**3GPP TSG-RAN WG2 #112-e Draft R2-20xxxxx**

**Electronic Meeting, November 02-13, 2020**

**Agenda Item: 8.11.3.1**

**Source: Swift Navigation**

**Title: PHASE 2 - [Post111-e][626][POS] Email Discussion on integrity use cases and specification impacts**

**Document for: Discussion, Decision**

1 Introduction

This document is Phase 2 of the following email discussion:

**[Post111-e][626][POS] Integrity use cases and specification impacts (Swift)**

Scope: Capture any additional integrity use cases and open issues on integrity, and draft a TP incorporating the existing agreements and any further progress.

Intended outcome: Summary to next meeting

Deadline: Long

The purpose of Phase 2 is to converge a text proposal for agreement at RAN2#112-e, taking into consideration the summary email comments from Phase 1. Moderator Summaries have been provided for Phase 1 and the comments are further addressed as part of the text proposals made in Phase 2. Phase 2 also takes into consideration the reduced scope for the study that was agreed at RAN #89-e [3][4]:

* *Reduce the scope of the SI “Study on NR Positioning Enhancements” by excluding the study of integrity solutions for RAT-dependent positioning methods and by excluding the study of integrity solutions for RAT-independent methods other than GNSS.*

2 Phase 2 – Text Proposals

2.1 Integrity Definitions

Intel and ESA proposed to move the agreed integrity definitions from Section 9.1.1 to Section 3.1 in Skeleton TR 38.857. Section 3.1 contains the definitions for the overarching SI.

**Agreed Definitions:**

**Target Integrity Risk (TIR):** The probability that the positioning error exceeds the Alert Limit (AL) without warning the user within the required Time-to-Alert (TTA).

NOTE: The TIR is usually defined as a probability rate per some time unit (e.g. per hour, per second or per independent sample).

**Alert Limit (AL):** The maximum allowable positioning error such that the positioning system is available for the intended application. If the positioning error is beyond the AL, operations are hazardous and the positioning system should be declared unavailable for the intended application to prevent loss of integrity.

NOTE: When the AL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Alert Limit (HAL) or Vertical Alert Limit (VAL) respectively.

**Time-to-Alert (TTA):** The maximum allowable elapsed time from when the positioning error exceeds the Alert Limit (AL) until the function providing position integrity annunciates a corresponding alert.

**Protection Level:** The PL is a statistical upper-bound of the positioning error that ensures that, the probability per unit of time of the true error being greater than the AL and the PL being less than or equal to the AL, for longer than the TTA, is less than the required TIR.

NOTE: When the PL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Protection Level (HPL) or Vertical Protection Level (VPL) respectively.

**Proposal 1: Add the agreed definitions to Section 3.1 of the Skeleton TR.**

**Proposal 2: Remove Section 9.1.1 (Definitions) of the Skeleton TR.**

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| **Company** | **Do you support the proposals?** |
| CATT | Only the definitions of terms will be moved to section 3.1 of the Skeleton TR, for example,  **Target Integrity Risk (TIR):** The probability that the positioning error exceeds the Alert Limit (AL) without warning the user within the required Time-to-Alert (TTA).  NOTE: The TIR is usually defined as a probability rate per some time unit (e.g. per hour, per second or per independent sample).  **Alert Limit (AL):** The maximum allowable positioning error such that the positioning system is available for the intended application. If the positioning error is beyond the AL, operations are hazardous and the positioning system should be declared unavailable for the intended application to prevent loss of integrity.  NOTE: When the AL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Alert Limit (HAL) or Vertical Alert Limit (VAL) respectively.  **Time-to-Alert (TTA):** The maximum allowable elapsed time from when the positioning error exceeds the Alert Limit (AL) until the function providing position integrity annunciates a corresponding alert.  But the relationship between the PL and KPIs and detail description about integrity still will be kept in section9.1. Because overview of integrity is required in the TR document.  Furthermore, the abbreviations should be summarized in section 3.3 Abbreviations in the TR, for example:  **AL Alert Limit**  **HPL Horizontal Protection Level** |
| Ericsson | Yes, we agree with both proposals. While we also consider that these definitions four definitions would be again brought up in Section 9 where the integrity KPIs are defined. |
| vivo | Better keep them in 9.1.1. We also don’t have definition in 3.1 in TS38.855. |
| Intel | Yes, we agree with proposals. In addition, agree with CATT, the abbreviation should be added in 3.3, e.g. Target Integrity Risk (TIR) |
| Convida | Yes. Also, agree with the Ericsson view that these definitions will need to be revisited in the main body of the TR. |
| OPPO | Yes, agree with both. |
| ZTE | Yes. We share the same view with CATT. |
| Huawei, HiSilicon | We agree with the Proposals.  For Proposal 2, we suggest to provide some explanation about the integrity KPIs in 9.1.1 after the definition of integrity, for better understand of 9.1.1.2-9.1.1.4. |
| Apple | Yes |
| Nokia | We agree with both proposals |
| ESA | We think section 9.1.1 is still needed to provide an introduction and overview of the integrity concept. We agree to move the four definitions to section 3.1 but, as already mentioned in other answers, they would be again brought up in Section 9 so some introduction or reference to section 3.1 can be included in section 9.1.1 to at least explicitly clarify where these definitions can be found.  We agree that the abbreviations would also need to be updated in section 3.3. |
| InterDigital | Yes, we agree with both proposals |

2.2 Text Proposals

The following text proposals are based on company feedback from Phase 1 (see Appendix A). To maintain consistency with the comments and agreements in Phase 1, the proposed text includes updated terminology, section numbering, section ordering, and additional detail where further descriptions were requested by companies. The Phase 2 proposals are also addressed in ascending order of the Skeleton TR, rather than the order in which they were presented in Phase 1 (cross-references are provided between the Phase 2 proposals and the Phase 1 feedback in Appendix A).

Companies are asked to indicate their support for the proposals and to propose any text edits or new text as part of their comments below, taking into consideration the terminology and scope of the current agreements (noting some objectives are yet to be treated online).

2.2.1 Integrity Concepts (see Appendix A – Phase 1, Section 2.3)

**Moderators Summary**

There was strong consensus from Swift, ESA, Spreadtrum, Ericsson, Apple, Interdigital, ZTE, Intel, Samsung, OPPO, Fraunhofer and Nokia to adopt Sections 9.2.3, 9.3.1, 9.3.2 from RP-2006541 as an initial baseline. It was noted that these sections can inform discussions on the implications of the integrity concepts within the 3GPP framework (Huawei, Vivo, CATT, OPPO, Fraunhofer, Nokia). ESA, Spreadtrum, Apple suggested minor refinements for the text descriptions in Sections 9.2.3 and 9.3.1 to further distinguish key terms and KPIs. ZTE, Samsung and Nokia suggested adding further descriptions on how the PL and Stanford Diagram should be interpreted, to assist the upcoming discussions addressing the remaining objectives and protocol impacts of the SI/WI.

The moderator has proposed additional text in Phase 2, including extended descriptions of the PL and Stanford Diagram and updated headings to reflect these changes, in line with the company feedback. It is intended that the Integrity Concepts section will introduce the general concepts of positioning integrity, but the specific integrity information, signaling procedures and associated specification impacts etc will be addressed as part of the remaining SI objectives, in particular the integrity methodologies.

**Phase 2 Text Proposal**

--------------------------------------------------Start Text Proposal-------------------------------------------------

9.1 Integrity Overview – Background Information

9.1.1 Integrity Concepts

As positioning demands continue to increase, the scale and connectivity of emergent applications such as self-driving vehicles have necessitated a standards-based approach. More devices connecting to the 3GPP network means more users rely on the network being trustworthy and interoperable. The ability to navigate safely means users must trust their estimated position with a high degree of confidence. Trustworthiness of position is the study of positioning integrity, which is defined in TS 22.872 as follows:

**Integrity:** A measure of the trust in the accuracy of the position-related data provided by the positioning system and the ability to provide timely and valid warnings to the UE and/or the user when the positioning system does not fulfill the condition for intended operation.

Various GNSS service providers already support integrity monitoring in their products, but there is no common standard for expanding the ecosystem of connected devices which can benefit from positioning integrity. This study investigates new integrity assistance data and procedures to be considered in LPP and associated specifications, to assist in quantifying positioning integrity for the UE.

9.1.1.1 Accuracy and Integrity

To understand the necessity of introducing the concept of integrity, it is important to understand how it differs from the more familiar concept of Accuracy.

Accuracy and integrity are related but separate concepts, and for many use cases, accuracy alone is insufficient to meet the requirements. Positioning devices and services are typically designed to report the distribution of errors that characterize the overall system performance, which is often specified as an error percentile representing the accuracy. For example, a road vehicle with an embedded UE positioning client may report a lane-level accuracy of <50cm 95th percentile. In this case, the UE is indicating that, based on all the computed positions, its estimated accuracy is better than 50 centimeters, 95% of the time. For the remaining 5%, the position error is unknown. In fact, these errors might reach 10s or 100s of meters due to multiple different error sources. The 5% of errors are essentially unbounded without any way to reliably validate their distribution. In the case of GNSS, these errors could include constellation geometry (i.e. Dilution of Precision), sharp atmospheric gradients or irregularities and local receiver effects such as high measurement noise or multipath.

Integrity is a method of bounding these errors to a much higher confidence. For example, a Target Integrity Risk (TIR) of 10-7/hr translates to a 99.99999% probability that no hazardously misleading outputs occurred in a given hour of operation. The TIR sets the target for determining which feared events need to be monitored in order to meet the specified Alert Limit (AL) at this level of probability. A lower TIR introduces a wider range of threats (i.e. feared events) that need to be monitored to improve confidence in the estimated position. Erroneous position estimates which do not meet the integrity criteria can then be omitted in the final positioning solution, allowing only the valid position estimates to be utilized, which also leads to higher accuracy.

9.1.1.2 Integrity Key Performance Indicators (KPIs)

The following KPIs for positioning integrity are defined for the study:

**Target Integrity Risk (TIR):** The probability that the positioning error exceeds the Alert Limit (AL) without warning the user within the required Time-to-Alert (TTA).

NOTE: The TIR is usually defined as a probability rate per some time unit (e.g. per hour, per second or per independent sample).

**Alert Limit (AL):** The maximum allowable positioning error such that the positioning system is available for the intended application. If the positioning error is beyond the AL, operations are hazardous and the positioning system should be declared unavailable for the intended application to prevent loss of integrity.

NOTE: When the AL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Alert Limit (HAL) or Vertical Alert Limit (VAL) respectively.

**Time-to-Alert (TTA):** The maximum allowable elapsed time from when the positioning error exceeds the Alert Limit (AL) until the function providing position integrity annunciates a corresponding alert.

The relationship between the KPIs and the Protection Level (PL), and their impacts on the positioning solution, are further examined below.

9.1.1.3 Integrity Protection Level (PL)

The Protection Level (PL) is a real-time upper bound on the positioning error at the required degree of confidence, where the degree of confidence is determined by the TIR probability.

The PL is defined as follows:

**Protection Level:** The PL is a statistical upper-bound of the positioning error (Pε) that ensures that, the probability per unit of time of the true error being greater than the AL and the PL being less than or equal to the AL, for longer than the TTA, is less than the required TIR.

**PL = Prob per unit of time (((ε> AL) & (PL<=AL)) for longer than TTA) < required TIR**

NOTE: When the PL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Protection Level (HPL) or Vertical Protection Level (VPL) respectively.

The PL is used to indicate the positioning system availability, as when the PL is greater than the AL, the system is considered unavailable (see Stanford Diagram below). The PL establishes a more rigorous upper bound on the positioning error by taking into consideration the additional feared events which have a lower occurrence (i.e. lower TIR) compared to the nominal events considered in the standard accuracy estimate alone. The lower the TIR, the more feared events that need to be considered.

Fault feared events are those which are intrinsic to the positioning system and typically caused by the malfunction of an element of the positioning system (e.g. constellation or ground network failures). Fault-free feared events occur when the positioning system inputs are erroneous, but the event is not caused by a malfunction of the positioning system. In the GNSS context for example, fault-free feared events include nominal effects experienced every day such as poor satellite geometry, larger atmospheric gradients, and signal interruption, all of which can degrade positioning performance without causing the system to fail. A common limitation of existing industry functional safety standards, as summarized in [2], is that only the fault conditions are considered. In practice, however, the fault-free conditions also have a material contribution to the total integrity risk budget and must therefore be monitored.

The PL is necessary to ensure all potential faults and fault-free events down to the required TIR are considered. It bounds the tails of the distribution with higher certainty (per unit of time) and provides a measure for ensuring only those positions whose positioning integrity has been validated within the TIR are included in the final positioning solution. By contrast, the standard accuracy estimate only considers a subset of feared events up to a nominal percentile (e.g. 2-sigma, 95%), based on the entire distribution of estimated position errors.

9.1.2.4 Relationship between the PL and KPIs

The TIR is a design constraint for a positioning system and represents the probability that a positioning error exceeds the AL, but the positioning system fails to alert the user within the required period of time (i.e. TTA). In practice, the TIR is very small. For example, <10-7/hr TIR (a common aviation requirement) translates to one failure permitted every 10 million hours (equivalent to 1142 years approximately).

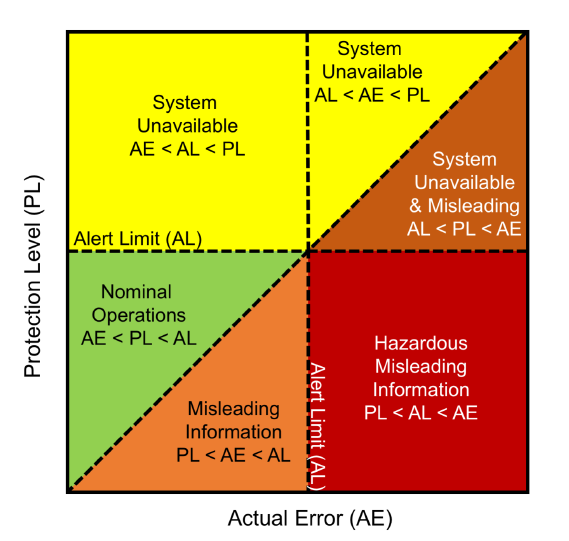
Integrity system failures are known as Integrity Events. An integrity event occurs when the positioning system outputs Misleading Information (MI) or Hazardous Misleading Information (HMI). MI occurs when, the positioning system being declared available, the estimated positioning error exceeds the PL but not the AL. Typically, positioning systems are designed to tolerate some level of MI, for example to account for communication latency when receiving network-assistance data, so as long as the system can operate safely within the AL. HMI occurs when, the positioning being declared available, the estimated positioning error exceeds the AL without annunciating an alert within the required TTA. To properly monitor for integrity in the positioning system, both the fault and fault-free conditions which potentially lead to MI or HMI need to be characterized for the network and the UE.

Figure 9.1.2.4-A illustrates the concept of integrity events (MI, HMI) with respect to the KPIs, PL and position error (PE).



**Figure 9.1.2.4-A:** Relationship between Position Error (PE), Protection Level (PL), Alert Limit (AL)   
and the MI and HMI integrity events [5][6].

A useful representation for interpreting the relationship between the Integrity KPIs and PL is the so-called Stanford Diagram [[7](#8q77eyvran0r)] in Figure 9.1.2.4-B. It should be noted that the Actual Error (AE) in this diagram (also referred to as the position error herein) is the difference between the true position and the estimated position, computed by the positioning device. In practice, the true position is not known.



**Figure 9.1.2.4-B:** Stanford Diagram for integrity events, adapted by [8].

Important observations can be made from Figure 9.1.2.4-B in the context of this study:

1. The conditions represented above the diagonal line (Nominal Operations, System Unavailable) mean the positioning system is operating as intended by correctly detecting when the system should or should not be available.
2. The conditions represented below the diagonal line mean the system is not operating as intended. These conditions are what the integrity system is designed to protect against, i.e. by monitoring the necessary fault and fault-free events to protect against MI or HMI for a given TIR. This concept is further described:
   * In the Stanford Diagram, the TIR is represented by the red block, i.e. the probability per unit of time of HMI occurring in the system. If any violation of the PL were considered an integrity event, i.e. anything below the diagonal line if the PL were equal to (P(AE >PL) < TIR), there would be zero tolerance in the system to recover from MI or HMI within the required TTA.

In practice, integrity systems are designed to tolerate some level of MI or HMI for a period of time within the TTA, without exceeding the TIR. This framework underpins the PL definition in this study (Section 9.1.1.3) and is particularly important for systems with communication latency, such as 3GPP, given assistance data can be monitored and sent by the network (i.e. the basis of this study). Sufficient time is therefore needed to signal that a fault is present. There is nothing prohibiting the TTA being set to zero for instantaneous detection, however a grace period must be accommodated to allow some level of functionality to be offloaded to the network when the network is utilized. Hence, the TTA depends on the overall integrity system design (including 3GPP and non-3GPP elements) and is specified by the positioning system owner (e.g. a vehicle manufacturer) alongside the TIR and AL.

1. Interpretations when the system is **available** (PL<AL):

* **Nominal Operations (AE<PL):** the solution is available and operating safely without an integrity event.
* **Misleading Information (AE>PL & AE<AL):** the solution is available but contains an MI integrity event due to AE>PL. It is still operating safely given AE does not exceed the AL.
* **Hazardous Misleading Information (AE>PL & AE>AL):** the solution is available but contains an HMI integrity event due to AE>AL. It is still declared safe (PL<AL) when it should not have been.

1. Interpretations when the system is **unavailable** (PL>AL):

* **System Unavailable, False Alert (AE<PL & AE<AL):** the solution is unavailable but is a false alert integrity event, given AE<AL.
* **System Unavailable (AE<PL & AE>AL):** the solution is unavailable and operating as intended without an integrity event given AE>AL was properly detected.
* **System Unavailable and Misleading (AE>PL & AE>AL):** the solution is unavailable and contains a MI (AE>PL) integrity event.

To summarize, the PL can also be considered an upper bound on the amount of the MI and HMI that can be tolerated within a system down to the required TIR.

---------------------------------------------------End Text Proposal-------------------------------------------------

**Proposal 3: Agree to adopt Sections 9.2.3, 9.3.1, 9.3.2 from RP-2006541 as baseline.**

**Proposal 4: Add the text proposal for Section 9.1.1 to the Skeleton TR.**

**Proposal 5: Add the definition of Integrity to Section 3.1 of the Skeleton TR.**

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| **Company** | **Do you support the proposals? Do you have any comments or proposed text edits?** |
| CATT | We support the proposal 3 and proposal 4. And we support to add the definition of terms to Section 3.1 of the Skeleton TR.  One question on the above text proposals:  1. Position Error (PE) is mentioned in Figure 9.1.2.4-A while Actual Error (AE) is mentioned in Figure 9.1.2.4-B. There is a note to describe the relationship of AE and PE: It should be noted that the Actual Error (AE) in this diagram (also referred to as the position error herein) is the difference between the true position and the estimated position, computed by the positioning device. But why are there two definitions, i.e. PE and AE? |
| Ericsson | We agree with all the three proposals, and some minor revisions are provided in the text proposal. On the question raised by CATT, we believe that the term PE is more suitable for the positioning 3GPP work, while to keep the originality of the Stanford Diagram, the term AE should be kept in the figure. The explanation is straightforward in the text, but the reasoning for two terms can be even more highlighted to shed more light. |
| vivo | We support proposal 3,4,5 with minor spelling change. |
| Intel | We support P3-P5.  1 same comments as CATT, What’s difference between PE here and AE in below figure? Seems they are same concept, and then can we use the same term?  2 The reference numbers in the TP should be added in section 2 of the 38.855, and then renumbering them. |
| Convida | Support P3-P5. TS 22.872 should be changed to TR 22.872. Also, add this to the references. |
| OPPO | Fine for P3.  For P4, now the TP above includes the definition of integrity KPI in 9.1.1.2, which according to P1/P5, should be a part of section 3.1, our understanding is that it means the section of 9.1.1.2 above would be moved to section 3.1 – based on that assumption, P4/5 is also fine for us (i.e., we assume no need for redundant part for the terminology definition).  Plus some minor rewording as above. |
| ZTE | We support all 3 proposals.  Agree with CATT. Based on our understanding, PE and AE are the same thing. We may need to aligning these two definitions. E.g. only use PE or AE in this TR.  One more comment about the definition of PL. From our point of view, ε stands for the positioning error. Hence, we wonder whether the definition should be modified shown below:  ***Protection Level:*** *The PL is a statistical upper-bound of the positioning error* ***(ε)*** *that ensures that.........(omitted)* |
| Huawei, HiSilicon | We generally agree with the proposals, but we have several concerns:  1. The use of “AE” is questionable, as raised by CATT.  2. We suggest to provide a brief introduction or explanation of serval concepts, including “integrity monitoring”, “feared events”, etc.  3. Other minor revisions are provided in the text proposal. |
| Apple | In general, we support the proposals, but we share the CATT concern about the confusion of PE and AE. From 3GPP perspective, the practical location system cannot provide AE, all the errors are just estimates based on probability. So, we need somehow avoid the term AE in the TR. Also, please find some inline comments above. |
| Sumitomo | Generally fine with the proposal. However, as commented by Apple, if it is possible, we also prefer to modify the equation for the definition of PL so that it can be mathematically correct and understandable. One of the examples is to take argmax of the probability w.r.t. PL like: PL = argmaxPL {*p* | *p* = Pr per unit of time (((ε> AL) & (PL<=AL)) for longer than TTA) < required TIR}  Note that we are not so confident what is the appropriate mathematical expression in actual TR. Also, even with the above expression, it is still not correct mathematical expression. Therefore, we don't intend to stick to the above equation expression. |
| Sony | In principle, we agree with all 3 proposals. |
| Nokia | The proposals are generally fine but we have the following comments:   * For the definition of integrity in Section 9.1.1, we think eventually the warning should be provided to the entity that is interested in consuming positioning information, which is not necessarily the UE. So we prefer to make the following text change:   **Integrity:** A measure of the trust in the accuracy of the position-related data provided by the positioning system and the ability to provide timely and valid warnings to the LCS client ~~UE and/or the user~~ when the positioning system does not fulfill the condition for intended operation.   * The TIR example in the following sentence is based on aviation requirement:   *For example, <10-7/hr TIR (a common aviation requirement) translates to one failure permitted every 10 million hours (equivalent to 1142 years approximately).*  However, given that aviation is not an identified use case in this SI, we suggest to use an example based on one of the agreed use cases  Similar to observations made by other companies, PE and AE seem to be the same to us, so alignment between terminologies is needed. |
| ESA | We support proposals 3, 4 and 5.  In section 9.1.1.1, as it is written it could mislead some readers and interpret that accuracy and integrity only differ because of the percentiles, so we propose to improve the explanation by changing the first sentence of the third paragraph:  From:  “Integrity is a method of bounding these errors to a much higher confidence.”  To:  “Each time a position is provided, integrity measures the trust on the provided position, so integrity is a method of bounding these errors and this can be done to a much higher confidence.”  We also agree that it would be better to align PE and AE terminologies.  We agree that the integrity warnings will need to be provided to the entity that is interested in consuming the positioning information. Hence, the integrity definition will need to be modified. |
| InterDigital | We support the 3 proposals. We also agree with Ericsson that the term ‘Position Error’ may be more suitable and 3GPP friendly than ‘actual error’. While AE may still be used in the Stanford Diagram and the accompanying text, further clarification may be needed when using PE and AE interchangeably in the subsequent sections.  For clarification and showing the relationship between PL and AE, we also think that a note may be included in the observations following the Stanford diagram, indicating that the instances where PL < AE (below diagonal line) can be considered as positioning failure events |

2.2.2 Use Cases (see Appendix A – Phase 1, Section 2.1)

**Moderators Summary**

There was good consensus from Swift, Huawei, ESA, Spreadtrum, Ericsson, Apple, Interdigital, Intel and OPPO to adopt the initial Automotive and Rail use case descriptions provided in R2-2006541. It was suggested to add further detail on why these use cases require integrity (Huawei, Intel, Samsung, Nokia), along with illustrative examples of the KPIs that could be expected on implementation (Huawei, ESA, Spreadtrum, CATT, Interdigital, Samsung). CATT suggested adopting a similar structure to TR 22.872, and Huawei suggested updating TR 22.872 with the examples identified through this study.

The moderator proposes to add ‘Section 9.2.4 - Use Case Summary’ to the Skeleton TR and the accompanying contents. Table 9.2.4 is primarily based on [9], as suggested by ESA, and supplemented by [8][10]. It summarises the typical KPI ranges to be expected on implementation for the Automotive and Rail use case categories.

Vivo, Spreadtrum, Apple, Intel, Oppo and Faunhofer noted that IoT use cases are now descoped from the study and this section can be removed. Ericsson, Sumitomo and Nokia acknowledged that RAT-Dependent IoT are descoped, but suggested there could be scope to consider outdoor IoT scenarios.

The moderator suggests that RAT-Dependent IoT use cases can be noted FFS in the ‘Use Case Summary’ text. If, however, there are specific RAT-Independent GNSS IoT scenarios to consider within the scope of this study, companies are requested to please propose these for consideration in Phase 2. Companies are also asked to propose text descriptions for the Rail use cases (Section 9.2.2), or to indicate if Table 9.2.4 alone is satisfactory to represent the general requirements.

**Phase 2 Text Proposal**

--------------------------------------------------Start Text Proposal--------------------------------------------------

9.2 Use Cases

RAT-Independent GNSS integrity monitoring has a long operational history in the field of civil aviation [11][12][13][14]. The integrity framework examined in this study extends beyond aviation, to address a broader suite of use case and architectural considerations for the 3GPP system. These concepts are further illustrated by the use case descriptions and KPIs provided below, including a particular focus on safety-critical and liability-critical applications, requiring the capability to validate the estimated position with greater trust.

Automotive and Rail have been highlighted as two industries which implement the most demanding safety-standards for positioning integrity. The following use case descriptions outline key integrity concepts and implications for users that require positioning integrity within their positioning system. An extended list of application examples is provided in the Use Cases Summary.

9.2.1 Automotive

9.2.1.1 Road-Level Identification and Road-User Charging

Positioning integrity is a key input to determining whether a road vehicle is traveling on a highway or a neighbouring access road (e.g. a collector-distributor lane). For example, consider a manufacturer wanting to ensure their Advanced Driver-Assistance Systems (ADAS) only activates when the vehicle is on a highway. This requires the UE to determine with a high degree of integrity which road the vehicle is traveling on, in order to avoid the potential for unintended ADAS functionality on the access road (or conversely to ensure the appropriate functionality has been activated on the highway). The road vehicle may also be subject to road-user charging with fees that vary depending which road is used, also requiring positioning integrity validation.

Consider an access road that is within 3 metres of a freeway, with a corresponding AL of 3 metres and TIR of 1 x10-7/hr specified by the vehicle manufacturer. The road vehicle connects to an integrity service provider via the mobile network to request UE-Based integrity assistance data. The assistance data is applied by the UE alongside its local positioning measurements in order to compute the real-time PL. So long as the PL remains below the AL, the positioning system is available and functioning as intended, and the road-level identification can be made safely. If the PL exceeds the AL, the impacted positioning system should be declared unavailable on the vehicle and a road-level determination is not possible. For example, a network-detected fault can be flagged in the integrity assistance data, resulting in a larger PL computed by the UE.

9.2.1.2 Lane-Level Identification

The same concepts and methods from 9.2.1.1 also apply to validating the lane in which the vehicle is traveling. Lane change warnings and manoeuvres are a crucial input to enabling various Levels of autonomy [32] which are illustrated in the 5GAA use case requirements [15], such as an AL of 1.5m and TIR of 1x10-7/hr or lower [10].

The ability to handle faults almost instantaneously on a road vehicle is absolutely critical in order to recover the situation and avoid a potential collision between lanes. The UE is responsible for monitoring localized events which need to be detected in the shortest time possible, i.e. ‘highly dynamic’ feared events (e.g. multipath, cycle slips and satellite feared events in the case of GNSS). The network is therefore used to monitor the low dynamic threats, which are less time-critical but still depend on a reliable communication channel with the UE. In the automotive and other 5G positioning use cases, the TTA is also far more stringent (e.g. 100ms in some cases) compared with an aviation TTA of 6 seconds (or slower) for precision approaches. Hence, the low latency of the 3GPP communications presents a strong synergy for supplying integrity assistance data that is secure and assured.

Once again, the positioning system should remain available unless the PL exceeds the AL, in which case the system should be unavailable and the corresponding ADAS functionality on the vehicle disengaged. To avoid an integrity event, any feared event with an occurrence probability higher than the TIR (i.e. >1x10-7/hr) needs to be detected and mitigated within the TTA[[1]](#footnote-1). The UE application is typically responsible for issuing alerts to inform the preventative or remedial actions required by the positioning system.

If a feared event occurs at the network or UE, the positioning system should be capable of determining its effect on the PL relative to the AL, within the required TTA, such that the position reported by the UE remains fault-free (i.e. even if the fault-free position leads to the system being unavailable). The TTA therefore represents the ability of the system to recover before being impacted by a potential integrity event. For some use cases, the TTA may simply be set to zero depending on the implementation requirements.

9.2.2 Rail

9.2.3 IoT

9.2.4 Use Case Summary

Table 9.2.4 is adapted from [9] and supplemented by [8][10]. It summarises the typical KPI ranges to be expected on implementation for the Automotive and Rail categories. Importantly, the KPIs are illustrative only; KPIs are typically specified by the positioning system owner on implementation (e.g. a vehicle OEM), taking into consideration the 3GPP and non-3GPP components of the system.

|  |  |  |  |
| --- | --- | --- | --- |
| **AUTOMOTIVE EXAMPLES** | | | |
| **APPLICATION CATEGORIES** | **TIR** | **AL** | **TTA** |
| **Safety-Critical Applications**   * Warnings (red light, obstacle, queue, curve speed, blind spot lane change, pedestrians etc) * Automated Driving (lane-level or better) * Emergency Brake Assist * Forward Collision Avoidance | Typical range:  ≥10-8/hr to ≤10-6/hr | Typical range: ≥1.5m to <5m | Typically ranges from 100s of milliseconds to <10 seconds |
| **Payment Critical Applications**   * Road User Charging (RUC) * Pay Per Use Insurance * Taxi Meter * Parking Fee Calculation | Typical range:  ≥10-6/hr to ≤10-4/hr | Typical range: ≥1.5m to <25m |
| **Regulatory Critical Applications**   * Hazardous Material Tracking * E-Call * Geofencing (e.g. low emission zone) |
| **Smart Mobility**   * Freight and Fleet Management * Cargo/Asset Management * Vehicle Access/Clearance * Emergency Vehicle Priority * Speed Limit Information * In-Vehicle Signage * Reduce Speed Warning * Dynamic Ride Sharing |
| **RAIL EXAMPLES** | | | |
| **APPLICATION CATEGORIES** | **TIR** | **AL** | **TTA** |
| **Safety-Critical Applications**   * Absolute Positioning * Train Awakening * Cold Movement Detector * Track Identification * Level Crossing Protection * Train Integrity and Train Length Monitoring | Typical range:  ≥10-9/hr to ≤10-8/hr | Typical range: ≥2.5m to <25m | Typically  <7s |
| **Liability-Critical Applications**   * Trackside Personal Protection * Management of Emergencies * Train Warning Systems * Infrastructure Charging * Hazardous Cargo Monitoring * On-Board Train Monitoring and Recording Unit * Traffic Management Systems | TBD | Typical range: ≥25m to <62.5m | Typically ranges from seconds to <30s |

Table 9.2.4: KPI examples for the Automotive and Rail use cases [8][9][10].

(NOTE: KPIs are defined by the positioning system owner on implementation)

---------------------------------------------------End Text Proposal-------------------------------------------------

**Proposal 6: Add the agreed Automotive and Rail use cases and latest text proposal to Section 9.2 of the Skeleton TR.**

**Proposal 7: Remove the IoT Use Case (Section 9.2.3) from the Skeleton TR.**

**Proposal 8: Add the proposed Use Case Summary Section (9.2.4) to the Skeleton TR.**

**Proposal 9: Add a note in the Use Case Summary (9.2.4) that IoT use cases are FFS.**

|  |  |
| --- | --- |
| **Company** | **Do you support the proposals? Do you have any comments or proposed text edits?** |
| CATT | We support all the proposals 6,7,8,9.  Few comments on the TP:  1. IoT in proposal 9 should be IIoT.  2. Integrity service level may be discussed in Use Case Summary. We need to discuss whether the parameters of TIR, AL and TTA are the service requirement in the use case, or they are assistant data. |
| Ericsson | We agree with Proposal 6, 8 and 9, however, we still think that keeping the IIoT use-case is valid, and can have its own sectioning, while the text of it can be short and refer to the FFS part. |
| vivo | We support proposal 6.7.8.9 |
| Intel | We support P6-9. |
| Convida | Support P6, P8-P9. However, we do not support P7 and suggest leaving it as a placeholder. Per the SID language, we suggest 9.2.3 should be renamed (I)IoT and an editor’s note for FFS. |
| OPPO | We support P6-P9.  For P6 and P8, although we are general fine with it, still wondering whether the KPIs needs to re-checked, e.g., the AL for lane-level identification, is “≥1.5m to <5m” enough, or should be smaller, e.g., less than 1m? |
| ZTE | We share the same view with CATT. |
| Huawei, HiSilicon | We agree with Proposal 6, 8, 9. For Proposal 7, we prefer to keep the IIoT use cases.  And we have several suggestions.  1. Suggest to move NOTE 1 and the last paragraph (as below) to 9.1.1.2, as it’s a common illustration of the integrity KPIs not only for automotive use cases.  If a feared event occurs at the network or UE, the positioning system should be capable of determining its effect on the PL relative to the AL, within the required TTA, such that the position reported by the UE remains fault-free (i.e. even if the fault-free position leads to the system being unavailable). The TTA therefore represents the ability of the system to recover before being impacted by a potential integrity event. For some use cases, the TTA may simply be set to zero depending on the implementation requirements.  2. We’d better ask SA for the suggestion on the proposed Use Case Summary. |
| Apple | We agree with all proposals. In additional, we think SA1 may need to be involved for the work on use case and related KPI requirements. |
| Sumitomo | We agree with Proposal 6, 8, 9. For Proposal 7, we also prefer to keep the IIoT section as it is. It could be described as FFS. |
| Sony | We support Proposal 6,8, – 9. IoT still important. |
| Nokia | Agree with P6, P8, and P9.  For P7, we must point out that some IIoT use cases are operating in outdoor where GNSS positioning is still applicable, so we prefer to keep it in accordance to the RAN2 agreement. Also, Section 9.2.3 should be renamed as “Industrial IoT”.  The text for the section 9.2.3 can be FFS. |
| ESA | We support proposals 6, 8, and 9.  In addition, note that the documents employed as reference for the automotive and rail use cases also inlcude requirements for the availability of the system, that is, the percentage of time when PL<AL. Without any availability requirement, for example, a PL of several kilometers would always bound the error and satisfy the other requirements. Hence, we propose to include availability as an additional KPI. |
| InterDigital | We agree with Proposal 6, 8 and 9. We also agree with Ericsson, Convida and Huawei for retaining the IIoT use cases |

2.2.3 Integrity Error Categories (see Appendix A – Phase 1, Section 3)

**Moderators Summary**

ESA, CATT, Intel and Nokia proposed to remove the RAT-Dependent clause in Section 9.3.2 given RAT-Dependent is no longer in scope of the study. ESA proposed to include in the Skeleton TR the headings and categories of error sources agreed in R2-2008263, under a new sub-heading for GNSS (9.3.1.1). ESA also proposed to include as FFS the Jamming and Spoofing considerations for ‘External feared events’, and the GNSS receiver design faults, GNSS receiver noise and Incorrect reception and decoding of GNSS assistance data considerations for the ‘UE faults’.

**Phase 2 Text Proposal**

---------------------------------------------------Start Text Proposal-------------------------------------------------

9.3 Positioning Integrity Error Categories

9.3.1 RAT-Independent

9.3.1.1 GNSS

9.3.1.1.1 Faults in the correction data

1. Incorrect computation by the provider
2. External feared event impacting the provider

9.3.1.1.2 Faults in transmitting the data to the UE

1. Data integrity faults

9.3.1.1.3 External feared events

1. Satellite feared events
2. Atmospheric feared events
3. Multipath
4. Jamming
5. Spoofing

9.3.1.1.4 UE faults

1. GNSS receiver design faults
2. GNSS receiver noise
3. Incorrect reception and decoding of GNSS assistance data

---------------------------------------------------End Text Proposal-------------------------------------------------

**Proposal 10: Agree to remove Section 9.3.2 (RAT-Dependent) from the Skeleton TR.**

**Proposal 11: Add the agreed headings on error sources from R2-2008263 to Section 9.3.1 of the Skeleton TR.**

**Proposal 12: Add the updated headings (9.3.1.1, 9.3.1.1.3 d/e, 9.3.1.1.4 a/b/c) to Section 9.3.1 of the Skeleton TR.**

|  |  |
| --- | --- |
| **Company** | **Do you support the proposals? Do you have any comments or proposed text edits?** |
| CATT | Yes. |
| Ericsson | Agree with all proposals |
| vivo | Yes |
| Intel | Agree. |
| Convida | Yes |
| OPPO | Yes |
| ZTE | Yes |
| Huawei, HiSilicon | Yes. |
| Apple | Yes |
| Sony | Yes |
| Nokia | Yes |
| ESA | Yes, agree with all proposals. |
| InterDigital | Yes |

2.2.4 Protocol Impacts (see Appendix A – Phase 1, Section 3)

**Moderators Summary**

ESA, CATT, Intel and Nokia proposed to remove the RAT-Dependent clause in Section 9.4.2 as RAT-Dependent is no longer in scope of the study.

**Phase 2 Text Proposal**

---------------------------------------------------End Text Proposal-------------------------------------------------

9.4 Positioning Integrity Methods

9.4.1 RAT-Independent

---------------------------------------------------End Text Proposal-------------------------------------------------

**Proposal 13: Remove Section 9.4.2 (RAT-Dependent) from the Skeleton TR.**

|  |  |
| --- | --- |
| **Company** | **Do you support the proposals? Do you have any comments or proposed text edits?** |
| CATT | Yes. |
| Ericsson | Yes |
| vivo | Yes |
| Intel | Yes |
| Convida | Yes |
| OPPO | Yes |
| ZTE | Yes |
| Apple | Yes |
| Sony | Yes |
| Nokia | Yes |
| ESA | Yes |
| InterDigital | Yes |

2.2.5 Protocol Impacts (see Appendix A – Phase 1, Section 2.2)

**Moderators Summary**

There was strong consensus to establish Table 9.5 as the initial baseline. Huawei and CATT suggested specific impacts to each specification should be outlined, and that any impacts to specifications outside of RAN should be identified. Ericsson, Apple, OPPO, Fraunhofer and Nokia indicated that the study should first investigate the integrity concepts and architecture for handling integrity, before specific impacts to the specifications can be detailed. Further, it was noted that the specification impacts will depend on the outcomes from discussing the remaining study objectives. Ericsson, Intel and Nokia also queried whether broadcast will be supported (leading to TS 38.331 impacts), which is FFS.

The moderator recognizes that further detail on the proposed impacts to the specifications are needed to inform the scope of the future WID. It is also recognized that further discussion on the integrity concepts and associated methods for monitoring and reporting integrity parameters is needed before the specification impacts can be fully considered and proposed. These impacts will be a core focus of Section 9.4 (Integrity Methods) when it comes to analyzing the network-assistance data and procedures, but the specification impacts cannot be full detailed until this analysis and discussion is completed. It is suggested to rename the Remarks column to ‘Anticipated Impacts’ and to leave this as a placeholder for noting the potential impacts upon completing the remaining objectives of the SI.

**Phase 2 Text Proposal**

-------------------------------------------------Start of text proposal------------------------------------------------

|  |  |  |  |
| --- | --- | --- | --- |
| **Impacted TS/TR** | | | |
| TS/TR | Vers | Title | Anticipated Impacts |
| TS 38.305 |  | Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN |  |
| TS 38.331 |  | NR; Radio Resource Control (RRC); Protocol specification |  |
| TS 37.355 |  | LTE Positioning Protocol (LPP) |  |
| TS 38.455 |  | NR Positioning Protocol A (NRPPa) |  |

Table 9.5 – Anticipated impacts to RAN specifications

---------------------------------------------------End Text Proposal-------------------------------------------------

**Proposal 14: Add Table 9.5 to Section 9.5 of Skeleton TR.**

|  |  |
| --- | --- |
| **Company** | **Do you support the proposals? Do you have any comments or proposed text edits?** |
| CATT | The service levels in SA and Qos&alarm in CT specs will be impacted for service level from AMF and alarm to AMF if there is agreement on QoS in use case analysis.  SA : TS 22.261, TS 23.273  CT : TS 29.572 |
| Ericsson | Agree with Proposal 14 |
| vivo | Agree with Proposal 14 |
| Intel | Agree with P14. |
| Convida | Support P14 for the RAN2 perspective. There may be impacts outside of our scope (CT, SA). For 38.305 and 38.455, we suggest using the full titles as shown below, respectively:   * NG Radio Access Network (NG-RAN); Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN * NG-RAN; NR Positioning Protocol A (NRPPa)   The version column may not be necessary as we are using Rel-16 specs as a starting point. The table heading could reflect this, e.g. “Impacted Release 16 TSs/TRs” |
| OPPO | Yes |
| ZTE | Agree with proposal 14. |
| Huawei, HiSilicon | For the spec impacts in RAN, we are ok with the above proposals  We think some other specs impact should also be considered.   * SA specs impacts:   + SA1 needs to capture the integrity definitions, KPIs and use cases.   + SA2 needs to specify the system level procedure for integrity. * CT specs impacts: * CT4 needs to define the QoS in the LCS request. * CT4 needs to define the alert from LMF to LCS client. * OMA impacts:   + OMA needs to define the QoS for integrity and alert, similar to the CT impacts. |
| Apple | We share the same view with Huawei. Impact to other WGs could also be considered. |
| Sony | Yes |
| Nokia | Yes |
| ESA | Agree with proposal 14. |
| InterDigital | Yes, since the impacted specifications in the table are within the scope of RAN |

3 Conclusion

4 References

1. [R2-2008125](http://www.3gpp.org/ftp/TSG_RAN/WG2_RL2/TSGR2_111-e/Docs/R2-2008125.zip), Report from session on positioning and sidelink relay, Session Chair (MediaTek).
2. [R2-2006541](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_111-e/Docs/R2-2006541.zip), TP for Study on Positioning Integrity and Reliability, Swift Navigation, Deutsche Telekom, u-blox, Ericsson, Mitsubishi Electric, Intel Corporation, CATT, UIC.
3. RP-202094, Revised SID: Study on NR Positioning Enhancements, CATT, Intel Corporation
4. RP-202080, Moderator's summary for email discussion [89E][25][R17\_positioning\_scope] Final Round, CATT.
5. Zhu, N., Marais, J., Betaille, D., Berbineau, M, “GNSS Position Integrity in Urban Environments: A Review of Literature”, IEEE Transactions on Intelligent Transportation Systems, Vol. 19, No. 9, Sep 2018.
6. Chowdhury, D, “Integrity Concept for the Safe Operation of the Swift Navigation Positioning System”, Swift Navigation, <https://www.swiftnav.com/integrity-concept-safe-operation-swift-navigation- positioning-system>.
7. European Space Agency, “Integrity”, Navipedia, 2018, <https://gssc.esa.int/navipedia/index.php/Integrity>.
8. Reid, T., Houts, S., Cammarata, R., Mills, G., Agarwal, S., Vora, A., Pandey, G, “Localization Requirements for Autonomous Vehicles,” SAE International Journal of Connected and Automated Vehicles, Vol. 2, No. 3, pp. 173–190, Sep 2019.
9. GSA-MKD-RL-UREQ-250286, “Report on Rail User Needs and Requirements: Outcome of the European GNSS’ User Consultation Platform”, Issue/Revision: 2.0 Date: 01/07/2019 <https://www.gsc-europa.eu/sites/default/files/sites/all/files/Report_on_User_Needs_and_Requirements_Rail.pdf>
10. 5GAA Draft TR A-200118, “High Accuracy Positioning for C-V2X”, WG2 System Architecture and Solution Development, 2020.
11. Global Positioning System Wide Area Augmentation System (WAAS) Performance Standard, Department of Transportation USA, Federal Aviation Authority, Edition 1, October 2008.
12. International Civil Aviation Organization, “Annex 10 to the Convention on International Civil Aviation, Aeronautical Telecommunications: International Standards and Recommended Practices”, 2006.
13. RTCA DO-178C, “Software Considerations in Airborne Systems and Equipment Certification,” 2011.
14. DO-229D, RTCA, "RTCA DO-229D Minimum Operational Performance Standards for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment," 2013.
15. 5GAA, “C-V2X Use Cases: Methodology, Examples and Service Level Requirements”, 2019.

# Appendix A – Phase 1 Summary

This document addresses the agreements, open issues and draft TP for Phase 1 of the following email discussion:

* [Post111-e][626][POS] Integrity use cases and specification impacts (Swift)

Scope: Capture any additional integrity use cases and open issues on integrity, and draft a TP incorporating the existing agreements and any further progress.

Intended outcome: Summary to next meeting

Deadline: Long

The agreements from RAN2#111-e are provided below [1]:

**Agreements:**

1. Agree to adopt the Target Integrity Risk (TIR), Alert Limit (AL) and Time-to-Alert TTA) as the Integrity KPIs.

2. Agree to the following definitions of the KPIs:

**Target Integrity Risk (TIR):** The probability that the positioning error exceeds the Alert Limit (AL) without warning the user within the required Time-to-Alert (TTA).

NOTE: The TIR is usually defined as a probability rate per some time unit (e.g. per hour, per second or per independent sample).

**Alert Limit (AL):** The maximum allowable positioning error such that the positioning system is available for the intended application. If the positioning error is beyond the AL, operations are hazardous and the positioning system should be declared unavailable for the intended application to prevent loss of integrity.

NOTE: When the AL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Alert Limit (HAL) or Vertical Alert Limit (VAL) respectively.

**Time-to-Alert (TTA):** The maximum allowable elapsed time from when the positioning error exceeds the Alert Limit (AL) until the function providing position integrity annunciates a corresponding alert.

3. Agree to include the PL integrity definition with the following baseline; FFS if updates are needed.

**Protection Level:** The PL is a statistical upper-bound of the positioning error that ensures that, the probability per unit of time of the true error being greater than the AL and the PL being less than or equal to the AL, for longer than the TTA, is less than the required TIR.

NOTE: When the PL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Protection Level (HPL) or Vertical Protection Level (VPL) respectively.

4. The additional definitions are FFS on a ‘need-to-define’ basis.

5. Agree to study the Automotive, IIoT and Rail use cases as illustrative examples.

6. Agree to the Skeleton for Section 9 of TR 38.857.

The agreements have been included in the draft text proposal in Section 3 below. The open issues are further discussed in Section 2 below, providing additional considerations for the draft TP.

# 2 Open Issues

The following open issues are presented for discussion and inclusion in the draft TP.

2.1 Use Cases

Three use cases were agreed as illustrative examples of integrity in the draft TP – Automotive, IIoT and Rail [1]. Companies are asked to comment and/or provide suggested text for the TP, with a view to describing the application of integrity to these use cases in accordance with the study objectives.

|  |  |
| --- | --- |
| **Company** | **Please comment on the integrity use case descriptions (Automotive, IIoT, Rail)** |
| Swift Navigation | For the **Automotive** use case, we propose to adopt the Road-Level and Lane-Level Identification text provided in **Section 9.4.1** of [RP-2006541](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_111-e/Docs/R2-2006541.zip) [2], to illustrate the integrity KPIs and core integrity concepts in practice. |
| Huawei, HiSilicon | First, we propose to provide some description on why these use cases should be guaranteed with the integrity requirements, e.g.,  *“Integrity” should be specified for safety-critical or liability-critical applications, in terms of insurance of the quality of service.*  Second, for each use cases– Automotive, IIoT and Rail, we expect to study the corresponding integrity requirements and capture the corresponding KPIs (AL, TIR, TTA) by some exemplary values, which can be reflected in TR 22.872 Table 6.1-1. |
| vivo | According to RAN #89 e-meeting, RAT-dependent integrity was excluded from the study scope. So IIoT which is using indoor positioning should be removed as well. |
| ESA | For the **automotive** use case, we propose to complete the Road-Level and Lane-Level Identification text (section 9.4.1 of RP-2006541) with the summary of automotive use cases provided in section 4.1.3 of [R2-2007646](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_111-e/Docs/R2-2007646.zip).  With respect to the **rail** use case, we propose to illustrate the integrity KPIs with the text provided in section 4.2 of [R2-2007646](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_111-e/Docs/R2-2007646.zip). |
| Spreadtrum | RAT-dependent integrity is not in the scope based on RAN#89-E. So IIOT can be removed. For automotive, we think that the text provided in R2-2006541 can be a baseline. We propose to add a table to list KPIs clearer. For rail, the text in R2-2007646 can be a baseline. We think the text for both automotive and rail should have same style. |
| CATT | We propose to describe the use cases analysis following the structure of TR 22.872 (Study on positioning use cases (R16)).  x.1 Description  x.2 Pre-conditions  x.3 Service Flows  x.4 Post-conditions  x.5 Potential Requirements  Potential requirement of integrity KPIs will be specified in the TP, e.g. the level of integrity, integrity risk, and time to alarm. |
| Ericsson | We agree with the **Automotive** use-case text proposal suggested by Swift Navigation. For the **Industrial IoT** use-case, we have previously provided the TP in R2-2006954, which is in line with the automotive TP use-case, provides also Path and Zone Identification for AGV, and sheds some light on how integrity KPIs and concepts can benefit this use-case.  While the RAT-dependent positioning integrity is down prioritized by RAN, we still suggest to keep the same sectioning as per the agreements made in RAN2-111 to include IIOT as one of the use case, and with a sentence just indicating or a paragraph that this topic would not be studied within Rel.17 SI. |
| Apple | For the V2X and rail use cases, we agree to use related text in R2-2006541 and R2-2007646 as the baseline for the Text proposal. For IIOT case, I think we can postpone this use case to the next release as RAT-dependent positioning integrity is removed from the SID. |
| InterDigital | As in the suggested texts for Automotive use cases by Swift, we are fine to mention exemplary values for KPIs, i.e., TIR, AL and TTA. |
| Intel | Agree to use in Section 9.4.1 of [RP-2006541](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_111-e/Docs/R2-2006541.zip) as baseline for automotive use case. But at the beginning of section 9.4, Agree with Huawei, we need to add the general descriptions on “Integrity” is needed for safety-critical or liability critical applications.  For IIoT use case, agree with vivo, RAT independent positioning is not applicable for IIoT since IIoT is for indoor scenario. |
| Samsung | Have the same view on the need of explanation on why the integrity is necessary on those 3 use cases in the TP with Huawei. And also it will be helpful to have some example values of each possible KPIs for each use cases. |
| OPPO | While we are generally fine to include the use case analysis in the TR, specifically, considering the RAN#89-E decision on limiting to GNSS based positioning   * For V2X, considering we have an V2X positioning study in R17 @ RAN level, and probably as R18 WG level work, the overlapping issue has to be taken into account. E.g., the assumption of this study in R17 positioning is by assuming existing GNSS based positioning being used for V2X. * For IIoT, as commented above, it seems collides with the RAN#89-E decision on focusing on GNSS-based method. |
| Sumitomo Electric | Same view as Ericsson. Regarding IIOT use case, we think describing TP at this timing is still useful to illustrate one of the usecase examples for integrity. |
| Fraunhofer | Given that we do not study integrity of RAT-dependent positioning methods and the IIoT case relies on RAT-dependent positioning methods, we can remove the IIoT from the illustrative use cases of Rel. 17. |
| Nokia | It is preferred to outline the motivation of using integrity in each of the agreed use cases. For examples, the consequence of positioning integrity failure for each use case should be highlighted.  Regarding IIoT, we do not think there is a necessity to remove the section even though RAT-dependent method is no longer in the scope. We may still have applications such as motion control in outdoor scenarios, and it may shed some light on RAT-dependent methods if it is discussed in the future release. |

2.2 Protocol Impacts

There was general consensus in the email discussions to review the protocol impacts to the RAN positioning specifications in the SI, in order to inform potential changes as part of the subsequent WI. The following table is therefore proposed for inclusion in Section 9.5 of the draft TP below. Protocol impacts to other specification groups (e.g. SA, CT, OMA) can be considered if a need is identified through the SI findings.

-------------------------------------------------Start of text proposal------------------------------------------------

|  |  |  |  |
| --- | --- | --- | --- |
| **Impacted TS/TR** | | | |
| TS/TR | Vers | Title | Remarks |
| TS 38.305 |  | Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN |  |
| TS 38.331 |  | NR; Radio Resource Control (RRC); Protocol specification |  |
| TS 37.355 |  | LTE Positioning Protocol (LPP) |  |
| TS 38.455 |  | NR Positioning Protocol A (NRPPa) |  |

Table 9.5 – Impacted RAN specifications.

--------------------------------------------------End of text proposal------------------------------------------------

Companies are asked to comment if they agree with the table of specifications.

|  |  |
| --- | --- |
| **Company** | **Do you agree with the specification list for the SI phase?** |
| Swift Navigation | Yes. |
| Huawei, HiSilicon | Generally agree.  1) We also think the specific impacts on the listed specs should be provided.  38.305, 37.355 and 38.455 impacts:   * + Capture the integrity definitions and relevant KPIs.   + Capture the integrity assistance data that required to be transferred to/from UE or LMF.   + Capture measurements for integrity.   + Capture general procedure for supporting integrity.   2) Some other specs should also be listed.   * SA specs impacts:   + SA1 needs to capture the integrity definitions, KPIs and use cases.   + SA2 needs to specify the system level procedure for integrity. * CT specs impacts: * CT4 needs to define the QoS in the LCS request. * CT4 needs to define the alert from LMF to LCS client. * OMA impacts: * OMA needs to define the QoS for integrity and alert, similar to the CT impacts. |
| vivo | Yes |
| ESA | Yes |
| Spreadtrum | Yes. Only a few impacts to 38.331 because RAT-dependent integrity is not in the scope based on RAN#89-E. |
| CATT | Yes, agree.  Furthermore, the service levels in SA and Qos and alarm in CT specs will be impacted, because of service level from AMF and alarm to AMF:  SA: TS 22.261, TS 23.273  CT: TS 29.572 |
| Ericsson | Unicast integrity support:   * LPP + Stage 2   Broadcast integrity support   * LPP, NRPPa, Stage 2, RRC   We need to still study if various QoS levels/integrity levels are required or not. If there is no such classification then there are no impacts for SA or CT groups. |
| Apple | Instead of list what specification needs change, I think RAN2 need first illustrate the exact architecture and protocols for this work(e.g., any new interface or any new protocol/signaling expected). Then, the impact to the spec can be determined. |
| InterDigital | Yes, from RAN2 perspective |
| ZTE | Yes |
| Intel | Not quite sure what impact will be for TS38.331? i.e. whether the broadcast of integrity should be supported. |
| Samsung | Yes |
| OPPO | On the one hand, as commented by Apple, before concluding on the spec impact (which is normally done for WID after study conclusion), it is preferred that we should start from identifying the exact architecture and protocols used to implement the integrity, then one can answer the question whether there is some change to a spec (including the question from intel on 331), so that the spec impact could be briefed/illustrated for each TS.  On the other hand, if the intention of rapporteur is to reflect this in “Integrity Concepts” section, which is also fine for us. |
| Sumitomo Electric | Yes |
| Fraunhofer | We agree with Apple, the potential impact on the TS/TR is subject to the outcome of the work item that follows the study item. In particular, the general framework for handling integrity needs to be discussed and agreed upon first. |
| Nokia | For the time being it is okay to list them as the “potential” list of specifications that will be impacted. Whether they will be impacted depends on what architecture/procedures that RAN2 adopts eventually. As raised by Intel, so far it is unclear if we will support broadcast-based integrity and this is still questionable if we need to change TS38.331. |

2.3 Integrity Concepts

The Tdoc submissions and email discussions contained information and questions relating to the core integrity concepts and how these concepts will be interpreted and defined within the 3GPP system. The core integrity concepts are therefore important inputs for addressing the remaining objectives (e.g. to categorize the errors, to specify the integrity methodologies, to identify the protocol impacts and to support the definition of more ‘3GPP-friendly’ descriptions throughout the SI/WI). Companies are asked to comment on key topics to be addressed in the integrity concepts.

|  |  |
| --- | --- |
| **Company** | **Please identify the integrity concepts to be considered in the study** |
| Swift Navigation | We believe the Integrity Concepts (Section 9.1.2 of the Skeleton TR) should cover the following topics:   1. **What is positioning integrity?** 2. **Interpretation and relationship between the Protection Level and KPIs.**    1. Including the Stanford Diagram conceptual framework.   We think (1) and (2) can be addressed in part by including the text and diagrams from **Section** **9.2.3** (Accuracy versus Integrity), **Section 9.3.1** (KPI Descriptions), and **Section** **9.3.2** (Stanford Diagram) in [RP-2006541](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_111-e/Docs/R2-2006541.zip) [2]. |
| Huawei, HiSilicon | We think several issues should be illustrated for the integrity concepts.  1) Definition or explanation of threat models and failure modes.  2) The general system framework for positioning integrity should be captured.  3) How to conduct integrity validation according to the obtained information or assistance data, e.g. error sources, measurement results, calculated PL? Related signalling flow should be identified. |
| vivo | We prefer define integrity assisted data in more details like which information should be included and how does these information impact on integrity |
| ESA | We agree with Swift’s proposal of using RP-2006541 sections 9.2.3, 9.3.1 and 9.3.2 as a baseline for explaining the integrity concepts. To improve that baseline few recommendations are listed below:   * Section 9.2.3, *“For example, a Target Integrity Risk (TIR) of 10-7/hr translates to a 99.99999% probability that no hazardously misleading outputs occurred in a given hour of operation, which is a common requirement in aviation and automotive use cases”*. Because there are a wide range of automotive use cases with different requirements and, even in the safety-critical applications, there is no “usual” integrity risk, we propose to remove *“and automotive use cases”* from text above. * We propose to include in the integrity concepts a general explicit description of what we understand by position integrity. Something like the following text (from ETSI TS 103 246-3 V1.2.1 (2017-03)):   “The integrity of an estimated position is understood as the measure of the trust in the accuracy of the location-related data provided by the location system and the ability to provide timely and valid warnings to users when the location system does not fulfil the condition for intended operation.”   * In the second paragraph of section 9.3.1: add a paragraph on fault feared events as means of contrast to the fault free feared events line.   “   * *Fault feared events include any intentional or unintentional event that causes the malfunction of the system such as interference in GNSS frequency bands and spoofing events.*   ” |
| Spreadtrum | We generally agree with Swift’s proposal of using RP-2006541 sections 9.2.3, 9.3.1 and 9.3.2 as a baseline for explaining the integrity concepts. It is good to add the improvements provided by ESA. |
| CATT | We propose to illustrate:  1. the framework including the networks who collect errors and 3GPP positioning network.  2. the concepts of errors before addressing the remaining objectives (e.g. to categorize the errors). |
| Ericsson | We agree with the suggested additions by Swift Navigation to the TR. |
| Apple | We agree with Swift’s proposal of using RP-2006541 sections 9.2.3, 9.3.1 and 9.3.2 as a baseline. We also agree the additional descriptions provided by ESA. |
| InterDigital | We agree with Swift that explanations of integrity and KPIs are needed. We also agree with Swift that 9.2.3 is a good TP as the starting point to illustrate how integrity can provide confidence for positioning accuracy, and explain that the percentile performance does not guarantee overall confidence level. The Stanford Diagram provides a sufficient method to capture relationship between Protection Level and KPIs. Exemplary system behaviors of “system unavailable” can be explained here. |
| ZTE | We share the similar view with Swift Navigation. Introduction of positioning integrity and relationship between the PL and KPIs should be included in the integrity concept part.  Considering that the clause 9 is about the positioning integrity, we do not prefer to add too much description about accuracy in the clause 9.1.  We also believe that the Stanford Diagram is a great figure to illustrate different system conditions. Before we add the Stanford Diagram, we prefer to introduce some needed definitions like MI and HMI, more detail description from our side can be found in R2-2007937 and R2-2007938 .  We prefer to discuss whether to modify the definition of the protection level or add more description of the protection level in the related content. In our opinion, the current definition is not easy to understand. At least we should add the formula (provided by ESA) which may let readers have a better understanding of this definition.   * + P(ε > PL) < **Irisk**   + Prob per unit of time (((ε> AL) & (PL<=AL)) for longer than TTA) < **required TIR** |
| Intel | In general, we agree to use the text and diagrams from Section 9.2.3 (Accuracy versus Integrity), Section 9.3.1 (KPI Descriptions), and Section 9.3.2 (Stanford Diagram) in RP-2006541 [2] as baseline for the descriptions of Integrity concept.  Regarding the assistance data details, signaling flow, and how to handle KPIs in 3GPP, these should be further discussed under the SI/WI. |
| Samsung | I agree with the above Swift navigation’s comment, in general. However, 3GPP positioning has the baseline that UE measures the PRS and report the measurement result to the LMF (UE-assisted), or UE measures and calculate the position by itself (UE-based). So we wonder how those measurement results can be associated to the calculation of AL and PL. Normally AL seems to be understood easily while PL is not. So it is helpful to have some exemplary values on each KPIs. Even though there are some examples on the usage of the KPI metrics 9.4 in R2-2006541, still difficult to see the big picture of PL/AL calculation from 3GPP positioning perspective. |
| OPPO | While in general we are fine with the proposal from swift, we share the view from CATT. |
| Fraunhofer | In general, we agree with Swift’s proposal. In addition, discussions and alignment around general framework including signaling, entities involved in computing integrity parameters and exchanges and so on are needed. |
| Nokia | The new sections suggested by Swift navigation are okay, but we think the following should be studied and captured to comprehend integrity concept in 3GPP framework:   * Which entity provides AL? * Which entity provides PL? * What information should be exchanged/transferred to assist PL calculation?   The signaling aspects of these metrics (source and target entities) |

# 3 Text Proposal

The following section incorporates the existing agreements as text proposals within the agreed Skeleton.

-------------------------------------------------Start of text proposal------------------------------------------------

9 Positioning integrity and reliability

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

9.1 Integrity Overview – Background Information

9.1.1 Integrity Definitions

**Target Integrity Risk (TIR):** The probability that the positioning error exceeds the Alert Limit (AL) without warning the user within the required Time-to-Alert (TTA).

NOTE: The TIR is usually defined as a probability rate per some time unit (e.g. per hour, per second or per independent sample).

**Alert Limit (AL):** The maximum allowable positioning error such that the positioning system is available for the intended application. If the positioning error is beyond the AL, operations are hazardous and the positioning system should be declared unavailable for the intended application to prevent loss of integrity.

NOTE: When the AL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Alert Limit (HAL) or Vertical Alert Limit (VAL) respectively.

**Time-to-Alert (TTA):** The maximum allowable elapsed time from when the positioning error exceeds the Alert Limit (AL) until the function providing position integrity annunciates a corresponding alert.

**Protection Level:** The PL is a statistical upper-bound of the positioning error that ensures that, the probability per unit of time of the true error being greater than the AL and the PL being less than or equal to the AL, for longer than the TTA, is less than the required TIR.

NOTE: When the PL bounds the positioning error in the horizontal plane or on the vertical axis then it is called Horizontal Protection Level (HPL) or Vertical Protection Level (VPL) respectively.

9.1.2 Integrity Concepts

[TBC in Section 2 - Open Issues]

9.2 Use Cases

9.2.1 Automotive

[TBC in Section 2 - Open Issues]

9.2.2 Industrial IoT

[TBC in Section 2 - Open Issues]

9.2.3 Rail

[TBC in Section 2 - Open Issues]

9.3 Positioning Integrity Error Categories

9.3.1 RAT-Independent

9.3.2 RAT-Dependent

9.4 Positioning Integrity Methods

9.4.1 RAT-Independent

9.4.2 RAT-Dependent

9.5 Procedure and protocol impact analysis

[TBC in Section 2 - Open Issues]

--------------------------------------------------End of text proposal------------------------------------------------

Please provide any additional comments on the text proposal:

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ESA | Section 9.1.1 should be removed and definitions should be added to the Section 3.1 of TR 38.857.  Sections 9.3.2 and 9.4.2 should be removed to keep the ToC aligned to the SID objectives (i.e., RAT-dependent is no longer applicable when it comes to studying integrity in the position domain)  In Section 9.3.1 should introduce a 9.3.1.1 GNSS (3GPP positioning protocols support other RAT-independent techniques besides GNSS). Still in Section 9.3.1, under the proposed 9.3.1.1. GNSS, add the 4 categories of GNSS faults that were agreed at the last meeting (see below). In addition, R2-2007647 analyses several other faults under External feared events and UE faults categories. These faults, very impactful on position integrity, were recommended for further study in email discussion on Integrity Error Sources – R2 – 2008263.  9.3 Positioning Integrity Error Categories  9.3.1 RAT-Independent  9.3.1.1 GNSS  9.3.1.1.1 Faults in the correction data e.g.  a. Incorrect computation by the provider  b. External feared event impacting the provider  9.3.1.1.2 Faults in transmitting the data to the UE, e.g  a. Data integrity faults  9.3.1.1.3 External feared events, e.g.  a. Satellite feared events  b. Atmospheric feared events  c. Multipath  d. Jamming (FFS)  e. Spoofing (FFS)  9.3.1.1.4 UE faults  a. GNSS receiver design faults (FFS)  b. GNSS receiver noise (FFS)  c. Incorrect reception and decoding of GNSS assistance data (FFS) |
| CATT | The clauses of RAT- Dependent (e.g. 9.3.2 and 9.4.2) can be deleted because RAT-Dependent of integrity was excluded in SID after RAN #89-e meeting. |
| Ericsson | We can still keep the use case for IIOT as it has been already agreed; we can add remark saying RAT dependent integrity is not in scope of Rel-17. |
| Intel | Agree with ESA:  1 the definition in 9.1.1 shall be moved to 3.1;  2 the section Sections 9.3.2 and 9.4.2 should be removed since RAT dependent positioning methods have been excluded from the SI.  Regarding the sub-section under 9.3.1, it is related to whether for RAT independent positioning methods, we will only consider GNSS or, also consider other methods, e.g. WIFI/Bluetooth, etc. So far, we can keep it as it is. |
| Nokia | We can remove sections on RAT-dependent methods (9.3.2 and 9.4.2), based on the latest agreement in RAN #89e. On the other hand, we think the use case of IIOT can be kept. |

1. NOTE: If the lane-level requirement was simply specified by the accuracy estimate (e.g. <1.5m at the 95th percentile), 5% of the estimated positions may still be impacted by feared events which far exceed the required AL, potentially leading to an integrity event. Integrity KPIs are instead used to define probabilities of failure over a given period of time rather than relying on the combined statistical distribution of the estimated positions (which are potentially contaminated by fault and fault-free events that go undetected). The integrity methodologies allow an integrity risk to be allocated based on the probability of occurrence for each feared event, and then quantified as a contribution to the total TIR. This ensures only the integrity-validated positions are included in the positioning estimate, meaning the nominal accuracy should be easily achieved. [↑](#footnote-ref-1)