**3GPP TSG-RAN WG2 Meeting #117-e R2-22xxxxx**

**Online, Feb 21st – March 03rd, 2022**

**Agenda item: 9.2.3.1**

**Source: MediaTek Inc.**

**Title: Discontinuous Coverage Open Issues Input**

**Document for: Discussion and Decision**

# 1 Introduction

This document is aimed at providing the open issues, related to Discontinuous Coverage, submitted in R2-2202053 [1] in IoT-NTN, identify potential agreements, alternatives, and further enhancements. This is also available in OI 3.1 ~ OI 3.4 under Section 9.2.3.1 of R2-117-e Agenda v3.docx.

* [Pre117-e][013][IOT-NTN] Discontinuous Coverage Open Issues Input (MediaTek)

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# 2 Discussion

RAN2 agreements related to IoT NTN’s Discontinuous Coverage are mentioned below.

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| **RAN2 115-e [2]**   1. RAN2 confirms that the following will be supported: discontinuous coverage without excessive UE power consumption and without excessive failures / recovery actions. It is expected that this need to be taken into account at least for Idle mode. The requirement is applicable for all reference scenarios (GEO, MEO and LEO). 2. Sattelite assistance information will be used by the UE for predicting coverage discontinuity. The details of the assistance information is FFS. FFS whether any applicable agreements made in NR-NTN can be reused. 3. The details of UEs actions when predicted to be out of coverage is FFS, e.g., stopping unnecessary cell search in the Idle mode, and FFS to what extent this need to be specified. 4. It is FFS to what extent it needs to be specified the details of UE’s prediction of discontinuous coverage and its ability to detect when it is back in coverage. 5. RAN2 sends an LS to SA2 and CT1 (cc: RAN3) for the possible alignment work in their specification due to the support of discontinuous coverage. |
| **RAN2 116-e [3]**   1. Satellite Ephemeris Parameters (not same as for L1 pre-compensation, for the constellation, not just single satellite) is needed for the UE for predicting coverage discontinuity. Other info, e.g., beam info, elevation angle, reference location or corresponding is FFS. 2. Providing the start-time of (incoming) satellite’s coverage and end-time of serving satellite’s coverage is needed for Quasi-Earth Fixed satellites. 3. From RAN2 point of view, the existing power saving mechanisms e.g., DRX, PSM, eDRX, relaxed monitoring, and WUS can be reused in IoT-NTN. Minor enhancements in existing power saving mechanisms to support discontinuous coverage is FFS. |
| **RAN2 116bis-e [4]**   1. The contents of the ephemeris / assistance info for non-continuous coverage:   Confirm that we Reuse the satellite ephemeris orbital parameters, already agreed for UL pre-compensation, for multiple satellites (Ref L1 params from R1).   1. FFS on the maximum number of satellites, whose ephemeris information will be provided. 2. FFS whether avg ephemeris (using same format as instant) + alamanc can be used (Gatehouse Proposal) 3. FFS how to signal this (new SIB for this particular purpose, dedicated signalling). 4. FFS if to introduce additional new parameters like satellite footprint reference point on ground, satellite coverage radius etc. |

3.1 Number of Satellites Considered

In RAN2 #116-e it was agreed that satellite ephemeris parameters “for the constellation, not just single satellite” is needed for the UE for predicting coverage discontinuity. Hence, for providing the UE with sufficient information, there should be an upper bound of the maximum number satellites. The joint contribution in R2-2200623 [5] has suggested that ephemeris information of up to 5 satellites are sufficient for the UE to predict the coverage discontinuity with a good accuracy. Hence, based on this discussion, the rapporteur ass the following question:

**Question 1: Do companies agree that five is a reasonable number for the maximum number of satellites whose ephemeris information will be provided? Please provide an alternative number and associated comments and arguments for disagreement.**

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| Company | Agree / Disagree | Comments |
| Lenovo, Motorola Mobility | Agree | We are fine with the number addressing operators’ needs. |
| InterDigital |  | We don’t have a very strong view but it is not very clear where the number 5 comes from, even reading the referenced document – the examples given are 3 satellites and 10 satellites and the only analysis is the number of bytes.  We should allow signalling of as many satellites as necessary considering a typical maximum eDRX configuration, and how many satellites are likely to pass in this time. If we are not able to do a proper evaluation, then allowing a higher maximum number of satellites e.g. 8 to be signalled and let the operator decide how many need to be signalled in their deployment, because the number needed will vary depending on e.g. density of satellites, as well as distance from earth, orbit speed, and eDRX configurations. |
| GateHouse | Disagree | The maximum total block sizes for SIB and RRC, respectively is 640 bits for SIB and more than 1500 bits for RRC on PDSCH (TBS up to 2536 for QAM4).  The orbital elements (OE) format takes up 144 bits [RAN1 #107], so the absolute maximum of different OE sets that can be included in SIB is 4 and is >10 for RRC.  In the end, the maximum number should be decided based on the agreed method of signaling and the size of any additional parameters beyond the OE.  As indicated in our answer to question 2, the maximum number of satellites with the same OE can go well beyond the above-mentioned numbers by smart encoding of SAI.  If this smart encoding for SAI some reason declined, then 4 satellites max in case of SIB signaling and 10 satellites max in case of RRC signaling could make sense. |
| Qualcomm | - | Agree with InterDigitial. With further optimization in signaling, more satellites may be accommodated. |
| Nokia | Disagree | The reasonable number of satellites ephemeris depends on the Quesion2 and Question 3. Assuming each satellite ephemeris is 18 bytes, only 4 satellites info can be accommodated into NB-IoT SIB (85 bytes). Furthermore, we should also consider additional room for other assistance info, such as satellite footprint reference point on ground, satellite coverage radius or minimum elevation angle etc. |
| CATT | Disagree | We think we should discuss the rule or criteria to evaluate the maximum number of satellites. In the referenced document, it seems like the capacity of the SIB is the only criteria. But we think the most important thing is how many incoming satellites will at least cover the scope of the current satellites, at the same or different incoming time. For example, if we have the assumption that, all the satellites have the same coverage scope, maybe one incoming satellite is enough for at least quasi earth fixed cell. And if we assume that, at most three incoming satellites should cover the scope of the current satellite, and then the maximum number of satellites can be three, even the SIB can carry maximum 5 satellites information.  Even we just consider the capacity of the SIB, we think we can assume that, at the upcoming time t, there always is a satellite will cover the special area of the current serving satellite, for example, a circle area with reference point as center point and R as radius, and then for the UE in the special area, the upcoming t is enough to predict the coverage. For the rest area, only smaller number of satellites than 5 is needed, if the SIB can carry maximum 5 satellites information.  And at last, if we just consider the capability of the SIB, the assumption above is also useful to increase the possible maximum number of satellites, the information of which can be include in the SIB. |
| ZTE | - | We have similar view as Nokia. Considering the maximum SI message size in eMTC and NB-IoT are 936 bits and 680 bits respectively and the size of ephemeris orbital parameters is 18 byte, 3 or at most 4 satellites information in SIB can be considered.  Although dedicated signalling can contain more satellite information, we’d better try to avoid sending similar information to different UEs through dedicated signalling as this will cause unnecessary signalling overhead. It may be feasible to take satellites information in dedicated signalling just as supplementary information to that in SIB. |
| Xiaomi |  | We can first decide the principal for deciding the max number of the satellite, for example, based on the maximum SIB size. Based on the current maximum SIB size, may be the SIB can’t carry ephemeris data of 5 satellites. |
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3.2 Sharing of Satellite Ephemeris Information

Once the ephemeris information is finalized, the next step is to determine how to provide this information to the UEs. This information can be provided either using a new SIB [6], [7], [8], [9], [10], [11] or dedicated RRC Signalling [5] as well. The advantage of using RRC signalling lies in the relative easiness of signalling modifications and updates in future releases. Hence, based on this discussion, the rapporteur asks the following proposal:

**Question 2: Companies are requested to mention their preference for providing this ephemeris information between the two options mentioned below:**

* **Option-1: Using a new SIB.**
* **Option-2: Dedicated RRC Signalling.**

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| Company | Option-1 / Option-2 | Comments |
| Lenovo, Motorola Mobility | Option-1 is preferred  Open to Option-2 | We see some benefits of using RRC signalling not only for future updates but also for reducing SIB size and UE power consumption of SIB reception.  However, the Satellite Ephemeris Information is necessary for discontinuity prediction, so that UE can avoid unnecessary actions (e.g. cell searching in IDLE or reestablishment attempt in CONNECTED) when NW coverage is absent. From this perspective the Satellite Ephemeris Information needs to be broadcast for IDLE UEs.  We think RRC signalling can be useful as a supplement, but considering the progress of Rel-17 (unless we can make quick discussion and decisions in this meeting), we would like to study Option-2 in further releases. |
| InterDigital | Option 1 | Discontinuous coverage enhancements seem primarily for UIEs in Idle/Inactive, at least in Rel-17, and therefore system information is the correct place to signal this. |
| GateHouse | Option 2 is preferred,  Open to option 1 | As noted in our answer to question 1 the maximum potential number of OEs in SAI can be larger with RRC than with SIB.    We see an RRC approach as the more advantageous approach:   1. A SIB definition that is not clearly expandable to rel-18 and beyond may hold redundant information for future releases, which will create an extremely-hard-to-remove overhead. 2. A lower number of UEs is expected in rel-17 than rel-18 and beyond, so the gain of a broadcasting feature is less important early on and can be added when it is mature and won’t compromise future releases.     The RRC signaling approach would require an extension to piggyback SAI on the following messages (TS36.331)   1. RRCConnectionSetup (DoNAS) /RRCConnectionSetup-NB              (DoNAS) 2. RRCConnectionResume (EDT) /RRCConnectionResume-NB          (EDT) 3. RRCConnectionRelease (EDT) / RRCConnectionRelease-NB          (EDT)     Additionally, a dedicated RRC message could be declared:  ASN1 example:  RRCSatelliteAssistanceInformation :: = SEQUENCE {  SAI SatelliteAssistanceInformation,  nonCriticalExtension     SEQUENCE{}          OPTIONAL  }    ***P1: Define extensions to RRCConnectionSetup, RRCConnectionResume, RRCConnectionRelease, their NB-variants and a dedicated RRC message for SAI.***    A SAI ASN1 structure example (including additional parameters):  SatelliteAssistanceInformation :: = SEQUENCE {  SatelliteID                   OCTET                                              OPTIONAL, OP  OrbitalElements          OrbitalElements                                 OPTIONAL, Cond  EpochTime          OCTET STRING (SIZE 3)                OPTIONAL, Cond  NextSatellite                SatelliteAssistanceInformation          OPTIONAL, ON  nonCriticalExtension   SEQUENCE{}                                   OPTIONAL  ON  }    This structure allows for the declaration of information of multiple satellites.  Notably, we could in this way give the OE of a set of satellites in a constellation by transmitting the OE once for the first satellite and not transmit any orbital elements that it has in-common with the next satellite listed in the ASN1 structure.      ***P2: Define the SAI format for ASN1 as above: Any SatelliteAssistanceInformation  that does not include an element of OrbitalElements shall assume that element of OrbitalElements of its parent.***  **In addition to our views in the answers above, we think that a minor set of additional parameters are required:**  Prioritized list of additional parameters   1. Epoch                                    (24 bits) 2. Satellite ID                          (8 bits) 3. Validity timer                     (4-5 bits)     **Epoch** as a parameter becomes a requirement with RRC signaling. Alternatively, the base-station will have to propagate all OEs in every SAI each time it is transmitted to a new UE. Letting the Epoch denote the time between TX and the determination of the OE removes this computational overhead and with 24 bits a 4.6 hour window can be represented with 1 ms resolution.    **Satellite ID** is seen as extremely important for SAI. Alternatively, UEs can only know the ID of a satellite implicitly based on the SAI-list index and must throwaway all information upon receiving a new SAI – in contrast to updating the SAI. |
| Qualcomm | Option 1  Open to Option 2 | Option 2 can also be allowed. The network may also want to provide such information to each UE via RRC message. |
| Nokia | Option-1 in Rel-17 | The use of SIB facilitates that RRC Idle UEs can obtain the information without becoming RRC Connected. Instead, dedicated signaling would require UEs to become RRC Connected more frequently than they actually need based on their traffic to acquire new ephemeris. Option 2 can be discussed in later release. |
| CATT | Option 1 | At least using new SIB in Rel-17. Further discussion can be considered in next release. |
| ZTE | Option 1 | We agree with InterDigital that system information is the correct place to signal ephemeris information to UE in idle.  Moreover, as we assume the ephemeris information is common for UEs in a cell, using dedicated signaling is obviously signaling inefficient. |
| Xiaomi | Option 1 | We only discuss the idle UE for discontinuous coverage, SIB is a straightforward way to provide the ephemeris data for idle UE. |
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3.3 Using Average Ephemeris and Almanac Information

During RAN2 116bis-e [4] it was discussed that instead of using instantaneous ephemeris information across multiple satellites, it will be better to use an average ephemeris and almanac information. However, the size and feasibility of specifying almanac needs to be taken into account. Hence, based on the discussion during RAN2 116bs-e, the rapporteur asks the following question:

**Question 3: Companies are requested to mention their preference for using this mean ephemeris and Almanac information between the options given below:**

* **Option-1: Use only mean ephemeris across multiple satellites.**
* **Option-2: Use average ephemeris and almanac across multiple satellites.**
* **Option-3: Do not use average ephemeris and almanac, rely only on instantaneous ephemeris of multiple satellites.**
* **Option 4: Allow the option to signal any of the above options**

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| Company | Option-1 / Option-2 / Option-3 | Comments |
| Lenovo, Motorola Mobility | Option-3 | The instantaneous ephemeris of the serving satellite has to be provided to the UE for TA pre-compensation and UL sync, and it has to be accurate enough. The instantaneous ephemeris of neighbour satellites is also needed for purposes other than discontinuity prediction. Therefore we do not see the necessity to introduce average ephemeris for discontinuity prediction.  If the ephemeris size is a major concern, we prefer to reduce the size by only providing the different or delta values. That is, for example, satellites in the same constellation could be on the same orbit, and in this case the instantaneous ephemeris of neighbour satellites may only include the parameters that are different from the serving satellite ephemeris (e.g., only ***Mneighbour***), or only include the delta values compared to the serving satellite ephemeris (e.g., ***ΔMneighbour = Mneighbour - Mserving***). |
| InterDigital | Option 4 | It might not be possible to conclude, and the answer may be different depending on the deployment, therefore the sensible option would be to allow the option for the operator to choose which way to signal. |
| GateHouse | Option 1 | While sending the instantaneous OE of the serving satellite is a must for UL pre-compensation and may be exploited for pass prediction, sending the instantaneous OE of other satellites for the only purpose of long-term prediction is questionable, given that (1) such information will not be used for UL-precomputation in those other satellites and (2) accuracy prediction can be improved by relying on mean OE instead of instantaneous OE.  Mean OE can be encoded with the same format already agreed for oscillating/instantaneous ephemeris, so no need to define a new format.  How to obtain the mean OE is up to the operator, just like it is up to the operator to obtain an osculating (instantaneous) OE.    *P3: Mean orbital elements shall be stored in the orbital element format.*  On “Almanac” – this term addresses “coarse information about multiple satellites’ ephemeris”, so this has already been agreed – e.g. “SAI with multiple satellite ephemeris”. Don’t mind the term - No need to discuss further. |
| Qualcomm | - | It is not clear what is new in average/mean ephemeris. Has RAN1 discussed this?  RAN1 has agreed to only two formats PVT and orbital parameters. Without any further change in format, if average ephemeris can be provided to UE, that is up to network.  What is important is the provided orbital parameters are valid to use for a long time. |
| Nokia | Option-3 | It is not clear how Option-1 and Option-2 will help in predicting coverage. For simplicity, we prefer to reuse the satellite ephemeris orbital parameters already agreed for UL pre-compensation in Rel-17. Other enhancements can be further discussed in later release. |
| CATT |  | At least instantaneous ephemeris of multiple satellites should be provided to UE, to support the first access of the UE. And it can be left to UE implementation to use average ephemeris and Almanac information. |
| ZTE | Option-3 | Generally agree with Lenovo. How to reduce the signalling overhead, e.g., via delta configuration can be left to RRC running CR discussion. |
| Xiaomi | Option 3 | The instantaneous ephemeris data will be broadcasted for UE to access the network, so we prefer to reuse it. |
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3.4 UE Behaviour in Discontinuous Coverage

UE behaviour during discontinuous coverage is discussed in RAN2 116bis-e [4]. The options for UE behaviour can be broadly classified into two categories:

1. UE’s behaviour during the coverage discontinuity is left on UE implementation [6], [7], [13].
2. Specify UE behaviour during discontinuous coverage [8], [10], [12], [14]. This includes maintaining AS states, running related timers and informing NAS about coverage discontinuity etc.

Hence, the rapporteur raises the following question:

**Question 4: Regarding UE behaviour in Discontinuous Coverage companies are requested to mention their preference between the two options mentioned below:**

* **Option-1: Leaving UE behaviour during discontinuous coverage on UE Implementation**
* **Option-2: Specify UE behaviour (maintaining AS states, running related timers and informing NAS) during discontinuous coverage.**

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| Company | Option-1 / Option-2 | Comments |
| Lenovo, Motorola Mobility | Option-2 | At least for the UEs in IDLE, the UE behaviour during discontinuous coverage cannot rely on implementation. When an IDLE UE approaches coverage discontinuity or coverage holes, neighboring cell measurement triggering is mandatory when serving cell quality is lower than threshold, and UE will keep on measuring/scanning until it finds a suitable/acceptable cell when the coverage restores (could be hours after).  Besides, although the process of discontinuity prediction can be UE implementation, UE may need to inform NW about the results for aligned understanding, so that the NW will not try to page UE during discontinuous coverage. |
| InterDigital | Option 2, however | The question has been framed in an incomplete way. The question appears to address the UE behaviour in RRC\_CONNECTED only while neglecting Idle/Inactive behaviour – if in RRC\_CONNECTED we leave to UE implementation, then the network does not know whether e.g. UE just returns to idle, whether it maintains timers (and so may trigger RLF later) or whether it maintains the AS context and attempts to reconnect once coverage returns – the network has to know the UE behaviour in order to act accordingly ( e.g. locally release the connection after RLF would be triggered ). Hence we have to choose what to do – if we specify nothing, then UE should just continue to run the timers and may eventually trigger RLF if the coverage gap is sufficiently long. Another approach is to trigger RLF and/or go to idle mode immediately, and yet another options is to pause all timers and resume when back in coverage.  Since it is unlikely to converge in the last meeting we would suggest that the RRC\_CONNECTED UE behaviour is the same as legacy (so i.e. just trigger RLF after out of sync and timers expire – NOT leave to implementation) and we look at enhancements in R18.  What we do think needs to be specified is the idle mode behaviour and we address this in a contribution. In summary, the UE should be allowed not to perform measurements and not to monitor paging while in a discontinuous coverage gap. This will also allow some power saving in the RRC\_CONNECTED case, because once UE triggers the RLF/re-establishment there is no need to perform a cell search until back in coverage. |
| GateHouse | Option 1 | No strong opinion  Definitions to avoid unwarrented neighboor cell measurements could be a good idea as mentioned above, but at least in NTN NB-IoT handovers are not a concern.*.* |
| Qualcomm | Option 2 | It is agreed not to search and waste power when there is discontinuous coverage. Why to keep this option open by saying UE implementation. |
| Nokia | Option-2 | It would be good to discuss whether UE disables cell reselection measurements based on UE awareness of coverage availability and if UE can report its estimated coverage window to the NW. The latter one is quite important for paging in discontinuous coverage to facilitate UE and NW have synchronized understanding on when the UE is reachable. |
| CATT | Option 1 | Based on the coverage prediction, the UE can leave the connected mode, suspend and restart the cell search, camping or RRC connection setup procedure, and so on. |
| ZTE | Option-2 | Per our knowledge, SA2 also assume that, by using of awareness of discontinuous coverage in the UE, UE can disable Access Stratum procedures and avoid triggering NAS transactions in order to reduce UE power consumption. Therefore, we have similar view as some above comments that we need to specify the necessary UE behaviors when it’s in discontinuous coverage.  We list the following aspects that we think are necessary:   * 1. For UE in idle, UE can predict the start of discontinuous coverage according to the information in SIB. How to predict can be left to UE implementation. But it seems more companies think UE needs to stop most of the AS layer processes of idle mode (may behave like in PSM state). Then this part needs specification work. For example, what’s the condition of stopping AS processes (upon UE determines the cell will stop serving?), what AS processes need to be stopped, e.g., to stop performing measurements and cell reselection, to stop monitoring paging and other? How to handle the times, to stop or keep running?   2. For UE in idle, in order to further avoid the possible NAS processes, e.g., TAU or service request in discontinuous coverage, we think (also some other companies indicate) AS can notify NAS of some information related to discontinuous coverage. For example, AS can indicates the end time of serving satellite’s coverage and the start time of incoming satellite’s coverage to NAS.   3. For UE in connected mode, UE may not be able to exactly determine the discontinuous coverage as UE cannot read SIB. Meanwhile, the network can exactly know that the serving cell will stop the service. Then the network can passively release the RRC connection. In order that UE can differentiate whether this release is a normal release or a special one due to that coverage discontinuity is upcoming, we suggest to introduce a new release reason, e.g., “out of coverage”, to UE in RRC release message. Based on this release reason, after UE back to idle, UE can follow the process mentioned in above #1 bullet.   4. In the #3 bullet case, UE may not be able to further notify NAS of exactly information about discontinuous coverage (as mentioned in #2 bullet), then another legacy way can be used to inform and disable NAS, e.g., to use legacy IE *extendedWaitTime*. However, the current value range of the wait time (INTEGER (1..1800)) may be not enough to match the duration of coverage discontinuity, RAN2 can discuss how to extend the value of this timer. |
| Xiaomi | Option 1 | UE can keep dormancy when UE is in the discontinuous coverage and then performs cell selection when UE is back to the coverage. |
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# 5 Conclusion

**<Will be updated after companies’ responses>**

# 6 References

1. R2-2202053 Summary of [Post116bis-e][087][IoT-NTN] Open Issues
2. R2-115e Chair Notes EOM
3. R2-116e Chair Notes EOM
4. R2-116bise Chair Notes Jan 28 EOM\_rev2
5. R2-2200623: On Discontinuous coverage in IoT-NTN, MediaTek Inc.
6. R2-2200217: Discussion on remaining issues on Non continuous coverage, Intel Corporation
7. R2-2200252: Discussion on the support of discontinuous coverage for IoT over NTN, OPPO
8. R2-2200440: Details on the support of the discontinuous coverage, Qualcomm Incorporated
9. R2-2200850: Discussion on open issues for support of Non continuous coverage, CMCC
10. R2-2201009: Discussion on remaining aspects of discontinuous coverage in IoT NTN, Nokia, Nokia Shanghai Bell
11. R2-2201599: Discontinuous coverage in IoT NTN, Ericsson
12. R2-2200694: Remaining FFSs on discontinuous coverage in IoT NTN, ZTE Corporation, Sanechips
13. R2-2201181: Support of discontinuous coverage, Apple
14. R2-2201453: Discussion on non-continuous coverage, Huawei, HiSilicon.