**3GPP TSG RAN WG1 #109-e R1-22xxxxx**

**e-Meeting, May 9th – 20th, 2022**

**Agenda Item: 9.5.2.1**

**Source: Moderator (InterDigital, Inc.)**

**Title: Feature Lead summary #1 on Email discussion [109-e-R18-Pos-05] on integrity of RAT dependent positioning techniques**

**Document for: Discussion**

# Introduction

## RAN1 Task

As indicated in SID RP-213588, RAN1 is tasked to identify error sources for determining integrity for RAT dependent positioning.

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| ...   * Improved accuracy, integrity, and power efficiency:   + Study solutions for Integrity for RAT dependent positioning techniques [RAN2, RAN1]:     - Identify the error sources, [RAN1, RAN2].     - Study methodologies, procedures, signalling, etc for determination of positioning integrity for both UE-based and UE-assisted positioning [RAN2]     - Focus on reuse of concepts and principles being developed for RAT-Independent GNSS positioning integrity, where possible.   ... |

## Contact information

To facilitate discussions, please provide your contact information below.

|  |  |  |
| --- | --- | --- |
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## Priority indication in each section/subsection

In this document, [HIGH], [MED] and [LOW] are used to indicate priority of each discussion topic.

In the following, contributions from companies are summarized and proposals from the FL (feature lead) and template for collecting company inputs are listed.

# Background information

In TS 38.305, according to the principle of integrity operation, the network will ensure the following :

|  |
| --- |
| For integrity operation, the network will ensure that:  *P(Error > Bound for longer than TTA | NOT DNU) <=* *Residual Risk + IRallocation*  for all values of Irallocation in the range irMinimum <= *Irallocation* <= irMaximum  Bound for a particular error is computed according to the following formula:  *Bound = mean + K \* stdDev*  *K = normInv(IRallocation / 2)*  *irMinimum <= IRallocation <= irMaximum*  where: *mean*: mean value for this specific error, as per Table 8.1.2.1b-1  *stdDev*: standard deviation for this specific error, as per Table 8.1.2.1b-1 |

To following the principle above, an error source and associated parameters must be identified. More details about the principle of integrity from TS 38.305 are shown in Appendix A. Examples of GNSS related error sources described in TR 38.305 are shown in Appendix B.

# Email discussion information

Information regarding the email discussion can be found below.

[109-e-R18-Pos-05] Email discussion on integrity of RAT dependent positioning techniques by May 20 – Fumihiro (InterDigital)

* Check points: May 16, May 20

Please provide your initial inputs before Wednesday May 11th 23:59 UTC, so that there is enough time to modify summary and proposals before the 1st checkpoint.

# Suggested proposals for approval

## Suggested proposals for approval for the 1st checkpoint (May 16)

TBD

## Suggested proposals for approval for the 2nd checkpoint (May 20)

TBD

# Issues for discussion

## [HIGH] Issue #1 : Categorization and scope of study for error sources

List of error sources

Views on potential error sources for RAT dependent methods were proposed or discussed in the contributions [1-17]. The proposals presented in [2, 3, 6, 9] categorized error sources based on positioning methods (e.g., DL-TDOA, UL-AoA). The majority of contributions proposed error sources that are associated to timing or angle based positioning methods and seem to be in alignment that error sources are method-specific, i.e., there are unique error sources depending on the implemented positioning method.

There are specific error source or category of error sources identified in the contributions. Namely, the following error sources were commonly captured in the contributions.

* Inter-TRP synchronization error is identified as an error source for timing-based positioning methods [2, 3, 4, 5, 6, 8, 9, 13, 14, 16, 17]
* Uncertainties in AoA measurements or RSRP for angle-based positioning methods [1, 3, 4, 5, 6, 9, 13, 14, 16]
* Timing related measurements for timing-based positioning methods [1, 3, 4, 5, 6, 9, 13, 14]
* Multipath channel source [1, 2, 3, 5, 9, 10, 11, 13, 14].

In addition, a summary of error sources identified in contributions is presented in Table 1.

Table 1 Error sources categorized by angle/timing based positioning methods

|  |  |  |  |
| --- | --- | --- | --- |
| **Timing based positioning methods** | | **Angle based positioning methods** | |
| **Error sources** | **References** | **Error sources** | **References** |
| Inter-TRP synchronization (e.g., RTD) | [2, 3, 4, 5, 6, 8, 9, 13, 14, 16, 17] |  |  |
| TRP location | [3, 5, 17] | TRP location | [3, 5, 17] |
| Expected RSTD, uncertainty in RSTD | [10, 17] | ExpectedAoD/AoA, uncertainty in RSTD | [10, 17] |
|  |  | Beam information | [5, 9, 17] |
| Relative position of TRPs (GDOP) | [3, 5, 14] | Relative position of TRPs (GDOP) | [3, 5, 14] |
| Inherent issues with UE capability | [14, 16] | Inherent issues with UE capability | [14, 16] |
|  |  |  |  |
| TEG margins/difference in TEG margins | [4, 8, 10, 17] |  |  |
| Tx timing delay at UE/TRP | [2, 5, 6, 9] |  |  |
| Rx timing delay at UE/TRP | [2, 5, 6, 9] |  |  |
| Clock drift at UE/TRP | [3, 4, 5, 14] |  |  |
| Antenna calibration/ARP errors | [2, 4, 14] | Antenna calibration/ARP errors | [2, 4, 9, 14] |
| RS (e.g., low power, low bandwidth) | [5] | RS (e.g., low power, low bandwidth) | [5] |
|  |  | Phase error between antennas | [5] |
|  |  |  |  |
| Interference | [2, 5, 16] | Interference | [2, 5, 16] |
| Multipath | [1, 2, 3, 5, 9, 10, 11, 13, 14] | Multipath | [1, 2, 3, 5, 9, 10, 11, 13, 14] |
| Noise | [2] | Noise | [2] |
| UE velocity/mobility | [14, 16] | UE velocity/mobility | [14, 16] |
| Timing measurements at UE/TRP | [1, 3, 4, 5, 6, 9, 13, 14] | Angle/RSRP measurements at UE/TRP | [1, 3, 4, 5, 6, 9, 13, 14, 16] |
| LOS indicator | [4, 10, 16] | LOS indicator | [4, 10, 16] |
|  |  |  |  |
| Frequency of feedback from the UE | [14, 16] | Frequency of feedback from the UE | [14, 16] |
| Link/handover failure | [14, 16] | Link/handover failure | [14, 16] |
| Power outages, failure of regular software updates to the operating system, server configuration issues, hardware failure | [6, 14] | Power outages, failure of regular software updates to the operating system, server configuration issues, hardware failure | [6, 14] |
| Spoofing/jamming | [2, 14] | Spoofing/jamming | [2, 14] |
| RS configuration | [11] | RS configuration | [11] |
| Location estimate computation | [9, 11] | Location estimate computation | [9, 11] |

Categorization of error sources/criteria for an error source

Criteria to become an error sources is an important aspect for the study. Several contributions have indicated that the error should be quantifiable and a need to study statistical characteristics associated (e.g. distribution, mean, standard deviation) with the error source [1, 2, 4, 17].

Contributions [1, 2, 3, 4, 5, 8, 9,10, 14, 17] have indicated a need to study origins (e.g., UE, gNB, assistance information, measurements) of error sources and modeling aspects of error sources. Origin of the error sources will affect integrity computation for UE-based/assisted integrity. Whether the error source is associated with assistance information/signal transmission or measurements will determine volatility of the error source, i.e., whether the error source is dynamic or semi-static. Statistical parameters such as mean or standard deviation associated with an error model for the error source has an impact on integrity computation. As proposed in [1, 4] evaluation for modelling of an error source may be necessary based on the requirements in TS 38.101 and TS 38.104, TS 38.133 for the positioning measurement errors or evaluations assumptions in TR 38.857. Whether the error source is caused by an exceptional event or not may affect how the error source can be quantified.

Several contributions have categorized error sources based on predictability or nature of the change in error sources. Some examples are shown below

* Capture static/semi-static/dynamic factors [16]
* Identify nominal/feared/exceptional event [4, 14]

To summarize, as shown in the list below, the contributions proposed to study the following aspects related to error sources.

1. Whether error sources originated at UE or network side
2. Whether error sources originated from assistance information, signal transmission or measurements
3. Criteria to become an error source
4. Modeling of error sources (e.g., distribution, mean, standard deviation, range)

Relevant proposals from contributions related to aspects (e.g., modelling an error source) of error sources to study are listed below.

|  |
| --- |
| [1]  Proposal 1: Model the ToA error as the normal distribution, and report the error bound associated with the allocated integrity risk for the ToA measurement via the paired over-bounding Gaussian formula.   * + This should apply to all DL RSTD, UE Rx – Tx time difference measurement, UL RTOA, and gNB Rx – Tx time difference.   + The reference timing for DL RSTD should also have its reported bound.   Proposal 2: The AoA error is represented by the error of the following two quantities   * + Where and are the reported ZOA and AOA in the local coordinate system   Proposal 3: Model the AoA error quantities and as the normal distribution, and report the error bound associated with the allocated integrity risk for the AoA measurement via the paired over-bounding Gaussian formula.  [2]  Proposal 5: RAN1 to study how to model the RAT-dependent error sources.  [3]  Proposal 5: The error sources for RAT-dependent positioning can be divided into two parts to analysis that are affecting measurement accuracy errors and estimation accuracy errors.  [4]  Proposal 1: For the integrity of RAT-dependent positioning in Rel-18, there is a need to consider the integrity for both UE-assistant and UE-based positioning.  Proposal 2: For the integrity of RAT-dependent positioning, there is a need to consider at least the normal  error sources related to the generation, propagation and reception of DL/UL positioning reference signals. These errors may be modelled as Gaussian distribution with unknown but bounded bias and deviation. The values of the error bounds can be defined with the consideration of the minimum performance requirements defined by RAN4 (e.g., TS 38.101 and TS 38.104 for the generation of the DL/UL positioning reference signals, and TS 38.133 for the positioning measurement errors).  Proposal 3: For the integrity of RAT-dependent positioning, there is a need to consider the error sources related to each of the positioning methods.  [5]  Proposal 1: From the perspective of RAN1, error sources with respect to the assistance data and signal transmission and measurement can be identified first.  Proposal 2: RAN1 needs to study the error sources under various methods, including   * Angle-based measurement and timing-based measurement   [6]  Proposal 1: For positioning integrity to RAN-dependent positioning methods, feared event error sources and error models should be studied. The error sources can include PRS/SRS measuring error at UE side or gNB side, synchronization error between TRPs, Timing error between baseband and Antenna in which UE/TRP do not have the capability to calibrate.  [7]  Proposal 1: Consider RAT-dependent specific error sources e.g. related to reception of PRS transmissions, UL-SRS transmissions and NLOS aspects  [8]  Proposal 1: The Integrity for RAT dependent positioning shall study according to different positioning  methods or different measurement results.  Proposal 2: RAN1 shall study the criteria to be an error source for Integrity for RAT dependent positioning techniques. In our opinion, the most basic criteria to be an error source is that these error sources have an important impact on the measurement results and will arouse some measurement errors to a certain degree.  [14]  Proposal 1: RAN1 to study and identify internal and external feared/exceptional and nominal events with  respect to the UE, gNB and LMF.  Proposal 4: Study feared/exceptional events and error sources at the LMF including generic server issues, configuration of the AD and implementation-specific issues.  Proposal 5: Study feared/exceptional events and error sources at the NG-RAN side including timing and angular-based measurement quality/uncertainty/accuracy, network timing synchronization impairments, delays in reporting and GDOP.  Proposal 6: Study feared/exceptional events and error sources at the UE including UE capability, UE mobility, timing measurement quality/uncertainty/accuracy at the UE, delays in reporting and clock drifts.  Proposal 7: Study feared/exceptional events and error sources arising from the radio propagation environment including multipath, interference, radio link/beam failures, handover, sparse network  coverage.  [17]  Proposal 2: Specify integrity parameters for NR positioning assistance data received by UE via LPP that is identified as an error source.   * Integrity parameters include bounds in the form of mean and standard deviation used in the integrity overbounding model * Integrity parameters may include correlation time and DNU flags for each error source * Integrity parameters include Integrity Risk allocation maximum and minimum (IRmax and IRmin as defined for GNSS integrity). |

### Round#1 discussion:

Based on the analysis of the contributions, the proposal is made below. Companies are invited to provide views on whether the proposal can be supported, suggest modifications, or present additional aspects for the study.

**FL Proposal 1-1**

* Study sources of error for timing-based positioning and angle-based positioning methods, focusing on the following aspects
  + Origin of the error source
    - At UE or network side
    - From assistance information, signal transmission or measurements
  + Model of the error source (e.g., distribution, mean and/or standard deviation for integrity overbounding model, range)
  + Criteria to become an error source (e.g., whether it is quantifiable, how much influence an error source has on determination on integrity)
* It is encouraged to provide evaluation assumptions (e.g., requirements in TS 38.101, TS 38.104, TS 38.133, evaluation assumptions in TR 38.857) if evaluation is used to determine a distribution, mean and standard deviation or range of values of an error source
* UE-based/assisted DL positioning methods, UL and DL&UL positioning methods are considered in the study

Companies views:

|  |  |
| --- | --- |
| **Company Name** | **Comments** |
| CATT | We are in general fine with the proposal. |
| OPPO | Generally ok with the proposal and suggest to change “or” to “and/or” |
| Huawei, HiSilicon | One question for clarification: what ia the error source associated with signal transmission?  In general, we think that the following sections should be based on the categorization in 5.1.1. The current structure of discussion seems a little bit confusing. |
| vivo | To Huawei, it may come from our contribution, for example Tx TEG timing error, and the bandwidth of the signal.  And we also think the proposal can break to multiple proposals to discuss |
| FL | To Huawei: Thank you very much for the comment. The intention of Proposal 1-1 was to introduce the wayforward for the study (e.g., modelling, categorization). The intention was to agree on Proposal 1-1 first then try to make a progress on proposals listed in in 5.3 and 5.4. To make the progress, we needed to collect companies’ inputs which is why all proposals are introduced simultaneously. I hope the intention is clarified.  To vivo : Thank you for clarification. My plan is to leave all origins (assistance information, signal transmission or measurements) open for now. Regarding the size of the proposal, I would like to keep the current proposal, focusing on details for the study (e.g., categorization, modelling).  To OPPO : Thank you for the suggested wording. I will reflect the change in the updated proposal. |
| ZTE | OK with the proposal |
| NTT DOCOMO | We are fine with the proposal. |
| Samsung | General fine with the proposal. |

## [HIGH] Issue #2 : Multipath channel as an error source

### Round #1 discussions

From the summary of error sources in Table 1, the majority of contributions share the view that the multipath channel is an error source. For clarification, the FL would like to ask questions to companies regarding which aspects of the ultipath channel that should be considered as an error source.

**FL Question 2-1:**

Companies are invited to provide views on aspects of mutlpath channel that should be considered as error sources. For example, the following is a list of potential aspects related to multipath channels that may qualify as error sources:

* Error associated with an LOS/NLOS indicator
* Measurement errors caused by multipath channels, e.g., inaccurate measurements of ToA, AoA
* Error related to identification of multipath channels, e.g., inaccurate estimate of number of paths, relative delay, absolute/relative RSRPP

Companies views:

|  |  |
| --- | --- |
| **Company Name** | **Comments** |
| CATT | We assume UE/TRP may provide some information related to the reliability/confidence when it reports LOS/NLOS indicator. We are curious on how UE/TRP is able to provide the errors related to measurement errors caused by multipath channels or the identification of multipath channels. |
| OPPO | The multi-path would result in errors in positioning measurement, for which we think positioning measurement errors can cover it.  Regarding the error for LOS/NLOS indicator: the LOS/NLOS indicator itself indicates the probability of LOS or NLOS. But about the confidence of LOS/NLOS indicator itself, we are not sure if the UE or TRP is able to estimate that. |
| Huawei, HiSilicon | We assume that  For NloS indicator, it can be either in the AD or in the measurement report.  For Multi-path, it is in the measurement report, reflected in either the ToA/AoA quality or a new error bound associated with the ToA/AoA measurement. In this regard, we agree with OPPO’s comments.  For identification of multi-path, not sure how the number of paths effect the overall positioning accuracy, which should be lower priority.  In general, we think that is should be related to either error in the assistance data (NloS) or error in the measurement.  We are a little bit confused at the relationship between 5.2 and 5.3/5.4, it appears the error source in 5.2 may be associated timing-based methods (5.3) and angle-based methods (5.4). |
| vivo | Firstly, we believe with different bandwidths, the multi-path error will be different, and we agree with Huawei and OPPO that measurement errors can cover mult-path errors.  Secondly, for the LOS and NLOS, , additional delay caused by NLOS can also be regarded as an error source. |
| FL | To Huawei :  Thank you very much for your comment. The intention of 5.2 was to check the companies’ understanding on the role of the multipath channel as an error source. Once we understand the companies’ views, the proposals in 5.3 or 5.4 may be updated. Given a limited time, the intention was to collect companies views as much as possible during the initial round.  For now, 5.3 and 5.4 are also used to collect companies’ views on error sources that should be focused. As the first priority, I would like to make an agreement on the proposal for Issue #1 (the proposal in 5.1). |
| ZTE | From our point of view  We basically agree with OPPO and Huawei’s idea that measurements errors can cover muti-path errors  With respect to identification of muti-path, we think that some of the listed potential error like numbers of path do not have direct impact on positioning accuracy. We may need further discussion on this bullet |
| Samsung | Even though measurements errors are related to multi-path errors, the error sources can still be multi-path errors other than general measurements errors in our opinion. Like the error sources in GNSS (e.g. orbit, clock, code bias, phase bias, ionosphere and troposphere), all of them can be covered by measurements errors, while they are determined as the error sources here. In other words, since multi-path channel can lead to several measurement errors with different positioning method, like inaccurate measurements of ToA/AOA, it should be an error source if we can create the error distribution. Just like the clock, ionosphere and troposphere in GNSS. |

## [MED] Issue #3 : Error sources for timing-based positioning methods

### Round#1 discussions

From the summary of error sources in Table 1, the majority of contributions share the view that measurement errors, inter-TRP synchronization errors and TEG margin are potential error sources for the timing based positioning method. In [17], it is mentioned that “ExpectedRSTD” in assistance information can become an error source. The FL’s understanding is that ExpectedRSTD can be used to identify statistical characteristics of a timing related error source and it is included as one of the examples of the error source.

The following proposal is made. Companies are invited to provide views on whether the proposal can be supported, suggest modifications, or provide additional aspects for the study that should be considered.

**FL Proposal 3-1:**

* At leastthe following errorsources for timing-based positioning methods are studied
  + TRP/UE measurements errors (e.g., ToA, Rx-Tx timing difference, ExpectedRSTD)
  + Inter-TRP synchronization errors (e.g., RTD)
  + TRP/UE Timing error group (TEG) margin
* Other error sources are not precluded
* FFS : details of each error source, e.g., mean/standard deviation/range associated with each error source

Companies views:

|  |  |
| --- | --- |
| **Company Name** | **Comments** |
| CATT | For ExpectedRSTD (including the uncertainty), it could cause problem if the information is wrong, which results in the UE could not detect DL PRS signals. Our understanding is that it indicates the range for UE to detect the DL PRS signals. But, it may not present the statistical characteristics of a timing related error source in the measurements. Obviously, if ExpectedRSTD is not provided correctly, the UE may not be able to find the PRS signals within the search range. Thus, we are fine to include it as a potential error source, but it may need further discussion on how to model it.  We may also need to include the error sources related to the coordinates of the TRP antenna reference center. |
| OPPO | Generally Ok |
| Huawei, HiSilicon | We do not think TEG should be added as the error source. Is it the intention to add the confidence level of TEG margin reported by the UE?  Anyway the error source should be categorized as assistance data error source (targeting LMF-UE link) and measurement error source (targeting LMF-UE link and LMF-gNB link) |
| vivo | Firstly, we don’t think expected RSTD is measurement error.  Secondly, the second sub-bullet can be assistance data error  Lastly, TRP/UE Timing error group (TEG) margin-> TRP/UE Timing error  So, we propose to revise the proposal as follows  **Proposal 3-1:**   * At leastthe following errorsources for timing-based positioning methods are studied   + TRP/UE measurements errors (e.g., ToA, Rx-Tx timing difference~~, ExpectedRSTD~~)   + Assistance data error (e.g TRP location, Inter-TRP synchronization errors (e.g., RTD))   + TRP/UE Timing error ~~group (TEG) margin~~ * Other error sources are not precluded   FFS : details of each error source, e.g., mean/standard deviation/range associated with each error |
| ZTE | We don’t think that TRP/UE Timing error group(TEG) margin should be considered as error sources. TRP/UE Timing error should be included instead. |
| NTT DOCOMO | Regarding TEG, we have similar view to Huawei. |
| Samsung | General support the proposal. As we state in 5.2, although the error sources shall be studied according to different positioning methods or different measurement results, we should determine the real error sources rather than identify the measurements errors and assistance data error itself. Ideally, the object causing measurements errors and assistance data error should be the error source. The error source may be synchronization, multi-path, signal bias, phase bias…we are open to discuss it.  Refer to TEG, we think TEG itself should considered as error source, rather than the timing error. As the TEG is reported by UE/gNB and associated with the measurement. We are targeting to that reported TEG error as error source. |

## [MED] Issue #4 : Error sources for angle-based positioning methods

### Round #1 discussions

Based on the error sources indicated in Table 1, the majority of contributions share the view that measurement error is an error source for the timing based positioning method. In [17], it is mentioned that “expectedAoD/AoA” in assistance information can become an error source. The FL’s understanding is that expectedAoD/AoA can be used to identify statistical characteristics of a angle related error source and it is included as one of the examples of the error source.

The following proposal is made. Companies are invited to provide views on whether the proposal can be supported, suggest modifications, or provide additional aspects for the study that should be considered.

**FL Proposal 4-1:**

* At leastthe following errorsources for angled-based positioning methods are studied
  + TRP/UE measurements errors (e.g., AoA, RSRP, expectedAoD/AoA)
* FFS : details of each error source, e.g., mean/standard deviation/range associated with each error source

Companies views:

|  |  |
| --- | --- |
| **Company Name** | **Comments** |
| CATT | Similar to ExpectedRSTD, in our view expectedAoD/AoA is mainly for providing the search range of the angles. It may not present the statistical characteristics of angle measurement errors. Thus, we are fine to include it as a potential error source, but it may need further discussion on how to model it. |
| OPPO | ExpectedRSTD can not be used as error source directly since it does not have direct impact on the final measurement results.  Location calculation error shall be considered here as one source too. |
| Huawei, HiSilicon | The error source should be categorized as assistance data error source (targeting LMF-UE link) and measurement error source (targeting LMF-UE link and LMF-gNB link) |
| vivo | The same view as proposal 3.1, and suggest revising the proposal as follows  **Proposal 4-1:**   * At leastthe following errorsources for angle -based positioning methods are studied   + TRP/UE measurements errors (e.g., AoA, RSRP, ~~expectedAoD/AoA~~)   + Assistance data error (e.g TRP location, TRP beam antenna information) * Other error sources are not precluded   FFS : details of each error source, e.g., mean/standard deviation/range associated with each error |
| ZTE | OK with the proposal. Further discussion may be needed on expected AoD/AoA |
| Samsung | Seem view as shown in 5.3 and vivo’s version is better in our opinion. |

## [MED] Issue #5 : Reusing terms from GNSS integrity

### Round #1 discussions

In [1], it was proposed to reuse the terms used for GNSS integrity in Section 8.1.1a in TS 38.305, e.g., Positioning integrity, error, Bound, TTA, DNU, Residual Risk, irMinimum, irMaximum, Correlation Times, Target Integrity Risk. As the principle of operation in TS 38.305 can be directly applied to RAT dependent integrity, the FL thinks it is useful to agree to reuse the definition in TS 38.305 for GNSS integrity for the purpose of discussion of error sources. As a reference, the principle of operation in TS 38.305 is reproduced in Appendix A. The companies are invited to provide their views on the following proposal.

**FL Proposal 5-1**:

Reuse the definitions for RAT-dependent integrity and update the references to GNSS in Section 8.1.1a in TS38.305 to also include RAT-dependent methods.

Companies views:

|  |  |
| --- | --- |
| **Company Name** | **Comments** |
| CATT | We are in general fine with reuse the terms used for GNSS integrity. |
| OPPO | Ok with the proposal |

|  |  |
| --- | --- |
| Huawei, HiSilicon | Agree. |
| ZTE | OK with the proposal |
| NTT DOCOMO | We are fine with the proposal. |
| Samsung | Support |

## [LOW] Issue #6 : Signaling/Procedure related proposals

### Round #1 discussions

The following proposals are related to signaling or higher layer aspects and they are out of the scope of the RAN1 task which is to identify error sources. It is proposed to postpone discussion of the following proposals. Companies are invited to present their views.

|  |
| --- |
| [2]  Proposal 1: Reuse the above definitions for RAT-dependent integrity and update the references to GNSS to also include RAT-dependent methods.  Proposal 6: RAN1 to study anomaly detection (e.g., for spoofing and jamming) as part of RAT-dependent integrity as well as other methods for overcoming spoofing attacks.  [3]  Proposal 1: For RAT-dependent positioning, reporting mode1 and reporting mode2 of integrity results  reporting modes should be supported.Proposal 2: RAT-dependent positioning integrity is enabled by using existing NG-RAN positioning  architecture.Proposal 3: For RAT-dependent positioning integrity, LPP messages RequestLocationInformation and  ProvideLocationInformation are reused to transfer integrity KPIs/results  Proposal 4: For RAT-dependent positioning integrity, LPP messages RequestAssistanceData and  ProvideAssistanceData are reused to transfer integrity assistance data.  [7]  Proposal 2: Consider a maximum reporting time for positioning measurements in which the important/prioritized measurement data should be available within the maximum reporting time.  [10]  Proposal 6: For integrity result reporting, Mode 1 (PL reporting) and Mode 2 (integrity flag reporting) can be considered for UE-based and UE-assisted integrity  Proposal 7: Transmission of integrity alerts can be considered when detecting integrity related events or feared events for UE-based and UE-assisted modes  Proposal 8: Study how RAT independent and RAT dependent positioning methods can be made to be compatible with each other and leveraged for improving integrity  [14]  Proposal 8: Occurrence of feared/exceptional events require support of monitoring and proactive measures and to help the network adapt and recover the compromised positioning service.  [16]  Proposal 2 RAN1 can provide a list of dynamic error sources, and should communicate to RAN2 the need for new signaling for dynamic error sources. |

Companies views:

|  |  |
| --- | --- |
| **Company Name** | **Comments** |
| Huawei, HiSilicon | Generally agree with comments from FL to postpone the discussion. |
| Samsung | Support to postpone. |

## Other issues

If there are other issues that should be discussed, please indicate them below.

Companies views:

|  |  |
| --- | --- |
| **Company Name** | **Comments** |
|  |  |
|  |  |

# Summary of proposals from contributions

## [1] R1- 2203165 (Huawei, HiSilicon)

Observation 1: The TOA error is close to a normal distribution if super resolution ToA estimation is used.

Proposal 1: Model the ToA error as the normal distribution, and report the error bound associated with the allocated integrity risk for the ToA measurement via the paired over-bounding Gaussian formula.

* + This should apply to all DL RSTD, UE Rx – Tx time difference measurement, UL RTOA, and gNB Rx – Tx time difference.
  + The reference timing for DL RSTD should also have its reported bound.

Proposal 2: The AoA error is represented by the error of the following two quantities

* + Where and are the reported ZOA and AOA in the local coordinate system

Proposal 3: Model the AoA error quantities and as the normal distribution, and report the error bound associated with the allocated integrity risk for the AoA measurement via the paired over-bounding Gaussian formula.

Observation 2: No additional work is needed for handling the measurement reporting to support integrity with respect to the NLoS condition and the multi-path.

## [2] R1-2203177 (Nokia)

Proposal 1: Reuse the above definitions for RAT-dependent integrity and update the references to GNSS to also include RAT-dependent methods.

Observation 1: Different RAT-dependent methods have different error sources.

Proposal 2: For DL-TDOA and UL-TDOA the following error sources have been identified: multipath, noise, interference, synchronization offset/drift among TRPs, timing errors as defined in TS 38.305, spoofing, jamming, calibration errors, and antenna movement. RAN1 should determine a high-priority subset of error sources to be discussed in RAN1.

Proposal 3: For Multi-RTT the following error sources have been identified: multipath, noise, interference, timing errors as defined in TS 38.305, spoofing, jamming, calibration errors, and antenna movement. RAN1 should determine a high-priority subset of error sources to be discussed in RAN1.

Proposal 4: For UL-AoA and DL-AoD, the following error sources have been identified: multipath, noise, interference, spoofing, jamming, calibration errors, and antenna movement. RAN1 should determine a high-priority subset of error sources to be discussed in RAN1.

Proposal 5: RAN1 to study how to model the RAT-dependent error sources.

Proposal 6: RAN1 to study anomaly detection (e.g., for spoofing and jamming) as part of RAT-dependent integrity as well as other methods for overcoming spoofing attacks.

## [3] R1-2203336 (Spreadtrum)

Observation 1: The definition of integrity KPIs are the same regardless of the positioning methods.

Proposal 1: For RAT-dependent positioning, reporting mode1 and reporting mode2 of integrity results reporting modes should be supported.

Proposal 2: RAT-dependent positioning integrity is enabled by using existing NG-RAN positioning architecture.

Proposal 3: For RAT-dependent positioning integrity, LPP messages RequestLocationInformation and ProvideLocationInformation are reused to transfer integrity KPIs/results

Proposal 4: For RAT-dependent positioning integrity, LPP messages RequestAssistanceData and ProvideAssistanceData are reused to transfer integrity assistance data.

Proposal 5: The error sources for RAT-dependent positioning can be divided into two parts to analysis that are affecting measurement accuracy errors and estimation accuracy errors.

## [4] R1-2203468 (CATT)

Proposal 1: For the integrity of RAT-dependent positioning in Rel-18, there is a need to consider the integrity for both UE-assistant and UE-based positioning.

Proposal 2: For the integrity of RAT-dependent positioning, there is a need to consider at least the normal

error sources related to the generation, propagation and reception of DL/UL positioning reference signals.

These errors may be modelled as Gaussian distribution with unknown but bounded bias and deviation. The

values of the error bounds can be defined with the consideration of the minimum performance requirements

defined by RAN4 (e.g., TS 38.101 and TS 38.104 for the generation of the DL/UL positioning reference

signals, and TS 38.133 for the positioning measurement errors).

Proposal 3: For the integrity of RAT-dependent positioning, there is a need to consider the error sources related to each of the positioning methods.

Proposal 4: The following error sources may be considered for the Integrity of RAT-dependent positioning.

* gNB (TRP) error sources:
  + self-clock errors o synchronization errors (between TRPs)
  + TRP antenna reference point (ARP) errors (or antenna phase center errors)
  + TRP Rx/Tx/RxTx TEG margins
  + Differences of Rx/Tx/RxTx TEG margins of the same TRP
  + TRP measurement errors (RTOA/UL-AOA/UL-RSRP/UL-RSRPP/gNB Rx-Tx time difference measurements)
  + Multipath indication for TRP measurements
* UE error sources:
  + UE antenna reference point (ARP) errors (or antenna phase center errors)
  + Rx/Tx/RxTx TEG margins o Difference of Rx/Tx/RxTx TEG margins of the same UE
  + UE measurement errors (RSTD/ DL-RSRP/DL-RSRPP/UE Rx-Tx time measurements)
  + Multipath indication for UE measurements
* PRU error sources (when PRU is a TRP):
  + self-clock errors
  + PRU antenna reference point (ARP) errors (or antenna phase center errors)
  + PRU Rx/Tx/RxTx TEG margins
  + Differences of Rx/Tx/RxTx TEG margins of the same PRU
  + PRU measurement errors (RTOA/UL-AOA/UL-RSRP/UL-RSRPP/gNB Rx-Tx time difference measurements)
  + Multipath indication for PRU measurements
* PRU error sources (when PRU is a UE):
  + PRU antenna reference point (ARP) errors (or antenna phase center errors)
  + PRU Rx/Tx/RxTx TEG margins
  + Difference of Rx/Tx/RxTx TEG margins of the same PRU
  + PRU measurement errors (RSTD/ DL-RSRP/DL-RSRPP/UE Rx-Tx time measurements)
  + Multipath indication for PRU measurements

## [5] R1-2203567 (vivo)

Proposal 1: From the perspective of RAN1, error sources with respect to the assistance data and signal transmission and measurement can be identified first.

Proposal 2: RAN1 needs to study the error sources under various methods, including

* Angle-based measurement and timing-based measurement

## [6] R1-2203625 (ZTE)

Observation 1: It is beneficial to extend the integrity procedure for A-GNSS to RAT dependent positioning in Rel-18, so that the integrity can enable LCS client to make the correct decisions.

Proposal 1: For positioning integrity to RAN-dependent positioning methods, feared event error sources and error models should be studied. The error sources can include PRS/SRS measuring error at UE side or gNB side, synchronization error between TRPs, Timing error between baseband and Antenna in which UE/TRP do not have the capability to calibrate.

## [7] R1- 2203739 (Sony)

Observation 1: The LPP messages for RequestLocationInformation, ProvideLocationInformation,

RequestAssistanceData and ProvideAssistanceData, can be used for RAT based integrity KPIs/results

Observation 2: GNSS error sources can be the basis for exploring further error sources related to RAT dependent positioning.

Proposal 1: Consider RAT-dependent specific error sources e.g. related to reception of PRS transmissions, UL-SRS transmissions and NLOS aspects

Proposal 2: Consider a maximum reporting time for positioning measurements in which the important/prioritized measurement data should be available within the maximum reporting time.

Proposal 3: Consider RAT-independent integrity KPIs/results be available for adapting the RAT dependent positioning methods and integrity reporting.

## [8] R1-2203912 (Samsung)

Proposal 1: The Integrity for RAT dependent positioning shall study according to different positioning methods or different measurement results.

Proposal 2: RAN1 shall study the criteria to be an error source for Integrity for RAT dependent positioning techniques. In our opinion, the most basic criteria to be an error source is that these error sources have an important impact on the measurement results and will arouse some measurement errors to a certain degree.

Proposal 3: RAN1 shall study some possible error sources for Integrity for RAT dependent positioning techniques, and RAN1 can ask for RAN2’s further confirmation. The synchronization and TEG for time based positioning methods or measurement results shall be studied at least in our opinion.

## [9] R1-2203965 (OPPO)

Proposal 1:

The error sources for DL-DTOA method are:

- DL PRS measurement error;

- Multi-path channel and NLOS path;

- TRP synchronization error;

- Tx timing delay of TRP;

- Rx timing delay of UE;

- Location calculation error.

Proposal 2: The error sources of UL-DTOA include:

- SRS for positioning measurement error;

- Multi-path channel and NLOS path;

- TRP synchronization error;

- Tx timing delay of UE;

- Rx timing delay of TRP;

- Location calculation error.

Proposal 3: The error sources of DL-AoD method are:

- Errors in measuring DL PRS RSRP;

- Errors in Tx beam forming of DL PRS resource;

- Resolution of beamwidth of Tx beam of each DL PRS resource;

- Multi-path channel and NLOS path;

- Location calculation error.

Proposal 4: UL-AoA method has the following error sources:

- Errors in measuring SRS for positioning;

- Multi-path channel;

- NLOS path;

- Location calculation error.

Proposal 5: Multi-RTT method has the following error sources:

- Errors of measuring DL PRS;

- Errors of measuring SRS;

- Multi-path channel;

- NLOS path;

- Tx timing delay and Rx timing delay of UE;

- Tx timing delay and Rx timing delay of TRP;

- Location calculation error

## [10] R1-2204133 (InterDigital)

Observation 1 : KPI (AL, TTA and TIR) ranges for automotive, rail and IIoT use cases are shown in TR 38.857

Proposal 1: For error sources for determining integrity, LOS indicator, TEG, multipath information and uncertain or expectation in measurements should be considered.

Proposal 2: The integrity requirements corresponding to AL, TTA and TIR in TR 38.857 can be considered for RAT dependent positioning

Proposal 3: Study both UE-based and UE-assisted modes for a support for integrity for RAT dependent positioning methods

Proposal 4: Study and identify the assistance data that can be provided to UE for integrity for UE based on UE-assisted modes

Proposal 5: Study and identify the measurements/calculations that can be reported by UE for integrity for UE-based and UE-assisted modes

Proposal 6: For integrity result reporting, Mode 1 (PL reporting) and Mode 2 (integrity flag reporting) can be considered for UE-based and UE-assisted integrity

Proposal 7: Transmission of integrity alerts can be considered when detecting integrity related events or feared events for UE-based and UE-assisted modes

Proposal 8: Study how RAT independent and RAT dependent positioning methods can be made to be compatible with each other and leveraged for improving integrity

## [11] R1- 2204311 (CMCC)

Observation 1: The following error sources of RAT-dependent positioning should be considered:

- Channel states;

- PRS/SRS configurations;

- Location estimations computation

## [12] R1-2204386 (NTT Docomo)

Observation 1:

In order to identify which error source impacts on positioning accuracy performance, evaluation of how much the candidate error sources (e.g. TRP synchronization error) impact on positioning accuracy performance should be considered separately for timing based methods and angle based methods.

## [13] R1-2204523 (LG)

Observation 1: Each positioning method of RAT-dependent positioning can have different error sources

Observation 2: For study of identification of the error sources for time-based positioning methods (e.g. TDOA and Multi-RTT), timing measurement, TRP synchronization and multipath environment could be considered.

Observation 3: For study of identification of the error sources for angle-based positioning methods (e.g. AoD and AoA), angle measurement and multipath environment could be considered.

## [14] R1-2204560 (Lenovo)

Observation 1: Positioning integrity plays an important role in the safe operation of positioning systems, especially with regard to safety critical use cases.

Observation 2: The PL takes into account both feared/exceptional and nominal events.

Proposal 1: RAN1 to study and identify internal and external feared/exceptional and nominal events with respect to the UE, gNB and LMF.

Proposal 2: RAN1 to study feared and nominal events as well as error sources arising from the following RAT-dependent positioning methods:

* Timing-based positioning methods including DL-TDOA, UL-TDOA, Multi-RTT
* Angular-based positioning methods including DL-AoD, UL-AoA
* E-CID in conjunction with the above positioning methods

Proposal 3: Study error source identification for both UE-assisted and UE-based integrity methods.

Proposal 4: Study feared/exceptional events and error sources at the LMF including generic server issues, configuration of the AD and implementation-specific issues.

Proposal 5: Study feared/exceptional events and error sources at the NG-RAN side including timing and angular-based measurement quality/uncertainty/accuracy, network timing synchronization impairments, delays in reporting and GDOP.

Proposal 6: Study feared/exceptional events and error sources at the UE including UE capability, UE mobility, timing measurement quality/uncertainty/accuracy at the UE, delays in reporting and clock drifts.

Proposal 7: Study feared/exceptional events and error sources arising from the radio propagation environment including multipath, interference, radio link/beam failures, handover, sparse network coverage.

Proposal 8: Occurrence of feared/exceptional events require support of monitoring and proactive measures and to help the network adapt and recover the compromised positioning service.

## [15] R1-2204668 (Sharp)

Observation: For RAT-dependent positioning integrity improvement, same methodology with RAT independent positioning using equation for integrity operation can be reused, and the integrity field in assistance data for clarified error sources should be determined.

## [16] R1-2204951 (Ericsson)

Observation 1 Some UE and gNB capabilities could be identified as static factors/error sources. However, these error sources are already known to the UE gNB/LMF after capability exchange.

Observation 2 Semi-static error sources should normally be known to the positioning estimator

Observation 3 Dynamic error sources are generally unknown to the positioning estimator and should be communicated by the entity responsible for integrity computation (network or UE)

Observation 4 The various positioning related attributes and the error sources can be classified in static semi-static and dynamic attributes.

Proposal 1 The attributes impacting integrity are classified as static, semi-static and dynamic factors and shall be captured in the TR.

Proposal 2 RAN1 can provide a list of dynamic error sources, and should communicate to RAN2 the need for new signaling for dynamic error sources.

## [17] R1-2205039 (Qualcomm)

Observation 1: Rel-17 GNSS integrity feature allows for the following:

* LMF can specify target integrity risk for which the protection level is requested (in IntegrityInformationRequest), and UE can report integrity result for the location estimate, expressed as protection level together with achieved target integrity risk.
* LMF can indicate bounds on the assistance data, such as mean and variance of various correction data such as clock errors, troposphere and ionosphere errors.

Observation 2: Identifying assistance data inaccuracies as error sources and indicating their mean and variance for the overbounding model allows supporting of integrity for NR positioning while meeting the SID guidance to "Focus on reuse of concepts and principles being developed for RAT-Independent GNSS positioning integrity, where possible"

Proposal 1: Error sources for NR positioning integrity are uncertainties in Assistance Data information such as the following:

* RTDs
* TRP locations
* TEG margins
* Beam-shape information
* ExpectedRSTD / expectedAoD/AoA.
* Potential new assistance data added in Rel-18, for example, related to carrier phase positioning
* Potentially, the rate of time-variation of some or all of the above assistance data elements.

Proposal 2: Specify integrity parameters for NR positioning assistance data received by UE via LPP that is identified as an error source.

* Integrity parameters include bounds in the form of mean and standard deviation used in the integrity overbounding model
* Integrity parameters may include correlation time and DNU flags for each error source
* Integrity parameters include Integrity Risk allocation maximum and minimum (IRmax and IRmin as defined for GNSS integrity).

# Appendix A : Integrity Principle of Operation from TS 38.305

8.1.1a Integrity Principle of Operation

For integrity operation, the network will ensure that:

*P(Error > Bound for longer than TTA | NOT DNU) <= Residual Risk + IRallocation* (Equation 8.1.1a-1)

for all values of IRallocation in the range irMinimum <= *IRallocation* <= irMaximum

for all the errors in Table 8.1.2.1b-1, which have corresponding integrity assistance data available and where the corresponding DNU flag(s) are set to false.

The integrity risk probability is decomposed into a constant Residual Risk component provided in the assistance data as well as a variable IRallocation component that corresponds to the contribution from the Bound according to the Bound formula in Equation 8.1.1a-2. IRallocation may be chosen freely by the client based on the desired Bound, therefore the network should ensure that Equation 8.1.1a-1 holds for all possible choices of IRallocation. The Residual Risk and IRallocation components may be mapped to fault and fault-free cases respectively, but the implementation is free to choose any other decomposition of the integrity risk probability into these two components.

The validity time of the integrity bounds is set as equal to twice the SSR Update Interval for the given SSR Assistance Data message, i.e. the time period between the SSR Epoch Time and the SSR Epoch Time plus twice the SSR Update Interval in the GPS time scale.

Equation 8.1.1a-1 holds for all assistance data that has been issued that is still within its validity period. If this condition cannot be met then the corresponding DNU flag must be set.

Equation 8.1.1a-1 holds at any epochs for which Assistance Data is provided. Providing Assistance Data without the Integrity Service Alert IE or Real Time Integrity IEs is interpreted as a DNU=FALSE condition. For any bound that is still valid (within its validity time), the network ensures that the Integrity Service Alert and/or Real Time Integrity IEs are also included in the provided Assistance Data if needed to satisfy the condition in Equation 8.1.1a-1. It is up to the implementation how to handle epochs for which integrity results are desired but there are no DNU flag(s) available, e.g. the Time To Alert (TTA) may be set such that there is a "grace period" to receive the next set of DNU flags.

Only those satellites for which the GNSS integrity assistance data are provided are monitored by the network and can be used for integrity related applications.

Where:

**Error:** Error is the difference between the true value of a GNSS parameter (e.g. ionosphere, troposphere etc.), and its value as estimated and provided in the corresponding assistance data as per Table 8.1.2.1b-1

**Bound:** Integrity Bounds provide the statistical distribution of the residual errors associated with the GNSS positioning corrections (e.g. RTK, SSR etc). Integrity bounds are used to statistically bound the residual errors after the positioning corrections have been applied. The bound is computed according to the Bound formula defined in Equation 8.1.1a-2. The bound formula describes a bounding model including a mean and standard deviation (e.g. paired over-bounding Gaussian). The bound may be scaled by multiplying the standard deviation by a K factor corresponding to an IRallocation, for any desired IRallocation within the permitted range.

Bound for a particular error is computed according to the following formula:

*Bound = mean + K \* stdDev* (Equation 8.1.1a-2)

*K = normInv(IRallocation / 2)*

*irMinimum <= IRallocation <= irMaximum*

where: *mean*: mean value for this specific error, as per Table 8.1.2.1b-1

*stdDev*: standard deviation for this specific error, as per Table 8.1.2.1b-1

**Time-to-Alert (TTA):** The maximum allowable elapsed time from when the Error exceeds the Bound until a DNU flag must be issued.

**DNU:** The DNU flag(s) corresponding to a particular error as per Table 8.1.2.1b-1. Where multiple DNU flags are specified, the DNU condition in Equation 8.1.1a-1 is present when any of the flags are true (logical OR of the flags).

**Residual Risk:** The residual risk is the component of the integrity risk provided in the assistance data as per Table 8.1.2.1b-1. This may correspond to the fault case risk but the implementation is permitted to allocate this component in any way that satisfies Equation 8.1.1a-1.

The Residual Risk is the Probability of Onset which is defined per unit of time and represents the probability that the feared event begins. Each Residual Risk is accompanied by a Mean Duration which represents the expected mean duration of the corresponding feared event and is used to convert the Probability of Onset to a probability that the feared event is present at any given time, i.e.

*P(Feared Event is Present) = Mean Duration \* Probability of Onset of Feared Event* (Equation 8.1.1a-3)

**irMinimum, irMaximum:** Minimum and maximum allowable values of IRallocation that may be chosen by the client. Provided as service parameters from the Network according to Integrity Service Parameters.

Table 8.1.2.1b-1: Mapping of Integrity Parameters

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Error | GNSS Assistance Data | Integrity Fields | | | | |
| Integrity Alerts | Integrity Bounds (Mean) | Integrity Bounds (StdDev) | Residual Risks | Integrity Correlation Times |
| Orbit | SSR Orbit Corrections | Real-Time Integrity  (see Clause 8.1.2.1.8) | Calculated according to Equation 8.1.1a-3 | Calculated according to Equation 8.1.1a-3 | Probability of Onset of Constellation Fault  Probability of Onset of Satellite Fault  Mean Constellation Fault Duration  Mean Satellite Fault Duration | Orbit Range Error Correlation Time  Orbit Range Rate Error Correlation Time |
| Clock | SSR Clock Corrections | Mean Clock Residual Error Vector | Standard Deviation Clock Error | Clock Range Error Correlation Time  Clock Range Rate Error Correlation Time |
| Code Bias | SSR Code Bias | Mean Code Bias Error  Mean Code Bias Rate Error | Standard Deviation Code Bias Error  Standard Deviation Code Bias Rate Error |  |
| Phase Bias | SSR Phase Bias | Mean Phase Bias Error  Mean Phase Bias Rate Error | Standard Deviation Phase Bias Error  Standard Deviation Phase Bias Rate Error |
| Ionosphere | SSR STEC Correction | Ionosphere DNU | Mean Ionospherre Error  Mean Ionospherre Rate Error | Standard Deviation Ionosphere Error  Standard Deviation Ionosphere Rate Error | Probability of Onset of Ionosphere Fault  Mean Ionosphere Fault Duration | Ionosphere Range Error Correlation Time  Ionosphere Range Rate Error Correlation Time |
| Troposphere Vertical Hydro Static Delay | SSR Gridded Corrections | Troposphere DNU | Mean Troposphere Vertical Hydro Static Delay Error  Mean Troposphere Vertical Hydro Static Delay Rate Error | Standard Deviation Troposphere Vertical Hydro Static Delay Error  Standard Deviation Troposphere Vertical Hydro Static Delay Rate Error | Probability of Onset of Troposphere Fault  Mean Troposphere Fault Duration | Troposphere Range Error Correlation Time  Troposphere Range Rate Error Correlation Time |
| TroposphereVertical WetDelay | Mean Troposphere Vertical Wet Delay Error  Mean Troposphere Vertical Wet Delay Rate Error | Standard Deviation Troposphere Vertical Wet Delay Error  Standard Deviation Troposphere Vertical Wet Delay Rate Error |

# Appendix B : List of feared events from TR 38.857

#### 9.4.1.1 A-GNSS Positioning Integrity Methods

The 3GPP specifications can be extended to support the determination of positioning integrity, by defining information elements and signalling procedures to transport assistance information to mitigate feared events. A summary of the feared events studied in Section 9.3 is provided in Table 9.4.1.1 below, including examples of the types of assistance information to be considered for inclusion in LPP

**Table 9.4.1.1: Summary of A-GNSS feared events and integrity assistance information considerations (FFS).**

NOTE: The positioning integrity assistance information IEs are FFS as part of the WI.

**\***NOTE: The UE or LMF are responsible for mitigating these feared events locally, outside the scope of the specifications.

|  |  |  |
| --- | --- | --- |
| **Feared Event Category** | **Feared Event** | **Examples of positioning integrity assistance information (FFS)** |
| 1. Feared events in the GNSS Assistance Data | Incorrect computation of the GNSS Assistance Data, e.g. software bug, corrupt or lost data | Validity or quality flags for existing assistance information |
| External feared event impacting the GNSS Assistance Data, e.g. satellite, atmospheric or local environment feared events (Category 3) impacting the GNSS reference stations in the GNSS correction provider’s network. |
| 2. Feared events during positioning data transmission | Data integrity faults | Data corruption check, e.g. CRC |
| Data Authentication / Signature |
| 3. GNSS feared events | Satellite feared events  e.g. bad signal-in-space or bad broadcast navigation data | Satellite health or quality flags |
| Atmospheric feared events | Ionospheric indicator |
| Tropospheric indicator |
| Local Environment feared events, e.g. Multipath, Spoofing, Interference | Assistance information: Trustable time reference, Data Authentication / Signature, Regionalized indicator of multipath, interference, jamming, spoofing, etc |
| 4. UE feared events | GNSS receiver measurement error | *e.g., GNSS-MeasurementList* |
| Hardware faults | \* |
| Software faults | \* |
| 5. LMF feared events | Hardware faults | \* |

# Appendix C : Integrity parameters from TS 37.355

|  |
| --- |
| ***integrityInfo***  This field provides the integrity result for the *locationEstimate.*  - ***horizontalProtectionLevel*** provides the Horizontal Protection Level (HPL) for the *locationEstimate* along the semi-major axis of the error ellipse. Scale factor 0.01 metre; range 0 – 500 metres.  - ***verticalProtectionLevel*** provides the Vertical Protection Level (VPL) for the *locationEstimate*. Scale factor 0.01 metre; range 0 – 500 metres.  - ***achievableTargetIntegrityRisk*** indicates the achievable Target Integrity Risk (TIR) for which the HPL and VPL are provided. The achievable TIR is given by *P*=10-0.1n [hour-1] where *n* is the value of *achievableTargetIntegrityRisk* and the range is 10-1 to 10-9 per hour. If this field is absent, the achievable TIR is the same as the *targetIntegrityRisk* in *IntegrityInformationRequest*. |

NOTE: The Protection Level (PL) is a statistical upper-bound of the Positioning Error (PE) 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, i.e., the PL satisfies the following inequality:   
*Prob per unit of time* [((*PE>AL*) & (*PL<=AL*)) *for longer than TTA*] *< required TIR*  
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.  
A specific equation for the PL is not specified as this is implementation-defined. For the PL to be considered valid, it must simply satisfy the inequality above.