3GPP TSG-RAN WG2 Meeting #117 ***R2-220xxxx***

Electronic Meeting, February 21 – March 3, 2022

**Agenda item:** 8.11.2.4

**Source:** ESA

**Title:** [AT117-e][623][POS] Early discussion of integrity issues (ESA)

**Document for:**  Discussion

# 1. Introduction

The following email discussion has been triggered at RAN2#117bis-e:

**[AT117-e][623][POS] Early discussion of integrity issues (ESA)**

Discuss the need for signalling cross-covariance terms in the integrity assistance data, and identify if there are other critical issues that need treatment outside the running CR discussions.

      Intended outcome: Report to Wednesday online session

      Deadline:  Wednesday 2022-02-23 0200 UTC

The discussion below is mainly based on the remaining open issues provided by the following contributions:

* R2-2203525 [Pre117-e][610][POS] Open issue on GNSS positioning integrity (ESA)

Indirectly, the following contributions are also part of the material reviewed.

* R2-2201722 Summary of [Post116bis-e][628][POS] 37.355 running CR (Qualcomm)
* R2-2201723 37.355 running CR v4 (Qualcomm)
* R2-2202005 Report of email discussion [Post116bis-e][634][POS] Positioning open issues list (Intel)
* R2-2201765 GNSS integrity – Extended Discussion (Stage 3) (Swift Navigation)

# 2. Contact Information

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# 3. Open issues

## 3.1 Summary GNSS Integrity Issues as reported in R2-2203525

The below issues have been extracted from the R2-2203525 and reports their status as per companies views expressed during [Pre][610][POS] and summarized in R2-2203525 email discussion. Most of the items treated in this email discusson are agreed in principle (signalling details will be discussed in the running CRs thread). One item, namely cross-covariance for GNSS orbit and clocks errors, requires further discussion based on the technical arguments brought forward in the [610]. Furthermore, companies view on validity period parameter needs a quick “show of hands” given the fact that one potential problem has not been considered in the [610] discussion – loss of connectivity during a positioning session.

**Note: Open Issues should be defined for aspects that need to be closed, important to make already agreed functionality work in a reasonable way. Not yet agreed optimizations that may not be needed shall not be listed as Open Issues.**

**The topic has to be removed from Rel-17 scope if the corresponding open issues cannot be resolved.**

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| **ID** | **Open issues** | **Status as per companies views collected in R2-2203525** | **Source** |
| #1 | Use ***GNSS-RealTimeIntegrity IE*** or create a new IE to accommodate the Alerts for the satellite/constellation specific DNUs | **CAN BE CLOSED**  **Baseline in R17:**   * GNSS-RealTimeIntegrity IE can be used to signal faulty / DNU satellites. **[Proposal 1]** * Constellation DNU flag is not needed. **[Proposal 3]**   **Open elements (will be addressed as part of the running CRs for Stage 2 and Stage 3):**   * Clarify what condition can be interpreted DNU=FALSE. **[Proposal 2]**   Note: Stage 2 and Stage 3 needs updating to clarify what condition can be interpreted by the UE as DNU=FALSE. |  |
| #2 | Cross-covariance for the Orbit and Clock integrity bounds and whether these bounds should be included as a new IE or within the existing SSR Orbit and Clock IEs. | **PARTLY CLOSED**  **Baseline in R17:**   * bounding of GNSS errors is based on mean and variance (standard deviation). **[Proposal 4]** * Bounds for clock errors are included in GNSS-SSR-ClockCorrections IE and bounds for Orbit errors are included in the GNSS-SSR-OrbitCorrections IE (i.e., no new IE combining the two type of bounds). **[Proposal 6]**   **Future optimization:** Full cross-covariance matrix for the orbit-clock corrections can be revisited. **[Proposal 4]**  **Open elements (addressed in this discussion):**   * Provision of correlation / covariance parameters for orbit errors. **[Proposal 5]** |  |
| #3 | Residual Risk parameters proposed in Table 3.2-2 (R2-2201765) should be integrated into their corresponding SSR correction IEs or within a separate standalone IE. | **CAN BE CLOSED**  **Baseline in R17:**   * Integrity Residual Risk parameters will be included into corresponding exsiting IEs instead of a new IE for all. **[Proposal 7] & [Proposal 8].** Constellation and satellites fault probability and duration could go to GNSS-SSR-OrbitCorrections IE (priority 1) or, potentially, in GNSS-RealTimeIntegrity IE. **[Proposal 7]**   **Note:**   * Signaling aspects like decision between GNSS-SSR-OrbitCorrections IE and GNSS-RealTimeIntegrity IE will be addressed as part of the running CRs for Stage and Stage 3. |  |
| #4 | Validity period (and value ranges) for each of the bounds | **PARTLY CLOSED**  **Baseline in R17:**   * Integrity bounds are included in SSR IEs and therefore it has been voted not to add any additional validity time parameters (10-2 vote). **[Proposal 9]**   **Swift has challenged this vote by stating we have not addressed the loss of connectivity during a positioning session. Therefore, the proposal has been left on the list with “Potentially Agreeable” items instead of “Agreed in Principle”.**  **Open elements (addressed in this discussion):**   * What happens during a loss of service connectivity during a positioning session? Won´t the UE need to know for how long the integrity assistance data is still valid? **[Proposal 9]**   **Note:**   * The running CRs for Stage and Stage 3 will clarify what is the definition of the validity period for GNSS integrity assistance data. |  |
| #5 (R2-D3) | Periodic Assistance Data | **CAN BE CLOSED**  **Baseline in R17:**   * Periodic transmission of integrity data is supported **[Proposal 10].** At least gnss-Integrity-PeriodicServiceAlert-r17 needs to be added to the periodic GNSS assistance data **[Proposal 11].**   **Note:**   * The running CRs for Stage and Stage 3 will clarify if any other IE needs to added to the list of periodic assistance data. |  |
| #6 | Stage 3 details on the support of broadcast assistance data.  FFS: the detailed IE should depend on stage 3 details | **CAN BE CLOSED**  **Baseline in R17:**   * Introduce the following new posSIB **[Proposal 13]:**  |  |  |  | | --- | --- | --- | |  | *posSibType* | *assistanceDataElement* | | GNSS Common Assistance Data (clause 6.5.2.2) | *posSibType1-9* | *GNSS-Integrity-ServiceParameters* | | *posSibType1-10* | *GNSS-Integrity-ServiceAlert* | |  |
| #7 | Integrity requirements information to be included in the LPP signaling | **PARTLY CLOSED**  **Baseline in R17:**   * Add TIR and AL to the IntegrityInformationRequest-r17 IE. Their value range shall be based on table 9.2.4 in TR 38.857 **[Proposal 14].**   **Open elements (addressed in this discussion):**   * Views were split regarding TTA parameter. Marked as FFS. * Indicate Reporting Mode 1 or Reporting Mode 2 **[Proposal 15].** | Rapporteur |
| #8 (R2-D1) | Integrity Request Information |
| #9 (R2-D2) | Integrity Information Result | **CAN BE CLOSED**  **Baseline in R17:**   * Represent PL in IntegrityInfo-r17 IE as horiztonal and vertical component. Value ranges 0-500m, 1 cm resolution**.** Same for AL **[Proposal 19].**   **Open elements (addressed in this discussion):**   * TIR, AL, and TTA as optional parameter **[Proposal 19].** * Support Reporting Mode 2 **[Proposal 20].**   **Note:**   * The shape of HPL and HAL e.g. circle, 2D ellipse, etc. can be addressed in the running CRs for Stage 3. | Rapporteur |
| #10 (R2-D4) | Integrity Service Parameters | **CAN BE CLOSED**  **Baseline in R17:**   * The encoding proposed in v4 of running CR for Stage 3 R2-2201723 is confirmed **[Proposal 21] & [Proposa 22].** |  |
| #11 (R2-D5) | Code Bias Bounds | **CAN BE CLOSED**  **Baseline in R17:**   * The encoding proposed for SSR-IntegrityCodeBiasBounds-r17 in v4 of running CR for Stage 3 R2-2201723 is confirmed **[Proposal 23].** |  |
| #12 (R2-D6) | Phase Bias Bounds | **CAN BE CLOSED**  **Baseline in R17:**   * The encoding proposed for SSR-IntegrityPhaseBiasBounds-r17 in v4 of running CR for Stage 3 R2-2201723 is confirmed **[Proposal 24].** |  |
| #13 (R2-D7) | STEC Integrity | **CAN BE CLOSED**  **Baseline in R17:**   * The encoding proposed for STEC-IntegrityParameters-r17 and STEC-IntegrityErrorBounds-r17 in v4 of running CR for Stage 3 R2-2201723 is confirmed **[Proposal 25].** |  |
| #14 (R2-D8) | Gridded Correction Integrity | **CAN BE CLOSED**  **Baseline in R17:**   * The encoding proposed for SSR-GriddedCorrectionIntegrityParameters-r17 and TropoDelayIntegrityErrorBounds-r17 in v4 of running CR for Stage 3 R2-2201723 is confirmed **[Proposal 26].** |  |

# 4. Open issues

## 4.1 Open Issue 2: Cross-covariance and inclusion of integrity bounds for Clock and Orbit in a new or existing IEs.

From pervious discussion it was not clear why these parameters, for the Orbit and Clock integrity bounds, lead to improved performance in accordance with the principle of operation. There was no strong preference expressed for including these parameters therefore more discussions were recommended.

The magnitude of the Protection Limit varies in time with satellite geometry. The GNSS Integrity provider broadcast parameters that describe the residual decorrelation errors for each individual satellite. The user receiver computes the Protection Limit confidence bound by combining the range-domain error distributions for all satellites used in the navigation solution into the position domain. A common technique to model the range-domain distributions is the Gaussian distribution. Actually, GNSS errors are not following exactly a Gaussian distribution (i.e. zero-mean), therefore more complex alternatives can be considered.

**RAN2 agreed to use a paired-overbouding strategy which requires, besides of standard deviation, also the mean (used as bias with ± signs). Note, simple bounding can be also supported in LPP by seting the mean to zero.**

**Consequence of the RAN2 solution: Increassed signalling. Instead of providing just one parameter for each error, the distribution standard deviation, we know provide one additional parameter, the mean, for each satellite.**

**During [Pre117-e][610] we have debated the need to providing the UE with more parameters for the bounding of satellite clock and orbit errors. These parameters were presented in the shape of a symmetrical 4x4 matrix, for each satellite, and contains on the main diagonal the variance terms, and in the upper triangle the covariance terms.**

|  |  |
| --- | --- |
| **C:\Users\Florin-Catalin Grec\AppData\Local\Microsoft\Windows\INetCache\Content.MSO\FA54DDA7.tmp** |  |
| In SSR orbit data the position of the satellite is expressed in a 3D frame: Radial/Cross/Along-track | Full Cross-Covariance Clock-Orbit Matrix for one satellite as proposed by Swift and discussed in Open Issue 2 of R2-2203525. |

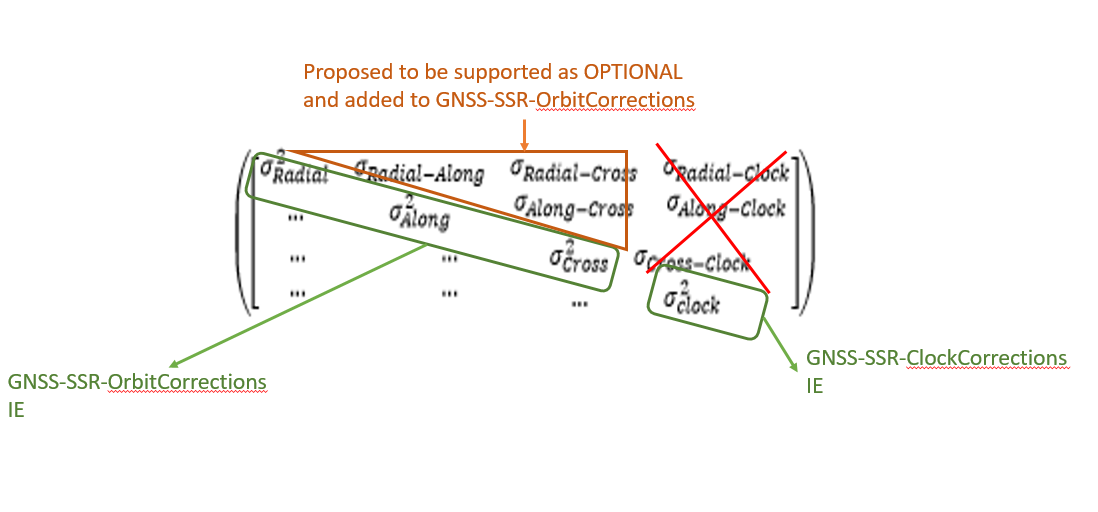
A significant majority (11-2) stated that the full cross-covariance matrix is an optimization rather than a need. In recent GNSS literature very good results are reported when providing only the elements on the main diagonal. For better performance, the Radial-Along covariance can also be considered while providing the full cross-covariance is not significantly better and it comes with more bandwidth costs.

In R2-2203525 it has been agreed in principle to:

* For Release 17, the bounding of GNSS errors is based on paired overbounding principle characterized by mean and standard deviation. In future releases provision of full covariance matrix for the orbital covariance can be revisited.
* Include integrity bounds for Clock in the GNSS-SSR-ClockCorrections IE and bounds for Orbit in the existing *GNSS-SSR-OrbitCorrections* IEs rather than combining them in a new joint IE.

**Proposal 5. For Release 17, besides the 3 required variance parameters for Orbit, the covariance parameters, in along-track/cross-track/radial frame, can be provided optionally.**

Consequences of these agreements and proposals:



**Q1: Do you agree that the three Orbital covariance terms should be supported in Rel17 and included as OPTIONAL fields in the GNSS-SSR-OrbitCorrections IE? Please clarify the reason for your choice.**

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| --- | --- | --- | --- |
| **Company** | **Yes** | **No** | **Comments** |
| ESA | (only OPTIONAL) |  | We can accept as optional these fields. **Not mandatory**.  We object to have these parameters as mandatory because we think they are not needed and are related to one particular implementation. Furthermore, the R-C and A-C have zero correlation (we will send zero values), there is no significant improvement on top of providing just the variance terms, and the number of parameters for bounding orbits of each satellite doubles (from 3 to 6). |
| OPPO |  | No. | Uneccesary optimization, which results in large signalling overhead. |
| Ericsson | Yes, as optional |  | The discussion [Pre117-e][610] we got presented with an interesting paper “Covariance Analysis of Real-Time Precise GPS Orbit Estimated from Double-Differenced Carrier Phase Observations” from 2019, analyzing the impact from different error representations, given data from a sparse set of ISG reference stations across the globe. It is reasonable to assume that these stations could be seen as subject to independent atmospheric delay error contributions.  What is important to keep in mind is that a different set of reference stations could give a different result. One particular case is a limited region with a much denser set of reference stations, such as a country where a service provider is maintaining a very dense network for high performance. In such a scenario, the atmospheric delay errors between reference stations cannot be seen as independent, but instead quite correlated. This could propagate into the cross-correlations of the orbit errors for example.  Not assessing whether any of the two scenarios above is most realistic, we just conclude that there can be cases not typically repreented by the papr above that could imply that there is value in including the orbital covariance terms as optional. |
| Swift Navigation | Y |  | We are fine to include them as OPTIONAL (which should also address the signalling overhead concerns raised by OPPO).  The existing *GNSS-SSR-OrbitCorrections* IE is decomposed into along-track, cross-track and radial errors. We’ve shown in the previous literature that the correlations between these errors (i.e. the orbit covariances) are significant and there should be an option to send them, as proposed in the image above (in brown). Otherwise we must unnecessarily inflate the bound to ensure we maintain the overbounding principle for the satellite feared events. In the image above, note that the orbit covariances are a generic mathematical formulation and not tied to any particular implementation. We acknowledge the consensus view that the full orbit-clock cross-covariance (marked red in the image) can be FFS for now. |
| CATT |  | No | The three Orbital covariance terms is an optimization rather than a need. |
| Qualcomm |  | No | We prefer adding the basis in this Release which are needed for all implementations, and with possible further adjustments/alignments with RTCM in future. Indeed, already the mean value of the error bounds would not need to be mandatory present, since not all services/providers may use a "paired overbounding". If the biases are very small, a sigma inflation would be more efficient and may be sufficient for many services/applications.  If the cross-covariance terms are to be supported, it must be a separate UE capability. |

## 4.2 Open Issue 4: Validity period for each error bound and value ranges

In R2-2203525 companies were requested to provide their view on the need for a validity period parameter for each integrity assistance data. Among the options traded, a significant majority is in favour of not adding any validity time as bounds for GNSS errors are directly included in the corresponding SSR assistance data.

There is one potential scenario that need to be clarify though: a loss of connectivity during a positioning session. Swift further clarified this potential scenario:

*“We still have not addressed the case of when a bound is issued and the service loses its connection (i.e. no DNU or SSR correction update is sent). This requirement has been consistently raised since the SI phase. No technical argument has been presented as to why these concerns can safely be ignored. If the service cannot guarantee that integrity will not be violated after a loss of connectivity, then it is simply not fit for purpose as an integrity system, and could lead to a hazardous condition occurring in a safety critical system.”*

**Q2: Do company believe the scenario described above is problematic? What does the UE do in this situation?**

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| --- | --- | --- | --- |
| **Company** | **Yes** | **No** | **Comments** |
| ESA |  | X | In case the service loses its connection (no DNU or SSR correction update is sent) we think it would be reckless from UE to continue attempting to perform high-accuracy positioning with or without integrity.  We would defer this to experts in positioning over control-plane but we don´t see the above scenario as a problem. |
| Ericsson | X |  | What if data is produced by a data feed every 30s and forwarded to a server. Could it be so that a UE requests the data, but the request arrives 10s after the data was forwarded to the server. Then the UE gets data that is only valid for 20 more seconds. For the UE, the 30s update rate does not inform about that the data is only valid for 20s, not 30s.  For broadcast, there is a generic validity for posSIBs |
| Swift Navigation | X |  | We’re open to an option that does not involve additional assistance data parameters, but right now we see two issues with making it equal to the SSR update rate:   1. As raised by Ericsson, there could be delays or latency in the message handling, which impact the reception time of the message, leading to a non-deterministic validity period. 2. How does the UE even know what the update period is?   This is why we proposed to add an explicit validity period (validityPeriodSeconds), noting there is some precedence for this already in LPP (e.g. udreValidityTime in DGNSS-CorrectionsElement). Overall we defer to the RAN2 experts on whether there’s another alternative that meets these requirements. |
| CATT | X |  | We think it is indeed a problem, but it can be put into Rel-18 to continue the discussion. |
| Qualcomm |  | X | We already discussed and agreed that "In Rel-17, we do not address the data transmission feared event (i.e. we rely on the system’s existing methods for assuring data integrity).". The UE would realize a "loss of connectivity" anyhow and when the assistance data do not arrive at the confirmed intervals. E.g.,  NOTE3: The target device expects a *ProvideAssistanceData* messages at the in Step 2 announced interval(s). If some or all of the assistance data is not available at each periodic interval, an error indication is provided in the positioning method specific IE (e.g., IE *A‑GNSS‑Error*).  The same seems to be the case for posSI. The UE expects the assistance data at the scheduled periodicity. If the error bounds are included in the SSR assistance data, it does not sound sensible to have/allow for different/separate validity times for the bounds and the corrections. |

# 5. Minor issues

## 5.1 Open Issue 8 (R2-D1): Integrity Request information

R2-2203525 left open two items: the need for TTA (views were almost 50-50) and reporting mode in the IntegrityInformationRequest-r17. Note, TIR and AL are agreed in principle as part of [610].

**Q3: Do companies agree that TTA is need? Please argument you choice.**

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| --- | --- | --- | --- |
| **Company** | **Yes** | **No** | **Comments** |
| OPPO |  |  | TTA should be transmitted towards the UE if mode 2 is needed to be supported. Otherwise, no. |
| Ericsson |  |  | Same view as Oppo |
| Swift Navigation | Y |  | The LMF and the UE must agree on the TTA. Imagine the LMF was assuming a TTA of 1s and the UE a TTA of 5s, then there could be a period of 4s where the integrity outputs are valid according the UE’s TTA but not the LMF’s TTA, causing an integrity volation at the LMF. Therefore it is necessary to send the TTA as part of the KPIs so the UE can ensure the correct TTA is used in the integrity computation and outputs. |
| CATT |  |  | Agree with OPPO |
| Qualcomm |  | X | We can not see a use of the AL and TTA to be provided to the UE. It is not needed for the calculation of a PL and it is also not described in Stage 2 "principle of operation" either. The decision of alert is done by comparing the AL specified and the PL calculated. If the application resides in the UE, the UE would know the application specific AL/TTA. If the application is in the network, the network would know. |
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From SI report:

Two modes of integrity result reporting are also identified below for consideration in the WI:

**- Mode 1 of Integrity Result Reporting : PL Reporting**

The integrity computing entity calculates the PL, based on the measurement, assistance information and TIR. Then, the calculated PL is directly reported to where the LCS client resides (Network or UE). Hence, the integrity computing entity does not judge whether the positioning system is still available, it simply provides whatever PL value it has obtained. It is left to the LCS client itself to determine if the positioning system is still available based on the reported PL.

**- Mode 2 of Integrity Result Reporting : Integrity Event Flagging**

The integrity computing entity calculates the PL, based on the measurement, assistance information and TIR. Then, the integrity computing entity further compares the calculated PL with the given AL to determine if the positioning system is still available to offer trustable position estimation. Thus, the integrity computing entity may only have to report a binary flag (0 and 1) to indicate whether the positioning system is available or not. Thus, in this case the LCS client can be directly informed about the system availability, without conducting further evaluation by itself.

**Q4: Do companies agree that IntegrityInformationRequest-r17 should include an indicator to tell the UE either Reporting Mode 1 or Reporting Mode 2?**

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| --- | --- | --- | --- |
| **Company** | **Yes** | **No** | **Comments** |
| OPPO |  |  | It depends whether or not we should support reporting mode 2. IF so, an indicator should transmitted towards the UE. |
| Ericsson | Y |  |  |
| Swift Navigation |  |  | If we decide to support Mode 2, then Yes. |
| CATT |  |  | If we support both reporting mode 1 and mode 2, we need to include the indicator. Otherwise, not. |
| Qualcomm |  | X | We cannot see any use case/benefit of this "mode 2". The application should compare the PL with the AL, and if the UE reports a location estimate to the network, the application obviously resides in the network. "Mode 2" would be a coarse quantization of PL. I.e., if the UE reports e.g., "safe" or "unsafe" states, the application in the network would not know how close (or far away) the PL is to AL, etc. |
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## 5.2 Open Issue 9 (R2-D2): Integrity Information Result

Nokia thinks Reporting Mode 2 in TR 38.857 should be supported as well, which allows the UE to raise the flag indicating whether there is an integrity risk.

**Q5: Do companies agree with the above statement?**

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| --- | --- | --- | --- |
| **Company** | **Yes** | **No** | **Comments** |
| OPPO |  |  | It depends whether or not we allow the UE AS layer to convey the flag towards the UE APP layer. According to the TS 23.273 MO-LR procedure, after the location estimated is obtained, it seems still involves the signaling procedure between 5GC entities, such as AMF, LMF and VGMLC before receiving of the location result at the UE APP layer via DL NAS TRANSPORT msg. Bearing this in mind, mode 2 cannot save the UE APP latency for being feeded with integrity information. |
| Ericson | Y |  |  |
| Swift Navigation |  | N, with comments | Is the question actually asking if Mode 2 should be supported? We don’t think Mode 2 is a critical requirement and seems to be an unnnecessary optimization for satisfying the R17 objectives, although we’re not fundamentally opposed to the feature if it’s the prevailing view. |
| CATT |  | N | We think supporting the reporting mode 1 is sufficient. |
| Qualcomm |  | X | The "flag" depends on the application specific AL. If the LMF has the UE calculated PL, it can determine any "flags" as desired for this application (similar to the location uncertainty shape reporting today. The UE does also not compare the "achieved accuracy" with the "requested accuracy"). This should be done by the application/user of the location information. |

The Protection Level is the main information to be included in the Integrity Information Result IE. In R2-2203525 Swift states in practice the user client should optionally report the TIR, AL and TTA that were used to calculate the Protection Level.

**Q6: Do companies agree that TIR, AL, and TTA should be provided optionally? Please argument you choice.**

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| --- | --- | --- | --- |
| **Company** | **Yes** | **No** | **Comments** |
| ESA |  | X | The LMF provides all this information to the UE as part of the integrity session. We think the LMF has already this values. |
| OPPO |  | X | Neither mode 1 nor mode 2 need such information |
| Ericsson |  | X |  |
| Swift Navigation | Y |  | The issue is that the UE’s implementation may not be able to achieve the requested KPIs. In that case there are two options: 1) either the UE can simply not compute integrity, or 2) it could compute integrity according to its best effort.  If there’s no possibility to return the KPIs that were actually used, then only Option 1 is possible, meaning that if the UE is not able to achieve the requested KPIs then no outputs can be provided (which may limit interoperability between different systems). If the achieved KPIs are included (Option 2), it enables flexibility for the UE to compute the integrity output according to its best effort (which increases interoperability). In general, in integrity algorithms the implementation is often tuned for specific KPI values and is not always general purpose and able to generate a PL for any arbitrary set of KPI inputs. |
| CATT |  | X | Agree with ESA. The LMF should already know these information. |
| Qualcomm |  | X | See comments above. |

## 5.3 Any other critical issue to resolve in Rel17

**Q7: Do you compay believe we missed something critical? Please note Open Issues should be defined for aspects that need to be closed, important to make already agreed functionality work in a reasonable way. Not yet agreed optimizations that may not be needed shall not be listed as Open Issues.**

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| **Company** | **Yes** | **No** | **Comments** |
| Ericsson | X |  | Spoofing, jamming, multipath was not addressed and should be indicated as items not completed in the work item, indicting the relevance to consider them for Rel 18  Furthermore, some basic additional information should be included from the UE in the position estimate reports to inform about the local environment, such as number of satellites used for estimating the position, HDOP or PDOP, positioning engine fix status (invalid, RTK fix, RTK float, standard precision position) as discussed in R2-2203359 |
| Swift Navigation |  | N | We agree with Ericsson that there are some remaining items marked FFS which would be relevant to consider in R18. |
| Qualcomm |  | No | Not yet agreed optimizations that may not be needed shall not be listed as Open Issues (and certainly not functionality beyond the WI description). |
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# 6. Summary

The proposals collected based on views from companies are allocated to three groups: Agreed in Principle (i.e. no objections during the discussion), Easily Agreeable, Open Issues.