be given to mobile UEs acting as anchors in areas where network or GNSS coverage is limited or non-existent, provided that the absolute locations of these mobile anchor UEs are known.

3.2 Relative Positioning in 3GPP

Figure 1 is an overview of the absolute and relative positioning scenarios as defined in the cyber-physical control applications [8] using three different co-ordinate systems that cover a broad range of use cases:

- I. Relative Positioning, variable coordinate system
- II. Relative Positioning, variable and moving coordinate system
- III. Absolute Positioning, fixed coordinate systems

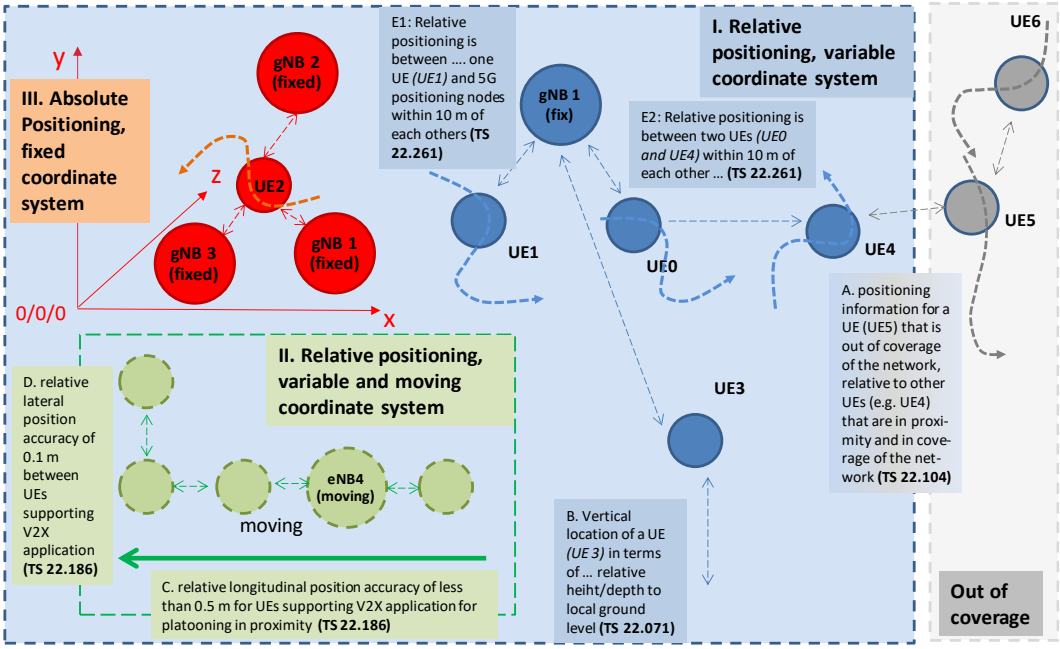

Figure 1: Overview on absolute and relative positioning coordinate systems as defined in Stage 1 specifications [8]

It can be noted that the current positioning RAN framework has catered mainly towards the absolute positioning framework, i.e. Framework III and therefore there is currently no RAN support to measurement and reporting procedures of the relative range, location, heading, speed with respect to other UE(s), which is essential for safety critical use cases such as V2X and Public Safety However, given the decentralized nature of the V2X and Public safety use cases, additional design considerations in 3GPP need to be considered to support I. and II. variable coordinate systems that include both relative moving and variable coordinate systems. SL positioning can be an enabler for both Framework I. and II. Relative positioning coordinate system to enable high-precision UE-to-UE relative location estimation as there are currently are no specified RAN methods to measure and report the relative range, location, heading, speed with respect to other UE(s), device(s).

Observation 8: SL positioning can enable RAN support for relative positioning in terms of the variable and moving coordinate systems.

3.3 Public Safety

The public safety positioning use case is especially important when considering both absolute and relative location estimation in-coverage, partial coverage, and especially out-of-coverage scenarios. Mission Critical Organizations require mission critical services to have an accurate absolute and relative positioning estimate such that first responders may be localized at any given time, especially during critical operations. This stringent positioning requirements are to be fullfilled for both indoor and outdoor environments. The level of positioning accuracy (and other KPIs) required is much more stringent than that required by local and regional regulatory requirements for commercial 5G users [9].

Table 5: Public Safety- First Responder Positioning Requirements [TS- 22.261, 9]

Public Safety Use Case	Horizontal Accuracy (m)	Vertical Accuracy (Absolute) (m)	Vertical Accuracy (Relative) (m)	Availability (%)
First Responders Tracking and guidance of 1st responders, with requirements for high accuracy in the horizontal domain and vertical domain, as well as accurate awareness of height variation to detect falls, combined to a high level of availability and reliability	< 1	< 2	<0.3	> (95 - Indoor) > (98- Outdoor)

Proposal 2: Consider Public Safety positioning requirements at least for the first responders use case in terms of both absolute and relative positioning accuracy KPIs for Rel-18 Positioning.

According to the ongoing SA1 study on ranging-based services [10], a distance based intelligent perception for public safety has also been identified with the KPIs shown in Table 6. This enables ranging-based functionality between UEs to assist in public safety efforts and coordination. It is important to note that the relative range between UEs is a higher priority than the absolute location and in addition, the number of concurrent UEs using such a ranging-based service is high.

Table 6: Public Safety- Distance-based Intelligent Perception [TR- 22.855, 10]

Ranging scenario	Ranging Accuracy (95 % confidence level)		Availability	Latency	Coverage, environment of use, Relative UE velocity, Ranging interval, Number of concurrent ranging operation for a UE, Number of concurrent ranging operation support in area						
	Distance Accuracy	Direction Accuracy			Effective ranging distance	Coverage	NLOS /LOS	Relative UE velocity	Ranging interval	Number of concurrent ranging operation for a UE	Number of concurrent ranging operation support in area

distance based intelligent perception for public safety	50cm	-	99 %	-	20m	IC/PC/ OOC	LOS	Static/ Moving (<20km /h)	-	100	-

3.4 Other Use Cases

It should be noted that the relative positioning requirements are not only limited to V2X and Public Safety coverage scenarios but serve other requirements for use cases such as IIoT as seen in Table 7. Relative positioning requirements should also extend to such use cases.

Table 7: IIoT Positioning Requirements [11]

Scenario	Horizontal accuracy	Availability	Heading	Latency for position estimation of UE	UE Speed	Corresponding Positioning Service Level in TS 22.261
Flexible, modular assembly area in smart factories (for tracking of tools at the work-place location)	< 1 m (relative positioning)	99 %	N/A	1 s	< 30 km/h	Service Level 3

Furthermore, commercial ranging service requirements with a target towards relative positioning are being discussed and developed in SA1 with tight ranging and orientation requirements in addition to other relative positioning KPIs. These commercial use case and requirements are currently being documented TR 22.855. Although the current RAN-based study focuses on V2X and Public Safety use cases, RAN plenary should also consider the outcome of other documented use cases requiring a relative positioning framework within 3GPP.

Proposal 3: Relative UE Positioning requirements in different coverage scenarios should also take into account additional relative positioning use case requirements, which have been documented for IIoT and Commercial applications in 3GPP.

4 Positioning KPIs

Additional positioning KPIs should also be considered given the new V2X and Public Safety use cases, which are over and above what has already been considered for Rel-16/Rel-17 positioning especially in the context of relative positioning. These include:

- Relative Positioning Accuracy
  - Horizontal and Vertical accuracies
  - Lateral and Longitudinal accuracies in the case of V2X
- Orientation accuracy
  - Depending on the elevation and azimuth plane
  - FFS absolute or relative orientation
- Concurrent UEs performing relative location estimation
- Applicable coverage areas
  - In-coverage, partial coverage and out-of-coverage scenarios
- Positioning Update rate

- Mobility
    - Absolute velocity (horizontal in case of V2X use cases)
    - Relative velocity
- Integrity and Reliability of the positioning estimate
    - Alert limit (AL)
    - Time to alert (TTA)
    - Target Integrity Risk (TIR)
    - Other QoS parameters such as relative accuracy confidence intervals, etc.

Integrity and reliability of the absolute and relative location are important for safety critical services such as V2X, e.g. to enhance Advanced Driver-Assistance Systems (ADAS). Such errors may also affect the reliability and integrity of the relative location estimate considering that a UE may perform relative positioning with multiple UEs in close proximity. Concepts such as AL, TTA and TIR can ensure the integrity and reliability in such use cases.

Observation 9: Integrity and reliability of a positioning estimate are especially important for safety critical use cases such as V2X and Public Safety.

In addition, the positioning requirements need to target a high availability of 99% due to the density of UEs in a given area and due to the safety critical nature of the use cases such as V2X and Public Safety.

Proposal 4: Consider at least the following additional positioning KPIs required for the V2X and Public Safety use cases:

- **Relative Positioning Accuracy**
- **Orientation accuracy**
- **Concurrent UEs performing relative location estimation**
- **Positioning Update rate**
- **Mobility parameters including relative velocity**
- **Integrity and Reliability positioning estimate metrics**

5 Conclusions

This contribution has noted the following observations:

Observation 1: The Rel-17 KPI of end-to-end positioning latency can be seen as a critical requirement for V2X and Public Safety positioning use cases and can be extended accordingly.

Observation 2: 3GPP has thus far supported Regulatory, Commercial and IIoT absolute positioning use cases.

Observation 3: High-precision location and orientation accuracy are required for higher automated driving levels, L4 and L5.

Observation 4: Accurate absolute positioning is especially challenging in partial coverage or out-of-coverage scenarios, e.g. long tunnels, underground parking lots.

Observation 5: The positioning availability requirements are especially stringent, i.e. 99% with respect to Rel-16 and Rel-17 requirements, which are 80% and 90%, respectively.

Observation 6: Relative positioning can complement the existing absolute RAT-dependent and RAT-independent positioning techniques to further improve the absolute location estimation accuracy.

Observation 7: Energy efficient absolute and relative positioning are an important consideration for fulfilling the VRU use cases.

Observation 8: SL positioning can enable RAN support for relative positioning in terms of the variable and moving coordinate systems.

Observation 9: Integrity and reliability of a positioning estimate are especially important for safety critical use cases such as V2X and Public Safety.

The proposals are summarized as follows:

Proposal 1: At least adopt the lane level and submeter V2X positioning requirements shown in Table 4 for Rel-18 Positioning.

Proposal 2: Consider Public Safety positioning requirements at least for the first responders use case in terms of both absolute and relative positioning accuracy KPIs for Rel-18 Positioning.

Proposal 3: Relative UE Positioning requirements in different coverage scenarios should also take into account additional relative positioning use case requirements, which have been documented for IIoT and Commercial applications in 3GPP.

Proposal 4: Consider at least the following additional positioning KPIs required for the V2X and Public Safety use cases:

- **Relative Positioning Accuracy**
- **Orientation accuracy**
- **Concurrent UEs performing relative location estimation**
- **Positioning Update rate**
- **Mobility parameters including relative velocity**
- **Integrity, Reliability and QoS positioning estimate metrics**

6 References

[1] RP-201384, New SID: Study on scenarios and requirements of in-coverage, partial coverage, and out-of-coverage positioning use cases, LG Electronics, FirstNet.

[2] TR 38.855, “Study on NR positioning support (Release 16)”, V16.0.0, March 2019.

[3] TR 38.857, “Study on NR Positioning Enhancements (Release 17)”, V1.0.0, December 2020.

[4] TS 22.186, “Enhancement of 3GPP support for V2X scenarios (Release 16)”, V16.2.0, June 2019.

[5] 5GAA, “C-V2X Use Cases, Methodology, Examples and Service Level Requirements”, WG1, V1.0, June 2019.

[6] 5GAA, “System Architecture and Solution Development; High-Accuracy Positioning for C-V2X”, White Paper, V1.0, February 2021.

[7] RP-210040, “LS reply to 3GPP RAN on requirements of in-coverage, partial coverage, and out-of-coverage positioning use cases”, 5GAA, March 2021.

[8] TR 22.832, “Study on enhancements for cyber-physical control applications in vertical domains (Release 17)”, V17.3.0, Sept. 2019.

[9] TS 22.261, “Service requirements for the 5G system; Stage 1 (Release 18)”, V18.1.1, Jan 2021.

[10] TR 22.855, “Study on Ranging-based Services; Stage 1 (Release 18)”, V0.2.0, Nov. 2020.

[11] TS 22.104, “Service requirements for cyber-physical control applications in vertical domains”, V17.2.0, Dec. 2019.