**3GPP TSG RAN WG2 #118-e R2-220xxxx**

**Online, 9th – 20th May, 2022**

**Agenda Item: 7.2.4**

**Source: GateHouse**

**Title: [draft] Report of [AT118-e][057][IOT NTN] Discontinuous coverage (Gatehouse)**

**Document for: Discussion**

# Introduction

This document is the report from the following offline discussion:

* [AT118-e][057][IOT NTN] Discontinuous coverage (Gatehouse)

      Scope:

 1. Based on Agreements related to R2-2205933, progress further to identify agreeable parts.

 2. Treat R2-2206160, determine agreeable parts (and related TPs)

      Intended outcome: Report, agreeable parameters definitions (TP)

      Deadline: For Online CB W2 Tue

During the 1st round of discussion, the rapporteur invites companies to provide their comments before the deadline that is set to: **Thursday, 12th of May – 1000 UTC.**

Hereafter the rapporteur will summarize, and the summary will be made available for the 2nd round of discussion on Thursday, 12th of May ~1300 UTC. The deadline for the 2nd round of discussions will be Monday 16th of May 12:00 UTC. Hereafter the rapporteur will summarize, and the results will be made available on Monday, 16th of May ~16:00 UTC.

# Contact

Delegates are encouraged to provide their contact information in the following table:

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| **Company** | **Name** | **Email** |
| GateHouse | René Brandborg Sørensen | rbs@gatehouse.com |
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# Agreements

This document is intended for discussion and agreement of parameters related to the discontinuous coverage case. The discussion will be based on the [post-RAN2#117-e discussion](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205933.zip) and the proposals of [R2-2206160](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2206160.zip).

The following agreements, based on the [post-RAN2#117-e discussion](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205933.zip), were made during the [first NTN IoT online session](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Inbox/Chairs_Notes/R2_118-e%20Chair%20Notes%202022-05-10%200600%20UTC.docx) in RAN2#118-e:

* P2, P3, P4, P6 are agreed
* P1 is agreed (can explore during R2 118-e whether optimizations/removal of some info is possible, optionality etc).
* (based on P1) Go for a single format / type of mean parameters for prediction of coverage (overrides earlier agreement).
* Include Satellite footprint reference location (coordinates) and coverage radius (for earth-fixed cells).
* Discuss further during R2 118-e for earth moving beams, and also clarify details for earth fixed cells (if needed)

The post-RAN2#117-e proposals:

Proposal 1: RAN2 will use SGP4 mean elements (Type 4) for sharing mean ephemeris, to support discontinuous coverage in IoT-NTN.

Proposal 2: RAN2 will explicitly use the epoch for sharing the mean ephemeris elements (of serving satellite, as well as the neighbour satellites) in IoT-NTN. RAN2 will discuss the possible format of epoch time as part of the new SIB.

Proposal 3: RAN2 will not discuss use of dedicated RRC signalling to share neighbour satellites’ ephemeris information, required for discontinuous coverage of IoT-NTN, in Rel-17.

Proposal 4: RAN2 will not discuss any further details of AS-NAS interaction for Discontinuous Coverage in IoT-NTN.

Proposal 5: RAN2 will include Satellite footprint reference location (coordinates) and coverage radius for earth-fixed cells (besides already agreed coverage start and end-times). RAN2 will discuss if elevation angle needs to be included for earth-moving beams.

Proposal 6: Network is not needed to explicitly indicate support of Discontinuous Coverage per PLMN by SIB1.

Proposal 7: RAN2 will discuss and finalize the contents and format of the new SIB.

Color code: Agreed, to be discussed.

# SGP4 ephemeris and Satellite footprint parameters.

As agreed, the satellite assistance information (SAI) to be transmitted in SIB32 consists of coverage information. This may come in the form of ON-timestamps for the earth-fixed (EF) scenario or as an SGP4-ephemeris in the earth-moving (EM) scenario, satellite footprint parameters and possibly a satellite/beam number.

## SGP4 ephemeris

### SGP4 reference frame

The standard reference frame of SGP4-propagators is true equator, mean equinox (TEME) of the epoch.

Question 4.1: Do you agree to specify the reference frame of the SGP4 format as TEME at epoch?

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### SGP4 parameters

In[R2-2206160](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2206160.zip) it is proposed that the range and granularity of the orbital parameters needed for SGP4 propagation should be based on the ranges and granularity already defined for TLE since the TLE is a well-known and tried standard-format for SGP4 parameters in the satellite community.

However, the elements included in TLEs [2] go beyond the requirements for SGP4 so that some of them could be skipped. In particular, the derivatives of mean motion, both first and second order, are not needed for SGP4 propagation [7], but are part of the TLE for compatibility reasons. In addition, the international designation of the satellite is not necessary for orbit propagation.

The necessary SGP4-based ephemeris parameters are further detailed in Table 2. The parameters in Table 2 are specified based on a conversion of the range/state-space covered by the character-encoded parameters in the TLE format (see Figure 2 and [9]) to state encoded parameters in Table 2.

 **Table 2**. SGP4 parameters: Units, range, bit size and granularity.

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| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Unit | Range | Min states | Nearest Bit | States | Granularity |
| *Example* | *SI* | *X to Y* | *Smin* | *B =* ⌈log2*(Smin)*⌉ | *S = 2B* | *(Y-X)/(S-1)* |
| Inclination | Deg | 0 to 180.0000 | 1800001 | 21 | 221 | 8.583073616e-5 |
| Arg of Perigee | Deg | 0 to 180.0000 | 1800001 | 21 | 221 | 8.583073616e-5 |
| Right Ascension of the Node | Deg | 0 to 360.0000 | 3600001 | 22 | 222 | 8.5830712318e-5 |
| Mean Anomaly | Deg | 0 to 360.0000 | 3600001 | 22 | 222 | 8.5830712318e-5 |
| Eccentricity | - | 0 to .9999999 | 1e+7 | 24 | 224 | 5.96046388e-8 |
| Mean Motion  | rev/day | 0 to 99.99999999 | 1e+10 | 34 | 234 | 5.82076609e-9 |
| Revolution Number at Epoch  | rev | 0 to 131071 | 131072 | 17 | 217 | 1 |
| B\* |  (earth radii)-1 | Nonlinear∓.99999∓9 | - | 23 | - | - |
| Epoch\* | sec | -1048575 to 1048575 | 221 - 1 | 21 | 221 | 1 |

Notes:

1. B\* is defined in TLE format as the string “∓CCCCC∓E” - where ∓ is a binary sign, C is a value 0 through 9 and E is an exponent valued 0 through 9. The nearest bit is very close to the required number of bits (21.93) hence we keep the industry standard intact and do not attempt to improve the nonlinear granularity. A decimal point is assumed after the initial sign. To clarify the bitmask for the B\* term we provide the following:
	1. Bit 0: Determines the sign of the decimal.
	2. Bit 1-17: Determine the value of the decimal, range: .00000 to .99999, nBits = 17, granularity: .00001.
	3. Bit 18: Determines the sign of the exponent.
	4. Bit 19-22: Determine the value of the exponent, range: 0 to 9, B = 4, granularity: 1.
	5. For bit 1-17 and bit-19-22 they can represent more cases than required by the granularity. However, the extra cases shall be disregarded, i.e.. the integers beyond the range of 99999 and 9, respectively, are discarded.
2. The granularity of the number of revolutions should be the integer 1 so the range has been extended from the TLE formats maximum of 99999 to 131071.
3. The variables, ”*Inclination, Arg of Perigee, Right Ascension of the Node, Mean Anomaly, Eccentricity and Mean Motion*“ all have slightly improved granularities compared to TLEs due to “extra” states being introduced when per-parameter encoding is introduced in contrast to TLEs character encoding.

This is a total of 205 bits, or 25.625 Bytes.

Question 4.2: Do you agree to specify the range and granularity of the orbital parameters needed for SGP4 propagation ..

1. .. based on the ranges and granularity already defined for TLE parameters
2. .. and adopt the parameters specified in table 2 for the SGP4 format? Any suggestions in comments.

 Epoch to be discussed in the next question

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The variable Epoch\* is a time offset between the beginning of the current week (Monday 00:00:00 UTC) of the SGP4 Epoch.

1. The Epoch time parameter within TLE is encoded as the last two digits of the Epoch year, and the Epoch day down to a granularity of ~1 microsecond and would need 44 bits. To reduce this size, Epoch\* defines the offset to the actual Epoch and is limited to a range of +/- 1048575 seconds (+/- ~12.1 days) referenced at the start of the current week. (This is considered a sufficient time to have a new TLE update).
2. It is reasonable that a new ephemeris is available before the old ephemeris (and any propagations) becomes too inaccurate. In the (unlikely) case that SGP4 ephemerides have Epochs that lay outside of this range, those can reasonably be propagated to the current week before being broadcast. Propagated ephemerides neither gain nor loose accuracy compared to the original ephemerides.
3. Since the SAI is for aiding UEs to predict coverage in the DC scenario a granularity of 1 sec is very reasonable as the added energy consumption for a UE to wake up approximately half a second in advance of predicted coverage (excluding prediction error over time) is negligible.

Question 4.3: Do you agree to specifying Epoch\* as a substitute for Epoch based on the above formulation?

* 1. Epoch\* as an offset to Epoch
	2. Epoch\* with reference to the beginning of the current week, Monday 00:00:00 UTC
	3. Epoch\* with granularity of 1 sec and a range of $\pm \frac{2^{21}-1}{2}$ seconds (~12.1 days) around the reference time.0
	4. It is up to the network to appropriately propagate the SGP4-parameters if they fall outside this range

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## Quasi earth fixed parameters

From [R2-2206160](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2206160.zip):

“The service start time, or “t-Service-r17” in [TS 36.311v17.0.0] is intended for quasi-earth-fixed cells. We have made the following observations:

1. TimeUTC-r17 is a 39 bits parameter than ranges over ~1700 years starting from Jan 1 1900 with a granularity of 10 ms. We believe this is excessive for scheduling MO-traffic opportunities between paging opportunities and the parameter range could be reduced to a range of one week with a granularity of one second to significantly reduce the ASN.1 parameter size.
2. We suggest transmitting a list of timestamps, instead of just one, that can be up to X long to match the bit size of the ephemeris parameters (X=10 for the proposed range/granularity). This will allow for several MO-traffic opportunities to be scheduled for UEs in quasi-earth-fixed cells between scheduled paging opportunities (MT-traffic).
3. The parameter name “t-Service-r17” causes some confusion with regards to the purpose of the parameter, e.g. it seems to indicate a service period, so we suggest renaming it in some way to include “Start” – for example “tServiceStart-r17”.
4. If the Quasi-Earth-fixed cell scenario is extended with additional parameters that are specific to the scenario in future Release, it would be advantageous to gather the related parameters, eg. tServiceStart-r17 in a SEQUENCE that can be extended in future releases.

**…**

ASN.1 coding example for 2, 3, 4 above:

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| -- ASN1STARTSatelliteInfo-r17 ::= SEQUENCE { satelliteSAI-r17 CHOICE { ephemerisOrbitalParameters-r17 EphemerisOrbitalParameters-r17 sgp4EphemerisParameters-r17 SGP4EphemerisParameters-r17  earthFixedCellParameters-r17 EarthFixedCellParameters-r17 nonCriticalExtension SEQUENCE {}  } satelliteID-r17 INTEGER (0..255) OPTIONAL, nonCriticalExtension SEQUENCE {} OPTIONAL, ...} EarthFixedCellParameters-r17 ::= SEQUENCE { t-ServiceStart-r17 SEQUENCE( SIZE (1..10)) OF INTEGER (0..1048575) nonCriticalExtension SEQUENCE {}}-- ASN1STOP |

“

**Question 4.4: Do you agree to specifying a “earthFixedParameters-r17” SEQUENCE - for the earth-fixed scenario - encompassing the following:**

1. **Redefining t-ServiceStart-r17 from the type TimeUTC-r17 (39 bit) to the suggested format of Epoch\*, but using 1 less bit (so 20 bits) – i.e. ranging from 0 to 12.1 days from the beginning of the current week (Mon, 00:00:00 UTC with a granularity of 1 sec)**
2. **Embedding the timestamp in a SEQUENCE structure along with a “nonCriticalExtensions” SEQUENCE to allow future extensions to the EF parameters.**
3. **Transmitting a list of EF-parameters instead of just a single set, so that more MO-opportunities can be had.**  **(~9 redefined t-ServiceStart-r17 per sgp4EphemerisParameters-r17 in terms of size in bits)**

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## Satellite footprint parameters

RAN2#118-e agreement:

* RAN2 will include Satellite footprint reference location (coordinates) and coverage radius for earth-fixed cells (besides already agreed coverage start and end-times). RAN2 will discuss if elevation angle needs to be included for earth-moving beams.

This is in line with proposals made in [R2-2205598](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205598.zip) and [R2-2206160](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2206160.zip). The following will discuss the schemes and parameterisation for satellite footprint parameters for the cases of earth-fixed (EF) cells and earth-moving (EM) cells.

### Reference point and radius (EF+EM)

In this scheme a reference point as a set of coordinates and a radius will define the edge of a beam (EF) or a cell (EM)

Question 4.5: Please provide answers to the following points:

1. Do you think that the reference point and radius footprint parameters can be useful in both the EF and the EM scenarios?
2. Do you agree that the reference frame should be given as an earth-fixed reference frame like ECEF (polar-coordinates)?
3. What should be the range and granularity of the reference point coordinates?
4. What should be the range and granularity of the cell radius?

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### Elevation angles (EM only)

In this scheme two elevation angles, define the cross-track (axis orthogonal to the direction of the satellite) footprint coverage width. In this scheme the elevation angles are given with regards to the satellite position. In [R2-2206160](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2206160.zip) the following description is made:

If a single value is given, the “Right-” and “Left minimum elevation angles” are assumed equivalent. That is, the footprint is even around the satellite track. To describe a footprint coverage that is offset from the satellite track, two minimum elevation angle thresholds can be specified. The right minimum elevation angle is the rightmost (with reference to the satellite direction) elevation angle. The left being the leftmost. Both angles can be given from -70 to 70 allowing a leftmost elevation angle to be placed on the right side of the reference satellite. A “left minimum elevation angle” that is located to the right of the reference satellite is indicated by a negative sign on the elevation angle and equivalently for a “right minimum elevation angle” to the left of the reference satellite. See Figure Y.



**Figure Y**. Satellites travelling “into the paper”. The left satellite depicts the case of a footprint cross-section that is even around the nadir and so a single elevation angle “a” is necessary to describe the case. In this case a UE will be within the footprint if the minimum elevation angle the UE will experience during a satellite pass is greater than “a”. The satellite to the right projects a footprint to the left of the satellite: the “right minimum elevation angle”, “b”, is on the left of the satellite - it is measured as any other elevation angle, but assigned a negative sign. In this case a UE will be within the footprint if the minimum elevation angle the UE will experience during a satellite pass is greater than “a”, less than “b” and the UE is located on the left of the satellite pass.

**Question 4.6: Please provide answers to the following points:**

1. Do you think that the elevation angle footprint parameter is useful in the EM scenario?
2. What should be the range and granularity of the elevation angles?

 [R2-2206160 proposal: -70 to 70 Deg with a granularity of 10.]

1. Should the transmission of a single elevation angle be allowed and understood as the case where both elevation angles are equal?

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## Other

### Satellite/Beam ID

A Satellite / Beam ID is suggested in R2-2206160. A satellite ID is suggested in [R2-2205143](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205143.zip).

**Question 4.7: Please provide answers to the following points:**

1. Should satellite / beam ID be an optional parameter.
2. What should be the range of IDs supported?

 [R2-2206160 + R2-2205143 proposal: 1 byte, integer, 0 to 255]

1. Should it be up to UE implementation to discard old SAI and maintain a list of SAI?
2. If no:
	1. Should SAI without satellite/beam IDs be treated as a temporary list that would be discarded for any newly received SAI without satellite/beam IDs?
	2. Should SAI without satellite/beam ID be treated as an extendable list that grows with every newly received SAI.
	3. Should UEs update SAI information upon receiving new SAI for the same satellite or beam ID?

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### Validity duration for satellite Epoch

[R2-2205143](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205143.zip) suggests to have a validity duration for the earth-moving case in the order of minutes.

“… Moreover, during email discussion, companies mentioned the observation that the epoch times of the ephemeris information sent for different satellites is unlikely to coincide. Each advertised satellite will come with its own epoch time, which only indicates the time at which the TLE was determined.”

The rapporteur points out that the EPOCH is not the time at which a TLE is determined – it is the time at which the TLE was determined for, i.e., the EPOCH can lie in the future. The TLE is most accurate around the EPOCH. Creating and assessing TLEs with EPOCHs in the future involves sampling the future orbit of the satellite using numerical integration methods, which are extremely accurate.

Furthermore, R2-2205143 suggests using legacy notification procedure to signal changes in SIB32.

**Question 4.8: Please provide answers to the following points:**

1. **Should validity duration be an optional parameter or be left to UE implementation?**
2. What should the range and granularity of the validity duration be?
3. Should the legacy notification procedure be used to signal changes to SIB32?

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### Other

**Question 4.9: Feel free to raise any other points – any additional parameters or behaviour that is essential for discontinuous coverage in Rel-17 that has not been considered.**

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# ASN1 proposals (TN)

 The following structure is based on an acceptance of all proposals of R2-2206160.

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| --- |
| -- ASN1STARTSystemInformationBlockType32-r17 ::= SEQUENCE { satelliteInfoList-r17 SatelliteInfoList-r17 OPTIONAL, -- Need OR nonCriticalExtension SEQUENCE {} OPTIONAL, ...}SatelliteInfoList-r17 ::= SEQUENCE (SIZE (1..maxSat-r17)) OF SatelliteInfo-r17SatelliteInfo-r17 ::= SEQUENCE { satelliteSAI-r17 CHOICE { sgp4EphemerisParameters-r17 SGP4EphemerisParameters-r17  earthFixedCellParameters-r17 EarthFixedCellParameters-r17 nonCriticalExtension SEQUENCE {}  } satelliteID-r17 INTEGER (0..255) OPTIONAL, satelliteFootprintParameters-r17 SatelliteFootprintParameters-r17 OPTIONAL, nonCriticalExtension SEQUENCE {} OPTIONAL,} EarthFixedCellParameters-r17 ::= SEQUENCE { t-ServiceStart-r17 SEQUENCE( SIZE (1..10)) OF INTEGER (0..1048575) nonCriticalExtension SEQUENCE {}}SGP4EphemerisParameters-r17 ::= SEQUENCE { inclination-r17 INTEGER (0..2097151) periapsis-r17 INTEGER (0..2097151) longitude-r17 INTEGER (0..4194303) anomaly-r17 INTEGER (0..4194303) eccentricity-r17 INTEGER (0..16777215) meanMotion-r17 INTEGER (0..17179869183) revNoEpoch-r17 INTEGER (0..131071) bStar-r17 BIT STRING (23) epochStar-r17 INTEGER (-1048575..1048575)} SatelliteFootprintParameters-r17 ::= SEQUENCE { elevationAngleR-r17 INTEGER (-7..7) OPTIONAL, elevationAngleL-r17 INTEGER (-7..7) OPTIONAL, refPointX-r17 INTEGER (X1..X2) OPTIONAL, refPointY-r17 INTEGER (Y1..-Y2) OPTIONAL, refRadius-r17 INTEGER (1..200) OPTIONAL, nonCriticalExtension SEQUENCE {} OPTIONAL,}-- ASN1STOP |

**Question 5.1: Please provide views on the above ASN.1 specifications structure without regard to the parameters, which are to be discussed in section 4. Are you okay with:**

1. SAI type as a CHOICE per satellite/beam.
2. earthFixedParameters-r17 SEQUENCE to hold parameters for the EF scenario – to ensure extensibility.
3. EF parameters as a list of parameters (timestamps) instead of a single instance (single timestamp).

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# Conclusion

TBD, TP for CR to be written based on replies. TPs (ASN.1 code) in section 5 are currently based on all proposals being agreeable.

# References

1. [R2-2205933](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205933.zip) "Email Discussion Report [Post117-e][906][IoT-NTN] Non-Continuous Converge”, MediaTek Inc.

1. [R2-2206160](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2206160.zip) “ASN.1 proposal for satellite assistance information for prediction of discontinuous coverage”, Sateliot, GateHouse, Mediatek, ESA, Eutelsat, Hispasat, Hughes/Echostar, Inmarsat, Ligado, Novamint, Omnispace,
2. [R2-2205598](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205598.zip) “Assistance Information for Predicting the Discontinuous Coverage”, Google Inc.
3. [R2-2205143](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Docs/R2-2205143.zip) “FFS and RILZ302, H000, O302 etc for SIB32”, ZTE Corporation, Sanechips

1. [R2#118-e](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_118-e/Inbox/Chairs_Notes/R2_118-e%20Chair%20Notes%202022-05-10%200600%20UTC.docx) “Monday online seesion, chair’s notes”