P3GPP TSG-RAN WG1 Meeting #104-e R1-21XXXXX

e-Meeting, January 25th – February 05th, 2021

Agenda Item: 8.4.2

Source: Moderator (Thales)

Title: FL Summary on enhancements on UL time and frequency synchronization for NR NTN

Document for: Discussion

# Introduction

This feature lead summary document captures the issues related to UL time and frequency synchronization in NR NTN. It contains a summary of the contributions under 8.4.2 at TSG-RAN WG1 #104-e. together with identified key open issues and recommends topics/questions to be handled via email discussions. The goal of this document is also to provide recommendation on prioritization of discussion and whether any issues should be postponed.

Please note the following checkpoints for agreements:

[104-e-NR-NTN-02] Email discussion/approval on UL time and frequency synchronization with checkpoints for agreements on Jan-28, Feb-02, Feb-05

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# Issue#1: Initial acquisition of TA before PRACH preamble transmission

## Issue#1-1: Indication of common TA (CTA)

The need of the common TA (also referred to as common timing offset in the last RAN1 meeting) was heavily discussed in the two previous RAN1 meetings (102-e and 103-e). This discussion was directly linked to the one on the reference point used for uplink time synchronization. Different options for this reference point were discussed in the two last RAN#1 meetings.

Based on RAN1meeting#103-e, a reasonable way forward is that the focus should be more on UE operation. That is from UE perspective, all discussed options of Reference Point are equally acceptable as they clearly indicate the expected UE behaviour. Therefore, **the concept of reference point for time synchronization at the satellite or at the gNB can be left to the network**.

From the UE perspective, it is the Common TA (CTA) that is relevant. The common time offset would be determined and broadcast by the network, and would implicitly define the reference point but the exact location/definition of the reference point would be an internal matter to the network.

Consequently, with the following agreement made in RAN#103-e, the concept of Reference Point for the delay at the satellite or at the gNB can be left to the network. The UE behaviour for delay pre-compensation is clear:

**Agreement:**

**In NTN, the network may broadcast**

* **A common timing offset value**
	+ **FFS details of the common timing offset**
* **FFS: A common timing drift rate**

**Before Msg1/MsgA transmission, the NR NTN UE in idle/inactive mode calculates its TA as follows:**

**Where:**

**is derived from the User specific TA self-estimation**

 **is derived at least from the common timing offset value if broadcasted by the network. The granularity of and whether is indicated as a Timing Advance or as a Timing Offset value [unit] are FFS. Upon resolving the FFS, one of the X in the equation will be removed.**

**depends on band and LTE/NR coexistence and is specified in TS 38.213 section 4.2.**

 **is specified in TS 38.211 section 4.1.**

**Note: UE will not assume that the RTT between UE and gNB is equal to the calculated TA for Msg1/Msg A.**

The focus in current RAN1 meeting should be on the details of the common timing offset, more specifically: We need to provide more details about the common TA component X in the above proposal: its value, its unit and granularity. The detailed signalling design can be left FFS for next meeting.

The following table recaps the proposals of the companies regarding the value of X:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Apple | Proposal 1: The common timing offset broadcast by network is equal to the feeder link RTT. |
| Huawei | Proposal 6: The common timing offset is determined as the RTD from the reference point to the satellite, i.e. by subtracting the delay compensated at the gNB from the feeder link RTD. |
| Ericsson | Proposal 4 The TA to be used by NTN UE in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED states should be as follows:where: and are defined as in Rel-16. is UE-autonomous TA calculated based on the GNSS-acquired UE position and the serving satellite ephemeris to pre-compensate for the service link RTT. is network-controlled common TA to compensate (e.g.) for feeder link RTT. |
| MediaTek, Eutelsat | ***Proposal 1****: The value of X in shall be determined as:** *UL subframe and DL subframe timing aligned at the gNB: if X is expressed at a unit of Tc or if expressed as a unit of time*
* *UL subframe and DL subframe timing aligned at the satellite: X = 0.*

*It is up to the network to configure the value of X.* |
| ETRI | Proposal 3: X derived from the common timing offset value may include the TA margin and the RTT of the feeder link. The range of values for X can include negative values. |
| Thales | Proposal 1For PRACH transmission, the NTN UE calculates its TA as follows:Where: is derived from the User specific TA self-estimation corresponding to the service link RTD and autonomously acquired by the UE based on its GNSS position and the satellite ephemeris.If indicated by the Network, the UE needs to apply which is a common timing offset to deal with the RTD on the feeder link.: a timing offset to account for the TA estimation uncertainty values are specified in TS 38.133 |
| Asia Pacific Telecom, FGI | Proposal 1 If the timestamp is not supported for initial access and if sharing gNB location has security concern, then NW shall provide the Satellite-gNB RTT, e.g., common TA, via system information. |
| Intel Corporation | Proposal 2: • If common timing offset indication is used to compensate propagation delay corresponding to feeder link, indication of common timing drift rate should be supported |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Proposal 1: The final equation for the full TA at UE should be, Proposal 2: gNB broadcasts the common TA value in the NTN specific SIB message along with other NTN specific broadcast messages. |

The following table recaps the proposals of the companies about unit and granularity of X:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| ZTE | Proposal 1: The common timing offset value should be indicated as a TA and broadcast in SIB.Proposal 2: The unit of indicated common TA can be chosen as  |
| Ericsson | Proposal 3: The TA for NTN should use the legacy granularity of T\_c units, i.e., the common TA component X should be placed within the brackets as follows:  |
| Huawei | Proposal 6: The common timing offset is determined as the RTD from the reference point to the satellite, i.e. by subtracting the delay compensated at the gNB from the feeder link RTD. |
| MediaTek, Eutelsat | ***Proposal 1****: The value of X in shall be determined as:** *UL subframe and DL subframe timing aligned at the gNB: if X is expressed at a unit of Tc or if expressed as a unit of time*
* *UL subframe and DL subframe timing aligned at the satellite: X = 0.*

*It is up to the network to configure the value of X.* |
| CMCC | **Proposal 2:** Support X be indicated as a Timing Offset value, and remove the first X in the equation, i.e., |
| OPPO | Observation 1: legacy TA granularity may burden the system information overhead.Proposal 1: CTA granularity is based on a multiple of 16 samples interval, e.g. N\*, where N is for FFS.  |
| Apple | **Proposal 4:** The TA used for Msg1/MsgA transmission is given by , where the value X is indicated as a timing advance. * If the reference point is set at satellite, then X= 0.
* If the reference point is set at gNB, then X is equal to the common timing offset.
* If the reference point is based on implementation, then X is equal to a fraction times the common timing offset.
 |
| Xiaomi | Proposal 2: The equation is proposed. |
| Panasonic | Proposal 1: We prefer the Common Timing Offset value formulation expressed by multiples of and with a value in the order of slot or half slot granularity. |
| Lenovo, Motorola Mobility | The formula in last meeting should be updated as:TA=(NTA+NTA,offset)\*Tc+XProposal 1: The unit of common timing offset indicated can be different from that of TA command and separately configured. |
| Asia Pacific Telecom, FGI | Proposal 3 [+X] in the equation can be removed and be equivalent, e.g., Proposal 4 X is indicated as a Timing Advance value |
| CATT | Proposal 3: Suggest to apply the following equation for TA calculation: |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Proposal 1: The final equation for the full TA at UE should be,  |

### Company views on Common TA indication

W.r.t the value of X, a general assumption within the TDocs submitted to RAN#104-e is that the CTA is equal to the RTD on the feeder link. That is, the reference point (RP) is located at the gNB/GW. [Huawei] observed that there will be a large timing offset between the DL and UL frame timing at the UE side when reference point for common timing offset is at the gNB and proposed that the common timing offset is determined as the RTD from the reference point to the satellite. Which means that the RP is located somewhere on the feeder link and gNB compensates the RP-gNB delay and subtracts it from the feeder link RTD.

Moderator view is that the exact location of the RP should be an internal matter to the network and therefore the common TA would be determined and broadcast by the gNB. As stated by [Ericsson] the CTA is a network-controlled common TA to compensate (e.g.) for feeder link RTT.

The concern of [Huawei] on the large timing offset between the DL and UL frame timing at the UE side when reference point for common timing offset is at the gNB can be discussed when the whole design is clearer. To cope with such issue (we need to discuss first if this is a real issue) the gNB can simply compensate a static RTD in a transparent way to the UE.

W.r.t the unit of X, three possible options were discussed within the Tdocs submitted to RAN#104-e:

* Option (1): X is expressed as the legacy granularity of **T\_c unit**; X to be placed within the brackets as follows:
* Option (2): X is expressed as **unit of time**; X to be placed outside the brackets as follows:
* Option (3): other than above options

Different views were provided and they are gathered within the following table:

|  |  |
| --- | --- |
| Option (1): X is expressed in the legacy granularity of T\_c units (X to be placed within the brackets) | ZTE, Ericsson, MediaTek, Eutelsat, Apple, Thales, Asia Pacific Telecom, FGI, CEWiT, IITH, IITM, Tejas Networks, Reliance Jio |
| Option (2): X is expressed as unit of time(X to be placed outside the brackets) |  CMCC, Xiaomi, Lenovo, Motorola Mobility, CATT |
| Option (3) | OPPO (granularity is based on a multiple of 16 samples interval)Panasonic (expressed by multiples of T\_c and with a value in the order of slot or half slot granularity) |

Further, in order to keep legacy TA procedures intact [Ericsson] proposed to add a separate term for UE-autonomous TA in the formula of the TA applied by the UE, different from which is the timing advance dynamically controlled by the network. As per Release 16 definition [refer to TS 38.211] For initial access (PRACH transmission), it is zero. After initial access, it is updated through an absolute timing advance command in RAR and subsequently through timing advance commands in MAC CE.

With the above considerations in mind and based on companies view on the value, unit and granularity of X, the initial proposal is made as follows:

**Initial proposal 1-1:**

**The Timing Advance applied by an NR NTN UE is given by:**

**where:
 and are defined as in Release-16.
 is UE-autonomous TA to compensate for the service link RTT.
 is network-controlled common TA.**

 **is specified in TS 38.211 section 4.1.**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Thales | We support the proposal |
| CATT | We are not supporting to this proposal.Firstly, we need the agreement for . In last meeting, we only agreed one X value.Secondly if is included in bracket, the timing unit would be Tc. The granularity of Tc would cost much signalling bits, instead, using ms should be enough, because the common TA doesn’t need very accurate indication.Secondly, for , it can be indicated by the network or set to zero by default if no indication. We need clarify the definition what is the network-controlled common TA. |
| Panasonic | We support the proposal. |
| Huawei  | Agree with the proposal. |
| ZTE | Supportive for this proposal. |
| Intel | Support the proposal |
| CMCC | Partial agree with this proposal.We are supportive to keep the same definition of as in Release-16. Nevertheless, the unit of X has not been thoroughly discussed. In our view, X may be time varying with continuous value (e.g., X(t) = a common timing drift rate + a common timing drift rate \* t, and t is continuous). So it is preferred to express X as unit of time and place it outside the brackets. |
| Apple | We do not support the proposal. 1. NTA, common is a network controlled common TA. However, the relationship between this common TA and the agreed “common timing offset value” needs to be clarified. Note that if the agreed common timing offset value is equal to feeder link RTT, then NTA, common could be different from that common timing offset value if timing reference point is not at gNB.
2. Overall, we think two values need to be broadcast by network.
	1. The first one is feeder link RTT, which is used to calculate the overall RTT between UE and gNB for determining the starting of RAR window.
	2. The second one is the TA between satellite and timing reference point. This value is used in the TA calculation formula as NTA, common.
 |
| OPPO | Fine |
| Ericsson | We support the proposal. |
| MediaTek | Support proposal 1.1 |
| Qualcomm | We don’t support the proposal. Considering that the feederlink RTD is large, unit of Tc for X will impose large signalling overhead. In addition, given that feederlink RTD is fast time-varying, it’s unclear if such an accuracy can ever be achieved by UE. |
| Sony | We support the proposal. |
| Spreadtrum | We support the proposal. |
| Xiaomi | Option (2) is preferred. If using the ms as time unit, the signalling overhead can be reduced. Moreover, if X is represented by the absolute time, rather than integer Tc, it will provide more flexibility for X indication.  |
| vivo | Support |
| Samsung | Support Initial proposal 1-1. |
| InterDigital | Support the proposal |
| ChinaTelecom | Support the proposal |
| LG | We agree with the intention of this proposal, but we have two clarification points as below.1. In this proposal, the definition of parameter is changed from the previous agreement (e.g., ).If this proposal is agreed, should we ignore the previous agreement regarding common timing offset?
2. Besides, we don’t need to rush to decide on the location of
 |
| Lenovo/MM | Support the proposal. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | We support the proposal |
| APT | Support Initial proposal 1-1 |
| Nokia, Nokia Shanghai Bell | We do not support this proposal. As such, we could be supportive of having the offset defined in units of T\_c (inside the brackets), but we are opposing to the definition of *NTA,UE-specific* as it is directly referring to “compensate for the service link RTT”. Such a definition would preclude any options that are relying on the *referenceTimeInfo-R16* IE. Any solution that is described here should preferably be agnostic to which method is being used (ephemeris or the reference time). |

### Updated proposal based on company views (First round of email discussions)

After the first round of email discussions, 18 over 24 companies are supportive of **Initial proposal 1-1.**

The following concerns were raised by some companies:

For [CATT, Qualcomm, Xiaomi] the granularity of Tc would cost much signalling bits:

Regarding the signalling overhead, the required bit number for LEO was evaluated by ZTE in [R1-2100245] and Thales in [R1-2100520] some preliminary inputs are given in sub-section (II) below.

Regarding the granularity, as proposed by some companies the unit is Tc but the **granularity (time resolution) should be proportional to the subcarrier spacing**: .Tc. Thus, the **finer time resolution is given** by SCS = 120kHz subcarrier spacing; that is *Tc.*

Another concern from [CATT]: the common TA doesn’t need very accurate indication. Moderator’s answer: common TA if indicated by gNB, will be applied by the UE as part of its calculation. Of course, this and all related components including should be calculated with sufficient accuracy (the maximum acceptable error on calculation should be within the requirements yet-to-be defined by RAN4 and the whole accuracy budget should be split between UE specific TA and Common TA).

Regarding the concern from [CMCC]: X may be time varying with continuous value: Some inputs on the characterization of X (the common TA) are provided in [Ericsson- R1-2100927], are copied in sub-section (I) below.

According to [Apple] the relationship between this common TA and the agreed “common timing offset value” needs to be clarified. Moderator’s answer: both are referring to the same RTT that the UE needs to add to its UE specific TA to get its Full TA:  **= Common-TA (in unit of Tc) = Timing Offset value [expressed as unit of time]**

For [Nokia] any solution that is described here should preferably be agnostic to which method is being used (ephemeris or the reference time). Moderator’s answer: Agree we can further work on refining the wording and change the definition of to make the proposal more generic.

Based on the above discussion and to make progress on this complex topic we need to share the same understanding about as well as the **common TA drift rate** discussed as Issue#1-2. Hence, the characterization of the common TA is needed.

To ease this common understanding, we can consider **one deployment scenario** in which the GW and gNB **are collocated** and the reference point for time synchronisation is at gNB. In this case, the gNB shall indicate the  **= the time varying RTT on the feeder link.** Other deployments can be considered afterward. When this case-study in crystal-clear we can easily generalise to other cases (if gNB is not co-located with the GW, we just need to consider the GW-to-gNB RTT which is a **static RTT** that can be compensated by the gNB .i.e not indicated within **).**

Some inputs about the characterization of the common TA and the required bit number for broadcast are provided in the following sub-section (I) and (II) hereafter:

1. **The characterization of the common TA**:

The common TA can be approximated by a linear function as described by Ericsson in [R1-2100927]:

#### **[Ericsson- R1-2100927]**

#### 2.2.2.2 Common TA

The purpose of the common TA is to compensate for the RTT of the feeder link and possibly other latencies in the satellite-gNB path. The common TA varies with time and can be approximated by a linear function as follows:

Where:

 is the slot number of the targeted UL slot

 is a ”timestamp” slot number

 is the common TA (in units) at slot number

 is the common TA drift rate (in units per slot)

The parameters , are broadcast regularly by the network to allow the UE to calculate the common TA, whereas the timestamp could be implicit from the DL slot number in which the parameters are signaled.

To determine the need for drift rate information, consider a VLEO 200 scenario, which can be considered as a worst case. In this scenario, the feeder link RTT changes at a rate of up to 50 µs/s as shown in Figure 4.



#### **[Ericsson- R1-2100927]**

This means that a common TA () that is correct at slot will be off by 10% of the CP length 10 slots later, as shown in Table 1. Very frequent signaling of the common TA would be needed if drift rate is not included that allows the UE to autonomously update with time.

Table 1: Feeder link RTT drift for different SCS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SCS [kHz] | Slot length [ms] | CP length PUCCH/PUSCH [µs] | Feeder link RTT drift per slot [% of CP] | Slots before drift exceeds 10 % of CP |
| 15 | 1 | 4.69 | 1.1% | 10 |
| 30 | 0.5 | 2.34 | 1.1% | 10 |
| 60 | 0.25 | 1.17 | 1.1% | 10 |
| 120 | 0.125 | 0.59 | 1.1% | 10 |

The benefit of providing a drift rate is further illustrated in Figure 5. The blue curve shows the feeder link RTT during one pass of a VLEO 200 satellite. The red curve shows a linear approximation based on a base value + drift rate value that are updated every 1.6 seconds (1600 slots with SCS=15 kHz). The approximation error is less than 10 % of the CP length. The significant reduction in signaling justifies the use of drift rate for the common TA.



1. **Signalling overhead**:

The required bit number for LEO is evaluated by ZTE in [R1-2100245] and Thales in [R1-2100520] when the  **= the time varying RTT on the feeder link** :

According to both contributions 19 bits will be needed to broadcast the  **with** ****granularity.**

Please note that this signalling overhead can be further optimized and reduced by considering:

**The minimum RTT on the feeder link** ≤ **≤The maximum RTT on the feeder link**

minimum RTT on the feeder link = RTT on the feeder link at the Nadir

The maximum RTT on the feeder link = 12.89 ms (600km) or 20.89 ms (1200km)

#### **[ZTE- R1-2100245]**

Additionally, w.r.t the granularity of indication, within the service of one cell, different numerologies may be supported simultaneously. UE with larger SCS could have shorter CP and thus more sensitive to TA variance. Therefore, small granularity, e.g., **, is preferred in the expression of to make indicated common TA compatible to all types of UEs. With consideration on the tradeoff between accuracy and signalling overhead, the required bit number for LEO is evaluated in Table 1.

Table 1 Required bit number for common TA expression

|  |  |  |
| --- | --- | --- |
|  | LEO-600 | LEO-1200 |
| Upper bound of RTT | 18.87 ms | 27.27 ms |
| Required bit number (granularity is ) | 26 | 26 |
| Required bit number (granularity is ) | **19 bits** | **19 bits** |

According to existing design, during the initial access stage, the maximum supported SCS is ** kHz, which leads to the minimum granularity of TA command as **. Then, by taking the with granularity as**, the indicated common TA is compatible to all possible numerologies. Meanwhile, w.r.t the UL transmission after initial access, TA adjustment/correction with finer granularity can also be handled by the closed-open MAC CE signaling from BS.

***Proposal 2:*** *The unit of indicated common TA can be chosen as .*

 **[Thales - R1-2100520]**

valuesare indicated in the SIB by index values of TA\_common = 0, 1, 2, ..., p

Where an amount of the common timing offset with subcarrier spacing of kHz is

p is the maximum range of TA\_common;

The maximum RTD on the feeder link that shall be supported in NTN are summarized in Table 2:

Table 2 The maximum RTD on the feeder link

|  |  |  |
| --- | --- | --- |
| Scenarios | GEO based non-terrestrial access network  | LEO based non-terrestrial access network  |
| Max propagation delay on the feeder link | 270.73 ms | 12.89 ms (600km)20.89 ms (1200km) |

In case of LEO based non-terrestrial access network, the maximum common timing offset on the feeder link for numerology  is given by : , where is calculated for 120kHz subcarrier spacing and TA\_common = p.

Thus,

Therefore, the maximum range of TA-Common is calculated for 120kHz SCS as depicted within Table 3 :

Table 3 The maximum common timing offset on the feeder link

|  |  |  |
| --- | --- | --- |
| Scenarios | GEO based non-terrestrial access network  | LEO based non-terrestrial access network  |
| maximum range of TA-Common | 4158413 | 197990 (600km)320870 (1200km) |
| Related IE size on the SIB (bits) | 22 | **18 bits (600km)****18 bits (1200Km)** |

Based on first round of email discussion, the Potential Proposal is made as follows. Companies are encouraged to provide views on the proposal:

**Updated proposal 1-1:**

**The Timing Advance applied by an NR NTN UE is given by:**

**where:
 and are defined as in Release-16.
 is UE self-estimated TA
 is network-controlled common TA.**

 **is specified in TS 38.211 section 4.1.**

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Agree |
| Huawei | Agree with the proposal |
| Xiaomi | In our view, X may be time varying with continuous value. So it is preferred to express X as unit of time and place it outside the brackets. If using the ms as time unit, the signalling overhead can be reduced. |
| ZTE | Agree with proposal |
| CATT | In order to achieve common understanding for common TA, should be clarified. So we suggest the following wording: **is network-controlled common TA, exact value is depending on time reference point configured at the gNB or at the satellite.**Regarding X configuration, we share same view with Xiaomi, and X can be moved out of bracket. Currently we concern the overhead of TA signalling with unit of Tc. |
| APT | Support Updated proposal 1-1  |
| Samsung | Agree  |
| vivo | Support |

## Issue#1**-2:** The need and indication of common TA drift rate

In previous RAN#1 meeting it was agreed that the Network may broadcast a common TA that the UE uses to compensate the RTT on the feeder link. But, the need of the common TA drift rate was left FFS.

For the majority of companies, according to the TDocs submitted to RAN#104-e the benefit of providing a drift rate is clear. But still few companies do not see the need for that. So, let’s discuss first the need of timing drift rate indication. The detailed signalling design can be left FFS for next meeting.

The following table summarizes the views of companies on this issue:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| ZTE | Proposal 3: Indication of common timing drift rate should be supported to assist TA adjustment. |
| Ericsson | Observation 3 Drift rate information significantly reduces the signaling load for common TA.Proposal 5 The characterization of the common TA should include drift rate information. |
| Huawei | Proposal 8: Timing drift rate is needed for tracking the variation of common TA and reduce the signaling overhead of TAC.Proposal 9: The common timing drift rate is indicated by the gNB. |
| Thales | Observation 1. Without indicating the timing drift over the feeder link, the accuracy of self-estimated TA will be degraded.Proposal 2.In case of LEO based NTN, the gNB shall broadcast the common timing drift over the feeder link if the common timing offset needs to be applied by the UE for the self-calculated TA |
| MediaTek, Eutelsat | Observation 1: Knowledge by the UE of the common timing drift rate over the feeder link is beneficial for the determination of the full TA for MAC timers and for robust DL synchronization.Proposal 2: The common timing drift rate over the feeder link is broadcast. |
| CMCC | Proposal 1: Remove the FFS before “a common timing drift rate”, i.e.,- In NTN, the network may broadcast  A common timing drift rate |
| Apple | Proposal 2: A common timing drift rate is broadcast together with the common timing offset. |
| Xiaomi | Proposal 5: The common timing drift rate indicated by network should be supported. |
| PANASONIC | Proposal 3: We see no need in adopting a common timing drift rate. |
| vivo | Proposal 4: Whether to broadcast a common timing drift rate and how to use the common timing drift rate need further study. |
| Lenovo, Motorola Mobility | Proposal 3: Support indication of timing offset drift rate. |
| Samsung | Observation 2: The gNB jointly indicates the TA variation rate and the Doppler shift.Proposal 5: The gNB signals common TA drift rate to enable autonomous TA update at UE. |
| Asia Pacific Telecom | Observation 1 For earth fixed cells, the propagation delay distributes as a U shape, and signaling common timing drift rates might be risky when UEs miss some of them.Observation 2 If UE applies the common timing drift to increase the received TA value, then UL transmission may have overlap due to a large gap between a new TA value and an old TA value.Proposal 2 Support of common timing drift rate in Rel-17 should be justified with reasonable reliability. |
| Sony | Observation 1: Applying beam-specific timing drift rate can improve the throughput approximately 15% than without timing drift rate case.Proposal 4: RAN1 should support the signalling of timing drift rate information to the UEs in a beam specific manner. |
| Intel | Proposal 2: • If common timing offset indication is used to compensate propagation delay corresponding to feeder link, indication of common timing drift rate should be supported |
| CATT | Proposal 5: There is no need to broadcast the common timing drift rate. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Proposal 3: In NTN, the network may broadcast a common timing drift rate to update the common TA. It can be broadcasted in the NTN specific SIB. |

### Company views on the need and indication of common TA drift rate

The need of indicating common TA drift over the feeder link was discussed in 16 TDocs. Diverse justifications were provided, from different stand points:

[MediaTek, Eutelsat] observed that the knowledge by the UE of the common timing drift rate over the feeder link is beneficial for robust DL synchronization. According to [Thales]without indicating the timing drift over the feeder link, the accuracy of self-estimated full TA will be degraded. [Ericsson, Huawei] observed that drift rate information significantly reduces the signalling load for common TA, further [Ericsson] proposed that the characterization of the common TA should include drift rate information. [CMCC] proposed to remove the FFS before “a common timing drift rate in the proposal agreed in RAN103-e and recalled in section 1.1. [Apple, Xiaomi, Lenovo, Motorola Mobility, Samsung, Asia Pacific Telecom, Sony, Intel, CEWiT, IITH, IITM, Tejas Networks, Reliance Jio] are also supportive of indication of timing drift over the feeder link.

On the other hand, companies [CATT, PANASONIC] do not see the need for that and [vivo] proposed to further investigate the need of broadcasting such drift rate.

By considering the above discussion, the following initial proposal is made:

Initial proposal 1-2:

**The gNB shall/ may broadcast the common TA drift rate as part of the common TA indication**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Thales | We support the proposalThe gNB shall broadcast the common timing drift over the feeder link if the common TA needs to be applied by the UE for the self-calculated TA |
| CATT | For common TA drift rate indication, it needs more investigations for its usage. Firstly, the feeder link TA variation can be maintained by the network, regardless the common TA indication or not.Secondly, it required additional signalling and complicated UE implementation. Thirdly, one accurate full RTT is not needed to manage by the UE, instead, relying on periodically feeder link RTT indication, one coarse RTT can be obtained by the UE. Therefore, broadcasting the common TA drift rate is not fundamental solution. |
| Panasonic | We do not support the proposal. DL/UL timing difference due to the feeder link delay could be managed by gNB implementation to some extent. The changing rate of the propagation delay between satellite and ground GW would not be constant depending on the satellite position, so that accurate compensation of the feeder link delay might not be possible even with an indication of the common timing drift rate. |
| Huawei | We support the proposal. Common TA drift rate is needed to tracking the timing drift of common TA and avoid frequent TAC command. A slight update to the proposal Initial proposal 1-2: **The gNB shall ~~may~~ broadcast the common TA drift rate as part of the common TA indication** |
| ZTE | Support, updates from HW is needed. |
| Intel | Support the proposal.  |
| CMCC | We support the proposal. |
| Apple | If the timing reference point is not set at satellite, then the common TA drift rate is needed. Otherwise, the common TA drift rate is not needed.  |
| OPPO | Before agreeing on the need or not need, we would like to understand the following questions1. Whether the drift is a linear function?
2. How to ensure the TA variation is monotonic?
3. The value of the drift itself is time varying or invariant? We do not prefer the UE to frequently read system information to get updated drift value.
4. Would it be more efficient for the network to handle the feeder link drift than for the UE to handle?

Without having the answers to the above questions, it is very hard to give our preference.  |
| Ericsson | We support the proposal (with presumed typo “shall may” changed to “may”). |
| MediaTek | Support proposal 1.2 with HW update |
| Qualcomm | More discussion is needed to understand the feasibility and the need of such signalling. |
| Sony | We support the proposal.To broadcast the common timing drift rate can increase the throughput according to our simulation (R1-2100860). In addition, this would also reduce the signalling overhead for common TA. |
| Spreadtrum | We shared the similar views with CATT |
| Xiaomi | We support the proposal.Timing drift rate is needed for tracking the variation of common TA and reduce the signaling overhead of TAC. |
| vivo | We support the proposal in general. The common timing drift rate shall be broadcasted if the common TA needs to be pre-compensated by the UE. Besides, the common timing drift rate obviously is suitable for TA update in connected mode. However, whether to use the common timing drift rate during initial access needs further study. |
| Samsung | Support |
| InterDigital | Support |
| ChinaTelecom | Support with HW’s updating |
| LG | Support the proposal, and updated proposal from HW is also fine. |
| Lenovo/MM | Agree with the proposal. And it seems the “may” in the proposal should be deleted. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | We support the proposalMechanism to update the common timing drift needs to be further discussed considering nature of change in common TA for different deployment scenarios. |
| APT | Neutral to Initial proposal 1-2We have a concern on how to maintain the TA alignment with NW, and how to deal with a command/signaling loss that carries a TA drift rate. |
| Nokia, Nokia Shanghai Bell | In general, we could be supportive of this proposal. |

### Updated proposal based on company views (First round of email discussions)

After the first round of email discussions, 19 companies are supportive of broadcasting the common TA drift rate as part of the common TA indication.

There is one clear objection from [Panasonic]. The reason provided is that DL/UL timing difference due to the feeder link delay could be managed by gNB implementation to some extent.

According to [CATT, OPPO, Qualcomm, Spreadtrum, APT] more discussion is needed to understand the feasibility and the need of such signalling.

From Moderator’s perspective, if we agree on the need of the Common TA. It would be difficult to understand how it can be characterized without the common TA drift rate. Many contributions provided inputs on the need and benefit of indicating a drift rate. Good justification can be found in **[Ericsson- R1-2100927]** copied in **sub-section 1.1.2 - I.The characterization of the common TA**. Please note that the timing drift rate was already discussed in the SI and as stated in **[38.821]** the indication of timing drift rate, from the network to UE, is also supported to enable the TA adjustment at UE side.

Based on the majority support, the following potential proposal is made as starting point for further discussion.

The detailed signalling design can be left FFS for next meeting.

Updated proposal 1-2:

**The gNB shall broadcast the common TA drift rate as part of the common TA indication**

Companies are encouraged to provide views on the updated proposal:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Agree |
| Huawei | Agree with the proposal. |
| Xiaomi | Agree  |
| ZTE | Agree, prefer to indicate this parameter to minimize the impact on gNB implementation  |
| CATT | Before we make the conclusion on how to configure the time reference point, we think it should be suspended.For the common TA and common TA drift, it is only necessary when UE is enforced to compensate the feeder link TA. But so far we don’t think it is one essential solution. |
| APT | Support Updated proposal 1-2. Agree with moderator’s note. |
| Samsung | Agree |
| vivo | Support |

## Issue#1-3: The need and the indication of TA margin

W.r.t the TA margin the following issues are being discussed:

• **The need of TA\_margin to account for the TA estimation uncertainty**: Following RAN#103-e discussions on this issue, a TA margin seems needed at least from RAN1viewpoint depending on requirements for UE-autonomous TA error, PRACH preamble format, common TA error, and common timing drift rate error.

• **Indication of the TA\_margin to the UE**

• **The value of TA\_margin**

The focus should be now on how the TA margin should be indicated to the UE. such discussion was started in last meeting but no consensus was achieved.

In last meeting, the Moderator recommendation was as follows:

FL recommendation:

Regarding the indication of TA margin used to account for TA estimation uncertainty when applying the TA pre-compensation in initial access, companies are encouraged to analyze the pro and cons of the two identified solutions:

- TA margin is indicated in SIB

- TA margin is included within the Common TA. i.e.; Common TA configuration absorbs the maximum TA uncertainty

The value of TA margin will be defined after the specification of UL time synchronization requirement

The Issue#1-3-2 was discussed in 11TDocs submitted to RAN1#104-e. The following table is the recap of proposals from different companies:

|  |  |
| --- | --- |
| **Companies** | **Proposals**  |
| ZTE | Proposal 4: The maximum TA uncertainty should be absorbed in common TA configuration to save signaling. |
| Ericsson | Observation 4 If the common TA includes a margin for maximum estimation error of the UE-specific TA, and the accuracy requirements of the UE-specific TA are appropriately set, the current unipolar TA command in Msg2 is sufficient, i.e., bipolar TA command or extended TA range is not needed in Msg2. |
| MediaTek, Eutelsat | Proposal 3: for UE with Autonomous acquisition of the TA, UE shall use one of:• TA\_offset of half the cyclic prefix of PRACH preamble which is added to Timing Offset value X broadcast by the network when applying the TA pre-compensation.• Timing Offset value X including a margin TA\_offset broadcast by the network when applying the TA pre-compensation |
| Thales | Proposal 4. TA margin is configurable parameter indicated in SIB |
| CMCC | Proposal 3: At least support including TA margin within the common timing offset value. |
| Apple | Proposal 6: TA margin is not signaled by network. |
| Spreadtrum Communications | Proposal 2: TA margin is indicated in SIB should be supported. |
| Panasonic | Proposal 2: Include the TA margin in the Common TA whereby the setting of the TA margin is up to the network implementation. |
| Lenovo, Motorola Mobility | Regarding whether TA margin indication is necessary or not, as common TA indication is already agreed, and the common TA can absorb the maximum TA uncertainty, so TA margin indication is not need.Proposal 2: TA margin indication is not supported. |
| LG Electronics | Proposal 4. Within pre-defined set of TA offsets, the TA offset can be provided by gNB via higher layer signing (e.g., SIB or dedicated RRC signaling).  The TA offset can be independently corresponding to different ROs (or RO groups) |
| CATT | Observation 4: TA margin is needed to make up for TA estimation uncertainty, and the maximum TA margin is 1/2 CP.Proposal 6: TA margin should be signaled in SIB. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Observation 1: TA margin is necessary to control any uncertainty in the full TA estimation at UE. It will be UE dependent.**Proposal 4**: TA margin should be configured to the UE directly or indirectly to control the uncertainty in the full TA estimation at the UE. Full TA equation including TA margin will be .**Proposal** 5: TA margin can be configured indirectly as fraction or multiple of the CP of the configured PRACH. . FFS Y value. |
|  |  |

### Company views

7 over 11companies (who discussed this issue in their TDocs) are with including TA-margin within the Common TA. i.e.; Common TA configuration absorbs the maximum TA uncertainty. Few companies are supportive of TA-margin indication in the SIB; for at least two main reasons: In case when the RP is located at satellite, the Common TA will be zero and it may not be necessary to provide the Common TA by gNB. Further, the need of TA\_margin is only relevant in case of TA acquisition for PRACH msg1/mgsA transmission. New value of Common TA acquired by the UE in connected state should not include TA\_margin.

At this stage, it might be difficult to have a consensus on this topic. Hence, we had better to wait until the design is clearer: To have more details about the value of maximum estimation error of the UE-specific, we need to wait until TA UL time synchronization requirements are defined. Therefore, the initial proposal is made as follows:

Initial proposal 1-3:

**The NTN UE calculates its TA as follows:**

 **is a margin for maximum estimation error of the UE-specific TA, whether it is included within the common TA or explicitly indicated in SIB is FFS**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Thales | We support the proposal |
| CATT | In principle we can support this proposal. But in case of detailed signalling design, we think TA margin can be indicted by the SIB or defined with a fixed value.For indicating the margin TA by common TA, it may be problematic if common TA is not indicated. Moreover, TA margin reflects one requirement of UE, which can be tested in RAN4, if it is merged by the common TA, it will be nothing to be evaluated for UE performance. |
| Panasonic | We support the proposal. |
| Huawei | We support the proposal. |
| ZTE | Not supportive. Since both value are from network, no need to introduce additional signalling and common TA offset is enough. |
| Intel | We share the same understanding as ZTE. TA margin indication is not needed. |
| CMCC | Not supportive. Firstly, TA margin can be absorbed by common TA. In this case, there is no need to explicitly express TA margin in the TA calculating formula.Secondly, as comments in Initial proposal 1-1, the unit of X has not been thoroughly discussed. It is preferred to express as unit of time and place it outside the brackets. |
| Apple | If TA margin is defined as a fixed value, then we do not need network indication. Hence, we propose the following modification of the proposal.“…whether it is included within the common TA or explicitly indicated in SIB **or pre-defined** is FFS” |
| OPPO | No need to have a separate proposal 1-3. The TA margin may be transparent to UE. |
| Ericsson | Too early to put the NTA,margin in the equation (even in bracket), as the intention is to wait for further progress in the design. |
| MediaTek | Support proposal 1.3. To our does not need to be necessarily signalled. It could be a value given in the specifications (e.g. TS 38.211) |
| Qualcomm | We don’t see the need of signalling of TA margin. It can be absorbed by PRACH CP and hence should be a variable depending on PRACH format. |
| Sony | We support the proposal. |
| Spreadtrum | We support the proposal. |
| Xiaomi | TA margin indication is not needed.If TA margin is necessary, as common TA indication is already agreed, the common TA can absorb the maximum TA uncertainty, so TA margin indication is not need. |
| vivo | Support. The value of is related to the accuracy requirements of UL time synchronization. |
| Samsung | Not supportive. No need to introduce unnecessary signalling. TA-margin can be included in the common TA. |
| InterDigital | Not support. We also think TA margin can be absorbed by common TA so it is transparent to the UE. |
| LG | Support the proposal.We slightly prefer the explicit indication in SIB, but the solution that a TA margin is included within the common TA is also acceptable to reduce the specification impact. |
| Lenovo/MM | Support the proposal. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | We support the proposal in principle.As mentioned in our contribution, the TA margin can be configured directly or indirectly; directly by gNB through broadcast msg or indirectly, it can be interpreted as fraction of CP. But it can not be part of common TA as it will be UE specific TA margin rather than cell or group specific. So we support broadcasting it separately. |
| APT | Agree to wait. Support Initial proposal 1-3 |
| Nokia, Nokia Shanghai Bell | The common TA should cover the common delay which would be observed either on the service link or on the entire link from gNB to UE (feeder link + service link). Any further uncertainty associated with location estimation of the nodes in the system (GNSS inaccuracy, propagation path not reflecting the Euclidian distance between UE and satellite) should be covered by the CP of the random access preamble (up to gNB configuration), and the accuracy of this should be addressed in RAN4. |

### Updated proposal based on company views (First round of email discussions)

W.r.t TA margin indication , after first round of email discussion, it is clear that the views are still split. But TA margin seems needed depending on requirements for UE-autonomous TA error, PRACH preamble format, common TA error, and common timing drift rate error.

Base on the above, the following potential proposal is made as follows. we can further work on refining the wording:

Updated proposal 1-3:

**For UE with Autonomous acquisition of the TA, to handle the UE’s estimation uncertainty, UE shall use a margin when applying the TA pre-compensation.**

Companies are encouraged to provide views on the updated proposal 1-3:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | We support proposal for margin, and suggest an alternative wording to include TA margin in common TA or explicitly indicate it Updated proposal 1-3: **A margin**  **is used by the UE to apply the TA pre-compensation.** * **Whether the margin**   **is included within the common TA or explicitly indicated in SIB is FFS**
 |
| Huawei | Agree with the proposal. |
| Xiaomi | We support proposal for margin, and suggest including TA margin in common TA. |
| ZTE | W.r.t TA margin issue, since the needs and corresponding signal method are still open discussion, the proposal from moderator is not acceptable (i.e., shall). The corresponding decision can be postponed once the corresponding conclusion on requirement is done by RAN4.  |
| CATT | Agree this proposal. |
| APT | Support Updated proposal 1-3. Better to add FFS as mentioned by MTK. |
| Samsung | It is not clear what “UE shall use a margin..”. Once RAN4 defines a requirement and margin, then we think RAN1 does not need to define the margin. |
| vivo | Agree |

## Issue#1-4: TA command in RAR

In the last RAN1 meeting, the following working assumption was made on TA command in RAR

Working assumption:

It is assumed that the requirement on UL time pre-compensation for Msg1/MsgA transmission of an NR NTN UE in idle/inactive mode will be defined such that the existing TAC 12-bit field in msg2 (or msgB) can be reused without any extension.

TA command in RAR was discussed in 6 TDocs. Related proposals and observations are summarized in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CMCC | Observation 1: The design of TA maintenance/update method based on TAC in RAR is still unclear.Proposal 4: Withdraw the following working assumption, and postpone the discussion about the bit size of the TAC field in msg2 (or msgB) until the design for TA maintenance/update based on TAC in RAR becomes clear.- (Working assumption) It is assumed that the requirement on UL time pre-compensation for Msg1/MsgA transmission of an NR NTN UE in idle/inactive mode will be defined such that the existing TAC 12-bit field in msg2 (or msgB) can be reused without any extension. |
| CATT | Proposal 8: Confirm the working assumption that the existing TAC 12-bit field in msg2 (or msgB) can be reused without any extension. |
| Apple | Proposal 7: The requirement that the existing TAC 12-bit field in Msg2/MsgB is reused is that a UE pre-compensates an accurate UE specific TA and TA margin in its Msg1/MsgA transmission. |
| LG Electronics | Proposal 8. Regarding TA command in RAR, support enhancement approaches to cover large cell coverage. Increase the step size of TA command field in RAR. Support multiple reference points. |
| Ericsson | Observation 4 If the common TA includes a margin for maximum estimation error of the UE-specific TA, and the accuracy requirements of the UE-specific TA are appropriately set, the current unipolar TA command in Msg2 is sufficient, i.e., bipolar TA command or extended TA range is not needed in Msg2. |
| Thales | Proposal 6.The residual timing error committed on the first TA acquisition should be indicated by the gNB using TA command (TAC) field in msg2 (or msgB) and applied by the UE to adjust its existing TA. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Proposal 6: Agree the working assumption on TAC 12-bit field reuse. |

### Company views

[CMCC] proposed to withdraw the following working assumption, and postpone the discussion about the bit size of the TAC field in msg2 (or msgB) until the design for TA maintenance/update based on TAC in RAR becomes clear. [CATT] and [Apple] confirm the working assumption on TA command in RAR. [LG Electronics] proposed to support enhancement approaches to cover large cell coverage.

The intention of the working assumption on TA command in RAR made in RAN1#103 is to have as design target not extending existing TAC 12-bit field in msg2 (or msgB). Basically TA command in RAR will be used by gNB to indicate the residual error made on UE-specific TA, if the accuracy requirements of time pre-compensation are appropriately set there will be no need to extend TAC field in Msg2. As consequence, with this working assumption the discussion about the bit size of the TAC field in msg2 (or msgB) is postponed. Of course we will come back on this topic when the requirement on UL time pre-compensation for Msg1/MsgA transmission of an NR NTN UE in idle/inactive mode will be defined.

Initial proposal 1-4:

**Confirm the following working assumption:**

**It is assumed that the requirement on UL time pre-compensation for Msg1/MsgA transmission of an NR NTN UE in idle/inactive mode will be defined such that the existing TAC 12-bit field in msg2 (or msgB) can be reused without any extension.**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Thales | We agree  |
| CATT | We need to confirm this working assumption, not saying it is valid. |
| Panasonic | We agree. |
| Huawei | Agree to confirm the working assumption. |
| ZTE | Confirmation of this Working assumption can be postponed since the discussion related to common TA and TA margin is still pending. Without such indication, additional extension may be needed. |
| Intel | Agree |
| CMCC | In the last RAN1 meeting, in the formula of the TA applied by the UE, is defined as a term which is derived from the User specific TA self-estimation. Nevertheless, in the current specification, is set to be equal to the TAC in RAR, i.e., . Therefore, based on progress achieved in the last meeting, how to use the TAC field seems unclear.Nevertheless, in line with former initial proposal 1-1 for issue #1, i.e., to add a separate term for UE-autonomous TA in the formula of the TA applied by the UE and to keep the same definition of as in Release-16, there will be no confusion on the usage of TAC field in RAR. So we can support the working assumption if the same definition of can be kept as in Release-16, as suggested by initial proposal 1-1. |
| Apple | Agree |
| OPPO | OK |
| Ericsson | We are fine with the working assumption. So far nothing has been presented that justifies a change to the TAC format in RAR. Note that per RAN1 practise, the bar of reverting a working assumption is high, e.g. it needs to be shown that the system is broken due to the working assumption. |
| MediaTek | Agree with FL recommnedation |
| Qualcomm | Support |
| Sony | Agree. |
| Spreadtrum | Support |
| Xiaomi | We agree |
| vivo | Agree |
| Samsung | Agree. Also, we can discuss to confirm the work assumption.  |
| LG | Confirm the working assumption |
| Lenovo/MM | Agree with the recommendation. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | We are okay with recommendation. |
| APT | Agree  |
| Nokia, Nokia Shanghai Bell | Agree with this proposal. |

### Updated proposal based on company views (First round of email discussions)

The majority of companies are supportive to confirm the working assumption. [ZTE] proposed to postpone the cconfirmation of this Working assumption since the discussion related to common TA and TA margin is still pending. Without such indication, additional extension may be needed. The answer to [ZTE] is given by [Ericsson]: So far nothing has been presented that justifies a change to the TAC format in RAR

Companies are encouraged to provide their comments on updated proposal 1-4:

Updated proposal 1-4:

**Confirm the following working assumption:**

**It is assumed that the requirement on UL time pre-compensation for Msg1/MsgA transmission of an NR NTN UE in idle/inactive mode will be defined such that the existing TAC 12-bit field in msg2 (or msgB) can be reused without any extension.**

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Support proposal.gNB estimates initial TA from PRACH preamble and indicates TAC TA in range {1, 2, .., 3846} with 12 bits in RAR in random access procedure. The initial TA command, NTA=TA\*16\*64\*2-μ \*Tc depends on the numerology (subcarrier spacing 2μ\*15 kHz, Tc=0.509 ns). The maximum NTA is 2ms, 1ms, 0.5ms, 0.25ms for μ =0, 1, 2, 3 respectively. The TA margin will be very small in practise because the UE pre-compensation is very accurate and can be well within 1 us as was shown in simulations by Ericsson, Huawei, and MediaTek. The TA margin does not seem to justify a change in the specifications for the TAC 12-bit field in Msg2 )r Msg B). |
| Huawei | Agree with the proposal |
| Xiaomi | Support the proposal. |
| ZTE | Postpone the decision for confirmation unless the whole mechanism is stable. No benefits for clearly confirmation.  |
| CATT | Support the proposal.  |
| APT |  Support Updated proposal 1-4 |
| Samsung | Support the proposal. |
| vivo | Agree |

# Issue#2 : TA update in connected mode

The issues related to TA in connected mode are listed in the table hereafter and discussed in the subsequent sections:

|  |  |
| --- | --- |
| **Main identified issues** | **Linked issues to be discussed in present RAN1 meeting** |
| * Issue#2: TA update in connected mode
 | Issue#2-**1**: UE capability of TA acquisition in RRC Connected state |
| Issue#2-**2**: TA maintenance |
| Issue#2-**3**: TA acquisition during Handover |

## Issue#2-1: UE capability of TA acquisition in RRC Connected state

On the UE capability of time and frequency compensation, it has been agreed in the last RAN1 meeting that an NTN UE in **RRC\_IDLE** and **RRC\_INACTIVE** states is required to support UE specific TA calculation and frequency pre-compensation based on its GNSS-acquired position and the serving satellite ephemeris. Moreover, it has been agreed also that an NR NTN UE in **RRC\_CONNECTED** mode shall be capable to perform frequency pre-compensation using its acquired GNSS position and satellite ephemeris. These agreements are summarized in the following table:

|  |  |  |
| --- | --- | --- |
|  | **RRC state** | **Agreed at RAN1#103-e** |
| An NTN UE **is required** to at least support **UE specific TA calculation** based at least on its **GNSS-acquired position** and the **serving satellite ephemeris** | **RRC\_IDLE** and **RRC\_INACTIVE** | **YES** |
| **RRC\_CONNECTED** | **NO** |
| An NR NTN UE **shall be capable** of at least using its **acquired GNSS position** and **satellite ephemeris to perform frequency** pre-compensation | **RRC\_IDLE** and **RRC\_INACTIVE** | **YES** |
| **RRC\_CONNECTED** | **YES** |

Proposals and observations related to this issue are summarized in the following table:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Qualcomm | Proposal 1: An NTN UE in RRC\_CONNECTED state is required to at least support UE specific TA calculation based at least on its GNSS-acquired position and the serving satellite ephemeris |
| Ericsson | Proposal 2 An NTN UE in RRC\_CONNECTED state is required to support UE specific TA calculation based on its GNSS-acquired position and the serving satellite ephemeris. |
| Apple | Proposal 8: UE maintains its timing advance value based on its GNSS location and satellite ephemeris information. |
| Panasonic | Proposal 4: In RRC\_CONNECTED mode, RAN1 to ensure that Gnb-guided Timing Advance is feasible and consider assistance by UE autonomous TA update based on GNSS location. |
| Intel | Proposal 3: * For TA update in connected mode, combination of the following timing advance (TA) determination methods shall be supported for NTN
* UE autonomous TA determination based on UE position and satellite ephemeris
* TA commands received by the UE
 |

### Company views

[Qualcomm, Ericsson, Apple, Panasonic, Intel] proposed that an agreement on UE capability to perform in RRC\_CONNECTED state UE specific TA calculation based on its GNSS-acquired position and the serving satellite ephemeris should be discussed in current meeting.

Obviously, such agreement is a pre-requisite to continue the discussion on TA maintenance in connected state. Therefore, the following initial proposal is made as follows:

**Initial Proposal 2-1 An NTN UE in RRC\_CONNECTED state is required to support UE specific TA calculation based at least on its GNSS-acquired position and the serving satellite ephemeris**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Thales | in RRC\_CONNECTED state, an NTN UE should be also required to support UE specific TA calculation based on its GNSS-acquired position and the serving satellite ephemeris  |
| CATT | Support this proposal. |
| Panasonic | We support the proposal. |
| Huawei | Agree with the proposal. |
| ZTE | Support, but this proposal is already covered by the **Proposal 2-2-1** if mixed is supported. |
| Intel | Support |
| CMCC | Agree with the proposal. |
| Apple | Agree with the proposal. |
| OPPO | OK |
| Ericsson | We support the proposal. |
| MediaTek | Support Proposal 2.1 |
| Qualcomm | Support |
| Sony | We agree in the case of Ues with GNSS capability. |
| Spreadtrum | We support the proposal. |
| Xiaomi | We agree the proposal. |
| Vivo | Support |
| Samsung | Support |
| InterDigital | Support |
| ChinaTelecom | Support |
| LG | Support the proposal |
| Lenovo/MM | Agree with the proposal. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | We also assert that this agreement is necessary to provide the TA update in RRC\_CONNECTED mode.  |
| APT | Support Initial Proposal 2-1 to support a PDCCH ordered RACH in RRC\_CONNECTED. |
| Nokia, Nokia Shanghai Bell | In RRC\_CONNECTED mode, any UE behaviour should be under control of the Gnb. It would create risk of instability of the TA control loop if the UE is performing autonomous adjustments of its transmit time without the Gnb knowing the exact time and amount the UE performed the auto-compensation. If this is not the case, the Gnb timing advance commands would be based on an old UL signal which is no longer valid. Further, it should be noted that when the UE is in RRC\_CONNECTED mode, it has been through the initial access (RACH) procedure, and would be assumed to be in time synchronized mode. Hence, it does not make sense to split into issue #2-1 and issue #2-2 (as any updates after MsgB/Msg3 would be seen as maintenance). If UE loses time synchronization to the system, it should consider its time advance to not be aligned anymore, and a RACH procedure is needed for recovery. |

### Updated proposal based on company views (First round of email discussions)

During the last GTW online session, the following agreement was made:

Agreement:

**An NTN UE in RRC\_CONNECTED state is required to support UE specific TA calculation based at least on its GNSS-acquired position and the serving satellite ephemeris.**

**FFS: Operation of closed loop and open loop TA control**

## Issue#2-2: TA maintenance

There was a preliminary discussion on TA update in connected mode in RAN1#103-1, but no consensus was achieved.

In last meeting, based on clear majority FL recommendation was made as follows:

For TA update in RRC\_CONNECTED state, combination of both open ( i.e. UE autonomous TA estimation based on UE position and satellite ephemeris, and common TA estimation and common timing drift rate) and closed control loop (i.e., received TA commands) shall be supported for NTN.

RAN1 to provide more details about open-loop and closed-loop control.

In current meeting, we need first to have an agreement on the support of combined open and closed-loop for TA maintenance. Then, we will try to provide more details on **how and when** the UE shall perform TA update in connected mode.

The following proposals and observations on TA maintenance were provided by the different companies:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| ZTE | **Proposal 5:** Combined open and closed-loop method should be applied for TA maintenance in connected mode.**Proposal 6:** In connected mode, TA value should be update as follows:where* is original TA, which refers to the value applied for the latest UL transmission.
* is the TA adjustment value due the open-loop processing including variation of TA for service and feeder link based on the GNSS and indicated information.
* is the TA command based closed-loop adjustment, where  is indicated in MAC CE TA command.
 |
| Thales | Proposal 7**.**For TA update in RRC\_CONNECTED, the UE needs to update its TA as follows:Proposal 3.If the network indicates a common timing offset corresponding to the RTD on the feeder link, the UE shall calculate the as follows:Where  is the timing drift rate on the feeder link indicated by Gnb is the time interval since last time the is received on the SIB.  |
| Huawei | **Proposal 8**: Timing drift rate is needed for tracking the variation of common TA and reduce the ignalling overhead of TAC.**Proposal 9**: The common timing drift rate is indicated by the Gnb. |
| Ericsson | **Proposal 4**The TA to be used by NTN UE in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED states should be as follows:where: and are defined as in Rel-16. is UE-autonomous TA calculated based on the GNSS-acquired UE position and the serving satellite ephemeris to pre-compensate for the service link RTT. is network-controlled common TA to compensate (e.g.) for feeder link RTT. |
| Qualcomm | Observation 1: Closed-loop timing control via MAC-CE is still needed for Ues that performs autonomous timing compensation based on GNSS-acquired position and the serving satellite ephemeris. |
| MediaTek, Eutelsat | Proposal 4: For TA update in RRC\_CONNECTED, UE pre-compensation of satellite delay is used and MAC CE TA command can be further used for UL timing alignment correction |
| CMCC | Proposal 5: For TA update in connected mode, support combined mechanism of both open and closed loop.Proposal 6: Support TA update in asynchronous way, i.e., TA update should be completed just before corresponding uplink transmission is performed. In other times, e.g., between a TA command received and the corresponding uplink transmission, whether and when to do TA update can be left to UE implementation. |
| ETRI | Proposal 4: In the case of TA update in RRC connected mode, a combination of autonomous update of UE and adjustment by TA command can be supported. It may be necessary to consider conditions for triggering autonomous update of UE and the update periodicity. In addition, conditions under which the autonomous update of UE can be disabled may be considered. |
| CAICT | Proposal3: Adopt combined open and closed loop for TA update in RRC connected state. |
| OPPO | Proposal 3: For Msg3 TA adjustment, NTA\_old is the latest determined self-estimated TA prior to the Msg3 transmission occasion.Proposal 4: Connect UE shall rely on its capability for track UE-specific TA variation on the service link. Gnb can further adjust the TA following legacy MAC-CE mechanism. |
| Spreadtrum | Proposal 3: Both open and closed control loops are supported in connected mode. |
| Xiaomi | Proposal 3: Open and closed loop mechanisms for TA adjustment should be supported in NTN. Proposal 4: TA Maintenance mechanism based DCI should be considered. |
| Nokia | Proposal 5: Network should be in control of the timing advance updates applied at the UEProposal 6: If UE is performing autonomous update of timing advance during RRC\_CONNECTED mode, the network should know the details of such adjustments in advance.Observation 11: Using referenceTimeInfo-R16 and UE based understanding of GNSS time will suffer less from the satellite movement in terms of timing advance as the reference point is at a static location (the Gnb).Proposal 7: Self adjustment by the UE based on GNSS time and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well. |
| Vivo | Observation 1: TA information may be out of date, resulting in the loss of UL performance.Proposal 2: The update of TA information should be considered to guarantee the availability of UL time synchronization. Proposal 3: The mechanism of TA update should be further studied. |
| Samsung | Observation 2: The Gnb jointly indicates the TA variation rate and the Doppler shift.Observation 3: Based on the indicated TA variation rate r\_TA (and the current TA), the UE can autonomously adjust its TA.Observation 4: Based on the indicated Doppler shift f\_D (and the compensated frequency offset), the UE can determine the residual Doppler shift and pre-compensate its UL transmission. Proposal 5: The Gnb signals common TA drift rate to enable autonomous TA update at UE. Proposal 6: The Gnb can jointly signal common TA drift rate and Doppler shift such as the UE derives Doppler shift from common TA drift rate ignallin by Gnb or vice versa. |
| InterDigital, Inc. | Proposal 2: support combined open-loop and closed loop TA update. |
| Asia Pacific Telecom | Proposal 5 Wait more progress on the open control loop in initial access to discussion coexist both open and closed control loops for UL transmission timing. |
| LG | Proposal 10. RAN1 should discuss how to update and/or report the UE specific TA in case when the NTN UE is in RRC\_CONNECTED states. |
| Intel | Proposal 3: • For TA update in connected mode, combination of the following timing advance (TA) determination methods shall be supported for NTNo UE autonomous TA determination based on UE position and satellite ephemeriso TA commands received by the UE |
| CATT | Proposal 9: Both open-loop and close-loop methods should be supported for TA maintenance in UL transmission of NTN. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Proposal 7: Gnb should provide the set of instructions to refine the TA estimated by the UE for better control of the Gnb over UE specific TA estimation.Proposal 12: UE will correct the TA in connected mode using velocity information of satellite apart from the MAC-CE TA based update.**Proposal 13**: In connected mode, combination of open and closed loop TA update should be adopted. New TA value update equation will be, . **Proposal 14**: The will be determined by UE using estimated drift value and additional drift provided by Gnb. |

### Company views

According to companies proposals and observations listed above, there is a clear majority that apart from the open loop mechanism (( i.e. UE autonomous TA estimation based on UE position and satellite ephemeris) for TA maintenance, the closed-loop timing control via MAC-CE is still needed.

Three main open questions were discussed in different Tdocs: **(Q1)** **What Gnb needs to indicate to UE to assist TA maintenance? (Q2) How the UE shall maintain its TA in connected state? (Q3) And when the UE shall perform its TA update in Connected state?**

**W.r.t first question: (Q1) What Gnb needs to indicate to UE to assist TA maintenance?**

For the update of open loop component, many companies proposed that Gnb needs to indicate the Common TA and timing drift rate on the feeder link.

For the update of closed loop component, the TAC in RAR messages (mgs2 and mgsA) shall be used as proposed by the majority.

Further, [Xiaomi ] proposed that TA Maintenance mechanism based DCI should be considered.

**(Q2) How the UE maintains its TA in connected state?**

[LG] proposed that RAN1 should discuss how to update the UE specific TA in case when the NTN UE is in RRC\_CONNECTED states.

Some “preliminary” solutions are proposed by some companies within the Tdocs submitted to RAN1#104-e: [CMCC], [Huawei], [ZTE], [Ericsson], [Thales] and [MediaTek, Eutelsat]. Please refer to related Tdocs for more details about the prosed solution.

**(Q3) When the UE shall perform its TA update in Connected state?**

[CMCC] Support TA update in asynchronous way, i.e., TA update should be completed just before corresponding uplink transmission is performed. In other times, e.g., between a TA command received and the corresponding uplink transmission, whether and when to do TA update can be left to UE implementation.

[ETRI] It may be necessary to consider conditions for triggering autonomous update of UE and the update periodicity. In addition, conditions under which the autonomous update of UE can be disabled may be considered.

[OPPO] For Msg3 TA adjustment, NTA\_old is the latest determined self-estimated TA prior to the Msg3 transmission occasion.

[Nokia] Network should be in control of the timing advance updates applied at the UE. And, if UE is performing autonomous update of timing advance during RRC\_CONNECTED mode, the network should know the details of such adjustments in advance.

[Asia Pacific Telecom] proposed to wait more progress on the open control loop in initial access to discussion coexist both open and closed control loops for UL transmission timing.

Moderator view: It will be challenging to answer all these questions in one meeting. Let’s go step by step. (Q1) is also linked to issue#1-2 on the indication of timing drift rate. We need first to have an agreement on broadcast of timing drift rate. W.r.t to questions (Q2 and Q3), let’s discuss this issue in the two coming sections: first we discuss the update of TA component controlled by Closed loop in 2..2.2 then in 2.2.3 we will discuss the update of TA component controlled by open loop.

But first, we need to agree on combination of both open and close loop for TA maintenance. The initial proposal is made as follows:

**Proposal 2-2-1**

**For TA update in RRC\_CONNECTED state, combination of both open ( i.e. UE autonomous TA estimation, and common TA estimation) and closed (i.e., received TA commands) control loops shall be supported for NTN.**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Thales | Both open and closed control loops should be used for TA maintenance |
| CATT | In our view, UE should support both open loop and close-loop TA estimation/compensation. The combination of two ways would be confusing, because it will trigger the discussion on how to do the combination. So we need to agree two TA estimation methods are both supported firstly. |
| Panasonic | We support this proposal. |
| Huawei | Agree with the proposal.  |
| ZTE | Supported.  |
| Intel | Support the proposal |
| CMCC | We support this proposal. |
| Apple | We are fine with the proposal.  |
| OPPO | OK |
| Ericsson | We are fine with the proposal. |
| MediaTek | Support proposal 2.2.1 |
| Qualcomm | Support |
| Sony | We support this proposal. |
| Spreadtrum | We support this proposal. |
| Xiaomi | Both open and closed control loops should be supported for TA maintenance. |
| Vivo | Support |
| Samsung | Supporting that it is done by configuration. |
| InterDigital | Support |
| LG | Agree with CATT. So, we prefer the updated proposal as below:**Proposal 2-2-1****For TA update in RRC\_CONNECTED state, ~~combination of~~ both open ( i.e. UE autonomous TA estimation, and common TA estimation) and closed (i.e., received TA commands) control loops shall be supported for NTN.** |
| Lenovo/MM | Agree with the proposal.  |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Support the proposal.  |
| APT | Good summary. Neutral to **Proposal 2-2-1**. If the UE-calculated TA report exists in Msg3, NW and UE may have UL timing alignment in RRC\_CONNECTED. Only use the closed control loop shall work. To further reduce ignalling overhead, there are many ways. TA drift rate can be used to save MAC CE commands, e.g., considering only the closed control loop, sending 3 MAC Ces in 30ms is equal to sending 1 MAC CE with a TA drift rate and let UE to update every 10ms by itself. |
| Nokia, Nokia Shanghai Bell | We prefer network-controlled closed-loop TA update. If the UE further applies open-loop TA update, the network must know the details of the open loop adjustment in advance. Self adjustment by the UE based on GNSS time and the time provided by *referenceTimeInfo-R16* suffers less from satellite movement as the Gnb reference is a static point, and should be supported as well. |

* **Update of TA component controlled by Closed loop**

If proposal on issue#1-1 the Timing Advance applied by an NR NTN UE is given by**:**

For TA maintenance, the UE needs to update based on closed loop and (**)** based on open loop mechanism.

In current specification, only closed control loop (i.e., received TA commands) is used. The TAC provided in mgs2 is an **absolute** timing advance, whereas the subsequent TAC provided within the MAC CE are **relative**. The Gnb requires uplink transmission from the UE to adjust timing advance. Uplink transmissions allow the Gnb to measure the existing timing and accordingly determine whether or not any adjustment is required. Depending on Gnb implementation, an event driven TAC may be sent when the uplink time error exceeds a specific threshold or the Gnb may send a periodic TAC. When the UE receives a MAC TAC, it updates its existing TA by adding the (T\_A-31).16.64/2^μ corresponding to TA adjustment by Gnb and restarts the **timeAlignmentTimer** which defines the maximum time the UE can remain uplink synchronized without having received a TAC from the Gnb. If this timer expires the UE assumes that it has lost uplink synchronization.

In NTN, for TA component updated based on closed loop: **,** the following solution can bediscussed:

**Solution#1**: The same mechanism as existing specs shall be used. With exception that the TAC provided in mgs2 and subsequent TACs provided within the MAC CE indicate the residual timing error committed on the TA acquisition/update.Closed loop will dynamically controls the component which will beused to compensate for inaccuracies in the UE-autonomous estimation as follows:

* When TAC ( in msg2/msgB is received, UE receives the first adjustment and is updated as follows**:**

* When TACs (provided within the MAC CE is received, is updated as follows**:**

Companies are encouraged to provide their comments on proposed solution#1: Do you agree with Solution#1 above? Please elaborate

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | Reusing the existing TA calculation procedure is preferred. |
| Panasonic | We agree to this solution. |
| Huawei | Agree with Solution#1, it is aligned with the current specification. |
| ZTE | Supported.  |
| Intel | OK |
| Apple  | Agree |
| OPPO | We have a different option on TAC in msg2. Since the UE has estimated UE-specific TA and this TA has not been made aware by the network, the TA provided by Msg2 should also be a relative TA, instead of an absolute TA. In our view, a same TA updating way is used for TAC in Msg2 and TAC in MAC-CE.  |
| Ericsson | In principle, we agree with the proposed solution#1. |
| MediaTek | Support solution #1 |
| Qualcomm | Agree in principle. But further discussion is needed.  |
| Sony | Agree with proposed modification – even the TAC received in msg2/msgB ought to be a relative TAC because it is effectively a TA offset error after considering **.**  Which the UE uses to advance the transmission of the PRACH preamble. |
| Spreadtrum | Agree with Solution#1 |
| Xiaomi | Support closed-loop frequency control commands by MAC-CE.For efficient time and frequency control, DCI should be considered. |
| Vivo | We agree the proposal. Moreover, the requirement on UL time pre-compensation should be defined for that the existing TAC provided within the MAC CE can be reused without any extension.  |
| Samsung | Agree |
| ChinaTelecom | Agree |
| LG | Agree with solution #1 that reusing the existing TA calculation procedure. So, we don’t need to make the agreement regarding this issue. |
| Lenovo/MM | Agree with solution#1. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Principally okay with motivation of the proposal. But with line “*With exception that the TAC provided in mgs2 and subsequent TACs provided within the MAC CE are* ***relative***”, we have still confusion in understanding. Because Even in present NR spec it is relative for both TAC based update and MAC-CE based update as it only affects NTA . May be, some clarification will be helpful. |
| APT | Neutral. Agree to reuse the closed-loop control in Rel-16 NR. |
| Nokia, Nokia Shanghai Bell | We do not agree with the above. The algorithm that the UE uses to estimate the time offset needed for initial access should be such that it is **guaranteed** that there is never a need for indicating a negative TAC. This is a simple matter of math, and the UE should be able to operate accordingly. |

* **Update of TA component controlled by open loop**

If proposal on issue#1-1 the Timing Advance applied by an NR NTN UE is given by**:**

For TA maintenance, the UE needs to update based on closed loop and (**)** based on open loop mechanism.

For TA component updated by open loop, the following solution is discussed in some contributions:

**Solution#1 :**

Where:

 is the timing drift rate on the service link

 is the common TA drift rate

 **is FFS**

Companies are encouraged to provide their comments on proposed solution#1 above: Do you agree with Solution#1 above? Please elaborate

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | For open-loop TA estimation, it could be relying on DL reference signal tracking or ephemeris information derivation. Regarding common timing drift rate based TA calculation, it can belong to close-loop TA solution. For UE specific TA drift, it may not be one good way to describe UE implementation. For example, UE can calculate its TA based on ephemeris information and time unit, not have a specific TA drift. |
| Panasonic | We do not support this approach, since we don’t see the need for adopting a timing drift rate. |
| Panasonic | We support the proposal. |
| ZTE | Supported.  |
| Intel | OK |
| Apple  | We are fine with the proposal. |
| OPPO | We are not sure if the drift is a definite linear function? If so, how frequent it remains linear. From the UE perspective, the UE specific service link TA adjustment can be kept implementation. For the feeder link TA adjustment, the UE shall not be expected to update the feeder link drift value very often.  |
| Ericsson | The UE-specific TA should be autonomously calculated by the UE based on UE-satellite distance, i.e., there is no need to define drift rate for UE-specific TA in the specification.The common TA, since its control is open-loop, should not be defined only by relative increments/decrements since it would then be misaligned if ignalling is lost. Instead the common TA should be defined in absolute terms. Ericsson’s proposal is to define it as follows:Where: is the slot number of the targeted UL slot is a ”timestamp” slot number is the common TA (in units) at slot number  is the common TA drift rate (in units per slot) |
| MediaTek |  needs to be used by the UE based on implementation assuming common timing drift is signalled. The UE has no way to know the common timing drift over the feeder link (or alternative the Gnb position).  seems not needed. The UE needs to determine the UE-specific TA from ephemeris and can propagate the UE-specifc TA in advance to pre-compensate delay over access link before transmitting. Note that the cannot be considered to be constant in time due to the radial distance (UE-satellite) changing over time.  |
| Qualcomm | Need of common timing drift rate is unclear. |
| Sony | We agree this solution. UE-specific and common TA drift rate can reduce the inter symbol interference according to our tdoc (R1-2008360).  |
| Xiaomi | Solution#1 above is ok. But “in units” should be removed in this phase. |
| Vivo | Due that Gnb is stationary and the moving trajectory of satellite is fixed, can be valid without frequently update for a long time. While due to the random of UE movement, may be only valid when it is calculated. Therefore, it is better to calculate the updated offset value of UE-specific TA directly than using **Solution#1** can be revised as as follows:    |
| Samsung | Agree |
| LG | The timing drift rate on the service link ( is not necessary, since the UE specific TA is autonomously calculated at UE side, in other words, it can be based on the UE implementation.  |
| Lenovo/MM | Generally agree with solution#1 and we prefer that is the common TA drift rate (in units) |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | Okay will proposal but open loop TA update may happen even before RRS-CONNECTED mode e.g. for msg-3 transmission, RRC-resume request etc. Therefore, open loop update need not to associate with RRC-CONNECTED mode only.  |
| APT | Neutral. Not sure how to ensure UE can always have GNSS capability to calculate the timing drift rate on the service link. Also, not sure whether double correction happens from both closed- and open-loop controls. |
| Nokia, Nokia Shanghai Bell | As stated earlier, the UE should not be doing autonomous TA updates without the Gnb knowing the exact time and amount that the UE performs such updates. |

### Updated proposal based on company views (First round of email discussions)

During the last GTW online session, the following agreement was made:

**Agreement:**

**For TA update in RRC\_CONNECTED state, combination of both open (i.e. UE autonomous TA estimation, and common TA estimation) and closed (i.e., received TA commands) control loops shall be supported for NTN.**

**FFS: Details of the combination of open and closed loop TA control**

W.r.t to the update of TA component controlled by the closed loop mechanism. The majority of the companies are supportive of solution#1 provided in section 2.2.1

[Nokia] does not support this solution because the algorithm that the UE uses to estimate the time offset needed for initial access should be such that it is **guaranteed** that there is never a need for indicating a negative TAC.

The concern raised by [Nokia] is related to the bipolarity of the TA command. TA\_margin was proposed as workaround to avoid such negative TAC. Indeed, if the initial acquired TA includes a margin for maximum TA estimation error, unipolar TA command in msg2 is sufficient and TAC will indicate the residual error on the TA first acquisition which is positive.

Based on companies views collected during the first round of email discussion, the following potential proposal is made as follows:

**Initial Proposal 2-2-2**

**For TA update in RRC\_CONNECTED state, closed loop will dynamically controls the component which will be used to compensate for inaccuracies in the UE-autonomous estimation:**

* **When TAC ( in msg2/msgB is received, UE receives the first adjustment and is updated as follows:**

* **When TACs ( provided within the MAC CE is received, is updated as follows:**

Companies are encouraged to provide views on the initial proposal 2-2-2:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Support the proposal. The specified closed-loop TA mechanism in TA can be fallback mechanism in case some inaccuracies in the UE-autonomous estimation and it is up to the Gnb whether to send a TA MAC CE.  |
| Huawei  | Agree with the proposal. But there is no need to mention the usage of the closed-loop TA adjustment. It can also be used to cope with other inaccuracies or factors such as UE mobility as well. Hence, we suggest to delete “**which will be used to compensate for inaccuracies in the UE-autonomous estimation:**”.  |
| Xiaomi | Support the proposal. Furthermore, consider DCI for UL time and frequency control. |
| ZTE | It seems that no need to provide additional discussion/confirmation on the existing mechanism defined in spec since no updates is foreseen. Anyway, the close-loop solution is used to correct the synchronization errors regardless of source. |
| CATT | Agree this proposal. |
| APT | Support Initial Proposal 2-2-2. We have concern about “**in RRC\_CONNECTED state**”. The msg2/msgB belong to Random Access Procedure and the random-access procedure is triggered by a number of events, e.g., * Initial access from RRC\_IDLE
* Transition from RRC\_INACTIVE
* UL data arrival during RRC\_CONNECTED when there are no PUCCH resources for SR available

Based on our understanding, this TA update may apply to all UE states (RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED) for NR NTN. |
| Samsung | Support |
| vivo | Agree |

## Issue#2-3: TA acquisition during Handover

### Company views

[Mitsubishi] and [Ericsson] proposed to support RACH-less HO in NTN. [Mitsubishi] observed that RRC connected UEs performing handover from a source to a target cell deployed by a same satellite and served by a same gateway need not acquire timing advance through a RACH procedure. And proposed to support network assistance indicating to the UE whether to skip timing advance acquisition during handover. [Ericsson] proposed that UEs are allowed to autonomously adjust its TA to seamlessly continue its RRC connection after the service link switch from one satellite to another during a RACH-less handover.

Moderator view: RACH-less HO for NTN will need more investigation and from RAN1 viewpoint we need to confirm the feasibility of RACH-less HO in NTN.

Also, this feature was discussed in RAN2 in November meeting (RAN WG2 meeting #113-e) and the conclusion captured in Report of 3GPP TSG RAN2#112-e meeting [R2-2100001] is the following:

RACH-less HO for NTN is de-prioritized in this release. Chair Note: RACH-less HO for NTN is de -prioritized for now (we can come back to this later in this release).

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Mitsubishi | **Observation 2**: In LEO systems with fixed beams (moving footprint), for a RRC connected UE performing handover, the gNBs of the source cell and respectively the target cell are often collocated.**Observation 3**: RRC connected UEs performing handover from a source to a target cell deployed by a same satellite and served by a same gateway need not acquire timing advance through a RACH procedure.**Proposal 3**: Support network assistance indicating to the UE whether to skip timing advance acquisition during handover. |
| Ericsson | **Proposal 6** UEs are allowed to autonomously adjust its TA to seamlessly continue its RRC connection after the service link switch from one satellite to another during a RACH-less handover. |

With the above in mind, the following initial proposal is made as follows:

**Initial Proposal 2-3-1:**

**RACH-less HO for NTN is de-prioritized in this release**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Thales | We support the proposal |
| CATT | In RAN2, RACH less HO has been deprioritized, so we support this proposal. |
| Panasonic | We support the proposal. |
| Huawei | Agree with the proposal. |
| ZTE | Up to RAN2. |
| Intel | Up to RAN2 |
| Apple | Agree |
| OPPO | OK |
| Ericsson | Note that “RACH-less HO for NTN is de-prioritized in this release“ is not a RAN2 agreement, only a proposal. There is only a chair note that it is de-prioritized for now but can be come back to in this release.RAN1 should await RAN2 progress and not make more far-reaching decisions on de-prioritization.It is believed that the RACH capacity will be limited even in sparsely populated areas due to the large supported cells in NTN. RACH-less HO will offload the PRACH resources and thus reduce the collision rate. It also has the potential to reduce the interruption time since it is possible to use dense pre-allocated grants in the HO command. |
| MediaTek | Support proposal 2.3.1. RAN2 may first discuss. |
| Qualcomm | Up to RAN2 |
| Sony | We support the proposal |
| Spreadtrum | We support the proposal. |
| Xiaomi | We support the proposal. |
| vivo | Support |
| Samsung | Agree |
| LG | Support the proposal |
| Lenovo/MM | Support the proposal. |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | We believe, this should be discussed further. RACH-less hand over is possible in NTN and will be useful to avoid signal delay and latency incurred by RACH based handover. |
| APT | Support **Initial Proposal 2-3-1** |
| Nokia, Nokia Shanghai Bell | We think this discussion is better handled in RAN2 |

### Updated proposal based on company views (First round of email discussions)

Based on the first round of email discussion the majority is supportive of initial proposal 2-3-1. For [Ericsson] RAN1 should await RAN2 progress and not make more far-reaching decisions on de-prioritization. According to [CEWiT, IITH, IITM, Tejas Networks, Reliance Jio] RACH-less HO for NTN should be discussed further.

Given the views expressed so far, it is reasonable that RAN1 wait for RAN2 progress on this topic

**Moderator Recommendation 2-3-1:**

**RAN1 should wait for RAN2 progress on RACH-less HO support in NTN**

Companies are encouraged to provide views on Moderator Recommendation 2-3-1:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Support moderator’s recommendation |
| Huawei | Agree with the moderator’s recommendation. |
| Xiaomi  | Support the recommendation. |
| ZTE | Agree |
| CATT | Agree |
| APT | Support Moderator Recommendation 2-3-1 |
| Samsung | Agree  |
| vivo | Agree |

# Issue#3: Indication of frequency precompensation offsets

In RAN1#103e, it was agreed that an NR NTN UE in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED states shall be capable of at least using its acquired GNSS position and satellite ephemeris to perform frequency pre-compensation to counter shift the Doppler experienced on the service link.

* 1. Issue#3-1: Reference point for UL frequency synchronization

Initial discussions on reference point for UL timing and frequency synchronization have started during RAN1#103e. It has been vain to reach any agreement related directly to the concept of reference point since there is no consensus on a clear and shared definition of what it really means.

Some companies [Ericsson, Huawei] are in favour to at least support the case where the reference point for UL frequency is located at gNB and to left the reference point definition under the control of the network. Other companies [Apple, Spreadtrum Communications] preferred to have it located at satellite to avoid additional signalling.

Based on these observations, and as it has been handheld for timing synchronisation, it seems legitimate to focus the discussions on the features which can enable flexible reference point definition in the system. This feature is discussed in section

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| **Companies** | **Comments and Views** |
| CMCC | Proposal 13: If UE performs frequency pre-compensation to counter the Doppler shift experienced on the service link based on its acquired GNSS position and satellite ephemeris, gNB can manage the other sources of frequency error (e.g. satellite transponder, feeder links). |
| Apple | Proposal 9: The reference point for frequency synchronization is at satellite, and UE pre-compensates the Doppler shift on the service link. |
| Spreadtrum Communications | Proposal 4: The reference point for UL frequency synchronization in NTN is located at the satellite. |
| Vivo | Observation 2: The compensation of common frequency offset is related to the reference point for frequency.Proposal 5: Decide reference point for frequency before discussing the compensation of common frequency offset. |
| Ericsson | Observation 1 All time slots will be misaligned by twice the feeder link delay and the frequency will be affected by the feeder link Doppler shift, if the satellite is used as reference for time and frequency requirements.Observation 2 Using satellite as reference for time and frequency requirements affects compatibility with existing rel-16 gNB.Proposal 1 The reference point for time and frequency in an NTN should be under control of the network and should at least support the option of having gNB as the reference point. |
| Huawei | When the referent point for UL frequency synchronization is located at the gNB or on the feeder link, the indication of frequency offset from feeder link or gNB location will be needed as UE has no information of gNB location. When the referent point for frequency is located at satellite, the signalling can be avoided. Observation 2: UL frequency synchronization at the gNB or feeder link will introduce additional signaling overhead. |
| MediaTek | ***Proposal 5****: RAN1 working assumption is that GW pre/post compensates common Doppler shift / Doppler shift variation over the feeder link in a transparent way to the UE and gNB.* ***Proposal 6****: RAN1 working assumption is that GW pre/post compensates any transponder frequency error at the satellite in a transparent way to the UE and gNB.* |

### Companies views

Based on companies proposals, the initial proposal is as follows:

**FL recommendation 3-1: Focus the technical discussions on the features to be supported in the specs to avoid spending times on synchronization reference point definitions which is more a question of implementation.**

Companies are encouraged to provide their comments and views in the following table:

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| **Companies** | **Comments and Views** |
| CATT | In our view, reference point concept is one useful intermediate terminology, which can be used for technical clarification.  |
| Panasonic | We agree. |
| Huawei | Agree.  |
| ZTE | Supported.  |
| Intel | Agree |
| CMCC | Agree. |
| Apple | Fine with the proposal. But it may be beneficial to use the terminology for clarification.  |
| Ericsson | We are fine with the proposal. |
| Spreadtrum | Agree. |
| Xiaomi | In our view, reference point definition is one useful terminology, which impacts signalling design.  |
| vivo | The reference point for UL frequency synchronization can depend on the network implementation and can be transparent for UE. |
| Samsung | Agree |
| LG | Agree with CATT |
| Lenovo/MM | We generally agree with the feature lead’s recommendation and we think that the frequency domain reference point should be under control of the network. |
| APT | At least support the case where the reference point for UL frequency is located at gNB. This sounds like a reasonable proposal. This makes impacts on whether UE or NW shall take care of the Doppler shift on the feeder link. If UE shall take care of this, then the UL timing and UL frequency may align at the gNB, which may provide better support for ATG and HIBS and be a better foundation for the future release of NTN, e.g., Rel-18. |
| Nokia, Nokia Shanghai Bell | The technical aspects of the standardization will very much depend on the location of the reference point. The solutions developed will use baseline assumptions (like the reference point at satellite or at the gNB), which will implicitly make a determination of the actual reference point. Hence, this discussion needs to be taken (whether or not the feeder link is included in the considerations for the developed solution). |

### Updated proposal based on company views (First round of email discussions)

Based on the companies feedback, a majority of companies are in line with the FL recommendation. In order to clarify further the intent of the recommendation, the objective is not to cut short technical discussions related to reference point but to treat proposals addressing the new features to be captured in the specs (which may be motivated based on considerations related to reference point configuration).

**FL recommendation 3-1: Focus the technical proposals on the features to be supported in the specs to avoid spending times on synchronization reference point definitions which is more a question of implementation.**

* 1. Issue#3-2: Indication of frequency precompensation offset on DL

As already discussed in RAN1#103e and highlighted once again by the companies below, it is beneficial to support common frequency offset pre-compensation on DL transmissions at gNB. In some NTN scenarios, it is needed to reduce UE complexity by keeping up a reasonable size for the PSS/SSS searching space.

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| **Companies** | **Comments and Views** |
| Nokia | Proposal 8: The gNB or satellite pre-compensates in the DL a common frequency offset per beam/cell, caused by the Doppler effect on feeder and service link, to minimize the PSS/SSS searching space for the UE.Observation 14: The supported cell diameter depends on the distance for which the UE-specific frequency offset at the cell edge remains below a certain level. Small SCS and elevation angles support smaller cells. |
| Apple | Proposal 10: Support gNB pre-compensates the frequency offset in downlink transmissions.. |
| Huawei | Observation 3: For DL transmissions, applying a common frequency offset pre-compensation is beneficial to reduce UE complexity. |

Since the specifications are written from the UE’s perspective, it is not necessary to have an agreement on whether the gNB shall support such precompensation scheme. However, when the gNB applies such common frequency pre-compensation in DL, it may be needed to indicate the amount of frequency pre-compensation to the UEs. More specifically, the TX frequency offset at the satellite transmitter relative to the nominal DL TX frequency of the service link shall be indicated. **Indeed, a UE that uses the gNB DL frequency as frequency refererence (which is the typical UE behaviour) needs this information to determine its nominal UL TX frequency**. Several companies [CMCC, Xiaomi, Ericsson, Qualcomm, Huawei, Thales,CATT] have provided technical analysis and justifications in this sense. However, some companies observed that depending on the UE implementation [Huawei] or the pre/post compensation implementation at gNB side [Intel], the indication of this DL frequency offset may not be needed. In any case, it seems beneficial to introduce this feature which can be enabled when needed.

How to indicate this offset in case of precompensation by the gNB can be further discussed. It has been observed [Nokia, Thales] that depending on the scenario and the implementation this offset may change rather quickly. For instance, in case of DL Doppler precompensation in an earth fixed beam scenario, the precompensated frequency offset is going to change proportionally to the radial acceleration between the satellite and the reference location on earth (e.g. beam center) w.r.t. which the DL precompensation is performed. Knowing this, the best parameter(s) to indicate this offset are still to be discussed and defined. The following options have been mentioned:

* Indication of the absolute frequency offset
	+ The granularity and unit are FFS
* Indication of the reference point location w.r.t. which the Doppler DL precompensation is performed
	+ This can only help deriving the part of the pre-compensated frequency offset related to Doppler.
	+ The format is FSS.

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| **Companies** | **Comments and Views** |
| CMCC | Proposal 11: Support the following moderator’s proposal,- If NR NTN gNB applies frequency pre-compensation in DL, the gNB should broadcast a parameter giving the amount of frequency pre-compensation. This parameter should indicate the TX frequency offset at the satellite transmitter relative to the nominal DL TX frequency of the service link |
| Xiaomi | Proposal 6: Pre-compensation value for DL frequency should be indicated by network. |
| Nokia | Observation 12: For earth-moving cells the Doppler on the service link as observed at a reference point in the cell is constant over time.Observation 13: For earth-fixed cells the Doppler on the service link as observed at a reference point in the cell varies over time depending on the satellite location. |
| Ericsson | Proposal 7 If gNB applies frequency pre-compensation in DL, the gNB should broadcast a parameter giving the amount of pre-compensation. This parameter should indicate the TX frequency offset at the satellite transmitter relative to the nominal DL TX frequency of the service link. The amount of DL pre-compensation applied should be configurable but bounded by a maximum offset at the UE receiver to limit UE synchronization complexity.Observation 5 The gateway needs to provide the gNB with information from which the amount of feeder link Doppler shift can be derived. |
| Qualcomm | Proposal 4: Support optional network frequency pre-compensation of SSB or all DL signals and support the signaling of the compensated value if pre-compensation is applied. |
| Thales | Proposal 11.If NR NTN gNB applies frequency pre-compensation in DL, the gNB should broadcast:•In case of earth-fixed cell, the beam-specific ECEF co-ordinates of a fixed Reference Point w.r.t the common Doppler shift experienced on the DL service link is pre-compensated by the gNB.•In case of earth-moving beam, the beam-specific common Doppler shift value. |
| Huawei | Observation 1: For autonomous frequency adjustment, when the UE internal clock driven by the received DL signals, the UL frequency error can be minimized if pre-compensated common frequency offset of service link part is known by the UE.Observation 4: Indication of pre-compensated common frequency is needed at least when UE’s internal clock is driven by the received DL signals. |
| Intel | Observation 1: • Compensation of common frequency offset for DL transmission can be done in order to decrease UE complexity for DL frequency synchronizationo Indication of frequency offset value pre-compensated for DL transmission at the gNB side is not necessary to achieve UL synchronization |
| CATT | Proposal 10: Common Doppler shift compensation information of DL and UL can be indicated to UE, which is used to help UE to do accurate frequency compensation. |
| MediaTek | We think this issue needs to be further discussed in RAN1, or discussed in RAN4. If the sync raster of 100 kHz for frequency range < 3 GHz is not used, the pre-compensation by gNB of common Doppler shift on access link may not be needed. This would require discussion in RAN4 as it is a specification change. This is not seen necessarily a significant issue for he PSS/SSS search. One advantage is that the issue of Doppler discontinuity during beam switching is avoided, which reduces complexity of frequency tracking. |

### Companies views

Based on companies proposals, the initial proposals are as follows:

**Initial proposal 3-2: If NR NTN gNB applies frequency pre-compensation in DL, the gNB should broadcast parameters giving the amount of frequency pre-compensation. These parameter should indicate the TX frequency offset at the satellite transmitter relative to the nominal DL TX frequency of the service link**

* **How to indicate this offset is FFS.**

Companies are also invited to provide initial inputs on how to indicate this offset when needed:

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| **Companies** | **Comments and Views** |
| CATT | We are supportive to this proposal. |
| Panasonic | We support this proposal. |
| Huawei  | Agree with the proposal.  |
| ZTE | According to the SI, such pre-compensation is done usually in per beam specific. Indication of such information may have some benefits, e.g., accelerating the RF tuning, but more discussion is needed for the signalling.  |
| Intel | More discussion is needed on how to apply this parameter, e.g. it can be used for handover or beam switch.  |
| CMCC | Agree with the proposal. |
| OPPO | This TX frequency offset indication is not necessarily mandated for the serving satellite, because the offset is common to all the UE. If the offset is not indicated, the UE will assume the offset is zero and based on this, the UE can determine a nominal DL TX frequency, which is naturally the same for all the UEs. In this case, a nominal UL frequency can be determined and all the UEs are normally aligned. There is no multiplexing issue. The network can further adjustment the actual receive frequency via post-compensation. Thus, to our understanding, there is no problem if the network does not indicate Tx frequency offset. This should be left for network to decide.  |
| Ericsson | We support this proposal. |
| MediaTek | We think this issue needs to be further discussed in RAN1, or discussed in RAN4. If the sync raster of 100 kHz for frequency range < 3 GHz is not used, the pre-compensation by gNB of common Doppler shift on access link may not be needed. This would require discussion in RAN4 as it is a specification change. This is not seen necessarily a significant issue for he PSS/SSS search. One advantage is that the issue of Doppler discontinuity during beam switching is avoided, which reduces complexity of frequency tracking. |
| Qualcomm | Agree |
| Sony | Support the proposal |
| Spreadtrum | Agree with the proposal. |
| Xiaomi | We support the proposal. |
| vivo | In our view, the pre-compensated common frequency offset applied for DL can be the same as the post-compensated common frequency offset applied for UL. If the frequency error, e.g., the local oscillator frequency error of UE, can meet UL frequency synchronization requirements or even be neglected, the indication of common frequency offset pre-compensated at the gNB can be avoided; otherwise, it needs to be signalled to UE. |
| Samsung | Agree |
| LG | In our view, it should be clarified the difference between the indication of pre-compensation frequency offset on DL and the indication of pre-compensation frequency offset on UL. To be specific, if these two pre-compensation values could be equal or similar, we don’t need to provide both parameters to NTN UE. |
| Lenovo/MM | Agree with the proposal. For earth fixed beam, we prefer the position of the reference point to be indicated; and for earth moving beam, we prefer a frequency offset value to be indicated. |
| APT | Support **Initial proposal 3-2** |
| Nokia, Nokia Shanghai Bell | We are in principle OK with this proposal, as this could help the UE in estimating the frequency offset to apply for the UL transmissions. |

### Updated proposal based on company views (First round of email discussions)

[CATT, Panasonic, Huawei, ZTE, Ericsson, Qualcomm, Sony, Spreadtrum, Xiaomi, Vivo, Samsung Lenovo/MM, APT Nokia, Nokia Shanghai Bell] are supportive of the proposal.

[Intel] asked for more discussion on the possible use(s) of this offset by the UEs. [Intel] mentioned HO and beam-switch.

Based on the companies contributions, the initial intent for such indication is to assist UEs which use the gNB DL frequency as frequency reference (which is the typical UE behaviour) and need this information to determine their nominal UL TX frequency. Other possible usage can be further discussed.

[OPPO] indicates that the indication of this TX offset is not necessarily mandated even when common frequency pre-compensation by the gNB is performed.

As a consequence, the Moderator suggestion is to replace “should” in the initial proposal by “may”.

[MediaTek] prefer to further discuss the issue of DL frequency precompensation. From their perspective it is preferable to restrict the synchronization raster so common DL frequency precompensation may be avoided.

From moderator perspective, the vast majority of the companies agree that there are scenarios where DL frequency precompensation may be implemented and the proposed network indication may be needed and as a consequence should be supported. On the contrary, the discussions on whether the synch raster restriction may be supported have not started. Finally, it would be up to the network to decide whether such indication should be enable or not so there is no incompatibility between the feature proposed here and the solution proposed by MediaTek.

[LG] asked for further clarifications on the difference between the indication of pre-compensation frequency offset on DL and the indication of pre-compensation frequency offset on UL.

Based on Moderator understanding, the motivation for initial proposal 3-2 (i.e. indication of pre-compensation frequency offset on DL) is the following:

* When the gNB applies a common frequency pre-compensation in DL, UEs that use the gNB DL frequency as frequency refererence (which is the typical UE behaviour) need to know the amount of frequency pre-compensated to determine its nominal UL TX frequency. Since the UE use its DL RX frequency (locked on DL reference signals) to generate its UL TX frequency, it needs to know to which amount this DL RX frequency is shifted w.r.t to the reference DL frequency of the service link. To retrieve this information, it must be aware of the common frequency shift due to gNB pre-compensation. The frequency budget details can be found in [16].

On the other hand, the motivation for initial proposal 3-3 is the following:

* To enable flexible gNB implementation (e.g. no post compensation of feeder link Doppler shift), it is beneficial in some scenarios to indicate to all UEs a common frequency offset to be applied by all the UEs in addition to their self-estimated frequency pre-compensation.

The resulting proposal is :

**Updated proposal 3-2: If NR NTN gNB applies frequency pre-compensation in DL, the gNB may broadcast parameters giving the amount of frequency pre-compensation. These parameter should indicate the TX frequency offset at the satellite transmitter relative to the nominal DL TX frequency of the service link**

* **How to indicate this offset is FFS.**

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| **Companies** | **Comments and Views** |
| MediaTek | Support proposal with modification. It is only possible for gNB to indicate the TX frequency offset in case of earth-moving beams. For earth-fixed beams, the TX frequency offset is not constant and will vary with a Doppler shift variation rate of up to 0.27ppm/s (600km) or about 540 Hz/s. There are two ways signalling could be used to allow the UE to determine the TX frequency offset* For earth-moving beam, the TX frequency offset is indicated
* For earth-fixed beam, the beam-specific ECEF co-ordinates of a fixed Reference Point (RP) corresponding to the beam centre are indicated.

We suggest alternative wording**Updated proposal 3-2****Updated proposal 3-2: If NR NTN gNB applies frequency pre-compensation in DL, the gNB may broadcast parameters to determine the amount of frequency pre-compensation.** * **For earth-moving beam, the TX frequency frequency offset at the satellite transmitter relative to the nominal DL TX frequency of the service link is indicated.**
* **For earth-fixed beam, the beam-specific ECEF co-ordinates of a fixed Reference Point (RP) corresponding to the beam centre are indicated.**
* **How to indicate the parameters is FFS.**
 |
| Huawei | Agree with the proposal |
| Xiaomi | Agree with the proposal. |
| ZTE | Agree with this proposal and if such indication is needed, we may only need to focus on the signalling design for this value instead of other complicated solution. |
| CATT | We agree this proposal. It can help UE to differentiate the Doppler shift and oscillator error. |
| APT | Support Updated proposal 3-2. Indicating RP is one of signalling methods and has been included in FFS.  |
| Samsung | Agree  |
| vivo | Agree with the proposal. The indication of common frequency offset pre-compensated at the gNB is needed to reduce the impact of local oscillator frequency error. |

* 1. Issue#3-3: Indication of precompensation frequency offset on UL

In RAN1#103e , it was discussed whether an NR NTN UE shall be capable to apply at each transmission a common frequency offset indicated by the network in addition to the geometry based frequency pre-compensation to counter shift the Doppler experienced on the service link.

It has been observed in several contributions [Panasonic, Ericsson, CMCC, Intel] that the frequency post-compensation scheme at gNB is left to implementation. As consequence, it appears reasonable [Ericsson, Panasonic, Intel, CATT] to support the indication by the network of a common frequency offset to be applied by all the UEs in addition to their geometry based frequency pre-compensation. The gNB can set this offset equal to the amount of UL Doppler shift on the feeder link to eliminate the need for post-compensation at the gNB receiver, but it may also set it to a different value, or omit it, in case it prefers to perform (partial) post-compensation.

[Huawei, CMCC] proposed to indicate the frequency offset post-compensated by the gNB so the UE can take it into account when performing pre-compensation. At the end, this approach is equivalent to the solution mentioned above.

At the end, supporting such feature seems beneficial to enable flexible gNB implementations.

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| **Companies** | **Comments and Views** |
| CMCC | Proposal 12: If NR NTN gNB applies frequency post-compensation in UL, the gNB should broadcast a parameter giving the amount of frequency post-compensation, to achieve a common understanding between UE and gNB. This parameter should indicate the RX frequency offset at the satellite receiver relative to the nominal UE RX frequency of the service link.Proposal 13: If UE performs frequency pre-compensation to counter the Doppler shift experienced on the service link based on its acquired GNSS position and satellite ephemeris, gNB can manage the other sources of frequency error (e.g. satellite transponder, feeder links). |
| Panasonic | Proposal 6: Support of a common frequency offset relative to the UE frequency source and indicated via SIB. |
| Nokia | Observation 15: Frequency pre-compensation relying on GNSS-provided UE location and satellite ephemeris allows for UL pre-compensation of only the Doppler experienced on the service link. |
| Ericsson | Proposal 8 : The gNB may broadcast a parameter giving an additional frequency shift that the UE should apply at PRACH transmission. The value of this parameter should be configurable. It may be used for compensating for the Doppler shift observed on the uplink of the feeder link.Observation 5 The gateway needs to provide the gNB with information from which the amount of feeder link Doppler shift can be derived.Proposal 10 A UE should apply a frequency offset at UL transmission comprising the estimated service link Doppler shift and an additional offset based on broadcast information from the network. |
| Huawei | Observation 5: For UL transmissions, frequency offset post-compensation can be applied at the gNB and the value should be known by the UE to determine UL pre-compensation. Observation 6: If the post-compensated common frequency offset applied for UL is zero or the same as the pre-compensated common frequency offset applied for DL, the indication of frequency offset post-compensated at the gNB can be avoided otherwise it needs to be signaled to the UE.Observation 7: If common frequency offset is indicated by the network, the value may differ within a large range.Proposal 2: The signaling design of common frequency offset needs further study. |
| OPPO | Observation 2: for frequency synchornization, UE only pre-compensates residual frequency shift for uplink may introduce orthogonality issue with different UE.Proposal 5: for uplink frequency synchronization, a UE shall pre-compensate the UE-specific Doppler shift on service link w.r.t a gNB’s uplink nominal frequency. |
| Intel | Proposal 1: • The following alternatives are considered to handle time and frequency offset introduced in feeder linko Alt 1: pre-compensation at the UE side Requires indication of the corresponding delay and Doppler values to the UEo Alt 2: post-compensation at the gNB side |
| CATT | CATT Proposal 10: Common Doppler shift compensation information of DL and UL can be indicated to UE, which is used to help UE to do accurate frequency compensation. |
| MediaTek | This proposal 3.3 at least needs the clarification provided by Huawei. It should be further discussed whether the post compensation is for the access link or feeder link. In case the post compensation is over the feeder link, the UE does not need to include the value of the post compensation when pre-compensation for the Doppler over the feeder link. |

### Companies views

Based on companies proposals, the initial proposals are as follows:

**Initial proposal 3-3: Support the indication by the network of a common precompensation frequency offset on UL.**

**When indicated, an NR NTN UE shall be capable to apply this offset at each transmission in addition to the UE-specific frequency pre-compensation to counter shift the Doppler experienced on the service link.**

* **How to indicate this UL common frequency offset is FFS**

Companies are also invited to provide initial inputs on how to indicate this offset when needed:

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| **Companies** | **Comments and Views** |
| CATT | We are supportive to this proposal. |
| Panasonic | We support this proposal. |
| Huawei | We think the current wording is a bit confusing, we think the indication should be the post-compensation that is done at the gNB side. We suggest changes below**Initial proposal 3-3: Support the indication by the network of a common ~~pre~~post-compensation frequency offset on UL.** **When indicated, an NR NTN UE shall be capable to apply this offset at each transmission in addition to the UE-specific frequency pre-compensation to counter shift the Doppler experienced on the service link.*** **How to indicate this UL common frequency offset is FFS**
 |
| ZTE | It should be clarified whether such indication on common pre-compensation value is same as the frequency used for DL pre-compensation or UL post-compensation. Without clear understanding on the whole mechanism, prefer to postpone this issue. |
| Intel | We are OK with this proposal if it is applied to compensate for feeder link Doppler. |
| CMCC | We support this proposal in principle. Huawei’s modification is preferred.  |
| Apple | We do not see the necessity of additional indication of a common pre-compensation frequency offset. UE can simply pre-compensate the service link Doppler.  |
| OPPO | Similar to initial proposal 3-2, the gNB can indicate this offset, but it is not mandatory. In this sense, the wording of the initial proposal 3-2 seems reasonable.  |
| Ericsson | We support this proposal. |
| MediaTek | This proposal 3.3 at least needs the clarification provided by Huawei. It should be further discussed whether the post compensation is for the access link or feeder link. In case the post compensation is over the feeder link, the UE does not need to include the value of the post compensation when pre-compensation for the Doppler over the feeder link. In case the post-compensation is done over the access link, the need is not clear assuming UE can do pre-compensation of Doppler shift based on ephemeris. |
| Qualcomm | Necessity of a common UL frequency compensation is unclear. |
| Sony | Support the proposal |
| Xiaomi | We support the proposal. |
| vivo | **a common ~~pre~~post-compensation frequency offset on UL**In our view, the post-compensated common frequency offset applied for UL can be the same as the pre-compensated common frequency offset applied for DL. Therefore, considering signalling overhead, the indication of a common post-compensation frequency offset on UL by the network is not necessary. |
| Samsung | It seems no need to have two indications for DL and UL separately.  |
| LG | Same as in 3.2.1In our view, it should be clarified the difference between the indication of pre-compensation frequency offset on DL and the indication of pre-compensation frequency offset on UL. To be specific, if these two pre-compensation values could be equal or similar, we don’t need to provide both parameters to NTN UE. |
| Lenovo/MM | Agree with the proposal. |
| APT | Support **Initial proposal 3-3** to support UL frequency alignment at the gNB rather than at the satellite. |
| Nokia, Nokia Shanghai Bell | Based on the assumption that the UE is able to acquire a stable frequency reference from the external GNSS system, the UE would be able to calculate the experienced doppler in the DL, and perform a corresponding compensation action for the UL transmissions. |

### Updated proposal based on company views (First round of email discussions)

[CATT, Panasonic, OPPO, Ericsson, Lenovo/MM, APT] are supportive of the initial proposal.

[Intel] is supportive of the proposal if the UL frequency offset indicated corresponds to the frequency shift experienced on the feederlink.

[Huawei, CMCC] preferred to update the proposal since in their views the UL frequency offset indicated should correspond to the frequency offset post-compensated by the gNB.

[Apple, MediaTek, Vivo, Samsung, Nokia] do not see the needs or benefits for the proposed feature.

[ZTE] prefers to postpone the discussion.

Based on the companies feedback, the moderator would like to make the following clarifications:

A typical example of scenario where this frequency offset indication is needed is the one where the gNB does not implement the post-compensation of the Doppler shift on the feeder link. As a consequence, to maintain frequency alignment w.r.t. to UL reference frequency at gNB input, it is up to the UEs to pre-compensate this offset on top of their self-estimated frequency pre-compensation on the service link. when generating their UL TX frequency. As a consequence, this additional common frequency offset should be indicated by the network.

Of course, there are many other scenarios where such indication may not be needed. In this case, such indication can be disabled by the network.

[Huawei, CMCC] would like to indicate instead the post-compensated frequency offset at gNB side so the UE can take into account when generating its UL TX frequency. From moderator perspective, it seems more natural and flexible (see scenario presented above) to indicate directly the common offset to be applied by the UE on top of its self-estimated pre-compensation. Moreover, since this common frequency offset is applied at UL TX, it feels more appropriate to consider it as a precompensation offset. However, it is ok to remove the mention of pre/post compensation since the second sentence of the proposal explicitly defined how this offset should be applied by the UEs.

Considering the moderation clarifications, companies are invited to further comment on the following proposal

**Updated proposal 3-3: Support the indication by the network of a common frequency offset on UL.**

**When indicated, an NR NTN UE shall be capable to apply this offset at each transmission in addition to the UE-specific frequency pre-compensation to counter shift the Doppler experienced on the service link.**

* **How to indicate this UL common frequency offset is FFS**

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| **Companies** | **Comments and Views** |
| MediaTek | We think this proposal can be further discussed. To our understanding, the intention is that the gNB can set this offset equal to the amount of UL Doppler shift on the feeder link to eliminate the need for post-compensation at the gNB receiver, or set it to a different value, or omit it, in case it prefers to perform (partial) post-compensation.The feeder link is typically in a higher frequency band – e.g. Ka band (17 GHz DL, 27 GHz UL). The Doppler shift and Doppler shift variation rate could be an order of magnitude higher than on the service link – i.e. around 500 kHz and 5 kHz/s respectively. At least, the impact on DL synchronization and periodicity of SIB to broadcast the common frequency offset over the feeder link should be further discussed. We think it is preferable if the gNB pre-compensate / post-compensate the frequency error on the feeder link in a transparent way for the UE. This removes need for signalling.  |
| Huawei | We would like to understand the necessity to signal the feeder link frequency offset to the UE. At lease we have not seen any implementation complexity or performance benefit by leaving the frequency offset post-compensation for the feeder link at the gNB. To us, it is more straightforward to indicate the post frequency compensation of the service link part if part of the frequency offset is post-compensated by the gNB. |
| Xiaomi | We are OK with this proposal if it is applied to compensate for residual service link Doppler shift. |
| ZTE | Negative to this proposal. From solution perspective, no need to for UE to handle the impacts on link frequency offset and further justification may be needed for this issue later. |
| CATT | We agree this proposal. Without this indication, different UE may have different implementation for frequency compensation, which leads to UL signal non-orthogonal. |
| APT | Agree MTK. This needs more discussion.As mentioned by MTK, we quote as below.“*The feeder link is typically in a higher frequency band – e.g. Ka band (17 GHz DL, 27 GHz UL). The Doppler shift and Doppler shift variation rate could be an order of magnitude higher than on the service link*” We agree this is true for regenerative payload where feeder link is not part of NR Uu interface.However, based on 3GPP TR 38.821 V16.0.0, 5.1 Transparent satellite based NG-RAN architecture, we quote the context below. *[TR 38.821] Hence the satellite repeats the NR-Uu radio interface from the feeder link (between the NTN gateway and the satellite) to the service link (between the satellite and the UE) and vice versa.**[TR 38.821] The Satellite Radio Interface (SRI) on the feeder link is the NR-Uu. In other words, the satellite does not terminate NR-Uu.*We are not sure whether S band for service link and Ka band for feeder link is a feasible implementation for the transparent architecture.  |
| Samsung | Agree with MediaTek in that we need further discussion. |
| vivo | The indication of a common frequency offset on UL by the network is unnecessary, in consideration of the additional signalling overhead and UE complexity. In our view, the common frequency offset applied for UL can be maintained at the network. And the common frequency offset is same for all of UEs. |

# Issue#4: Close control loop for UL frequency alignment

In RAN1#103e, it was agreed that an NR NTN UE in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED states shall be capable of at least using its acquired GNSS position and satellite ephemeris to perform frequency pre-compensation to counter shift the Doppler experienced on the service link. This can be seen as an open control loop to maintain UL frequency synchronization.

In addition to this already agreed mechanism, some companies [Qualcomm, Xiaomi] proposed to support closed loop frequency control commands via MAC-CE. However, the benefits of such solution have not been discussed in detail. On the contrary, some companies [Huawei, Spreadtrum Communications] explicitly mentioned that the introduction closed-loop UL frequency compensation is not needed for GNNS equipped UE.

|  |  |
| --- | --- |
| :**Companies** | **Comments and Views** |
| Xiaomi | Proposal 7: The residual offset value of UL frequency at the reference point should be indicated by network. |
| Qualcomm | Proposal 2: Support closed-loop frequency control commands by MAC-CE.Proposal 3: Consider group-common DCI for UL time and frequency control. |
| Huawei | Proposal 3: For GNSS UE, closed-loop UL frequency compensation is not needed. |
| Spreadtrum Communications | Proposal 5: Autonomous frequency adjustment based on UE GNSS implementation is enough for UL frequency synchronization. |

## Companies views

Based on companies proposals, the initial proposals are as follows:

**FL recommendation 4: RAN1 to further investigate the needs and benefits to support closed-loop UL frequency compensation for GNNS equipped NR NTN UE**

Companies are invited to provide initial inputs on this topic:

|  |  |
| --- | --- |
| :**Companies** | **Comments and Views** |
| CATT | Close-loop frequency compensation is not supported. We didn’t see the need for further investigation.  |
| Panasonic | Agreed. |
| Huawei  | For our understanding, a GNSS UE can calculate the frequency offset for its UL transmissions in RRC connected mode based on the frequency offset estimated by tracking DL reference signal and the indicated frequency pre-compensation. The accuracy of estimated frequency offset for UL frequency adjustment can be ensured even without closed-loop frequency compensation. |
| ZTE | Agree. Needs should be justified. |
| Intel | Same view as Huawei |
| CMCC | Agree.  |
| Ericsson | We are fine with this proposal. |
| MediaTek | Agree with FL recommendation. |
| Qualcomm | Although it is expected that UEs with GNSS capability can accurately compensate the UL frequency most of the time, we do see that there are cases where accurate UL frequency cannot be ensured due to UE movement and infrequent GNSS reading. |
| Sony | Support the proposal |
| Spreadtrum | Support this proposal |
| Xiaomi | Agree |
| vivo | Support |
| Samsung | Okay |
| LG | Agree |
| Lenovo/MM | Agree with the recommendation and we don’t see the need for close-loop UL frequency compensation. |
| APT | Support **FL recommendation 4** |
| Nokia, Nokia Shanghai Bell | We are in principle OK to further investigate this topic. Given the formulation, we understand it such that this is related to UEs in RRC connected mode. But the reference should be that the GNSS equipped UE should be able to track the needed frequency offset based on either ephemeris data or the received DL signals and time provided by *referenceTimeInfo-R16*. |

## Updated proposal based on company views (First round of email discussions)

The large majority of the companies are in line with the FL recommendation. Several companies do not see the need for UL frequency control loop. [Qualcomm] mentioned that there will be scenarios where it would be needed due to UE movement and infrequent GNSS reading.

Based on the companies feedback, the FL recommendation remains the same. Companies willing to support UL frequency control loop should provide more details on the benefits of such mechanism.

**FL recommendation 4: RAN1 to further investigate the needs and benefits to support a closed control loop for UL frequency adjustment with GNNS equipped NR NTN UE.**

|  |  |
| --- | --- |
| :**Companies** | **Comments and Views** |
| MediaTek | We do not see a need to ask RAN1 to further investigate this issue. It can wait until more progress on Issue#6 and Issue#7 is made. It is of course fine if proponents want to further discuss.  |
| Huawei | We hold the same view as the first round discussion, a GNSS UE can calculate the frequency offset for its UL transmissions in RRC connected mode based on the frequency offset estimated by tracking DL reference signal and the indicated frequency pre-compensation. We would like to understand why this is actually needed and the scenarios where this could provide some performance benefit. |
| ZTE | Further discussion is needed with clear justification on the benefits. |
| CATT | We don’t see the needs. |
| APT | Support FL recommendation 4 |
| vivo | Support |

# Issue#5: UE time/frequency synchronization based on GNSS-acquired frequency reference and time stamps

According to [Nokia] using referenceTimeInfo-R16 and UE based understanding of GNSS time will suffer less from the satellite movement in terms of timing advance as the reference point is at a static location (the gNB). [Nokia] proposed to support UE time synchronization based on GNSS-acquired frequency reference and time stamps. According to [Nokia] this is a feasible solution and should be standardized as well.

Further [Nokia] proposed to support UE frequency adjustment based on GNSS-acquired frequency reference, DL signals and measurements and the time provided by referenceTimeInfo-R16. The UE in RRC\_connected mode shall track the frequency offset from DL reference signals and time provided by referenceTimeInfo-R16 to apply frequency pre-compensation in UL.

The mentioned benefits for such solution are the following:

* Compared to GNSS location-based solution, this has the benefit that errors in UE location information, as well as location deviation of the satellite, do not directly lead to UL frequency pre-compensation errors.
* In case GNSS is not available or sufficiently accurate, the UE in connected mode will still be able to perform UL frequency pre-compensation based on the DL reference signals and time information provided by the network.

Such method would come in addition to the one already agreed based on geometric calculations from the UE position and the satellite ephemeris. [Ericsson] proposed to not support it since in their view it is not justified to add a second (mandatory) solution.

Finally, the compatibility of UEs implementing different frequency adjustment solutions in the same cell shall be further investigated as observed by [Qualcomm].

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Nokia | Proposal 4: Self-adjustment by the UE and TA calculation in RRC idle or inactive mode based on GNSS-provided time reference and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well.Observation 11: Using referenceTimeInfo-R16 and UE based understanding of GNSS time will suffer less from the satellite movement in terms of timing advance as the reference point is at a static location (the gNB).Proposal 7: Self adjustment by the UE based on GNSS time and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well.Proposal 9: UE frequency adjustment based on GNSS-acquired frequency reference, DL signals and measurements and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well.Proposal 10: A UE in RRC\_connected mode tracks the frequency offset from DL reference signals and time provided by referenceTimeInfo-R16 to apply frequency pre-compensation in UL.Proposal 11: In case of GNSS loss, the UE shall be able to maintain frequency synchronization offset from DL reference signals and timing information provided by the network. |
| Ericsson | Proposal 16 The measurement-based method for access offset determination is not needed.Proposal 13 RAN1 to determine the relevance of the case of NTN coverage but no GNSS coverage. |
| Qualcomm | Observation 2: There could be an UL frequency bias between UEs that are frequency synchronized with GNSS and UEs that are frequency synchronized using DL frequency. |
| Huawei | Proposal 1: The solution for UE autonomous frequency compensation can be up to UE implementation according to its hardware capability. |

## Companies views

Based on companies proposals, the initial proposal is as follows:

**Iinitial proposal 5-1-1:**

**Self-adjustment by the UE based on GNSS time and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well**

Companies are invited to provide initial inputs on this topic:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | We already have the solution based on GNSS and ephemeris information for timing calculation, so we didn’t see the need to have another solution.  |
| Panasonic | We do not support this proposal. The drawbacks of the time-stamping method were already discussed during RAN1#103e (tight integration between GNSS receiver and NR module, higher power consumption, and increased SIB frequency). |
| Huawei | We are fine with the proposal but would like to clarify that there is no specification impact with this solution. |
| ZTE | Not clear about the definition of “self-adjustment”. Does it refer to the adjustment for oscillator or timing/frequency compensation? For the 1st one, it can be the implementation solution and UE can tune its oscillator based on any trustable source. For the latter one, it can be taken later once the location based on solution is done if companies have strong motivation and justification for the additional method.  |
| Intel | Considering that many companies prefer to consider only one solution based on satellite ephemeris we are OK to prioritise it. However, we agree with the proposal.  |
| Apple | We do not see the spec. impact of UE’s self-adjusting based on GNSS time and timestamp. It may be left to UE implementation. |
| Ericsson | We do not support the proposal. It is already agreed that the UE shall support the method based on geometric calculations. The likelihood of a second optional method being implemented in both UE and network is too small to justify the standardization effort. Further, the method based on referenceTimeInfo-R16 suffers from that ageing of the TA measurements makes it difficult to know (predict) the TA to apply at a given point in time. |
| MediaTek | It should be further discussed what needs to be specified. RAN1#102e has already agreed the timestamp method and ephemeris methods. Agreement:* In Rel-17 NR NTN, at least support UE which can derive based on its GNSS implementation one or more of:
	+ its position
	+ a reference time and frequency
* And, based on one or more of these elements together with additional information (e.g., serving satellite ephemeris or timestamp) signalled by the network, can compute timing and frequency, and apply timing advance and frequency adjustment at least for UE in RRC idle/inactive mode.
* FFS: Details on additional information signalled from network

The RAN1#’102e agreement should allow further specification for the timestamp method if necessary.To our understanding, the timestamp is already specified in Rel-16. It is a choice of implementation in the device requiring tight integration between GNSS receiver and NR module, higher power consumption, increased SIB frequency, and increased reliance on GNSS for accurate GNSS-acquired time reference.  |
| Qualcomm | We don’t support the proposal. |
| Xiaomi | We already have the solution based on GNSS and ephemeris information for timing calculation, so we didn’t see the need to have an additional solution. |
| vivo | Negative to the proposal.The solution mentioned above is beneficial when the GNSS capability of UE is limited. But this scenario is not included in the scope. |
| Samsung | No need. It would be recommended to focus the essential mechanism. |
| LG | We don’t support the proposal. This is because, first of all, supporting two options for UE specific TA calculation has disadvantages in terms of UE implementation complexity. In addition, in order not to increase the specification work/impact, it is desirable to support the unified solution regarding both the UE specific TA calculation and the frequency pre-compensation for the service link.Beside, in our contribution, following proposal was suggested regarding this issue.Proposal 1. The option of UE-specific TA calculation based on the time difference between the reference time provided by network and the reference time acquired by the GNSS is not supported in Rel-17 NTN. |
| Lenovo/MM | We don’t support this proposal as this is a second solution for the same issue. |
| APT | Neutral to **Initial proposal 5-1-1**. We wonder whether satellite ephemeris may provide a timestamp already. |
| Nokia, Nokia Shanghai Bell | We are OK with this proposal |

**Iinitial proposal 5-1-2:**

**UE frequency adjustment based on GNSS-acquired frequency reference, DL signals and measurements and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well.**

Companies are invited to provide initial inputs on this topic:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | Not sure how to use the referenceTimeInfo-R16 for frequency offset calculation. |

|  |  |
| --- | --- |
| Panasonic | We do not support this proposal. The drawbacks of the time-stamping method were already discussed during RAN1#103e (tight integration between GNSS receiver and NR module, higher power consumption, and increased SIB frequency). |
| Huawei | Again, we don't see any spec impact and it is only a UE implementation choice. |
| ZTE | Same comment as above. |
| Intel | Considering that many companies prefer to consider only one solution based on satellite ephemeris we are OK to prioritise it. However, we agree with the proposal.  |
| Apple | We do not see the spec. impact of UE’s self-adjusting based on GNSS frequency and DL signals and measurements. It may be left to UE implementation. |
| Ericsson | We do not support the proposal for similar reasons as for Initial proposal 5-1-1. |
| MediaTek | We have same comment as above. We can further add that the UE frequency adjustment based on GNSS-acquired frequency reference would be a UE-specific implementation method with high impact on receiver algorithms in UE, which are typically not specified. Hence, it is not clear what is proposed. |
| Qualcomm | It’s up to UE implementation to use GNSS or not for frequency synchronization. No spec impact. |
| Xiaomi | We don't see any necessary to standardized the additional solution. |
| vivo | No specification impact. |
| Samsung | No need. It would be recommended to focus the essential mechanism. |
| LG | We don’t support the proposal for same reasons as in proposal 5-1-1. |
| Lenovo/MM | We don’t support this proposal as this is a second solution for the same issue. |
| APT | Neutral to **Initial proposal 5-1-2**. We wonder whether satellite ephemeris may provide a timestamp already. |
| Nokia, Nokia Shanghai Bell | We are OK with this proposal |

## Updated proposal based on company views (First round of email discussions)

The majority of contributing companies do not support initial proposal 5-1-1 and 5-1-2. [Nokia, Intel] are supportive of both initial proposals.

In general, several companies do not see the needs or benefits to support such additional solutions. In addition, there is not clear understanding of what would be the specification impacts to support such solutions if any. As a consequence, the following FL recommendation is made:

**FL recommendation 5-2-1:**

**RAN1 to further investigate the benefits as well as the specs impacts to support a second solution for NR NTN UE timing and frequency adjustment based on GNSS-acquired frequency reference, DL signals measurements and the time provided by referenceTimeInfo-R16.**

|  |  |
| --- | --- |
| :**Companies** | **Comments and Views** |
| MediaTek | We do not see a need to ask RAN1 to further investigate this issue. It is of course fine if proponents want to further clarify whether there is an impact on the specifications or something to discuss on the UE-specific algorithm implementation in RAN1. |
| Huawei | Agree with the proposal even though we still have not identified the specification impact of this method. |
| Xiaomi | Agree with the recommendation. |
| ZTE | Agree with this proposal. The performance of this solution including additional enhancement should be considered for the timing and frequency compensation due to the movement of satellite. |
| CATT | Not clear what is necessity and what is the speciation impact for this second solution. |
| APT | Support FL recommendation 5-2-1 |
| vivo | Not necessary |

# Issue#6: Serving satellite ephemeris format

Discussions about satellite ephemeris have already started during RAN1#103e. The satellite ephemeris format to be used is still undecided. Two main options are foreseen:

**Option 1**: Adopt a satellite ephemeris format based on orbital elements. The date associated to the state vectors should be provided (implicit or explicit methods can be further discussed). Possibly, additional elements associated to the propagator model considered can be included (e.g. drag term from TLE format).

**Option 2**: Adopt a satellite ephemeris format based on satellite position and velocity state vectors. The date associated to the state vectors should also be provided (implicit or explicit method can be further discussed). Possibly, additional elements associated to the propagator model considered can be included.

The following proposals and observations on serving satellite ephemeris format were provided by the different companies:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| ZTE | Proposal 7: Ephemeris format based on instant state vectors with implicit time should be at least supported with the consideration of ATG/HAPS scenarios. |
| CMCC | Observation 2: For satellite application, different forms of orbit representation can be easily translated to each other.Observation 3: UE should have the capability of performing satellite orbit propagation based on any provided orbit representation at a reference time.Observation 4: Only satellite ephemeris in instant state vectors format (Option 2) has the ability for implicit compatibility to support HAPS and ATG scenarios.Proposal 14: For serving satellite ephemeris broadcast by the gNB, at least support instant state vectors format (Option 2). |
| Ericsson | Proposal 13 RAN1 to determine the relevance of the case of NTN coverage but no GNSS coverage.Observation 7 Satellite ephemeris can be represented in different forms including orbital elements and orbital state vector.Observation 8 Different forms of orbit representation can be translated to each other.Observation 9 Orbit representation is associated with a reference time, whether it is implicit or explicit. In NTN, UE would need to derive satellite position, timing and/or Doppler at points in time different from the reference time.Observation 10 Ephemeris is needed not only for the serving satellite but also for other satellites for different purposes including RRM measurements, idle/inactive measurements, handover, etc., which are expected to be discussed in RAN2.Proposal 14 NTN UE should have the capability of satellite trajectory calculation based on a provided orbit representation at a reference time.Observation 11 Satellite ephemeris with sufficient accuracy to support timing and frequency offset pre-compensation shall be made available to the NR NTN UE.Observation 12 Satellite ephemeris with sufficient accuracy to support timing and frequency offset pre-compensation can come with low frequency updates.Proposal 15 RAN1 to study the required accuracy of satellite ephemeris to support timing and frequency offset pre-compensation. |
| Huawei | Observation 12: Keplerian orbit elements indication for service and neighbour satellites can be optimized to reduce the overall signalling overhead.Proposal 10: The satellite ephemeris should take into account the requirement from both RAN1 and RAN2 • Accuracy requirement on time/frequency synchronization• Neighbouring satellite ephemeris for mobility management purpose  |
| MediaTek | Observation 5: Two use cases with different requirements for satellite ephemeris can be considered:• Use case 1 - Satellite ephemeris used for UE pre-compensation for UL synchronization for cell access: The gNB broadcast the satellite ephemeris with low latency, high accuracy, and for a single satellite. This use case mainly is within scope of RAN1 discussions.• Use case 2 - Satellite ephemeris used for UE wake up from DRX for next satellite flyby and RRM measurements: The gNB broadcast the satellite ephemeris with high latency, low accuracy, and for multiple satellites. This use case is mainly within scope of RAN2 discussions.Observation 6: The Orbital parameters Periapsi, eccentricity, Semi-major axis, vary significantly within seconds. This is explained by the perturbations that affect the orbital propagation, mainly the non-sphericity of the Earth shape (Earth’s oblateness). Earth radius at pole is 21 km smaller than Earth radius at equator. For a nearly polar orbit (and very close to the Earth), it impacts significantly the propagation of the orbital elements.Observation 7: A UE first coming into coverage of a satellite needs to immediately access if it is paged or if it needs to transmit data. The UE must be able to receive the satellite ephemeris on NTN SIB broadcast with periodicity 0.5s or 1 s. A longer SIB periodicity is not desirable due to short satellite dwell time (~10 minutes)Observation 8: The UE needs to convert orbital parameters to state vectors Position and Velocity to determine satellite delay and Doppler shift which increases complexity. Observation 9: The orbital parameters are not applicable to HAPS/ ATG. HAPS vehicles do not follow a Keplerian Orbit. ATG is fixed on the ground and do not follow a Keplerian Orbit. Only the position maybe needed for HAPS/ATG with saving of 50% on the Position and Velocity or about 8 or 9 Bytes. For HAPS/ATG, there is no need for UE wake up befor next satellite flyby.Observation 10: An accuracy of 41.2 m for the position and 1.36 m/s for the velocity can be achieved by propagating orbital parameters to a time of 60 seconds following epoch time t0. After 10 minutes, the position error and velocity error are 4 km and 13.9 m/s; after half an hour, the position error and velocity error are 33 km and 40 m/s. The orbital parameters need to be broadcast with low latency and high accuracy for UE pre-compensation.Observation 11: For the use case of UE pre-compensation, assuming satellite ephemeris format type orbital parameters or satellite ephemeris format type Position and Velocity sate vectors are broadcast with low latency and high accuracy- the overhead can be 16 bytes on NTN SIB. - there is no need to include the epoch time which can be implicitly known as a reference time linked to the Downlink subframe where the NTN SIB is broadcast.Proposal 10: The base Station broadcast Position/ Velocity and implicit Time in each beam in the satellite cell:- Satellite location/velocity in ECEF coordinates- Validity Time is the end of SFN where SIB was transmitted (from the satellite)Proposal 11: Satellite Position and Velocity information field sizes broadcast on SIB with periodicity X- The field size for position is 78 bits- The field size for velocity is 54 bits- Value of X – e.g. 200 ms, 500 ms, 1000 ms, 1500 ms, 2000 msObservation 12: An accuracy in the order of 36.9 meters for the position and 1.3 m/s for the velocity can be achieved by propagating position and velocity to a time of 60 seconds following epoch time t0.Observation 13: Satellite position error < 120 m requirement and satellite velocity 1.5 m/s requirement can be met in the device with periodicity of 10 seconds or longer using propagation of satellite position and velocity based on gravity. |
| Samsung | Proposal 1: A gNB signals the serving satellite ephemeris to UEs in system information, including the followings:• index to a pre-defined table of satellite altitude levels and altitude offset scaling factors, i.e., NTN type• satellite altitude offset• satellite position• satellite velocity• reference time for satellite position and velocity. |
| InterDigital, Inc. | Proposal 3: For GEO, ephemeris data consists of satellite position in (x, y, z) ECEF coordinates.Observation 1: Due to fast movement of LEO satellites, a coordinate-based ephemeris representation will become quickly obsolete and require frequent updates.Observation 2: Over the timescales of initial access, error to orbital prediction introduced by e.g. atmospheric drag is relatively minor and should allow sufficiently accurate estimates for timing pre-compensation.Proposal 4: For non-GEO, ephemeris data contains information regarding orbital trajectories of satellites. |
| CATT | Observation 1: From technique essence point of view, the constellation ephemeris data is equivalent to Satellite position status vector, where Satellite position status vector is the outcome of constellation ephemeris data derivation and reflects instant satellite position.Observation 2: In RRC-IDLE mode and initial cell search, constellation ephemeris data is more preferred due to less update required and long aging time, while satellite position status vector is preferred to apply in connected modeObservation 3: For constellation ephemeris data, parameter M0 can be updated in a short cycle and other parameters (a, e, ω, Ω, i) can be updated in a long cycle. Short term ephemeris information and long term ephemeris information can be separately indicated to UE.Proposal 1: Constellation ephemeris data and Satellite position status vector can be supported both and UE can use them in different occasions.Proposal 2: In order to reduce system overhead, consider different updating cycle for short term ephemeris parameters and long term ephemeris parameters. |

## Company views

The issues and observations collected from the contributing companies have been summarized in the table below:

Table 1 Summary on satellite ephemeris considerations

|  |  |  |
| --- | --- | --- |
| Issues & Observations | Option 1 | Option 2 |
| Format | Different forms of orbit representation can be translated to each other [Ericsson, CMCC, CATT]. |
| Precision(s) | The required accuracy for the satellite ephemeris format [Thales, Ericsson] shall be driven based on the prediction budget error on satellite position and velocity vectors (to be derived from timing/frequency synchronization requirements) and the foreseen prediction time horizon. The format resolution can be chosen [Thales] such that the quantization noise impact on orbit prediction error is negligible.When performing orbit prediction based on past satellite ephemeris, it is required [Thales, Ericsson] to estimate the time between the satellite ephemeris date and the instant of prediction. Then, the precisions related to absolute and/or relative time knowledge at UE side shall be investigated [Thales] to quantify its impact on the orbit prediction error. |
| Propagator models | The propagator model to be used at UE side can be left to implementation [Thales]. Yet, the adopted ephemeris format can strongly orientate the choice of model (e.g. TLE format and TLE propagation models). |
| Overhead | The serving satellite ephemeris broadcast periodicity is driven by the initial access latency and may be rather low [Thales, MediaTek]. The overhead introduced shall be carefully quantified. Several leads can be foreseen to reduce the overhead. |
| Implicit time provision [Thales, ZTE, MediaTek]Define separate formats for GEO orbits, LEO orbits and HAPS/ATG [Thales, Samsung, InterDigital] | Implicit time provision [Thales, ZTE, MediaTek]Keplerian orbit elements indication for service and neighbour satellites can be optimized [Huawei, Thales] to reduce the overall signalling overhead. |
| Reference time provision | There are several ways to provide a time reference or date associated to the satellite ephemeris broadcast.The first approach is to transmit this date explicitly [Ericsson, Thales]. It is the simplest approach but it increases signalling overhead. It can also be done in an implicit way [Ericsson, Thales, ZTE, Mediatek] to limit the signalling overhead. * For instance, the date can be considered equal to the reference time linked to the Downlink subframe where the NTN SIB is broadcast [MediaTek, Thales].
* Another method [Thales] is to establish a common understanding in the system concerning the received satellite ephemeris and the dates associated. For instance, it can be established that satellite ephemeris updates are performed every X minutes starting from 00h00 UTC. Every time satellite ephemeris information is broadcast, it is assumed that the date associated is the time of the latest update.
 |
| Unified ephemeris format | Ephemeris are going to be used for other purposes than UL synchronization. It would be beneficial to come up with a unified framework compatible with:* Each type of NTN scenario (GEO, LEO, HAPS and ATG)
* RAN1 requirements on time/frequency synchronization [Thales, Ericsson, MediaTek, Huawei]
* RAN2 requirements on Neighbouring satellite ephemeris for mobility management purpose [Huawei] and RRM measurements [MediaTek]
 |
| Compatible with HAPS and ATG [ZTE,CMCC, Samsung] but propagation models shall be adapted [Thales, MediaTek]. | Not compatible with HAPS and ATG |

Initial simulation results to evaluate the orbit prediction error at UE side have been provided assuming a satellite ephemeris format based on orbit elements [ Ericsson, Huawei, Mediatek] and PV state vectors [MediaTek].

 [MediaTek, ZTE, CMCC, InterDigital] are in favour to support at least an ephemeris format based on option 1.

The initial proposal is made as follows to capture that NTN UE will have to support trajectory prediction based on any of the formats that will be specified.

Initial proposal 6-1: NTN UE should have the capability of satellite trajectory prediction based on any provided orbit representation at a reference time.

Companies are encouraged to provide their views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | Need more clarification on the capability of satellite trajectory prediction. In our view, the predication capability is relying on the modelling and orbit parameters, so we can’t agree one general agreement without details. |
| Panasonic | We support this proposal. |
| Huawei | We support the proposal |
| ZTE | It’s not clear how to define such capability. As normal behaviour, once the specification with agreement to indicate certain information (e.g., orbit information) is agreed to for TA calculation, the UE should be able to conduct corresponding pre-compensation. The “prediction” capability mainly is related to updates of this information, e.g., periodicity or UE triggered. It can be discussed later. |
| Intel | Support |
| CMCC | We support the proposal. |
| Apple | Support |
| Ericsson | We support this in general but also wonder if this is only needed for satellite UE (i.e., not applicable to HAPS/ATG UE). |
| MediaTek | This proposal needs clarification. For the orbit representation, it is preferable to mention orbital parameters or position and velocity state vectors. We think an alternative wording would be helpful Alternative wording for Initial Proposal 6-1: gNB broadcast serving satellite ephemeris with validity time at the end of SFN where SIB was transmitted (from the satellite) for prediction by the UE of the satellite position and velocity, where the serving satellite ephemeris can be orbital parameters or position and velocity state vectors.  |
| Qualcomm | Agree in principle but clarification is needed.  |
| Spreadtrum | We support the proposal. |
| Xiaomi | It’s not clear how to define the prediction capability. It can be discussed later. |
| Samsung | We support initial proposal 6-1. |
| InterDigital | We support the proposal |
| LG | Agree with Qualcomm. |
| APT | Support Initial proposal 6-1 |
| Nokia, Nokia Shanghai Bell | Do not support – we do not specify such capability. In essence it is sufficient to mandate that the UE fulfils the RAN4 requirements related to timing and frequency offset for initial access (and potentially also during connected mode). How the UE extracts this information is not relevant from specification point of view. Basically, RAN1 (and RAN2) should provide the needed information and how the UE derives/projects this into useful information to fulfil requirements is not important. |

Initial proposal 6-2: RAN1 to at least support ephemeris format based on satellite position and velocity state vectors

* **Details on state vectors formats are FFS**
* **Details on time reference provisioning/format are FFS**

Companies are encouraged to provide their views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | For our side, two kinds of ephemeris formats can be supported, not at least. |
| Panasonic | Priority should be given to the orbital element format due to its better efficiency, i.e., less frequent SIB updates are required compared to the PVT format. Modified Initial proposal 6-2: RAN1 to at least support ephemeris format based on **satellite orbital elements**• Details on orbital element formats are FFS• Details on time reference provisioning/format are FFS |
| Huawei | We don’t agree with the proposal. We understand that there are parallel discussions in both RAN1 and RAN2 regarding how the satellite ephemeris can be used as well as the satellite ephemeris format. The key factors that needs to be taken into account include the accuracy in order to meet the synchronization requirement, signalling overhead as well as its applicability to different use cases. It should be noted that the two ephemeris formats are theoretically equivalent and can be transformed to each other via Keplerian equations. Based on our evaluation, the ephemeris format based on orbital elements can provide an acceptable accuracy for frequency/timing synchronization with a lower signalling overhead. The signalling overhead can be further reduced based on physical law and application. Therefore, we are supportive of the proposal from Panasonic.  |
| ZTE | Supportive |
| Intel | Support |
| CMCC | We support this proposal. In our view, for satellite application, different forms of orbit representation can be easily translated to each other. Therefore, UE should have the capability of performing satellite orbit propagation based on **any** provided orbit representation at a reference time.Furthermore, both options may perform similar on the metrics of signaling overhead, complexity to implement accurate orbit propagation model, and compatibility with a potential unified ephemeris format to be used for other purposes (e.g. RRM measurements, handover, idle/inactive measurements), since the two forms of orbit representation can be easily translated to each other.Nevertheless, in the metric of compatibility to universal scenarios (e.g., NTN, ATG, HAPS), instant state vectors (i.e., PVT) format is superior to satellite orbital elements. Only the former solution has the ability for implicit compatibility to support HAPS and ATG scenarios, since orbit concept is meaningless in HAPS and ATG scenarios.Thus, for serving satellite ephemeris broadcast by the gNB, we suggest to at least support instant state vectors format. |
| MediaTek | We support this proposal. We agree with Huawei that the two formats give similar accuracy of prediction. We would also be fine with both formats supported and up to the network which one to use, but think the Alternative wording for Initial Proposal 6-1 suggested by MediaTek could be discussed first. To our understanding, typical satellites have an on-board GNSS receiver that reports position and velocity of satellites for orbit control and pre/post compensation of delay and Doppler shift over feeder link. The GW / gNB would need to convert the satellite position and velocity to orbital parameters if broadcast. Then, the UE would need to convert orbital parameters to position and velocity state vector for UE pre-compensation of delay and Doppler shifty over the access link. Hence, we have preference for position and velocity state vectors as it seems lower complexity. It has the benefit of implicit compatibility with HAPS and ATG |
| Qualcomm | Both should be supported. |
| Spreadtrum | We support the proposal. |
| Xiaomi | Two kinds of ephemeris formats can be supported. |
| Samsung | We support initial proposal 6-2. |
| InterDigital | Both should be supported |
| APT | Support Initial proposal 6-2 |
| Nokia, Nokia Shanghai Bell | We are OK with this proposal |

**FL recommendation 6-1**: **RAN1 to further investigate the details regarding ephemeris formats based at least on satellite position and velocity state vectors**

* **Explicit or implicit time reference**
* **Range/Granularity/Units for position and velocity vector elements**
* **Separate formats for GEO orbits, LEO orbits and HAPS/ATG**

Companies are encouraged to provide their views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | This proposal can be suspended. We need firstly discuss the Initial proposal 6-2. |
| Panasonic | Modified FL recommendation 6-1: RAN1 to further investigate the details regarding ephemeris formats based at least on **orbital elements**• Explicit or implicit time reference• Range/Granularity/Units for orbital elements• Separate formats for GEO orbits, LEO orbits and HAPS/ATG |
| Huawei | This proposal is closely related to 6-2 and we are fine with the change from Panasonic. On the other hand, 6-2 should be concluded in the first place. |
| ZTE | This proposal seems to be overlapped with 6-2.  |
| CMCC | We support this proposal.  |
| Qualcomm | support |
| Xiaomi | This proposal can be suspended. We need firstly discuss the Initial proposal 6-2. |
| Samsung | We support FL recommendation 6-1. The reference time can be implicitly signalled, e.g. by referring to the system frame number and/or slot index. Also, the elements of the position and velocity vectors can be expressed in earth-centered earth-fixed (ECEF) coordinates. In addition, the overhead of utilizing separate formats for GEO, LEO, and HAPS/ATG is relatively low; for reference, see Table 1 in our contribution. |
| InterDigital | Agree with Huawei and Xiaomi. Initial proposal 6-2 should be concluded first. |
| APT  | Support FL recommendation 6-1 |
| Nokia, Nokia Shanghai Bell | We are OK to further investigate |

## Updated proposal based on company views (First round of email discussions)

Regarding initial proposal 6-1

[Panasonic, Huawei, Intel, CMCC, Spreadtrum, Samsung, InterDigital, APT, Ericsson] are supportive of the proposal.

[CATT, ZTE, MediaTek, Qualcomm, LG, Xiaomi] asked for additional clarifications and [ZTE, Xiaomi] proposed to postpone the discussion.

[Nokia, ZTE] observed that in principle such agreement on UE capability is not needed and that future requirements related to time and frequency alignment when pre-compensation is applied would be sufficient.

[Ericsson] observed that equivalent proposals may be needed for HAPS and ATG.

From moderator perspective, the need for further clarifications remains unclear because the proposal seems quite explicit. From moderator pov, there is no need to add more details on the supported ephemeris formats to agree on this.

The comments from [ZTE, Nokia] make sense:到此 However, having such agreement may be beneficial to progress on the topic of ephemeris format and the associated accuracy.

As a consequence, it would be good to further discus the initial proposal. Companies that wish to clarify the proposal are invited to do so. Companies are also invited to comment further on whether having such an agreement is beneficial/needed or not.

Updated proposal 6-1:

NTN UE should have the capability of satellite trajectory prediction based on any provided orbit representation at a reference time.

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | We think the wording of the proposal need to be clarified further. We think mention of “any provided orbit representation” is ambiguous. Huawei, Ericsson, MediaTek, Thales have provided analysis and simulations on satellite ephemeris (orbital parameters of Position and Velocity state vectors) for two format types included in the TR 38.821 which showed very good accuracy. We think the wording can be revisedNTN UE should have the capability of satellite trajectory prediction based on ~~any~~ the provided orbit representation at a reference time. |
| Huawei | Agree with the proposal  |
| Xiaomi | The UE trajectory prediction capability has not been explicitly defined. This proposal can be suspended.  |
| CATT | Not sure how to define the predication capability. Actually existing satellite UE always owns this capability. Without this capability, NTN system doesn’t work. In order to make it clear, maybe we can modify it as:NTN UE should have the capability of satellite trajectory prediction based on Kepler orbit parameters or PVT information at a reference time. |
| ATP | Support Updated proposal 6-1 |
| Samsung | Support |

Regarding initial proposal 6-2,

The companies views on which ephemeris format should be supported are still divided

 [ZTE, Intel, CMCC, MediaTek, Spreadtrum, Samsung,InterDigital, APT, Nokia ] are fine with the initial proposal to support at least ephemeris formats based on satellite position and velocity state vectors.

[Panasonic, Huawei] preferred to support at least ephemeris formats based on satellite orbital elements.

For [Panasonic], this type of format enable less frequent update from the network. However, there is no clear understanding on the benefit aforementioned. Based on the companies contributions, it seems that both formats can be considered as equivalent in terms of satellite trajectory prediction precision [3, 10, 16].

According to [Huawei] feedback, the format based on orbital elements is preferred because it enables further overhead optimization. Since the technical contributions proposing a full description of ephemeris format based on orbital elements are limited, it may be too early to conclude on this aspect.

[CATT, Qualcomm, Xiaomi] would like to support two types of ephemeris format: one based on orbital elements and one based on position/velocity state vectors. From moderator perspective, the initial proposal is in line with the demand of these companies.: supporting additional type of ephemeris format is not precluded at this stage.

Companies are invited to further comment and justify their preferred option among the ones captured in the proposal below. Based on this first round outputs, Option 1 seems to be the best WF for this meeting. However, if this option is still unacceptable for some companies then the discussion should be postpone.

Updated proposal 6-2:

Option 1: RAN1 to at least support ephemeris format based on satellite position and velocity state vectors

* **Details on state vectors formats are FFS**
* **Details on time reference provisioning/format are FFS**

Option 2: RAN1 to at least support ephemeris format based on orbital elements

* **Details on orbital elements formats are FFS**
* **Details on time reference provisioning/format are FFS**

Option 3: RAN1 to at least support two types of ephemeris format: one based on orbital elements and one based on position/velocity state vectors.

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | These options for the satellite ephemeris format are for the UE pre-compensations. There is no needed for Option 3. To our knowledge, a different type of satellite ephemeris than orbital parameters or Position and Velocity state vectors as not been discussed. RAN1 cam make agreements on the discussed ephemeris formats types as in Option 1 and Option 2. . For UE pre-compensation Option 1 and Option 2 are sufficient. We suggest some minor revisions Updated proposal 6-2: For UE pre-compensation, the network supports the following format options: Option 1: RAN1 to at least support ephemeris format based on satellite position and velocity state vectors* **Details on state vectors formats are FFS**
* **Details on time reference provisioning/format are FFS**

Option 2: RAN1 to at least support ephemeris format based on orbital elements* **Details on orbital elements formats are FFS**
* **Details on time reference provisioning/format are FFS**
 |
| Huawei  | We are supportive of Option 2 or Option 3. From UL time and frequency offset pre-compensation point of view, either option 1 or option 2 could work. Option 2 is helpful for mobility management as discussed in RAN2. Hence the most likely outcome is option 3. |
| Xiaomi | Option 2 is preferred. |
| ZTE | We can start to define the details for Option-1/2 including the format. Potential combination may a choice for progress but clear usage/benefits should be identified.  |

FL recommendations can be made later on when companies have converged.

# Issue#7: GNSS accuracy requirement

On GNSS accuracy requirement the following recommendation was made in Feature Lead summary at RAN1#103e based on company proposals and comments:

FL recommendation:

RAN1 to consider the assumptions defined by RAN4 on GNSS positioning accuracy.

Regarding the assumption about GNSS availability and the need for possible measurements gap during NTN operation, the following recommendation was made:

FL recommendation:

It is up to RAN4 to decide whether interruptions or measurement gaps are required for GNSS measurements during NTN operation

[Nokia] and [MediaTek, Eutelsat] made some observations on GNSS accuracy. They are summarized in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Nokia | Observation 1: The UE GNSS-based time pre-compensation has the main purpose to guarantee that the initial random access attempt falls into the time window for the RACH occasion as defined by the gNB and minimize the interference to adjacent UL time slots/symbols. Frequency pre-compensation shall ensure that the Doppler effect is mitigated so that the preamble can be received by the gNB with minimized frequency offset.Observation 2: There are several sources of inaccuracy in estimating the time and frequency synchronization between UE and gNB by using GNSS information: lag of the ephemeris information, precision of the ephemeris data, GNSS inaccuracy, orbit perturbations and altitude modelling, delay on GNSS acquisition and information conversion at the UE and atmospheric delays.Observation 3: Full reliance on third part GNSS systems leave the 3GPP systems exposed to vulnerabilities that cannot be solved by enhancements of 3GPP standards or device implementation. |
| MediaTek, Eutelsat | Observation 3: GNSS accuracy in the device and on-board of satellite are expected to be sufficiently accurate from RAN1 viewpoint and are for discussions on RAN4. |
| Ericsson | Proposal 12 It is up to RAN4 to determine the need for supporting GNSS measurement gaps in RRC\_CONNECTED state. |

## Company views

Based on the above observations and proposals. FL recommendation made is last RAN1 meeting can be captured in an initial proposal as follows:

**Initial Proposal 7-1**

**It is up to RAN4 to decide whether interruptions or measurement gaps are required for GNSS measurements during NTN operation**

Companies are encouraged to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | Agree. |
| Panasonic | We agree. |
| Huawei | Agree |
| ZTE | Fine to do it in RAN4, and detailed analysis is preferred per band, at least for FR1 and FR2. Meanwhile, simultaneous process for the baseband signal and received GNSS signalling should be also justified since such behaviour is required for TA adjustment. |
| Intel | OK |
| CMCC | Agree. |
| Apple | Agree |
| Ericsson | We support the proposal |
| MediaTek | Agree. Up to RAN4 to discuss GNSS accuracy requirements, GNSS measurement gaps for ephemeris method (GNSS position TTFF) or timestamp method (GNSS-acquired time reference in the device) |
| Xiaomi | We agree. |
| Samsung | Agree |
| LG | Agree |
| APT | Support Initial Proposal 7-1 |
| Nokia, Nokia Shanghai Bell | In this proposal we are missing the consideration on **how** the UE is expected to behave for cases where the UE is not having proper understanding of geo-location and GNSS based time. This issue is somehow related to the requirements that are discussed in issue#8, which could potentially be combined in the LS sent to RAN4. That is, further asking whether RAN4 has any idea of the estimation accuracy that can be expected from external systems that are outside the control of the 3GPP system (GNSS systems). |

## Updated proposal based on company views (First round of email discussions)

During last GTW online session the following conclusion is made:

**Conclusion:**

**It is up to RAN4 to decide whether interruptions or measurement gaps are required for GNSS measurements during NTN operation**

# Issue#8: UL Time and frequency synchronization requirements

Regarding the requirements on UL synchronization, the following recommendation was made in last RAN1 meeting:

FL recommendation:

RAN1 to further investigate the UL synchronization requirements in terms of time alignment and frequency error for:

• Initial access (i.e. PRACH transmission)

• UL transmissions in RRC Connected State

Coordination with RAN4 can be further discussed during the next meeting.

In the TDocs submitted to RAN1#104-e, only [MediaTek, Eutelsat], [Nokia] and [Thales] provided some proposals regarding the the requirements on UL synchronization:

The proposals on GNSS-assisted TA and frequency compensation requirements are summarized in the following table:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| MediaTek, Eutelsat | **Proposal 7**: For TA update in RRC\_IDLE and RRC\_INACTIVE states, UE pre-compensation of satellite delay of PRACH transmission is within a timing error at the gNB ∆T=±CP/2 corresponding to a satellite position error ΔU  For FR1 assuming PRACH format 0, ∆T=56.6 μs or ∆U<±7735 m  For FR2, assuming PRACH format C0, ∆T=2.5 μs or ∆U<±378 m.**Proposal 8**: For TA update in RRC\_CONNECTED state, in case of open-loop TA only is used the UE pre-compensation of satellite delay of UL transmission is within a timing error at the satellite ∆T=±CP/2 corresponding to a satellite position error ΔU  With numerology µ=0, ∆T=2.34 μs or ∆U<±351 m .  With numerology µ=1, ∆T=1.17 μs or ∆U<±175 m  With numerology µ=2, ∆T=0.58 μs or ∆U<±87 m. Observation 4: UE pre-compensation of satellite Doppler shift within an accuracy of ±0.02ppm included in the total frequency error for UL transmission of ±0.1 ppm could be considered for UL frequency synchronization as working assumption in RAN4. In term of satellite position accuracy (ΔU) and satellite velocity accuracy ΔV, this corresponds to  For LEO ∆U<±120m  ∆V<±1.5 m/sec For GEO ∆U< ±21 km  ∆V< ±2.7 m/sec**Proposal 9:** For UE in RRC\_IDLE, RRC\_INACTIVE, and RRC\_CONNECTED states, RAN1 working assumption is that accuracy of UE pre-compensation of satellite Doppler shift meets the maximum UL frequency error of ± 0.1ppm for UL transmission. |
| Nokia | **Proposal 1:** The aggregate contribution of all sources of time inaccuracy and multipath propagation delays must not violate the limits imposed by the cyclic prefix of the random access preamble.Observation 4: The long preamble formats provide a more relaxed CP constraint but a more stringent frequency Doppler pre-compensation constraint, especially considering the very high speed observed in LEO deployments and the usage of high frequency bands.**Proposal 2**: The GNSS-assisted pre-compensation solution used by the UE must meet the demands of the preamble format chosen by the operator. The UE must ensure that requirements in TA adjustment and frequency pre-compensation for all preamble formats are met at any time. |
| Thales | Proposal 8.The UE shall be able to acquire its User specific TA with an accuracy better than ± , depending on the PRACH format and configuration.Proposal 9.The UE 3D positioning error ΔU and the satellite 3D positioning error ΔS shall accommodate the following requirement: ΔU + ΔS < c/2 \* min((CP-Delay spread)/2,GP/2,(Minimal Relative Cyclic Shift Duration)/2) Proposal 10.In connected mode, the UE shall be able to update its TA with an accuracy better than ±. depending on the numerology in use.**Proposal 12.**The UE shall be able to compensate the frequency offset due to the satellite mobility when generating its UL carrier frequency. The residual frequency error shall be sufficiently low such that it can be considered within the tolerated frequency error of 0.1 ppm already captured in the specification. |

## Company views

Based on the above, it seems that from RAN1 viewpoint the UL synchronization requirements shall be only defined by RAN4.

Moderator view: RAN1 needs to coordinate with RAN4 on this topic. Therefore, the initial proposal is made as follows:

Initial proposal 8-1:

**RAN1 should send an LS to RAN4 with the following questions:**

**Question 1: RAN1 would like to ask RAN4, to indicate what are the NTN UL time synchronization requirements?**

**• Initial access (i.e. PRACH transmission)**

**• UL transmissions in RRC Connected State**

**Question 2: RAN1 would like to ask RAN4, to indicate what are the NTN UL frequency synchronization requirements?**

**Question 3: RAN1 would like to ask RAN4, to indicate what are the implication of NTN UL synchronization requirements on satellite position and velocity?**

Companies are encouraged to provide their comments and propose other relevant questions in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | agree |
| Panasonic | We support sending an LS on requirements to RAN4. |
| Huawei | Not sure about the motivation. It would be good to clarify what the exact question we are after before sending the LS.  |
| ZTE | W.r.t the Q1~2, we are fine to let RAN4 provide some information on the requirement if no RAN1 consensus can be achieved. But w.r.t the Q3, not sure whether RAN4 is cable to define the “implication” to the requirement on satellite position and velocity. From testing perspective, RAN4 only care about the RRM performance. The requirement on the satellite position and velocity seems to be more RAN1/2 issue, e.g., frequency for updating, etc. |
| Ericsson | We support the proposal. Sub-bullets of Question 1 should be copied to Question 2 as well. |
| MediaTek | We would agree with proposals but we think such LS should clarify RAN1 understanding of minimum requirements from RAN1 view point and for example include some initial requirements for consideration by RAN4 (e.g. MediaTek proposals 7. 8. 9 as summarised in Table with company proposals above). It would be up to RAN4 to further discuss requirements from RAN4 viewpoint. |
| Xiaomi | We agree. |
| Samsung | Okay to send an LS with modification “indicate” to “define”. |
| APT  | Support Initial proposal 8-1 |
| Nokia, Nokia Shanghai Bell | In principle OK with sending a LS for RAN4 with these questions, but for Q3, it would probably be worth providing a few scenarios for their calculations (that is inclination angle, satellite velocity, satellite altitude (LEO/GEO), etc). |

## Updated proposal based on company views (First round of email discussions)

10 companies provided views after the first round of email discussion. Most companies agree that some coordination with RAN4 on synchronization requirements would be needed. As stated by [MediaTek ] the LS to RAN4 should clarify RAN1 understanding of minimum requirements from RAN1 view point and for example include some initial requirements for consideration by RAN4.

Companies are encouraged to refine the wording and provide views on the following potential proposal:

Potential proposal 8-1:

**RAN1 should send an LS to RAN4 with the following questions:**

**Question 1: RAN1 would like to ask RAN4, to indicate what are the NTN UL time synchronization requirements?**

**• For initial access (i.e. PRACH transmission)**

**• For UL transmissions in RRC Connected State**

**Question 2: RAN1 would like to ask RAN4, to indicate what are the NTN UL frequency synchronization requirements?**

**• For initial access (i.e. PRACH transmission)**

**• For UL transmissions in RRC Connected State**

**Question 3: RAN1 would like to ask RAN4, to indicate what are the implication of NTN UL synchronization requirements on satellite position and velocity?**

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Support potential proposal 8-1. This is under discussion in RAN4. The LS would clarify that RAN4 can first discuss and send LS to RAN1 when they reach conclusions. Requirements are in scope of RAN4.  |
| Huawei | We are fine with the proposal. |
| Xiaomi  | We are ok with the proposal. |
| ZTE | Supportive |
| CATT | Agree |
| APT | Support Potential proposal 8-1. |
| Samsung | Support |
|  |  |
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|  |  |
|  |  |

# Issue#9: UE centric precompensation

An alternative solution that would simplify the time and frequency compensation mechanisms was proposed by [Ericsson].

The principles of this UE centric precompensation solution is captured in the following observation made by [Ericsson]: If the position of a reference point of the feeder link and the UL and DL carrier frequencies of the feeder link are signalled to the UE, the UE can autonomously determine the time and frequency offset of both the service link and the link between the satellite and the reference point of the feeder link, which would simplify the time and frequency compensation procedures.

The proposal made by [Ericsson] is the following:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Ericsson | Proposal 11 Support broadcasting a reference point of the feeder link and UE autonomous determination of the time and frequency offset of both the service link and the link between the satellite and the reference point of the feeder link. |

## Company views

By considering the proposal from [Ericsson], the initial proposal is made as follows:

**Initial proposal 9-1:**

**Support broadcasting a reference point of the feeder link and UE autonomous determination of the time and frequency offset of both the service link and the link between the satellite and the reference point of the feeder link.**

Companies are encouraged to provide their comments on UE centric precompensation in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CATT | We didn’t see the need to have this proposal. With the indication for the timing and frequency compensation information of network, UE can do synchronization with reference point. Broadcasting a reference point of the feeder link is redundant.  |
| Panasonic | We see no need for this, since the reference point is implicitly handled via the common TA value. Also, the proposal contradicts the concept of reference point for time synchronization at the satellite or at the gNB can be left to the network (see Issue#1-1: Indication of common TA (CTA)). |
| Huawei | Given the Common TA based solution is already on the table, we don’t see the need to broadcasting a reference point explicitly. |
| ZTE | Broadcasting of the reference point of feeder link is not preferred. The required value can be indicated by the gNB directly including impacts of other consideration from scheduling perspective. |
| Intel | Support the proposal |
| CMCC | We are supportive to this proposal. |
| Apple | The motivation of broadcasting a reference point of feeder link is not clear, considering a common TA is broadcast by network.  |
| Ericsson | We support the proposal. |
| MediaTek | This proposal needs clarification and amendment. There is fundamentally no serious issue for the UE pre-compensation for the delay over the feeder link if the gNB location can be broadcast with sufficient accuracy (i.e. up to several 100ms or kms). The pre-compensation of the Doppler shift over the feeder link would need to be further discussed depending on the accuracy of the gNB position. The feeder link typically use a higher band for the feeder link (e.g. Ka band), which increases the accuracy requirements for the UE pre-compensation.  |
| Xiaomi | Broadcasting the reference point of feeder link is not preferred. The reference point can be implicitly handled via the common TA value. |
| Samsung | With having K\_offset, we don’t see the necessity of this proposal. |
| LG | In our view, more discussion is needed regarding to indicate the reference point position. |
| APT | Clarification. If a reference point is set to a gNB/GW, then do we still have concerns about sharing where a gNB/GW is? If there is no security concern, then we support broadcasting GNSS location for a reference point (especially for a gNB/GW). |
| Nokia, Nokia Shanghai Bell | The reference point for time and for frequency should be defined as gNB or satellite. The reference points should be under the control of the network.  |

## Updated proposal based on company views (First round of email discussions)

In the first round of email discussion, 14 companies provided views on issue#9.

[Intel, Ericsson, CMCC] are supportive of the proposal

[APT] support broadcasting GNSS location for a reference point if there is no security concern.

[ CATT, Panasonic, Huawei, Samsung] do not see the need of broadcasting a reference point.

For [ZTE, Xiaomi] Broadcasting of the reference point of feeder link is not preferred

According to [MediaTek, Apple] this proposal needs clarification and amendment. Particularly, the pre-compensation of the Doppler shift over the feeder link would need to be further discussed depending on the accuracy of the gNB position.

[LG] more discussion is needed regarding to indicate the reference point position.

For [Nokia, Nokia Shanghai Bell] the reference points should be under the control of the network.

Given the views expressed so far, support of broadcasting a reference point needs further discussion. The moderator recommendation is as follows:

**FL recommendation 9-1:**

**On support of broadcasting a reference point, proponents are encouraged to provide more details on the feasibility of such solution by taking into account companies’ concerns on this issue.**

Companies are encouraged to provide their comments on FL recommendation 9-1:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | We think more analysis is needed for potential impact of large Doppler shift on the feeder link for initial DL synchronization as commented for Issue#3-3 in Updated proposal 3-3 in Section 3.3.2. |
| Huawei  | Our view is that there is no need to broadcast a reference point as it is indicated by common TA. In addition, common TA may include TA margin which cannot be evaluated by the referent point, then the indication of referent point will be meaningless. |
| Xiaomi  | We are fine with the recommendation. |
| ZTE | No needs to indicate the RP. |
| CATT | Need more analysis. In our view, current common TA discussion has taken into account this solution. |
| APT | Support FL recommendation 9-1 |
| Samsung | We are fine with the recommendation but it seems we don’t need to make an agreement. |
| vivo | Considering an agreement that the common TA is broadcasted by network has been reached, it is unnecessary to broadcast the reference point. |
|  |  |
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# Issue#10: TA Reporting

## Updated proposal based on company views (First round of email discussions)

[CEWiT, IITH, IITM, Tejas Networks, Reliance Jio ], [Samsung] and [LG Electronics] proposed to support TA reporting to gNB. The reasons provided are the following:

* [CEWiT, IITH, IITM, Tejas Networks, Reliance Jio]: as UE estimate its own TA (e.g., UE specific TA part),it will be advantageous to report back the estimated TA to the gNB: The gNB for better control over UE behaviour.
* For [Samsung ] UE’s estimated TA value is reported to gNB, if K\_offset is updated UE-specifically.

Some methods for TA reporting were proposed: [LG] proposed to support implicit reporting of TA estimated by the UE. and according to [CEWiT, IITH, IITM, Tejas Networks, Reliance Jio ] UE can report back the TA value applied in terms of the number of steps. This will reduce the required bits for TA reporting compared with reporting actual TA estimated at UE.

The following proposals on TA reporting were provided by proponents companies:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| CEWiT, IITH, IITM, Tejas Networks, Reliance Jio | **Proposal 8:** UE should report the applied TA to the gNB for better control over UE behaviour.**Proposal 10:** UE will report the applied TA to the gNB in terms of number of steps used in the quantization of TA. |
| Samsung | **Proposal 2:** UE’s estimated TA value is reported to gNB, if K\_offset is updated UE-specifically. |
| LG Electronics | **Proposal 5.** Support implicit reporting of TA estimated by the UE. The different TA (or the range of TA) can be mapped to different ROs (or RO groups).**Proposal 10.** RAN1 should discuss how to update and/or report the UE specific TA in case when the NTN UE is in RRC\_CONNECTED states.  |

Moderator’s view: TA reporting would be beneficial only for timing relationships, e.g if K\_offset is updated UE-specifically. And therefore, such discussion should be handled under AI 8.4.1 on timing relationships. Once sufficient progress has been made on the update of K\_offset after initial access.

**FL recommendation 10-1:**

**Handle TA Reporting proposals under A.I. 8.4.1** **or under A.I. 8.4.2 once sufficient progress has been made in A.I. 8.4.1.**

Companies are encouraged to provide their comments on Moderator recommendation 10-1:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Support FL recommendation 10-1 |
| Huawei | Agree |
| Xiaomi | Agree  |
| ZTE | Agree |
| CATT | Agree |
| APT | Support FL recommendation 10-1 |
| Samsung | Agree |
| vivo | Agree |
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# Conclusion

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