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 – Mohamed (Thales)

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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: |

### 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 |

## 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.  |

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

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

• **Issue#1-3-1**: **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.

• **Issue#1-3-2**: **Indication of the TA\_margin to the UE**

• **Issue#1-3-3**: **The value of TA\_margin**

### Issue#1-3-2: Indication 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. |

### Issue#1-2-3: The value of TA\_margin

The value of TA margin will be defined after the definition of UL time synchronization requirement. So we will come back on this issue later on in this Release.

## Issue#1-3: 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.

FL Recommendation:

**The following working assumption is still valid:**

**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 |

# 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 |

## 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 signaling 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 signaled 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 |

### Update of TA component controlled by Closed loop

If proposal 1-1-1 (related to issue#1-1) which applies to RRC idle, Inactive and Connected states is agreed: 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 are **relative** and 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/msgA 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 |

### Update of TA component controlled by open loop

If proposal 1-1-1 (related to issue#1-1) which applies to RRC idle, Inactive and Connected states is agreed: The Timing Advance applied by an NR NTN UE is given by**:**

If Proposal 2-2-1 is agreed, 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 TDocs:

**Solution#1:**

Where:

 is the timing drift rate on the service link (in units)

 is the common TA drift rate (in units)

 **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 |

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

[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 |

# 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

|  |  |
| --- | --- |
| **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. |

### 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:

|  |  |
| --- | --- |
| **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 |

* 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.

|  |  |
| --- | --- |
| **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.

|  |  |
| --- | --- |
| **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. |

### 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:

|  |  |
| --- | --- |
| **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.  |

* 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.

|  |  |
| --- | --- |
| **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. |

### 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:

|  |  |
| --- | --- |
| **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. |

# 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 |

# 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.  |

**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.  |

# 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 |

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 |

**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.  |

# 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 |

# 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. |

# 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 |

# Conclusion

TBC

# References

1. R1-2009748 FL Summary on enhancements on UL time and frequency synchronization for NR NTN THALES
2. R1-2100157 Discussion on UL time and frequency synchronization OPPO
3. R1-2100223 Discussion on UL time and frequency synchronization enhancement for NTN Huawei, HiSilicon
4. R1-2100245 Discussion on UL synchronization for NR-NTN ZTE
5. R1-2100305 Considerations on Enhancements on UL Time Synchronization in NTN CAICT
6. R1-2100382 UL time and frequency compensation for NTN CATT
7. R1-2100442 Discussion on UL time and frequency synchronization enhancements for NR-NTN vivo
8. R1-2100520 Considerations on UL timing and frequency synchronization in NR NTN THALES
9. R1-2100540 UL time synchronization acquisition for NTN Mitsubishi Electric RCE
10. R1-2100595 UE Time and frequency Synchronisation for NR-NTN MediaTek Inc.
11. R1-2100655 On UL synchronization for NR NTN Intel Corporation
12. R1-2100704 Discussions on UL time and frequency synchronization enhancements in NTN LG Electronics
13. R1-2100758 Discussion on NTN uplink time synchronization Lenovo, Motorola Mobility
14. R1-2100808 Consideration on enhancements on UL time and frequency synchronization Spreadtrum Communications
15. R1-2100860 Enhancement for UL time synchronization Sony
16. R1-2100927 On UL time and frequency synchronization enhancements for NTN Ericsson
17. R1-2100972 UL time and frequency synchronization in NTN Asia Pacific Telecom, FGI
18. R1-2100985 On UL time/frequency synchronization for NTN InterDigital, Inc.
19. R1-2101043 Enhancements on UL time and frequency synchronization for NTN CMCC
20. R1-2101079 Discussion on UL timing synchronization for NTN ETRI
21. R1-2101118 Discussion on UL time and frequency synchronization for NTN Xiaomi
22. R1-2101207 Enhancements on UL time and frequency synchronization for NTN Samsung
23. R1-2101297 Time and frequency synchronization for NTN systems Nokia, Nokia Shanghai Bell
24. R1-2101384 Discussion on Uplink Time and Frequency Synchronization for NTN Apple
25. R1-2101465 UL time and frequency synchronization for NTN Qualcomm Incorporated
26. R1-2101648 Discussion on UL time and frequency synchronization for NTN PANASONIC R&D Center Germany
27. R1-2101717 UL time synchronization methods for NTN systems CEWiT,IITM,IITH,Tejas Networks,Reliance Jio